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DESCRIPTION OF A NEW SPECIES OF *CHLAMYS* (MOLLUSCA: PELECYPODA) FROM THE GALÁPAGOS ISLANDS

By

Leo G. Hertlein

INTRODUCTION

The known marine molluscan fauna of the Galápagos Islands in general is sparser than that of the mainland. Eleven species of scallops (Pectinidae) have been reported living in the Galápagos Archipelago. These are: *Pecten* (*Flabellipecten*) *sericeus* Hinds, *Pecten* (*Oppenheimopecten*) *galapagensis* Grau, *Chlamys* (*Chlamys*) *lowei* Hertlein, *Chlamys* (*Argopecten*) *circularis* Sowerby, *Chlamys* (*Nodipecten*) *magnifica* Sowerby, *Cyclopecten* (*Cyclopecten*) *exquisitus* Grau, *Cyclopecten* (*Cyclopecten*) *pernomus* Hertlein, *Cyclopecten* (*Delectopecten*) *polyleptus* Dall, *Cyclopecten* (*Delectopecten*) *zacae* Hertlein, and from very deep water, *Cyclopecten* (*Cyclopecten*) *liriope* Dall and *Cyclopecten* (*Hyalopecten*) *neoceanicus* Dall. Seven of these are known to occur along the adjacent mainland.

In 1969, Mr. Anthony D'Attilio, San Diego Society of Natural History, sent six paired valves (four with the animal) and four single valves representing a species of *Chlamys* to Allyn G. Smith, Department of Invertebrate Zoology, California Academy of Sciences, with a request for identification of the species. These subsequently were submitted to me for study. A search of the Academy's collection as well as of the literature failed to reveal any similar species described from the eastern Pacific. Upon receipt of this information Mr. D'Attilio requested me to describe the species which appears in the present paper.

ACKNOWLEDGMENTS

The writer here expresses his thanks to the following persons: to Mr. Anthony D'Attilio, San Diego Society of Natural History, for permission to describe the new species and to retain paratypes; to Mr. Allyn G. Smith, California Academy of Sciences, for advice concerning the specimens; to Mr. Barry Roth of the same institution for critical reading of the manuscript and for arrangement of the illustrations; to Dr. Thomas R. Waller, Division of Invertebrate Paleontology, United States National Museum, for information concerning comparative species in the collections of the National Museum; to Mr. Maurice Giles, Staff Photographer, California Academy of Sciences, who prepared the photographs from which the illustrations were made.

DESCRIPTION OF NEW SPECIES

Family Pectinidae Rafinesque

Genus **Chlamys** Röding in Bolten

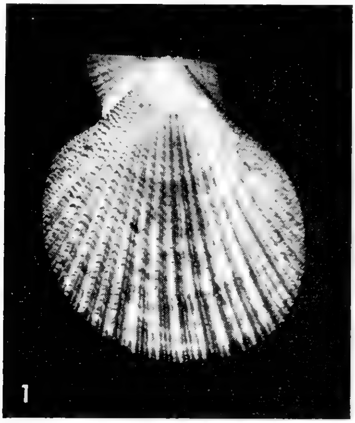
Chlamys (Chlamys) incantata Hertlein, new species.
(Figures 1–5.)

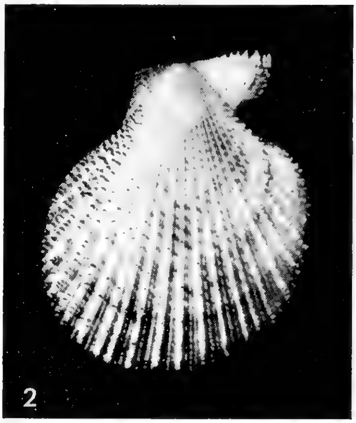
Diagnosis. A species of *Chlamys* differing from other west American species in possessing very narrow, compressed, rather low, spinose ribs.

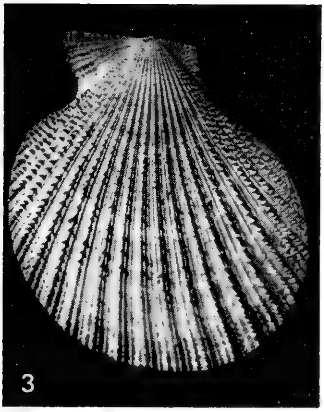
Description. Shell averaging about 45 mm. in height, ovate, valves gently and nearly equally inflated, hinge line rather short. Right valve sculptured with about 25 major ribs which are narrow, compressed, rather low, and occasionally unequally spaced; on top of each of these ribs is a row of spines which are concave ventrally; submargins with 5 or 6 very fine riblets; interspaces vary in width but are much wider than the ribs, nearly flat-bottomed, and sculptured with 1 to 3 fine radial threads, each bearing a row of spines, the ribs and interspaces crossed by fine concentric imbricating lines of growth; auricles unequal, the anterior one the larger, sculptured with about 5 spiny radial riblets, the hinge line above the auricle with scaly sculpture, below the auricle a well developed byssal notch about half the length of the auricle, below this along the margin there are 4 pectinidial teeth; posterior ear short, slightly concave, sloping rather steeply downward, sculptured with about 6 radial riblets. Left valve sculptured similar to the right but lacking a byssal notch. Hinge with one pair of slight cardinal crura. Interior of valves lightly grooved corresponding to the external ribbing. Color of the exterior of the valves whitish, the spines rosy, lending a roseate appearance to the valves, more pronounced on the left one.

Dimensions. Length 40 mm., height 45 mm., length of hinge line 21 mm., convexity (both valves together) approximately 13 mm. The largest specimen, a left valve, is 48 mm. high.

Type material. Holotype no. 52263, also paratypes, San Diego Society of Natural History, from off Academy Bay, Santa Cruz (Indefatigable) Island,







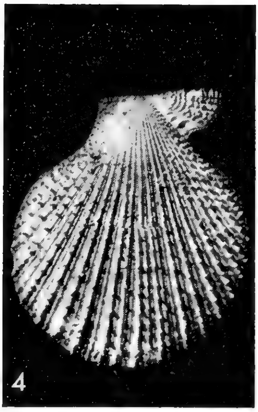


Figure 1. *Chlamys* (*Chlamys*) *incantata* Hertlein, new species. Holotype no. 52263 (San Diego Society of Natural History), from off Academy Bay, Santa Cruz (Indefatigable) Island, Galápagos Islands, dredged in 200 meters. View of the exterior of the left valve; height 45 mm. Figure 2. *Chlamys* (*Chlamys*) *incantata* Hertlein, new species. View of the exterior of the right valve of the holotype. Figure 3. *Chlamys* (*Chlamys*) *incantata* Hertlein, new species. Paratype (SDSNH), from the same locality as the holotype. View of the exterior of a left valve; height 48 mm. Figure 4. *Chlamys* (*Chlamys*) *incantata* Hertlein, new species. Paratype (SDSNH), from the same locality as the holotype. View of the exterior of a right valve; height 39.5 mm. Figure 5. *Chlamys* (*Chlamys*) *incantata* Hertlein, new species. View of the interior of the right valve shown in figure 2.

Galápagos Islands; dredged in 200 meters; Mrs. Jacqueline DeRoy collector, July 25, 1969.

Paratypes are deposited in the California Academy of Sciences, the American Museum of Natural History, and in the United States National Museum.

Comments. The shape, spinose sculpture, and rosy coloration of this new species are somewhat similar to those of *Chlamys hastata* Sowerby (see Arnold, 1906, pl. 42, figs. 1, 1a, 2, 2a; Grau, 1959, plates 27, 28) from California, but the ribs are more numerous, lower, more compressed, and not arranged in pairs on the right valve.

The fewer ribs (25) on the new species serve to separate it from *Chlamys amandi* Hertlein (1935, p. 305; *Pecten australis* Philippi, 1845, p. 56 "Patriae: Insulae Chonos."; not *Pecten australis* Sowerby, 1842) from Chile, which has 30 to 34 ribs which are only slightly scaly toward the submargins.

The sculpture of *C. incantata*, new species, bears a general resemblance to that of the species described as *Pecten* (*Chlamys*) *coccymelus* by Dall (1898, p. 741, pl. 34, fig. 1) from strata of middle Miocene age at Plum Point Maryland. Dall called attention to the similarity of the fossil form to juvenile *Pecten madisonius* Say, but believed it to be a distinct species. Mansfield (1936, p. 177) stated that it "may be an immature specimen representing a varietal form of *P. madisonius*," and Rowland (1936, p. 1008) suggested that it "may be a case of arrested development."

The sculpture of the new species described here bears a general similarity to that of illustrations of *Pecten* (*Chlamys*) *nympha* Bavay (1906, p. 246, pl. 7, figs. 3 and 4). The type specimen of that species was described as only about 15 mm. high. The type locality was given as "Habitat Caribaeum Mare?". The type specimen in the Muséum National d'Histoire Naturelle de Paris, was originally in a carton which also contained a specimen of *Pecten antillarum* Récluz, a typical inhabitant of Caribbean waters. Dr. Thomas R. Waller (written communication, December 30, 1969), who has given considerable time to a study of the Pectinidae of the western Atlantic, stated that he feels certain that *Pecten* (*Chlamys*) *nympha* is a synonym of *Chlamys benedicti* Verrill and Bush (in Verrill, 1897, p. 74; not *Pecten benedicti* Lamarck, 1819) described from "off Martha's Vineyard, 1356 fath., dead; West Indies, in 25 to 72 fath., living." Adult specimens of *C. benedicti* (Weisbord, 1964, pl. 14, figs. 8–11) are quite distinct from the new species described here from the Galápagos Islands.

The specific name of this new species, "*incantata*," is derived from the vernacular appellation, "Las Islas Encantadas" (the Enchanted Islands), sometimes applied to the Galápagos Islands.

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THREE NEW LAND SNAILS FROM ISLA SANTA CRUZ (INDEFATIGABLE ISLAND), GALÁPAGOS

By

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From late January to early March, 1964, I had the opportunity to collect land snails on one of the larger of the Galápagos Islands as a participant in the Galápagos International Scientific Project (GISP). This expedition was sponsored by the University of California, the California Academy of Sciences through the Belvedere Scientific Fund, and the Charles Darwin Foundation. Assistance, both financial and material, was provided by the government of the Republic of Ecuador, the United States Navy, the National Science Foundation of the United States*, the Shell Oil Company, and the California Maritime Commission whose training vessel, the *Golden Bear*, provided transportation of personnel and equipment to and from the Galápagos.

The major portion of the five weeks in the Galápagos Islands was spent in collecting on Isla Santa Cruz (Indefatigable). The decision to concentrate on this island was made for several reasons. First, it is large, high, and well forested, containing all of the life zones occurring in the Galápagos group; second, the Darwin Research Laboratory close to the village of Academy Bay made an ideal headquarters; and third, the well developed trail from Academy Bay into the highland area, which was pioneered by the members of the California Academy's 1932 Expedition sponsored by Templeton Crocker, cut through all life zones and made good collecting spots accessible (see map, fig. 1). These reasons fortunately tied in with the fact that the late winter and spring of 1964 proved to be a good time to find land snails on Isla Santa Cruz. There was considerable

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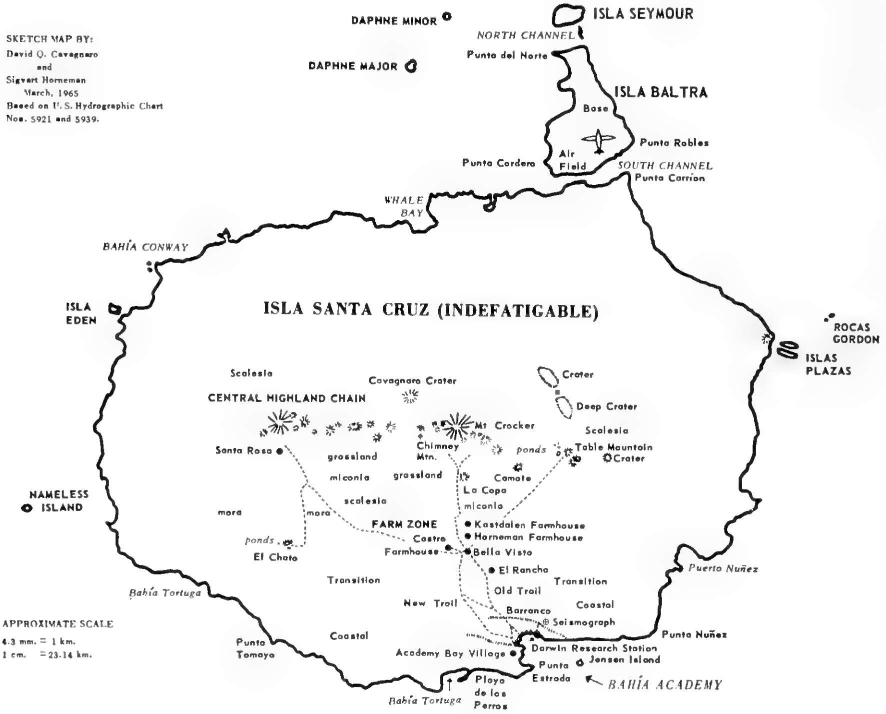

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FIGURE 1. Outline map of Isla Santa Cruz (Indefatigable Island), Galápagos Islands, with some of the principal features sketched in.

rainfall, even in the Arid Zone along the shores of the island, which promoted snail activity.

The collections made through personal efforts were considerably augmented by other GISP scientists during their field work on other islands as well as Santa Cruz. To these appreciation is due. In addition, special thanks go to André and Jacqueline De Roy, a Belgian couple living at Academy Bay, for much pertinent information on possible productive collecting areas. Although not an active conchologist like his wife, M. De Roy became interested in the species of land snails to be found on his island and has made a number of special trips into uncollected areas in the highlands of Isla Santa Cruz in the past several years with signal success.

The following new species discovered as a result of these efforts make a significant addition to the land snail fauna of the Galápagos. The symbols "CASG" and "CASIZ" represent separate collections maintained by the California Academy of Sciences' Geology and Invertebrate Zoology departments, respectively, the latter consisting mainly of specimens preserved in alcohol.

Naesiotus deroyi A. G. Smith, new species.

(Figures 2–9.)

DESCRIPTION. Shell fairly large for the genus, elongate-conic, yellowish white at the apex graduating to pure white on the body whorl. Whorls about 7, gently rounded, the sutures well impressed. Aperture subquadrate, with 2 prominent denticles, the first a strong, rounded boss on the columella, and the second a less strong, somewhat laterally compressed, subtriangular, parietal denticle positioned a short distance behind the plane of the aperture. Peristome thickened slightly but not reflected except on the basal portion, which partly covers a small shallow umbilicus. The peritreme is completed by a fairly heavy wash of callus. The columellar axis is simple, solid, and only slightly twisted. (See fig. 4.)

Nuclear whorls 2½, erect, sculptured by many fine, closely spaced, occasionally anastomosing, slightly sinuate and protractive transverse lirae. The first postnuclear whorl is relatively smooth and marked by hardly noticeable lines of growth. Beginning with the second postnuclear whorl, a rough irregular but generally transverse wrinkling appears, becoming very heavy, somewhat warty, and more or less patternless on the penultimate and especially on the body whorl. Underlying this strong wrinkled sculpture are fine, closely spaced, spiral lirae, also beginning on the second postnuclear whorl, but not overriding the raised areas forming the wrinkles.

The animals, in alcohol, are yellowish white in color with no apparent special markings on the mantles. Unfortunately, I did not see specimens alive.

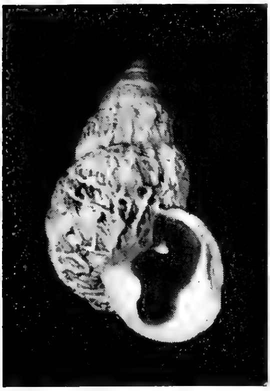
HOLOTYPE. An adult shell (CASG Type Collection, no. 13730) with animal in alcohol (CASIZ Type Series, no. 466), the shell measuring: height, 19.8; maximum diameter, 12.0; height of aperture, 8.8; maximum width of aperture, 7.6 mm. Number of whorls, 6¾. The apical angle of the spire is about 50°. (See figs. 2, 3.)

PARATYPES. Seventy-two specimens collected with the holotype. These have been deposited in various museums having recognized type collections, including the CASIZ Type Series, and in several private collections.

TYPE LOCALITY. Isla Santa Cruz (Indefatigable Island), Galápagos, on the northwest side at an elevation of about 264 m. (870 ft.), on a species of thorny bush (locally called "mora," the botanical name not available) by André De Roy, 18 February 1964.

OTHER MATERIAL EXAMINED (ALL FROM ISLA SANTA CRUZ).

(1) Three adult specimens (CASG no. 40129) found in a locality "1–2 hours walk west of the Horneman Farm,"—at an elevation of about 200 m. (650 ft.).



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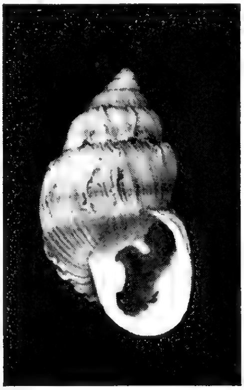

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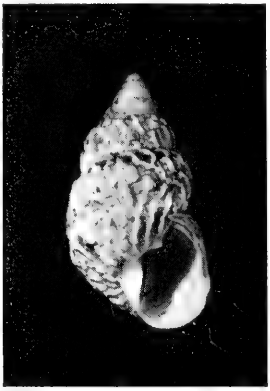

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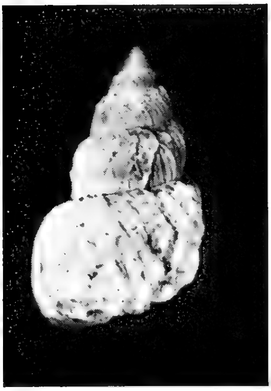

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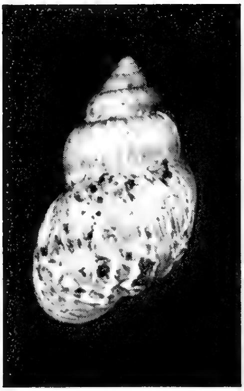

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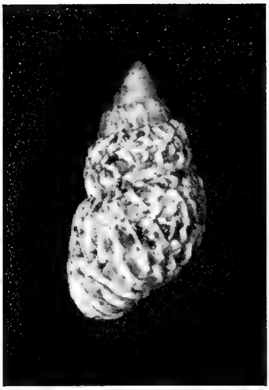

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Figure 2. *Naesiotus deroyi* A. G. Smith, new species. Holotype. Height, 19.8 mm. Apertural view. CASG Type Collection, no. 13730. Figure 3. Same. Back view. Figure 4. Same. Shell with cut-away section to show configuration of columella. Paratype. Height, 18.1 mm. CASG Type Collection, no. 13731. Figure 5. *Naesiotus* cf. *N. deroyi*. Adult

These were the first ones found by André and Jacqueline De Roy in 1963 in the same general area as the type lot collected in 1964. Others are in the De Roy Collection.

(2) Six adult shells, typical (CASG no. 40076), collected on the trail 6 miles to the west of the village of Bella Vista, on bushes, by André De Roy, 10 June 1964.

(3) One typical but rather small subadult (CASG no. 40302), collected in an area to the north of the central chain of craters well north and slightly west of the village of Santa Rosa, on the ground in a dense forest of *Scalesia pedunculata*, by André De Roy, 26 November 1966.

(4) One juvenile (CASG no. 40122), collected 5 miles northwest of Bella Vista, on "mora," at about 265 m. (870 ft.) elevation by André De Roy, 18 February 1964.

(5) Three rather small adults (CASG no. 40225), collected on the north side of the hill nearest to Santa Rosa Spring, on grass in a grassy glade, 200 m. (650 ft.) elevation, by André De Roy, 29 June 1965.

(6) Fourteen adults and subadults (CASG no. 40022), found 2 km. northeast of the village of Santa Rosa, on the ground, by André and Jacqueline De Roy, 28 June 1965. This series is not typical.

(7) Seven specimens (mostly subadults) preserved in alcohol (CASIZ Coll.), taken about 2 km. northeast of Santa Rosa, in open *Scalesia* forest hanging on the leaves of various plants and bushes, by André De Roy, 27 November 1966. This and the preceding lot are similar.

Remarks. This is one of the largest and most strikingly sculptured of the Galápagos species of *Naesiotus*. No species closely similar has been described. While an average specimen is about 20 mm. high, with 7 whorls or slightly less, an unusually large one may be as much as 23 mm. in height, with the whorls numbering 7¼ to 7½. It appears to be a terminal species in the group of Galápagos snails that have developed a heavily wrinkled sculpture on nearly all of the postnuclear whorls rather than on the last portion of the body whorl, which

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shell from lot no. 6 with weaker wrinkled sculpture. Hypotype. Height, 17.4 mm. CASG Type Collection, no. 13733. Apertural view. Figure 6. Same. Back view. Figure 7. *Naesiotus deroyi*. Adult shell from lot no. 5. Hypotype. Height, 17.5 mm. CASG Type Collection, no. 13734. Apertural view. Figure 8. Same. Back view. Figure 9. Galápagos *Naesiotus* related to *N. deroyi*. Left to right: *N. rabidensis* (Dall, 1917) from Isla Rabida (Jervis Island), hypotype, height, 13.5 mm. (CASG Type Collection, no. 13735); *N. sculpturatus* (Pfeiffer, 1846) from Isla Santiago (James Island), hypotype, height, 13.6 mm. (CASG Type Collection, no. 13736); *N. darwini* (Pfeiffer, 1846) from the same island, hypotype, height, 15.9 mm. (CASG Type Collection, no. 13737); *N. deroyi*, holotype, fig. 2.

is the type of sculpture on such species as *Naesiotus lycodus* (Dall, 1917), *N. ochsneri* (Dall, 1917), and several others. So far, *N. deroyi* has been collected in the highland area of Isla Santa Cruz, only toward the northwest side of the island; it seems to prefer the moister forested area characterizing the *Scalesia* Zone. The nearest relative is *Naesiotus darwini* (Pfeiffer, 1846) from James Island, which is smaller, chunkier, and has a finer and much less rude type of wrinkled sculpture. Other species in the group include *N. sculpturatus* (Pfeiffer, 1846) from James Island, and *N. rabidensis* (Dall, 1917) from Jervis. (See fig. 9.)

Snails from lots 6 and 7 listed under "other material examined" come from the same general locality as the others. However, they are smaller in size than those from the type locality, averaging 17.1 mm. in height, with a range of 15.7–17.6 mm. Color is a light yellow-brown and all shells have a narrow, darker brown band encircling the periphery of the whorls; many have the entire base tinged with the same brown color. The wrinkled sculpture is much less strong, some shells having smooth patches with no wrinkles at all. (See figs. 5, 6.) As in some other Galápagos snail species, this particular population evidently represents an evolutionary trend of recent origin. Whether a subspecies is in the process of development is difficult to say until the range limits of both forms can be determined and other related factors studied. At present, it seems sufficient to call attention to the occurrence of another race closely allied to *N. deroyi.*

It is with considerable satisfaction that I take this opportunity to name a striking new species of Galápagos land snail for M. André De Roy, who collected the first specimens as well as the type and other lots.

Naesiotus cavagnaroi A. G. Smith, new species.

(Figures 10–18.)

DESCRIPTION. Shell fairly large for the genus, smooth, broadly elongate-conic, with a fairly heavy texture and a tumid body whorl. Normal color pattern is reddish brown to chocolate brown with a narrow yellowish band coloring the sutures of the postnuclear whorls and encircling the body whorl slightly below its periphery. Whorls about 6½, rounded, the sutures impressed. Aperture ovate, white inside, with 2 well developed denticles, the first an elongate, rounded swelling on the columella, the second one smaller, arcuate, and parietal, set well inside the retractive plane of the aperture and forming a U-shaped bay with the columellar denticle. Peritreme rather sharp, thinned down toward its edge, not reflected, the outside edge yellowish in color. The peritreme is completed by a heavy layer of callus, especially in older shells. There is a small shallow umbilicus partly covered by the basal reflection of the peristome. The columella is simple and only slightly twisted.

Nuclear whorls about two, dimpled, appearing smooth to the naked eye but under magnification revealing a sculpture of extremely fine, closely spaced, transverse lirations that are slightly sinuate and beaded at their summits as a result of being cut by excessively fine spiral striae. Postnuclear whorls sculptured by lines of growth and very fine, closely spaced, spiral striations, the latter best seen under considerable magnification.

The surface of most shells exhibits a rather dull finish overall, with a tendency in some toward a more shining exterior. Occasional shells are yellowish in color with no suggestion of a revolving band. Animals in alcohol are tuberculate dorsally and light grey in color, there being no appreciable color difference between those occupying normally colored or xanthic shells.

Holotype. An adult shell preserved without the animal has been deposited in the CASG Type Collection, no. 13738. It measures: height, 22.7; maximum diameter, 13.9; height of aperture, 10.4; maximum width of aperture, 9.1 mm. Number of whorls, 6½. Apical angle, about 70°. (See figs. 10, 11.)

Paratypes. A total of 52 specimens collected with the holotype. Of this total 30 have adult shells, 17 are subadults, and 6 are juveniles. Of this same total, 10 have xanthic shells (6 adults, 3 subadults, and 1 juvenile). About half of the type lot were collected alive; animals with their shells of a few of both color forms have been preserved in alcohol. A distribution of these paratypes will be made in a manner similar to that indicated for the previously described species (*Naesiotus deroyi*).

Type locality. Isla Santa Cruz (Indefatigable Island), Galápagos, about 7 km. northeast of the farming village of Santa Rosa in the vicinity of a series of small volcanic craters in a *Scalesia* forest; collected under lava rocks and dead wood by André De Roy, 27 November 1966.

Other material examined.

(1) Three dead, bleached, adult shells (CASG no. 40158) collected along the trail near the summit of Mt. Crocker at an elevation of 650–870 m. (2130–2850 ft.) by Robert L. Pyle, 25 February 1964.

(2) Seven dead, bleached, adult shells (CASG no. 40237) collected near an isolated rocky crater (subsequently designated as Cavagnaro Crater), in a *Scalesia* forest on the north slope of the island at an elevation of about 500 m. (1600 ft.) by David Q. Cavagnaro, 10 April 1964.

(3) One dead, bleached adult shell (CASG no. 40512) found about 0.5 mile below Santa Rosa on the trail from Bella Vista by André and Jacqueline De Roy, 1 March 1965.

(4) One dead but fresh adult shell, 1 subadult and 1 juvenile (CASG no. 40229) collected in the *Scalesia* forest near Cavagnaro Crater, elevation about 625 m. (2050 ft.), by André and Jacqueline De Roy, 2 March 1965.

(5) Sixty-two dead adult shells (CASG no. 40221) collected on the ground


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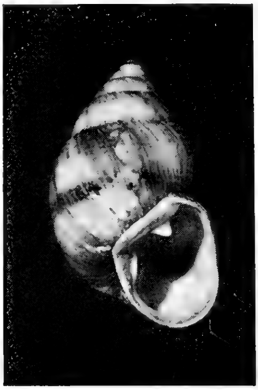
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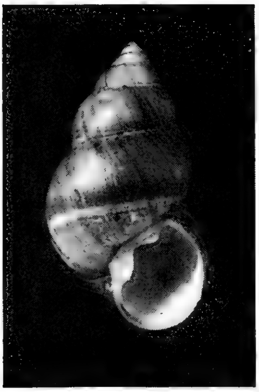
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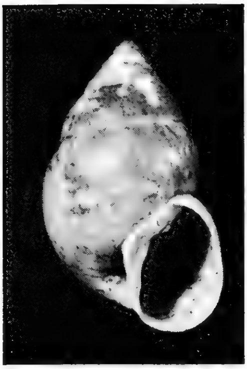
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FIGURE 10. *Naesiotus cavagnaroi* A. G. Smith, new species. Holotype. Height, 22.7 mm. CASG Type Collection, no. 13738. Apertural view. FIGURE 11. Same. Back view. FIGURE

in the vicinity of Cavagnaro Crater, elevation about 690 m. (2200 ft.), by André and Jacqueline De Roy, 2 March 1965.

(6) One dead, bleached, adult shell (CASG no. 40228) collected on the ground near Santa Rosa school by André De Roy, 2 November 1965.

(7) One dead, bleached, adult shell (CASG no. 40234) collected 2 miles from the Santa Rosa school on the trail from Bella Vista, by André De Roy, 2 November 1965.

(8) Seven dead, bleached, adult shells (CASG no. 40295) collected in the vicinity of Cavagnaro Crater, by André De Roy, 23 November 1966.

(9) Three bleached "bones" (CASG no. 40300) collected in a small lava cave to the west of Chimney Mountain, by André De Roy, 25 November 1966.

(10) Thirty-eight adult shells, all xanthic (CASG no. 27537), collected "at the very top of the island" (*i.e.*, summit of Mt. Crocker) by Templeton Crocker, 10 or 11 May 1932.

(11) Forty-seven adult shells, all xanthic but darker in color than the preceding lot (CASG no. 27538), collected "on the trip to top of Mt.," by Templeton Crocker, 10 or 11 May 1932.

(12) Two adults and 1 juvenile with color pattern reversed taken alive half way between Chimney Mountain and Santa Rosa Spring under low bushes in an open area, elevation about 600 m. (1950 ft.), by André and Tui De Roy, 27 June 1965.

(13) Thirty-three mostly adult shells taken alive (CASG no. 43333; 15 in alcohol are CASIZ Collection) 2 miles west of Mt. Crocker at the foot of a volcanic crater on the ground among small trees, by André and Jacqueline De Roy, 10 May 1970.

Remarks. This smooth brown snail with a yellowish revolving band has no close relatives of comparable size either on Isla Santa Cruz (Indefatigable Island) or on any of the other Galápagos Islands. Its range on Indefatigable is limited to the north slope of the island extending down from the summit of the

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12. Same. Shell with cut-away section to show configuration of columella. Paratype. Height, 22.0 mm. CASG Type Collection, no. 13739. Figure 13. Same. Xanthic colorphase, adult, from type lot. Paratype. Height, 21.2 mm. CASG Type Collection, no. 13740. Figure 14. Same. Xanthic shell, adult, with over-all greenish-brown color tone, from lot no. 11. Hypotype. Height, 23.1 mm. CASG Type Collection, no. 13741. Apertural view. Figure 15. Same. Back view. Figure 16. Same. Adult shell with color pattern reversed, from lot no. 12. Hypotype. Height, 18.8 mm. CASG Type Collection, no. 13742. Figure 17. Same. Adult shell with normal color pattern reversed, from lot no. 13. Hypotype. Height, 26.7 mm. CASG Type Collection, no. 13743. Figure 18. *Naesiotus duncanus* (Dall, 1893). Adult dead shell from Isla Pinzón (Duncan Island). Hypotype. Height, 18.7 mm. CASG Type Collection, no. 13744.

main volcanic crater, Mt. Crocker, generally in the *Scalesia* Zone, at elevations above 500 m. (1600 ft.). It is a ground snail, frequenting moist habitats under lava rocks, *Scalesia* dead-falls, or equivalent cover.

Naesiotus cavagnaroi is remarkably consistent in size and general configuration. Measurements of 15 adult shells from the type locality average 21.9 mm. in length and 13.4 mm. in maximum diameter, with about 6½ whorls. The corresponding range measurements for this series are 21.0–23.5 and 12.4–14.6, with the number of whorls ranging from 5¾ to 6½, the latter number being the most frequent. Young shells are prominently keeled at the base of the developing whorls.

The occurrence of xanthic shells along with normally colored ones is of particular interest. (See figs. 13–15.) No similar situation has been observed in any other Galápagos species of *Naesiotus*. According to André De Roy, who collected the type series, the ratio of xanthic to normally colored shells is about one to five, which is confirmed by the count of specimens sent by him for identification and study. There is no difference in the color of the animals and all xanthic shells seen fall within the range of measurements given above. Lot nos. 10 and 11 in the preceding list are all the bandless xanthic color form. They were collected by Templeton Crocker during the Academy's 1932 Galápagos Expedition at the time he and his party pioneered the first ascent of the island's main crater, later called Mt. Crocker in his honor. The series of shells he collected at the crater rim are of the same yellowish color as xanthic shells from the type locality of the species. The second lot, collected at a lower elevation on the way to the top, are darker in color with a greenish brown cast. Both of these lots evidently represent pure xanthic populations of the species; the exact localities where they were found are presently unknown and a search for them should be made.

The three specimens in lot no. 12 in the list of specimens examined have a color pattern that is the reverse of the normal one, being a light beige-brown overall with a dark brown encircling band. The two adult shells have red-brown nuclear whorls but in size and sculpture they are normal for the species. (See fig. 16.) Until recently this reverse color pattern was thought to be of rare occurrence, but an apparently pure colony of such shells was collected by the De Roys in the highland area in May 1970 (lot no. 13, preceding). Of the 33 shells sent in for study, 21 have the same reverse color pattern just mentioned except that the encircling brown band is bordered below by a whitish band of somewhat variable width (see fig. 17); 7 have weak or indistinct banding and thus approach the xanthic form; and 5 are similar to the xanthic shells occurring in the type lot. Compared with the type series, shells in this lot average slightly higher, several being a little longer spired with deeper sutures. The largest shell measures 26.7 × 14.5 mm. in height and maximum diameter. Mme. De Roy's comments on this lot (personal communication, 1 August 1970) are of such interest that they are repeated, as follows:

> Surprisingly, we found them living in an area where André had collected before, only that he searched a couple of hundred yards on either side. In fact, the area where this colony of snails is living is restricted (?) to a brushy patch surrounded by grass-covered hills and may be no more than 3 or 4 acres. Snails there are quite abundant but this could change before long, as barbed-wire fence already divides the place in two lots and the land will be converted into pastures.

Although the reverse color phase may possibly turn out to be a different species when the relation between it and the color phase considered to be the normal one is better known, present indications are that there is only a single species involved, in spite of the fact that there are four color forms.

Two described Galápagos species have some superficial resemblance to *Naesiotus cavagnaroi.* One is *N. duncanus* (Dall, 1893) from Duncan Island (Isla Pinzón), shown in figure 18, which has the same general shape and number of whorls although it is considerably smaller in size, has a less well developed parietal denticle, and lacks the columellar thickening or flange present on *N. cavagnaroi.* Unfortunately, *N. duncanus* has not been reported as having been collected alive and may, in fact, be extinct. The other similar species is the rare *N. jervisensis* (Dall, 1917), which again is much smaller than *N. cavagnaroi,* has a less well developed parietal denticle and columellar flange, but has the same type of fine spiral sculpture; it differs, however, in having the last whorl irregularly corrugated and in being unicolored and unbanded.

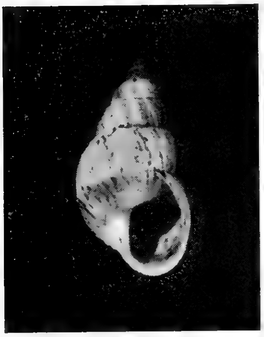
The species is named for David Q. Cavagnaro, California Academy entomologist and a member of the GISP, who collected some of the first specimens and also a number of other land snails of considerable scientific value on Isla Santa Cruz and on several other Galápagos islands he was able to visit.

Naesiotus scalesiana A. G. Smith, new species.

(Figures 19–25.)

Description. Shell of medium size for the genus, elongate to globose-conic, the apex rose-colored with the remaining shell whitish or tinged with beige, yellowish white, or very light red-brown. Whorls 5½ to 6½, almost flat-sided, the sutures only moderately impressed. Aperture subovate, usually without denticles; the peristome thin and unflared, hardly reflected at the base of the columella, leaving open a small but permeable umbilicus, not joined across the parietal wall of the body whorl with any appreciably thickened wash of callus.

Nuclear whorls nearly 3, erect, sculptured with extremely fine, closely spaced, nearly straight transverse riblets or lirae, extending all the way across them. Postnuclear whorls somewhat shining, the first one or two with coarse, irregular lines of growth, later ones with additional, irregulary placed, rather deep indenta-



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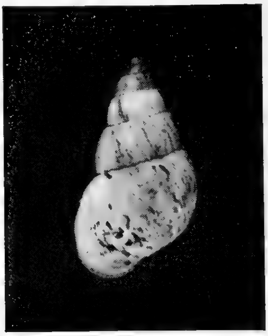

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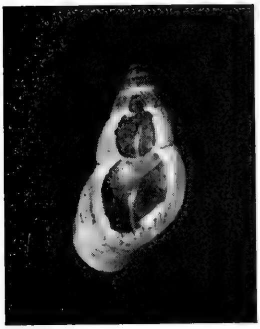

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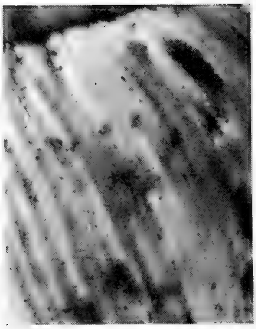

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FIGURE 19. *Naesiotus scalesiana* A. G. Smith, new species. Holotype. Height, 14.1 mm. CASG Type Collection, no. 13745. Apertural view. FIGURE 20. Same. Back view. FIGURE 21. Same. Shell with cut-away section to show configuration of columella. Paratype. Height, 13.6 mm. CASG Type Collection, no. 13746. FIGURE 22. Same. Enlarged view of portion

tions and elongate impressions, which are most prominent on the body whorl.

Animals in alcohol generally yellowish white, occasionally tinged with light gray on the dorsal surface, the foot usually being of a slightly lighter color tone. Rarely, an animal is quite dark-colored. There appears to be no correlation between the color of the animal and the color of the shell.

HOLOTYPE. An adult shell measuring: height, 14.1; maximum diameter, 7.5; height of aperture, 6.4; width of aperture, 3.7 mm. Number of whorls, 6¼. Apical angle, about 45°. CASG Type Collection, no. 13745.

PARATYPES. Ninety-two additional specimens preserved dry, deposited in various museums maintaining type collections including the CASG Type Collection, and 4 preserved in alcohol in the CASIZ Type Series, no. 470.

TYPE LOCALITY. Isla Santa Cruz (Indefatigable Island), Galápagos Islands, in the *Scalesia* Zone, Horneman Farm area, at an elevation of about 244 m. (800 ft.), on *Scalesia* trees and tall bushes, collected by A. G. Smith, 19 February 1964.

RANGE AND ECOLOGY. A total of 36 separate lots, in addition to the type lot, have been collected and are available for study. All of these have contributed to the present consideration of the species. They represent over 500 specimens, mostly preserved dry, although a representative series of animals were drowned and preserved in alcohol in an expanded condition.

Naesiotus scalesiana seems to be the most prevalent species throughout the *Scalesia* Zone on Isla Cruz. Its occurrence most often on the trunks and branches of *Scalesia* trees makes the name given to it an appropriate one. This habitat is shared with *N. lycodus* (Dall, 1917), also pink-tipped but with a much more wrinkled shell, which is almost as common at the type locality although it does not climb as high up as *N. scalesiana*. The latter species has been collected also, though sparingly, at the upper edge of the Transition Zone and in the lower part of the *Miconia* Zone but it does not seem to thrive outside the areas occupied by the forests of *Scalesia pedunculata* wherever they occur under conditions of heavier rainfall and hence of moister conditions than exist in the lower or the higher, somewhat dryer life zones.

Along the "old" or original trail from Academy Bay village to the highland

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of holotype to show sculptural detail. FIGURE 23. Same. Group of five adult shells from *Scalesia* Zone below Bella Vista village, Isla Santa Cruz. Allyn G. Smith and Ira L. Wiggins, collectors, 19 February 1964. Hypotypes. Height (left-hand shell), 13.3 mm. CASG Type Collection, nos. 13747, 13747a, 13747b, 13747c, 13747d. From CASIZ Color Slide, no. 955. FIGURE 24. Same. Group of five adult shells from type lot. Holotype at left (height, 14.1 mm.); the rest paratypes, CASG Type Collection, nos. 13748, 13748a, 13748b, 13748c. From CASIZ Color Slide no. 1937.

area on Isla Santa Cruz, Dr. Ira L. Wiggins and I first encountered *N. scalesiana* in 1964 in the Transition Zone at an elevation of about 120 m. (400 ft.) (CASG no. 40083, 2 adult specimens). It became quite common at the lower end of the *Scalesia* Zone on young *Scalesia* trees, along with *N. lycodus*, and continued prevalent in the vicinity of the village of Bella Vista, the areas of the Horneman and Kastdalen Farms, and for a short distance into the *Miconia* Zone (CASG no. 40070, 3 adult specimens). Elsewhere in the *Scalesia* Zone M. André De Roy and others collected it toward the eastern side of the island in the Table Mountain area (CASG no. 40232), on the northern side in the general vicinity of Cavagnaro Crater (CASG no. 40221), around the village of Santa Rosa, and to the south of Santa Rosa near the end of the trail into the Tortoise Reserve at El Chato.

The *Scalesia* snail lives in more of an arboreal habitat than any other Galápagos land snail with which I am familiar. On one collecting trip, Dr. Wiggins and I decided to sacrifice one large *Scalesia* branch to see just how far up the snail might go. We found two living adults (CASG no. 40231) at the very tip of the branch, about 35 feet from the ground, among the small sunflower-like *Scalesia* blossoms in flower at the time. It does not confine itself entirely to *Scalesia* plants and trees, however, but has been collected living on *Darwiniothamnus*, a bush of medium height, and below Santa Rosa village in thickets of thorny shrubs called "mora" by the native Ecuadoreans in company with another new species of Galápagos land snail, *Naesiotus deroyi*, described earlier in this report.

Unfortunately, nothing is known at present of the breeding habits of the species; its egg clusters were not found in 1964 and have not been reported subsequently.

INDIVIDUAL VARIATION. The type lot of *N. scalesiana* was selected for general consistency in size and color of the shells, and also for the accessibility of the type locality at the Horneman Farm, making it relatively easy for topotypical material to be collected. Color in the type lot ranges from almost pure white to an overall suffusion of beige or light brown; only one adult shell in the series has darker postnuclear whorls, with a body whorl having a distinctly brown and white banded pattern. (See fig. 24.) The rose-colored tip is consistent within the type lot and for most of the other shells at hand.

Variation in size within the type lot is shown in the following table of measurements of 25 adult paratypes, selected more or less at random:

Item	*Height (mm.)*	*Max. Diam. (mm.)*	*Apical Angle (°)*	*No. Whorls*
Tallest shell	15.2	7.6	49	6¼
Shortest shell	11.5	6.2	51	5½
Avg. of 25	13.3	7.1	50	5¾

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FIGURE 25. *Naesiotus scalesiana.* Shell with living animal. Collected by Robert L. Usinger and Earl G. Linsley, Bella Vista village, 4 February 1964. Author's field photo taken at Academy Bay. From CASIZ Color Slide, no. 440.

Shells from other localities on the island have measurements that are consistent with the preceding figures. A few adult shells from the vicinity of Santa Rosa have slightly more tumid whorls and lack the usual rose-colored apex.

Most shells have simple apertures with no parietal or columellar denticles or denticular swellings; this is true of all specimens in the type lot and of others collected in the Horneman Farm area. A few shells from the general vicinity of Santa Rosa do have small to subobsolete parietal denticles, and in some but not all of these there are perceptible swellings on the columella where a columellar tooth would normally occur, were one present. Such denticular processes are not a character of this species although they are normal in the apertures of other species of *Naesiotus* from Isla Santa Cruz and other Galápagos Islands. Whether the rare occurrence of apertural denticulation represents an evolutionary trend toward development of prominent teeth in the aperture, or away from this, is a question that cannot be answered from the present sparse knowledge of the biology of the species and its probable ancestral relationships.

A well rounded body whorl is characteristic of *N. scalesiana*, although occasionally an adult shell shows a barely perceptible angulation at its base near the periphery. As might be expected, this feature is seen more often on juvenile and subadult shells.

The indented sculpture on the body whorl is peculiar; it cannot be said to be malleate in terms of small, rounded hammer marks. Rather, it consists of pits in combination with elongated, sometimes anastomosing furrows that have the appearance of impressions made by a blunt point or an elongated, blunt edge. This type of sculpture varies somewhat in intensity between populations from which specimens have been collected. (See figs. 22, 25.) On the whole, however, the shells of *N. scalesiana* exhibit characters that are quite consistent throughout its range.

COMMENTS. It seems unusual that such an abundantly represented species of Galápagos land snail has escaped notice for so long a time. W. H. Dall did not recognize it as having been collected during earlier Galápagos expeditions; apparently neither Baur nor Wolf saw it. Reibisch (1892) reported nothing like it, his only large snail from Indefatigable Island (Isla Santa Cruz) being *Naesiotus wolfi*, an entirely different species which he described as new. It was not found by Snodgrass and Heller during the Hopkins-Stanford Expedition of 1897–98; nor was it collected by W. H. Ochsner during the California Academy's 1905–06 Expedition, which spent quite a little time at Academy Bay. The California Academy's 1932 Expedition did not find it even though in the first ascent to the rim of the main crater the party led by Templeton Crocker traversed the *Scalesia* Zone on the way to the top as well as on the way back. The United States National Museum has no specimens like it in its large representative collection of Galápagos land snails; however, it does possess a single adult specimen from an unidentified island, collected or obtained by Hugh Cuming, under the name *Bulimulus calvus* (Sowerby, 1833) (USNM no. 104,864) that is quite close to *Naesiotus scalesiana*. The first authentic collecting record known to me is a single shell found by Dr. Robert I. Bowman, "5 miles North of Academy Bay," March 2, 1953, at an elevation of 775 feet (CASG no. 34649). All shells collected subsequently were taken during the Galápagos International Scientific Project of 1964 and since.

Naesiotus scalesiana has no demonstrable relationship with any of the other 15 species of *Naesiotus* from Isla Santa Cruz, including the two previously described as new in this report. I have not seen shells like it from any of the other islands in the Galápagos Archipelago. Closest relatives would appear to be certain species of *Naesiotus* from the mainland of South America (Weyrauch, 1956, 1967) but lack of appropriate mainland material at the present writing places any detailed comparison beyond the scope of this discussion.

ACKNOWLEDGMENTS

Appreciation and thanks to André and Jacqueline De Roy of Academy Bay, Isla Santa Cruz, and to several scientists of the Galápagos International Scientific Project of 1964 have already been expressed. In addition, David Q. Cavagnaro, California Academy entomologist with the GISP, also should have special mention for his land-snail collecting efforts on top of a full-time entomological program.

I am greatly indebted to the California Academy's scientific photographer, Mr. Maurice Giles, for his excellent work in providing acceptable snail illustrations from actual specimens, and for his black-and-white reproductions of three of the author's 35 mm. color transparencies.

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PLIOCENE FOSSILS FROM BALTRA (SOUTH SEYMOUR) ISLAND, GALÁPAGOS ISLANDS

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INTRODUCTION

The present paper deals chiefly with invertebrate fossils which I collected while a member of the first Expedition of the *Velero III* to the Galápagos Islands in 1931–1932. A general account of the itinerary of this expedition appeared in a report by Fraser (1943, pp. 50, 260, 262, 272–273). A report dealing with fossils of Pleistocene age collected on this expedition was published by Hertlein and Strong (1939) and in a later paper the same authors (1955) reported on the Recent shells. Fossils believed to be of Pliocene age, chiefly mollusks, were collected during January, 1932. The pressure of other duties delayed completion of the present paper.

In addition to the collection which I assembled, Joseph R. Slevin collected a few fossils of Pliocene age in 1927 when he visited the island on Captain G. Allan Hancock's *Oaxaca*. A few other specimens received through the courtesy of Dr. A. Myra Keen of Stanford University, are included in the present paper.

The author is grateful for having had the opportunity to accompany the expedition offered by the late G. Allan Hancock, owner of the *Velero III*. The author acknowledges aid received from two other individuals, now deceased: A. M. Strong, who identified the micro-gastropods and E. H. Quayle who contributed information concerning the corals. Mr. Barry Roth, Department of Geology, California Academy of Sciences, furnished information concerning the identification of the species in the family Marginellidae, contributed helpful comments concerning certain other species, and also aided in the preparation of

the plates. The identifications of the corals listed in this paper were furnished by Dr. J. W. Durham, Department of Paleontology, University of California, Berkeley. The author is grateful to Carmen Angermeyer and to Jacqueline De Roy, residents of Academy Bay, Santa Cruz Island, Galápagos Islands, who presented many specimens of Recent shells from those islands to the California Academy of Sciences. These specimens have been very useful for comparison with fossil forms from that archipelago.

Photographs used to illustrate the fossils were prepared by Mr. Maurice Giles, Photographer, California Academy of Sciences. Margaret M. Hanna kindly retouched some of the photographs. The manuscript was typed by Enid Cook.

One new subspecies, *Diplodonta subquadrata baltrana*, is described in the present paper.

GENERAL REMARKS

Darwin visited the Galápagos Islands during the voyage of the *Beagle* in 1835. He mentioned (1844, p. 115; see ed. 3, 1896, p. 130) sea shells belonging to modern genera, apparently on Chatham Island, "embedded several hundred feet above the sea, in the tuff of two craters, distant from each other." Later Wolf (1895, pp. 250, 254, 265) reported the occurrence of fossil shells in the islands in palagonite tuff at a height of 100 meters above sea level.

W. H. Ochsner, during an expedition of the California Academy of Sciences to the Galápagos Islands on the schooner *Academy*, spent most of one year in the islands and discovered fossils on Isabela (Albemarle), Santa Cruz (Indefatigable), and Baltra (South Seymour) islands. On this expedition Ochsner collected the fossils of Pliocene age on Baltra (South Seymour) Island mentioned by Dall (1924) and later reported upon by Dall and Ochsner (1927, see especially pp. 94–99). They listed 28 species (and four others identified only as to genus) from beds believed to be of Pliocene age, 24 species from the "upper zone" and 4 in the "lower zone". Chesterman (1963, p. 344) reported on rocks of the Galápagos Islands and mentioned fossiliferous limestone and "fossiliferous tuffaceous sandstone" on Baltra (South Seymour), collected by Ochsner. He also described a specimen of andesite from the south end of the island.

Baltra Island is composed chiefly of lava and other pyroclastic material with very minor amounts of intercalated limestone and fossiliferous tuffaceous beds.

This island experienced faulting in comparatively recent time, the lines of fracture trending approximately east-northeast. This faulting resulted in alternating raised and depressed blocks. A depressed block separates Baltra (South Seymour) from Santa Cruz (Indefatigable) Island and a similar depressed block separates Baltra from Seymour (North Seymour) Island. Lewis (1956, p 290) remarked on the relatively recent faulting as did Williams (1966, pp. 55–70) who discussed the general geology of the Galápagos Islands. More recently, McBirney and Williams (1969, pp. 17–20, fig. 7) discussed the geology and petrology of Baltra, as well as that of other islands in the archipelago.

The fossil-bearing bed on the south end of the bay on the west side of the island is about 3 meters (10 feet) thick and dips about 5° or 6° south. Large angular blocks of lava in the lower portion of the bed offer evidence of deposition very near the shore.

The majority of the species in the present list were taken from the tuffaceous ashy bed. A number of small specimens were obtained by passing some of the white ashy material through a sieve.

COLLECTING STATIONS

Locality 1305 (CAS), cliff on southwest side of Baltra (South Seymour) Island, Galápagos Islands. Joseph R. Slevin collector, December 16, 1927. Pliocene.

Locality 27249 (CAS), white and yellowish tuffaceous strata interbedded with lava on the south side of the bay on the west side of Baltra (South Seymour) Island, Galápagos Islands. Leo G. Hertlein collector, January 16–18, 1932. Pliocene.

Locality 27251 (CAS), strata about 1.5 meters (5 feet) thick on the northern side of the bay, about the middle of the west side of the island, near the top of the plateau, Baltra (South Seymour) Island, Galápagos Islands. Leo G. Hertlein collector, January 14–15, 1932. Pliocene.

Locality 31838 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Fossils received by Dr. A. Myra Keen who presented them to the California Academy of Sciences, March 22, 1943.

LIST OF FOSSILS FROM BALTRA (SOUTH SEYMOUR) ISLAND*

An asterisk * indicates that the species is extinct.

COELENTERATA

Pavona gigantea Verrill
Psammocora (Stephanaria), species indeterminate

ECHINOIDEA

Encope micropora galapagana H. L. Clark, locs. 1305[1]; 27249 (CAS)
Eucidaris thouarsii Valenciennes, loc. 1305 (CAS)

PELECYPODA

Anatina (Raëta) undulata Gould, loc. 31838 (CAS)
* *Anodontia spherica* Dall and Ochsner, locs. 1305; 27251 (CAS)
Anomia peruviana d'Orbigny, loc. 27249 (CAS)

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[1] Reported from this locality as *Encope micropora* L. Agassiz by Grant and Hertlein (Publ. Univ. Calif. Los Angeles Math. Phys. Sci., vol. 2, p. 98, 1938).

Arca pacifica Sowerby, loc. 1305 (CAS)
Arca (*Arcopsis*) *solida* Broderip and Sowerby, loc. 27249 (CAS)
Atrina cf. *A. tuberculosa* Sowerby, loc. 27249 (CAS)
Barbatia reeveana d'Orbigny, loc. 27249 (CAS)
Cardium elenense Sowerby, loc. 27249 (CAS)
Chama species, loc. 1305 (CAS)
Chione undatella Sowerby, loc. 27249; (cf.) 31838 (CAS)
Chione species, loc. 1305 (CAS)
Chlamys (*Argopecten*) *circularis* Sowerby, loc. 27249 (CAS)
Chlamys (*Nodipecten*) *magnifica* Sowerby, loc. 27249 (CAS)
Ctena galapagana Dall, locs. 1305; 27249 (CAS)
Cuminga cf. *C. lamellosa* Sowerby, loc. 27249 (CAS)
Diplodonta subquadrata baltrana Hertlein, new subspecies, loc. 27249 (CAS)
Florimetis cognata Pilsbry and Vanatta, loc. 27249 (CAS)
Glycymeris maculata Broderip, loc. 27249 (CAS)
Megapitaria cf. *M. aurantiaca* Sowerby, loc. 27249 (CAS)
Megapitaria squalida Sowerby, loc. 31838 (CAS)
Modiolus capax Conrad, loc. 27249 (CAS)
Nioche cf. *N. zorritensis* Olsson, loc. 27249 (CAS)
Ostrea megodon Hanley, loc. 27249 (CAS)
Ostrea palmula Carpenter, loc. 1305 (CAS)
Ostrea species, loc. 27249 (CAS)
* *Pecten* (*Pecten*) *slevini* Dall and Ochsner, loc. 27249 (CAS)
Protothaca (*Tropithaca*) *grata* Say, locs. 27249; 31838 (CAS)
* *Protothaca* (*Tropithaca*) cf. *P.* (*T.*) *seymourensis* Dall and Ochsner, loc. 27249 (CAS)
Tagelus cf. *T. dombeii* Lamarck, loc. 27251 (CAS) (cast)
Tagelus species, locs. 27249; 31838 (CAS)

GASTROPODA

Acanthina grandis Gray, loc. 1305 (CAS)
Acteocina infrequens C. B. Adams, loc. 27249 (CAS)
Alaba supralirata Carpenter, loc. 27249 (CAS)
Alvania cf. *A. galapagensis* Bartsch, loc. 27249(CAS)
Alvania cf. *A. halia* Bartsch, loc. 27249 (CAS)
Alvania cf. *A. hoodensis* Bartsch, loc. 27249 (CAS)
Alvania cf. *A. nemo* Bartsch, loc. 27249 (CAS)
Amphithalmus trosti Strong and Hertlein, loc. 27249 (CAS)
Anachis cf. *A. tabogaensis* Bartsch, loc. 27249 (CAS)
Balcis cf. *B. berryi* Bartsch, loc. 27249 (CAS)
Bulla punctulata A. Adams in Sowerby, locs. 27249; 31838 (CAS)
Cancellaria cf. *C. ovata* Sowerby, loc. 27249 (CAS)
Cantharus janellii Kiener, locs. 1305; 27249 (CAS)
* *Cantharus* cf. *C. scissus* Olsson, loc. 27249 (CAS)
Cerithiopsis curtata Bartsch, loc. 27249 (CAS)
Cerithiopsis cf. *C. galapagensis* Bartsch, loc. 27249 (CAS)
Cerithium adustum Kiener, locs. 1305; 27249 (CAS)
Cheila equestris Linnaeus, loc. 27249 (CAS)
Conus fergusoni Sowerby, loc. 27249 (CAS)
Conus cf. *C. lucidus* Wood, loc. 27249 (CAS)

Cylichna cf. *C. defuncta* Baker and Hanna, loc. 27249 (CAS)
Cymatium lineatum Broderip, loc. 1305 (CAS)
Cypraea nigropunctata Gray, locs. 1305; 27249 (CAS)
Cytharella camarina Dall, loc. 27249 (CAS)
Diodora alta C. B. Adams, loc. 27249 (CAS)
Engina pyrostoma Sowerby, loc. 27249 (CAS)
Erato (*Hespererato*) *marginata galapagensis* Schilder, loc. 27249 (CAS)
Eulimostraca cf. *E. galapagensis* Bartsch, loc. 27249 (CAS)
Fissurella cf. *F. macrotrema* Sowerby, loc. 27249 (CAS)
Fissurella virescens Sowerby, loc. 27249 (CAS)
Fusinus dupetitthouarsii Valenciennes, loc. 27249 (CAS)
Gastrocopta munita Reibisch, loc. 27249 (CAS) [a land snail]
Granula cf. *G. minor* C. B. Adams, loc. 27249 (CAS)
Granula cf. *G. polita* Carpenter, loc. 27249 (CAS)
Granula species, loc. 27249 (CAS)
Granulina margaritula Carpenter, loc. 27249 (CAS)
Hipponix pilosus Deshayes, locs. 1305; 27249 (CAS)
Hipponix pilosus Deshayes, loc. 1305; 27249 (CAS)
Iselica cf. *I. kochi* Strong and Hertlein, loc. 27249 (CAS)
Malea ringens Swainson, loc. 1305 (CAS)
* *Mangelia* cf. *M. hancocki* Hertlein and Strong, loc. 27249 (CAS)
Mitra gausapata Reeve, loc. 1305 (CAS)
Mitra lens Mawe, loc. 1305 (CAS)
Modulus cerodes A. Adams, loc. 27249 (CAS)
Nassarius nodicinctus A. Adams, loc. 27249 (CAS)
* *Nerita oligopleura* Dall and Ochsner, loc. 27249 (CAS)
Odostomia (*Menestho*) *aequisculpta* Carpenter, loc. 27249 (CAS)
Odostomia (*Miralda*) *galapagensis* Dall and Bartsch, loc. 27249 (CAS)
Odostomia (*Chrysallida*) *rinella* Dall and Bartsch, loc. 27249 (CAS)
Oliva species, locs. 27249; 31838 (CAS)
Pedipes angulatus C. B. Adams, loc. 27249 (CAS)
Persicula imbricata Hinds, loc. 27249 (CAS)
Persicula cf. *P. phrygia* Dall, loc. 27249 (CAS)
Persicula species, loc. 27249 (CAS)
Polinices dubius Récluz, loc. 27249 (CAS)
Polinices uber Valenciennes, loc. 27249 (CAS)
Pyramidella (*Triptychus*) cf. *P.* (*T.*) *olssoni* Bartsch, loc. 27249 (CAS)
Pyramidella (*Voluspa*) species, loc. 27249 (CAS)
Pyrene castanea Sowerby, locs. 1305; 31838 (CAS)
Pyrene fuscata Sowerby, loc. 27249 (CAS)
Pyrene haemastoma Sowerby, loc. 27249 (CAS)
Rissoina cf. *R. firmata* C. B. Adams, loc. 27249 (CAS)
Rissoina signae Bartsch, loc. 27249 (CAS)
Strombina gibberula Sowerby, loc. 27249 (CAS)
Tectarius galapagensis Stearns, loc. 27249 (CAS)
* *Tegula forbesi* Dall and Ochsner, loc. 27249 (CAS)
Tegula snodgrassi Pilsbry and Vanatta, locs. 1305; 27249 (CAS)
Triphora cf. *T. galapagensis* Bartsch, loc. 27249 (CAS)
Triphora cf. *T. panamensis* Bartsch, loc. 27249 (CAS)

Trivia pacifica Gray, loc. 27249 (CAS)
Trivia radians Lamarck, loc. 27249 (CAS)
Turbo agonistes Dall and Ochsner, loc. 27249 (CAS)
* *Turbo vermiculosus* Dall and Ochsner, locs. 27249; 31838 (CAS)
Turbonilla (*Chemnitzia*) *houseri* Dall and Bartsch, loc. 27249 (CAS)
Turritella broderipiana marmorata Kiener, loc. 27249 (CAS)
Vermicularia eburnea Reeve, loc. 27249 (CAS)
Volvarina taeniolata Mörch, loc. 27249 (CAS)

Remarks on the Age and Relationships of the Fauna

This list contains 102 identified species, 1 coral, 2 echinoids, 26 pelecypods, and 73 gastropods. Of these, 7, and probably 8, are extinct. Twenty-eight species are only provisionally identified but are compared with known species. In addition to the 102 species, 8 forms are identified only as to genus.

The percentage of extinct species in the present faunal assemblage is approximately 7.8 percent. However, a greater number of extinct species evidently occur at the present locality as Dall and Ochsner described additional extinct species from apparently the same locality. They also described a number of extinct species from what they believed to be approximately correlative strata on Santa Cruz (Indefatigable) Island. Dall and Ochsner considered the age of the fauna which they reported from those two islands to be of probable Pliocene age. Five of the eight extinct species in the present faunal list have not been reported from fossil assemblages of Pleistocene age from either Isabela (Albemarle) or from San Salvador (James) Island. Furthermore, the occurrence of the fossils in ashy beds (which in some places are decidedly indurated), interbedded with volcanic flows, lends support to the viewpoint that these beds are of Pliocene rather than of Pleistocene age. McBirney and Williams (1969, p. 19) mentioned two lavas on Baltra Island reported to be 1.47 million years old.

Another factor contributing to the belief that the present fauna is of Pliocene age is the fact that *Anodontia spherica* Dall and Ochsner (reported from strata of Pliocene age in the Galápagos Islands) was reported by Pilsbry and Olsson (1941, p. 57) to occur abundantly and to be a characteristic species of their "Zone H" in strata referred to Pliocene age at Punta Blanca, Ecuador. Ten species in the present faunal list were included among those reported from that locality.

Most of the Recent species in this assemblage are known living in Galápagos waters. Those not known from there are chiefly elements of the Panamic fauna, but further collecting may reveal their presence in the Galápagos Archipelago. A consideration of the habitat of the Recent species in this fauna leads one to infer that the fossil forms lived under conditions similar to those now prevailing in the Galápagos Islands, namely, warm, shallow water.

An interesting occurrence among the fossil forms is that of a land snail, *Gastrocopta munita* Reibisch. This species now lives on Baltra (South Seymour) Island (Hertlein, 1932b, p. 69) as well as on most of the other larger islands in the Archipelago.

SYSTEMATIC PALEONTOLOGY

Pelecypoda

Chlamys (Nodipecten) magnifica Sowerby.
(Figures 5, 15, 25.)

Pecten magnificus Sowerby, variety *a*, Proc. Zool. Soc. London for 1835, p. 109, issued October 9, 1835. "Hab ad Insulas Gallapagos." "A single specimen of var. *a* was found in a coral sand at a depth of six fathoms." Sowerby, Thes. Conch., vol. 1, p. 65, pl. 15 (*Pecten*, pl. 5), fig. 114, 1842. "East Columbia." [lapsus calami for West "Columbia." Locality doubtful.] Reeve, Conch. Icon., vol. 8, *Pecten*, species 9, pl. 2, fig. 9, 1852. "Isle of Plata, West Columbia (in coral sand at a depth of from six to seventeen fathoms); Cuming." [Locality doubtful.] Kobelt, Syst. Conch.—Cab. von Martini und Chemnitz, *Spondylus* und *Pecten*, Bd. 7, Abt. 2, p. 164, pl. 46, fig. 1, 1888. (Description and illustration from Reeve.)

Pecten (*Lyropecten*) *magnificus* Sowerby, Grant and Gale, Mem. San Diego Soc. Nat. Hist., vol. 1, p. 182, pl. 9, fig. 1; pl. 10, fig. 6, 1931. Galápagos Islands.

Nodipecten magnificus Sowerby, Grau, Allan Hancock Pac. Exped., vol. 23, p. 132, pl. 44, 1959. "Galápagos Islands. (Ecuador doubtful.)"

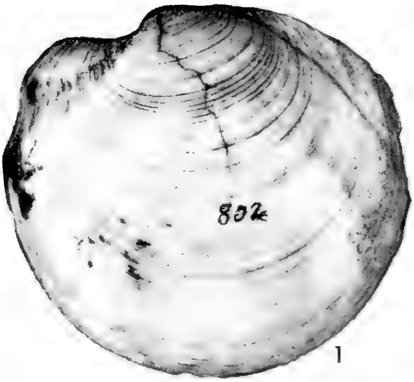
Lyropecten (*Nodipecten*) *magnificus* Sowerby, Olsson, Mollusks of the Tropical Eastern Pacific (Paleo. Res. Inst.: Ithaca, New York), p. 161, pl. 22, fig. 1, 1961. (Illustration from Reeve, 1852).

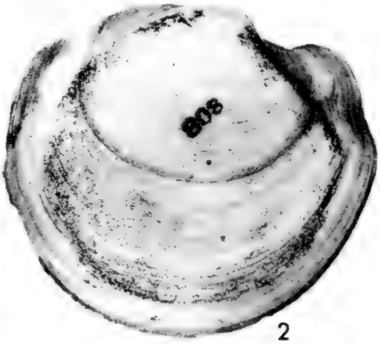
Two left valves, one nearly complete, the other only one half of a valve were collected at locality 27249 (CAS). The larger specimen is 126 mm. long and 122.3 mm. high. There are 13 or 14 radial ribs. The entire valve is covered with radial striae of which about 5 or 6 occur in each interspace. The ribs are decidedly nodose. The nodes are hollow and develop in the areas of "ledges" (Moore, 1934, p. 216) between concentric constrictions of the valve. The nodosity on the east American species, *Chlamys* (*Nodipecten*) *nodosa* Linnaeus, increases from north to south in its range into warmer waters.

A small left valve of *C. magnifica* 49 mm. high, was reported by Hertlein and Strong (1939, p. 369) from a raised beach on San Salvador (James) Island.

Two Recent right valves in the collections of the California Academy of Sciences, the larger one 127 mm. high, were collected by Ochsner on the beach at Baltra (South Seymour) Island. These are devoid of nodes. The color is bright red.

One right valve 59.8 mm. long and 60 mm. high, in the Academy's collection, received from Jacqueline De Roy, was dredged in 9 to 18 meters (5 to 10 fathoms) off Santa Fé (Barrington) Island.





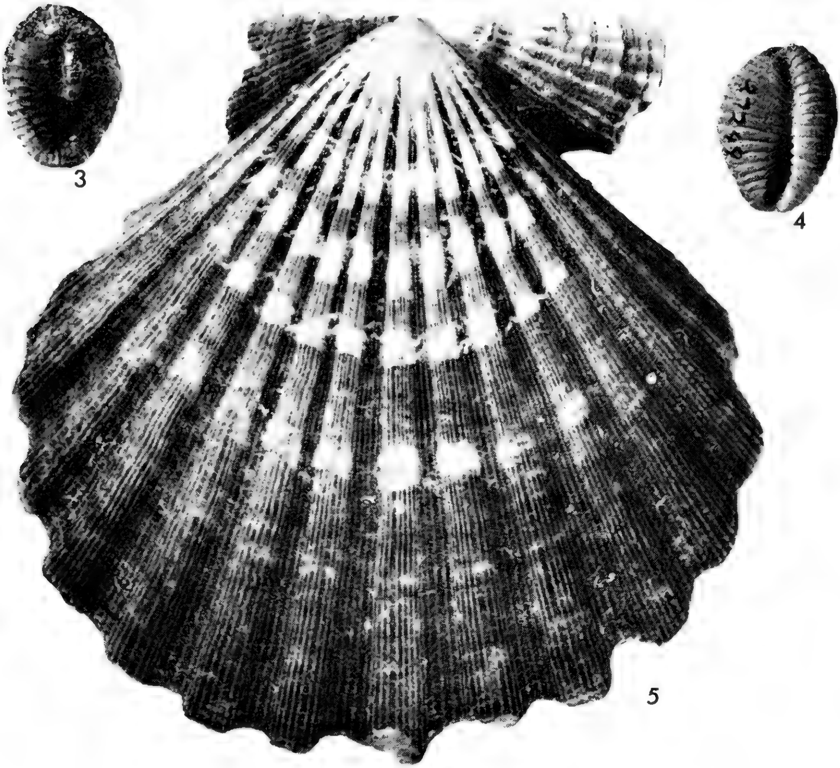


FIGURE 1. *Anodontia spherica* Dall and Ochsner. Hypotype, left valve, no. 13653 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 802 (CAS), about 1¼ miles northeast of the settlement of Vilamil, Isabela (Albemarle) Island, Galápagos Islands, elevated beach deposit, about 12 meters (40 feet) above sea level. Pleistocene. Length 65 mm. FIGURE 2. *Anodontia spherica* Dall and Ochsner. Hypotype, right valve, no. 13654 (Calif Acad. Sci. Dept. Geol. Type Coll.), from locality 803 (CAS), from virtually the same locality as the

Anodontia spherica Dall and Ochsner.
(Figures 1, 2, 6, 7.)

Lucina spherica Dall and Ochsner, Proc. Calif. Acad. Sci., Fourth Ser., vol. 17, no. 4, p. 121, pl. 3, fig. 8; pl. 4, figs. 2, 7, June 22, 1928; "from upper horizon (zone D) on east shore of Indefatigable Island, Galapagos Group. Probably Pliocene."

Loripinus (*Pegophysema*) *spherica* Dall and Ochsner, Pilsbry and Olsson, Proc. Acad. Nat. Sci. Philadelphia, vol. 93, p. 57, 1941. Pliocene of Punta Blanca, Ecuador.

Anodontia (*Lissosphaira*) *spherica* Dall and Ochsner, Olsson, Mollusks of the tropical eastern Pacific (Paleo. Research Inst.: Ithaca, New York), p. 222, pl. 30, fig. 2, 1961. (Figured specimen from Cabo Blanca, Ecuador, Pliocene. Reported as Recent from "Lower California to Ecuador. Columbia: Isla del Gallo.") Also earlier records.

Specimens assigned to this species in the present collection [locs. 1305 and 27251 (CAS)] are casts. Olsson reported this species living from Baja California to Ecuador but it has not been reported from the Panamic Province by other authors. I have not seen Recent specimens.

The deeply depressed posterior dorsal area on *Anodontia spherica* easily serves to separate it from *A. edentuloides* from the Gulf of California. The presence of well differentiated, deeply impressed, dorsal areas was the basis for the proposal of the subgenus *Lissophaira* Olsson.

Large specimens of *A. spherica* are 74 mm. long. Berry (1968, p. 71) mentioned specimens of *A. edentuloides* which are 75 mm. long.

Marks (1951, pp. 67–70), discussed the shell characters of *Anodontia* and *Pegophysema*, and some of the species referred to those groups. Apparently, the species cited by Marks (p. 69) as "*C. densata*" Dall and Ochsner is referable to *A. spherica*.

A large globose species, 82 mm. long, *Anodota sphericula* Basedow, was reported by Ludbrook (1959, p. 227, pl. 3, figs. 1, 2, 3; pl. 5, figs. 1, 4) from strata of Pliocene age in Australia. The posterior dorsal portion of the shell of that species lacks a depressed area: it is a typical *Anodontia* believed to be related to *A. philippiana* Reeve in the western Pacific.

Diplodonta subquadrata baltrana Hertlein, new subspecies.
(Figures 8 and 11.)

Description. Shell subquadrate, somewhat anteriorly attenuated, thin, beaks very low, anterior dorsal margin only slightly sloping; sculptured only

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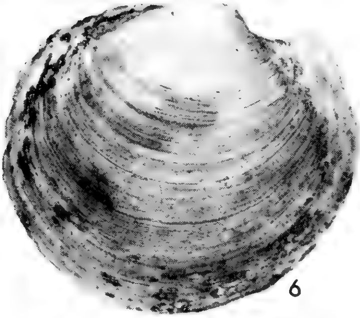
specimen shown in figure 1. Length 58 mm. Figure 3. *Trivia radians* Lamarck. Hypotype no. 13668 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Length 18 mm. Figure 4. *Trivia radians* Lamarck. Ventral view of the specimen shown in figure 3. Figure 5. *Chlamys* (*Nodipecten*) *magnifica* Sowerby. Hypotype, right valve, no. 13652 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 23167 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Recent. W. H. Ochsner Collector. Height 85 mm.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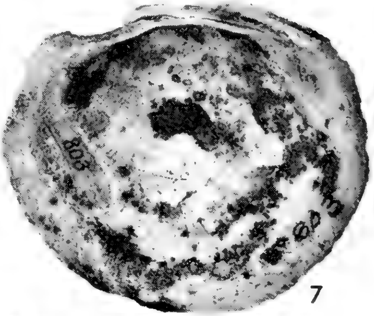

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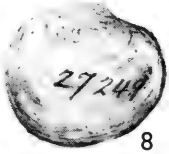

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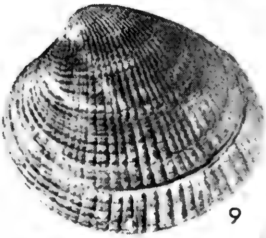
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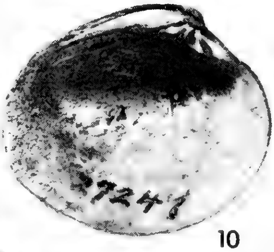

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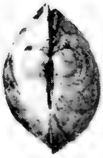
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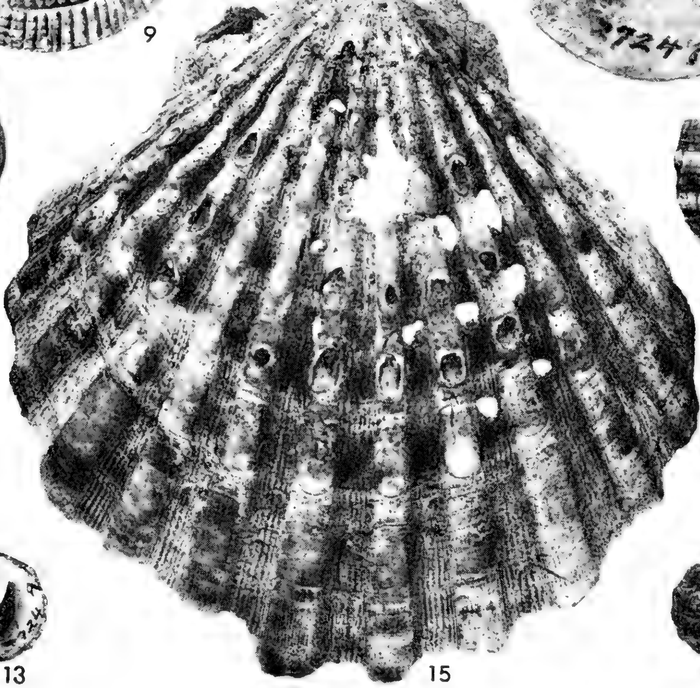
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FIGURE 6. *Anodontia spherica* Dall and Ochsner. Hypotype, right valve, no 13655 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 803 (CAS), about 1¼ miles northeast of the settlement of Vilamil, Isabela (Albemarle) Island, Galápagos Islands, elevated beach deposit, about 12 meters (40 feet) above sea level. Pleistocene. Length 54.5 mm. FIGURE 7. *Anodontia spherica* Dall and Ochsner. View of the interior of the specimen shown in figure

with fine concentric lines of growth. Dimensions: length 22.6 mm., height 20 mm., convexity (both valves) 14.6 mm.

Holotype, no. 13656, and paratype, a left valve, no. 13657 (California Academy of Sciences Department of Geology Type Collection), from locality 27249 (CAS), white and yellowish tuffaceous strata interbedded with lava, on the south side of the bay on the west side of Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. L. G. Hertlein, collector.

COMMENTS. Specimens of this new subspecies, in general features, resemble fossil forms of *Diplodonta subquadrata* Carpenter (see illustrations by Durham, 1950, pl. 19, figures 4, 4a, 1950) from Santa Inez Bay, Baja California, Mexico. The present fossils from Baltra Island differ from Carpenter's species in the narrower, somewhat attenuated anterior end and in the more nearly horizontal anterior dorsal margin. The general shape of the type specimen of the new subspecies resembles that of the Recent specimen of *D. subquadrata* from the Galápagos Islands illustrated by Hertlein and Strong (1947, plate 1, figure 11), more than it does that of the fossils illustrated by Durham.

The paratype, 21.2 mm. long, is less attenuated anteriorly than the holotype. An imperfectly preserved right valve also was collected at the type locality.

Protothaca (Tropithaca) cf. **P. (T.) seymourensis** Dall and Ochsner.
(Figures 38, 39.)

Twenty-one single valves of a venerid varying from 11 mm. to 39.4 mm. in length are present in the collection from locality 27249 (CAS), Baltra (South Seymour) Island. These vary greatly in shape and sculpture.

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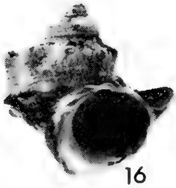
6. FIGURE 8. *Diplodonta subquadrata baltrana* Hertlein, new subspecies. Holotype no. 13656 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Length 22.5 mm. FIGURE 9. *Nioche* cf. *N. zorritensis* Olsson. Hypotype, left valve, no. 13658 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Length 39.5 mm. FIGURE 10. *Nioche* cf. *N. zorritensis* Olsson. View of the interior of the specimen shown in figure 9. FIGURE 11. *Diplodonta subquadrata baltrana* Hertlein, new subspecies. Dorsal view of the specimen shown in figure 8. FIGURE 12. *Nerita oligopleura* Dall and Ochsner. Hypotype no. 13666 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height 14.5 mm. View showing fine threadlets between major concentric cords. FIGURE 13. *Nerita oligopleura* Dall and Ochsner. Hypotype no. 13667 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from the same locality as the specimen illustrated in figure 12. Apertural view. Height 17.5 mm. FIGURE 14. *Nerita oligopleura* Dall and Ochsner. Dorsal view of the specimen shown in figure 13. FIGURE 15. *Chlamys* (*Nodipecten*) *magnifica* Sowerby. Hypotype, left valve, no. 13676 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height 128 mm.



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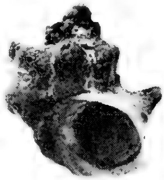

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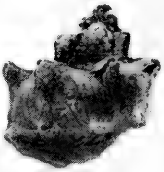

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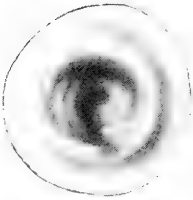

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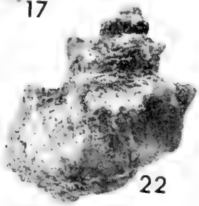

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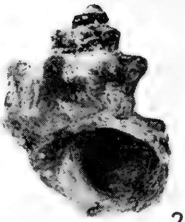

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Figure 16. *Turbo agonistes* Dall and Ochsner. Hypotype no. 13671 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 38977 (CAS), Baranco, Punta Nuñez, Santa Cruz (Indefatigable) Island, Galápagos Islands. Recent. Jacqueline DeRoy collector. Height 21 mm. Figure 17. *Turbo agonistes* Dall and Ochsner. Dorsal view of the specimens shown in figure 16. Figure 18. *Turbo agonistes* Dall and Ochsner. Hypotype no. 13672 (Calif.

One small specimen in the present series is quite similar in outline and sculpture to the early stage of growth of the type specimen of *Chione seymourensis* Dall and Ochsner from the same area.

The type specimen of *Chione seymourensis* Dall and Ochsner (1928, p. 123, pl. 3, figs. 1 and 5) was described "from upper horizon, Seymour Island, Galapagos Group. Probably Pliocene." It is a right valve, ovately rectangular in outline (see figs. 36, 37), lacks an escutcheon, and the radial sculpture is somewhat reduced in strength as a result of erosion. Dall and Ochsner mentioned a similarity between their species and *Chione pertincta* Dall, a Recent species living in the Galápagos Islands. Compared with *C. pertincta*, the type specimen of *C. seymourensis* is in general, more elongated, thinner, and it has finer radial sculpture.

Compared with *Protothaca grata* Say, the type specimen of *C. seymourensis* is more elongate in outline, the radial sculpture is coarser, the lunule is narrower, and the median cardinal tooth in the right valve is larger.

The variation in shape and sculpture in the present series of specimens is similar to that in a series of Recent specimens of *Protothaca grata* Say (the type species of the subgenus *Tropithaca* Olsson), and most of them are here referred to Say's species.

GASTROPODA

Tegula forbesi Dall and Ochsner.

(Figures 24, 29.)

Tegula forbesi Dall and Ochsner, Proc. Calif. Acad. Sci., Fourth Ser., vol. 17, no. 4, p. 116, pl. 2, fig. 13, June 22, 1928; "from upper horizon on Seymour Island, Galapagos Group. Probably Pliocene."

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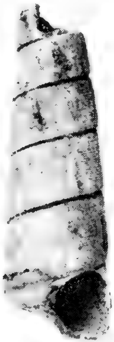
Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height 28.5 mm. Figure 19. *Turbo agonistes* Dall and Ochsner. Dorsal view of the specimen shown in figure 18. Figure 20. *Turbo agonistes* Dall and Ochsner. View of the exterior of the operculum of the specimen shown in figures 16 and 17. Figure 21. *Turbo agonistes* Dall and Ochsner. View of the interior side of the operculum shown in figure 20. Figure 22. *Turbo agonistes* Dall and Ochsner. Hypotype no. 13673 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from the same locality as the specimen shown in Figures 18 and 19. Height 33 mm. Dorsal view of an unusually large specimen. Figure 23. *Turbo agonistes* Dall and Ochsner. Apertural view of the specimen shown in figure 22. Figure 24. *Tegula forbesi* Dall and Ochsner. Hypotype no. 13660 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Galápagos Islands. Late Pliocene. Height 26 mm. Figure 25. *Chlamys (Nodipecten) magnifica* Sowerby. Hypotype no. 13652 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 23167 (CAS), Baltra (South Seymour) Island, Galápagos Islands. W. H. Ochsner Collector. Recent. Height 85 mm. View of the interior of the specimen shown in figure 5.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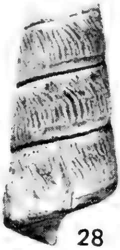
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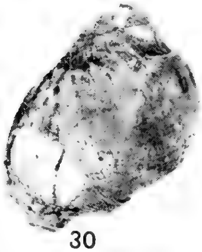
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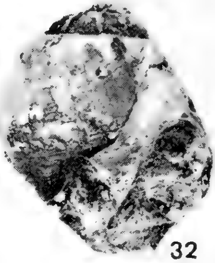
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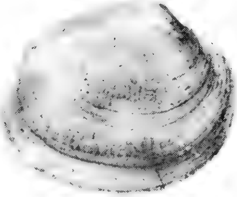
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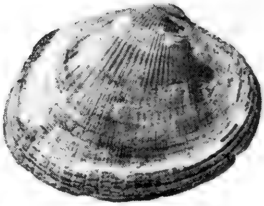
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FIGURE 26. *Turritella broderipiana marmorata* Kiener. Hypotype no. 13669 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height (incomplete) 53 mm. FIGURE 27. *Turritella broderipiana marmorata* Kiener. Dorsal view of the specimen shown in figure 26. FIGURE 28. *Turritella broderipiana marmorata* Kiener. Hypotype no. 13670 (Calif. Acad. Sci. Dept.

A few specimens of this species were collected at locality 27249 (CAS). The largest specimen is about 31 mm. in height, the last whorl is 48 mm. in maximum width. The concentric sculpture is much finer than that of *Tegula aureotincta* Forbes from California. This sculpture is more pronounced and regular on the upper surface of the whorls, and on the base much coarser, than that on specimens of *T. rugosa* A. Adams from the Gulf of California.

Turbo agonistes Dall and Ochsner.

(Figures 16, 17, 18, 19, 20, 21, 22, 23.)

Turbo agonistes DALL AND OCHSNER, Proc. Calif. Acad. Sci., Fourth Ser., vol. 17, no. 4, p. 115, pl. 2, figs. 12, 16, June 22, 1928; "on east shore of Indefatigable Island, Galapagos Group. Probably Pliocene."

A number of fossil specimens of this species were collected at locality 27249 (CAS). The shell of this species is quite different from any other described form.

Recently this species was found living in Galápagos waters. Four specimens from off Santa Cruz (Indefatigable) Island collected by Jacqueline De Roy; and one taken by Carmen Angermeyer 1½ miles west of Baltra (South Seymour) Island, were presented to the Academy. Recent shells are attractively colored, purplish on the base of the body whorl and orange or greenish above.

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Geol. Type Coll.), from the same locality as the specimen shown in figures 26 and 27. Height (incomplete) 40 mm. FIGURE 29. *Tegula forbesi* Dall and Ochsner. Hypotype no. 13660 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Width 24 mm. Basal view of the specimen shown in figure 24. FIGURE 30. *Polinices dubius* Récluz. Hypotype no. 13662 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height 37.5 mm. FIGURE 31. *Polinices dubius* Récluz. Apertural view of the specimen shown in figure 30. FIGURE 32. *Polinices dubius* Récluz. Hypotype no. 13663 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 804 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height 40.5 mm. FIGURE 33. *Polinices dubius* Récluz. Hypotype no. 13664 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from the same locality as the specimen shown in figure 32. Height 39.4 mm. Apertural view. FIGURE 34. *Polinices dubius* Récluz. Apertural view of the specimen shown in figure 33, showing notch in callus of inner lip. FIGURE 35. *Turbo vermiculosus* Dall and Ochsner. Hypotype no. 13661 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Height 34.6 mm. FIGURE 36. *Chione seymourensis* Dall and Ochsner. Holotype, right valve, no. 2970 (Calif. Acad. Sci. Dept. Geol. Type Coll.), "from upper horizon, Seymour Island, Galapagos Group Probably Pliocene." Length 34 mm. FIGURE 37. *Chione seymourensis* Dall and Ochsner. View of the hinge of the specimen shown in figure 36. FIGURE 38. *Protothaca* (*Tropithaca*) cf. *P.* (*T.*) *seymourensis* Dall and Ochsner. Hypotype, right valve, no. 13659 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from locality 27249 (CAS), Baltra (South Seymour) Island, Galápagos Islands. Late Pliocene. Length 21 mm. FIGURE 39. *Protothaca* (*Tropithaca*) cf. *P.* (*T.*) *seymourensis* Dall and Ochsner. View of the hinge of the specimen shown in figure 38.

Turbo vermiculosus Dall and Ochsner.

(Figure 35.)

Turbo vermiculosus DALL AND OCHSNER, Proc. Calif. Acad. Sci., Fourth Ser., vol. 17, no. 4, p. 115, pl. 2, fig. 15, June 22, 1928; "from upper horizon, Seymour Island, Galapagos Group. Probably Pliocene."

Three specimens of this species, none perfectly preserved, are present from locality 27249 (CAS), Baltra (South Seymour) Island. The largest specimen (figure 35) is 34.8 mm. high, the maximum diameter 23 mm.

This species has an unusually high spire for the genus. The surface microsculpture "minutely vermiculately granulose and punctate," as mentioned by Dall and Ochsner, is quite different from any described species of *Turbo* from the western Americas.

The shape and sculpture of the present species somewhat resemble that of *Turbo caboblanquensis* Weisbord (1962, p. 84, pl. 6, figs. 4, 5) described from strata of Pliocene age in Venezuela but the shell of that species is umbilicate.

Polinices dubius Récluz.

(Figures 30, 31, 32, 33, 34.)

Natica dubia RÉCLUZ, Proc. Zool. Soc. London for 1843, p. 209, issued June, 1844 "Hab. Chile? H. Cuming." SOWERBY, Thes. Conch., vol. 5, p. 86, pl. 458 (*Natica*, pl. 5), fig. 56, 1883. "Chili." REEVE, Conch. Icon., vol. 9, *Natica*, species 41, pl. 10, figs. 41a, 41b, 1855. "Hab. Chili?" TRYON, Man. Conch., vol. 8, p. 47, pl. 16, fig. 50, 1886. "Chili, Peru."

Polynices dubia Récluz, STEARNS, Proc. U. S. Nat. Mus., vol. 16, no. 942, pp. 401, 446, 1893. "Indefatigable Island."

One fairly well preserved specimen and four rather imperfect ones were collected at locality 27249 (CAS). These specimens agree exactly with the specimens identified by Dall and Ochsner under the name "*Neverita* cf. *reclusiana* Deshayes" (see figs. 32, 33, 34), from locality 804 (CAS). That locality is approximately equivalent to locality 27249 (CAS).

One of the specimens from locality 804 (CAS) retains most of the umbilical pad. The shape of the shell as well as the details of the callus agree closely with illustrations of *Polinices dubius*, a species reported by Stearns from the Recent fauna of the Galápagos Islands. Ranson (1959, p. 68) reported this species from an elevated beach at Guadalupito, Peru.

The general shape of the Galápagos fossils is similar to that of the fossil species described as "*Natica solida*" by Sowerby (1846, p. 255; see ed. 3, 1896, p. 612, pl. 3, figs. 40, 41.) from "Navidad, Chile; Santa Cruz, Patagonia?" [Miocene: Herm, 1969, p. 87] but the callus on the Galápagos species is much more extensive and with an indentation on the umbilical margin. Sowerby's species was renamed *Natica darwinii* by Hutton (1886a, p. 334; see also 1886b, p. 214) because of an earlier usage of the name *Natica solida* by Blainville (1825, p. 251).

Nerita oligopleura Dall and Ochsner.
(Figures 12, 13, 14.)

Nerita oligopleura Dall and Ochsner, Proc. Calif. Acad. Sci., Fourth Ser., vol. 17, no. 4, p. 114, pl. 2, fig. 11; pl. 6, fig. 15, June 22; "upper horizon, Seymour Island, Galapagos Group. Probably Pliocene."

About 30 specimens of this species were collected at locality 27249 (CAS). The smallest one is 6 mm. high, the largest one 20.5 mm. high and 21 mm. wide.

There are four coarse spiral ridges on the shell and, on well preserved specimens, two small spiral threads are visible in the interspaces between the ribs.

The shell of this species is quite different from any described west American species, as pointed out by Dall and Ochsner. The Galápagos fossil species bears a general resemblance to *Nerita asperata* Dujardin from the Helvetian, Middle Miocene, of France, illustrated by Cossmann and Peyrot (1917, pl. 7, figures 83, 84). However, close relationship with that species is not postulated.

Turritella broderipiana marmorata Kiener.
(Figures 26, 27, 28.)

Turritella marmorata Kiener, Spéc. Gén. et Icon. Coq. Viv., Famille Turbinacées, *Turritella*, p. 23, pl. 8, fig. 1 (two figs.), 1843–1844. "Habite."

Over a dozen specimens of a *Turritella*, mostly incomplete, were collected at locality 27249 (CAS). These agree closely with Kiener's illustrations of *Turritella marmorata*.

Kiener's figures depict a rather slender, elongated shell, the whorls nearly flat-sided, sculptured with fine, concentric threads, cream-colored with narrow wavy longitudinal brownish-violet lines or flecks.

Reeve (1849, species 6, plate 2, figures 6a, 6b) placed *T. marmorata* in the synonymy of *T. broderipiana* under which name two figures were shown. One (6a) represents a shell with fairly wide whorls, somewhat wider posteriorly below the suture, resulting in a slightly sinuous outline of the outer lip of the last whorl. The form shown in this illustration is similar to *T. gonostoma* Valenciennes. The other figure (6b) represents a slender, elongated shell with nearly flat-sided whorls comparable to Kiener's illustrations of *T. marmorata*.

Turritella broderipiana d'Orbigny (1840, p. 388), was originally described but not illustrated from "les environs de Payta, où elle a été pêchée sur les fonds de sable." The type specimen illustrated by Keen (1966, p. 3, pl. 1, fig. 21) reveals a slender, elongated shell with slightly concave whorls. Earlier, Keen (1958, p. 290) considered *T. marmorata* to be a variant of the extremely variable *T. gonostoma* Valenciennes (1832, p. 275; Kiener, 1843–1844, pp. 21–22, pl. 10, fig. 1). That species was originally described but not illustrated from "Habitat ad oras Americae australis in portum Acapulco Mexicanorum." The posterior portion of the whorls on *T. gonostoma* is often the widest; the color of rather dense gray-black mottled markings in contrast to the much narrower flammules of *T. broderipiana* and *T. b. marmorata.*

A Recent specimen in the collections of the California Academy of Sciences, closely resembling Kiener's illustrations of *T. marmorata,* collected by D. L. Frizzell at Cabo Blanco, Peru, is 116 mm. long (incomplete), the body whorl 22.9 mm. in diameter. Other specimens collected at the same locality and at Paita Bay, and at the mouth of the Brazos River at San Ramon south of Sechura, Peru, have similar color markings but the shells are much less tapering with correspondingly wider apical angle. One such shell collected by J. G. Marks at San Pedro, Ecuador, is 133 mm. long (incomplete), the diameter of the last whorl 38 mm. Evidently the slender and the broad shells either represent elements of a very variable series, or two distinct forms are living in the region of Ecuador and Peru.

The fossils from the Galápagos Islands closely resemble the slender form with flat-sided whorls shown in Kiener's illustrations of *T. marmorata.* In this character they differ from the type specimen of *T. broderipiana* (with slightly concave whorls) shown in Keen's (1966) illustration. On that basis, in the present paper, the form described by Kiener is treated as a subspecies of *T. broderipiana.*

Pilsbry and Olsson (1941, p. 43) mentioned that *Turritella alturana* Spieker, described from strata of Miocene age in Peru is "so close to the recent species [*T. broderipiana*] that they cannot be consistently separated."

The subgenus *Broderiptella* Olsson was proposed to include the *T. broderipiana* group represented in the northern South American region at least since middle Miocene time. This group of turritellas was discussed by Merriam (1941, pp. 50–51) and by Woodring (1957, pp. 110–112).

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A NEW SPECIES OF THE SCORPIONFISH GENUS *HELICOLENUS* FROM THE NORTH PACIFIC OCEAN[1]

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Abstract: *Helicolenus avius* is described as a new species in the fish family Scorpaenidae, subfamily Sebastinae. The type locality is the northwestern Pacific Ocean between Japan and Midway Island at the southern end of the Emperor Seamount Chain, 32°40′N., 172°17′E. to 35°05′N., 171°46′E., at a depth between 450 and 600 meters. A description and 2 figures are provided. Remarks on the genus *Helicolenus* are given.

Introduction

In the summer of 1970, around 21 and 22 August, the Japanese vessel *Daini-Oriento Maru* of the Tokusui Company, Ltd., was conducting night-time trawling operations for *Beryx spendens* at the Emperor Seamount Chain between Japan and the Hawaiian Islands. At several stations a total of more than 250 kg. of specimens of a new scorpionfish of the genus *Helicolenus* was captured. The genus *Helicolenus* is virtually worldwide in distribution, containing temperate and tropi-

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cal offshore species. According to Matsubara (1943), the genus *Helicolenus,* along with *Sebastiscus, Hozukius,* and *Sebastes,* constitutes the subfamily Sebastinae. Recently, Eschmeyer and Hureau (1971) suggested that the genus *Sebastes* may be a terminal North Pacific-evolving offshoot characterized by a reduced rather than an incipient suborbital stay. They suggested that the genus *Sebastes* may have evolved from a tropical ancestor, particularly one with a complete suborbital stay and one sharing the characters found in the worldwide tropical and temperate genus *Helicolenus* and the Oriental genera *Sebastiscus* and *Hozukius*. The discovery of another species of the genus *Helicolenus* may help in understanding the evolution of the subfamily Sebastinae and the family Scorpaenidae.

The new species is quite distinct from the other species referable to the genus *Helicolenus,* particularly in having reduced head spination, smaller scales, longer gill rakers, better developed toothed protuberances (dentigerous knobs) on the anterior ends of the premaxillaries, and a forked caudal fin.

As a final introductory comment, we wish to mention that *Helicolenus dactylopterus* frequently is the main ingredient in French Bouillabaisse, or the Mediterranean fisherman's stew. Perhaps this new species has similar qualities. Although some specimens were discarded, 245.8 kg. of the present new species was frozen quickly on board the collecting vessel and kept at -20°C. Mr. Tsujisaki, who collected the specimens, has informed us that the fish kept at this temperature remain in good condition for sale for three months. Chemical analysis of flesh from one specimen measuring 21 cm. in standard length was made by Mr. Masa-aki Takeuchi (Tokai Regional Fisheries Research Laboratory) and showed the following: body weight 212.5 grams, edible part 27 percent, water of flesh 72.6 percent, crude protein 19.2 percent, crude fat 5.6 percent, crude ash 1.3 percent, and calories per 100 grams 126.2. Species of *Helicolenus* frequently are one of the dominant fishes in their habitat, and the new species may prove to be of commercial value.

METHODS

Methods of measuring follow Eschmeyer (1969) and are similar to methods used for other teleostean fishes with a few exceptions. Measurements originating from the anterior end of the upper jaw (head length, snout length, standard length, jaw length) are taken from the anterior end of the premaxillaries, including the dentigerous knobs; pectoral fin length is measured from the base of the first ray to the end of the longest ray, with the fin pointing back; caudal fin length is measured from the posterior end of the hypural plate to the most distal ray when the upper and lower caudal fin lobes are squeezed together. Terminology of head spines for the genus *Helicolenus* is the same as used by Matsubara (1943) and by Eschmeyer (1969).

Abbreviations of depositories of specimens are as follows: ABE—personal collection of the senior author; BMNH—British Museum of Natural History; CAS—California Academy of Sciences; USNM—United States National Museum; ZIUT—Zoological Institute, Faculty of Science, University of Tokyo.

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Helicolenus avius Abe and Eschmeyer, new species.

(Figures 1–2.)

MATERIAL EXAMINED. All specimens were collected in the northwestern Pacific Ocean between Japan and Midway Island, at the southern end of Emperor Seamount Chain, between 32°40′N., 172°17′E., and 35°05′N., 171°46′E., at a depth between 450 and 600 meters (probably most from 475 m.), with a bottom trawl, vessel *Daini-Oriento Maru,* around August 21–22, 1970. *Holotype*: ZIUT 52457 (211 mm. S.L.). *Paratypes*: ABE 15256 (1, about 200 mm. T.L. [used for description of color in life only]); BMNH 1971 12.14.1 (1, 173 mm. S.L.); CAS 13614 (2, 172-200 mm. S.L.) and CAS 13615 (1, 178 mm. S.L., cleared and stained); USNM 206327 (2, 176–181 mm. S.L.).

DESCRIPTION. (Measurements and counts summarized in table 1; body shape and coloration in figures 1–2.) Dorsal fin with 12 spines and usually 13½ (13½–14½) soft rays. Anal fin with 3 spines and 6½ soft rays. Pectoral fin with 18–20 rays, most frequently 19; 3rd through 11th or 12th rays branched in available specimens. Pelvic fin with 1 spine and 5 soft rays. Gill rakers total 31–34, 9 or 10 on the upper arch and 22–24 on the the lower arch, increasing in size toward angle of gill arch; longest raker about ½ of orbit diameter. Vertebrae 25. Airbladder absent. Head spines mostly rudimentary or absent; preorbital (lachrymal) bone with two weak spinous points over maxillary, sometimes virtually absent; five preopercular spines present, second longest, all broad; supplemental preopercular spine absent; nasal spines present; opercular bone with two spines; preocular spine well developed; supraocular spine weak or absent; postocular and tympanic spines small, mostly covered by skin or developed as ridges only; upper posttemporal spine poorly developed or absent; supracleithral spine broad; nuchal spine sometimes present; other spines, including the parietal, sphen-

TABLE 1. *Counts and measurements for the type specimens of* Helicolenus avius. *(Measurements are in millimeters; see standard lengths in Material Examined section for depositories and catalog numbers.)*

Standard length	172	173	176	178	181	200	211
Dorsal rays	12+13½	12+13½	12+13½	12+13½	12+13½	12+14½	12+13½
Anal rays	3+6½	3+6½	3+6½	3+6½	3+6½	3+6½	3+6½
Pectoral rays	19, 19	19, 19	20, 20	20, 19	18, 18	19, 19	19, 19
Pelvic rays	1+5	1+5	1+5	1+5	1+5	1+5	1+5
Vertebrae			25	25			
Gill rakers	10+23	9+24	9+22	9+23	9+23	10+24	10+23
Head length	61.5	58.7	65.7	62.5	64.2	73.4	76.7
Body depth	48.8	49.1	53.4	50.3	50.7	56.9	57.4
Orbit diameter	18.0	17.3	17.9	18.5	17.8	22.3	22.0
Snout length	15.6	13.6	16.0	14.7	16.4	16.8	17.9
Interorbital width	9.2	9.1	9.5	9.2	10.8	11.9	12.2
Jaw length	30.0	29.6	28.3	30.1	30.8	34.7	35.5
Predorsal fin length	61.3	57.8	61.5	59.3	62.8	68.7	73.3
Length 3rd dorsal spine	17.5	18.9	20.2	—	—	22.8	21.1
Length 1st anal spine	8.0	6.9	6.3	7.8	8.0	8.9	8.7
Length 2nd anal spine	16.9	15.9	17.0	16.2	17.5	17.7	19.0
Length 3rd anal spine	17.2	16.2	18.1	15.6	18.5	18.2	18.6
Length pectoral fin	49.1	49.2	51.0	50.3	53.7	57.7	57.9
Length pelvic fin	31.4	29.0	31.0	28.7	31.2	33.0	32.7
Length caudal fin	39.8	42.3	43.2	42.0	44.2	46.9	51.5

otic, coronal, pterotic, lower posttemporal, and suborbital spine absent or present only as scarcely developed ridge. Scales on sides of body small, ctenoid; vertical scale rows from supracleithral spine to end of hypural about 100, difficult to count; pored lateral line scales about 50–55, plus 5 or more on the caudal fin; most of head with cycloid scales, including the maxillary, cheek, and interorbital area; snout unscaled; scales on belly, pectoral fin, and bases of vertical fins mostly cycloid. Premaxillary, dentary, vomer, and palatine toothed; longest teeth on the dentigerous knob of the premaxillary; all teeth short, conical, not arranged in definite rows.

Color pattern of preserved specimens as in figures 1–2. Most conspicuous feature the dark spots above and below the lateral line anteriorly and on the back and dorsal fin. Buccal cavity black posteriorly, pallid anteriorly. Peritoneum black. (Color in life, according to Mr. Tsujisaki, was unchanged when the frozen specimens were handed to the senior author. A color slide was made on 12 October, 1970, of one specimen (ABE cat. no. 15256) by the senior author soon after receipt of the specimens, and the following is taken from the slide. The coloration was also illustrated in Abe (1970)). Body mostly red above and white ventrally. Dorsal surface of body and dorsal fin mottled with dark brown spots on a red background; spots arranged as in figure 1 of a preserved specimen. Pectoral and caudal fins red with yellowish tips.

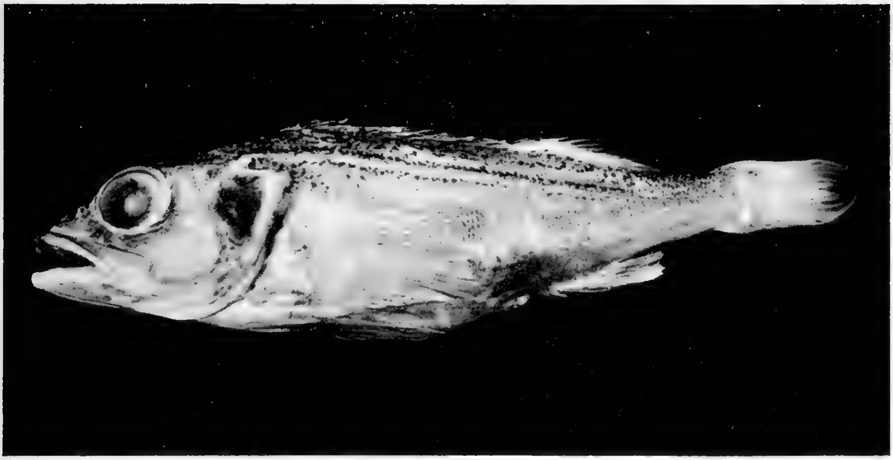

FIGURE 1. Lateral view of *Helicolenus avius*, CAS 13614, paratype, 172 mm. in standard length.

NAME. The specific name *avius* is the Latin word for "out of the way, remote or solitary." This name is in reference to the type locality, an isolated seamount. A Japanese name, "okikasago," meaning *Sebastes*-like or *Helicolenus hilgendorfi*-like fish, was given to this species (Abe, 1970).

DISTRIBUTION. This species is known only from the type locality. We expect that it might occur at other seamounts in the northwestern Pacific and particularly along the Hawaiian Island chain.

COMPARISON AND REMARKS. The subfamily Sebastinae has been defined by Matsubara (1943). Two of the four genera, *Sebastes* (including *Sebastodes*) and *Sebastiscus*, have an incomplete suborbital stay which does not attach to the preopercle. The other two genera of the subfamily, *Helicolenus* and *Hozukius*, have a complete suborbital stay. Species of *Helicolenus* lack an airbladder and have 25 vertebrae; while the single species of *Hozukius* has an airbladder and 26 vertebrae; the species show cranial differences also.

At most there are five or six closely related known valid species or subspecies belonging to the genus *Helicolenus*. *Helicolenus dactylopterus* (Delaroche, 1809) has a wide distribution in the Atlantic Ocean extending barely into the Indian Ocean in South Africa; synonyms include *H. maculatus* (Cuvier, 1829), *H. imperialis* (Cuvier, 1829), *H. maderensis* Goode and Bean, 1896, *H. thelmae* Fowler, 1937, *H. uruguayensis* Fowler, 1943, and as a subspecies *H. d. lahillei* Norman, 1937 (see Eschmeyer, 1969). *Helicolenus mouchezi* (Sauvage, 1875) is a senior synonym of *H. tristanensis* Sivertsen, 1945, and is known from the south Atlantic at Tristan da Cunha and in the southern Indian Ocean at Saint Paul and Amsterdam islands (see Eschmeyer and Hureau,

Figure 2. Lateral and dorsal views of the head of *Helicolenus avius*, CAS 13614, paratype, 172 mm. in standard length.

1971). The nominal Oriental species is *H. hilgendorfi* (Steindachner and Döderlein, 1884), although this species has been treated as *H. dactylopterus* by some authors. *Helicolenus lengerichi* Norman, 1937, is known from the southeastern Pacific. The Australian-New Zealand species is *H. papillosus* (Schneider, 1801) with the following as synonyms, *H. percoides* (Richardson, 1842), *H. cottoides* (Forster, 1849), *H. barathri* (Hector, 1875) and *H. macculochi* (Phillipps, 1927) (see Whitley, 1968, p. 83). *Helicolenus microphthalmus* Norman, 1935, was shown to belong to the genus *Sebastiscus* (Wheeler and Eschmeyer, 1968), and *H. rufescens* Gilbert, 1905, from Hawaii belongs in the subfamily Scorpaeninae (Eschmeyer, 1969). *Helicolenus avius* agrees with these six species or subspecies in such features as counts of fin rays, general body shape, absence of an airbladder, condition of the suborbital stay, and 25 vertebrae. *Helicolenus avius* differs from the other species of *Helicolenus* in the following features. In *H. avius* the caudal fin is forked while the caudal fin in the others is "square-cut" or only slightly emarginate; the gill rakers are longer in *H. avius;* the tubed lateral-line scales number more than 50 in *H. avius* while they are fewer than 35 in the other species; the body scales are smaller in *H. avius,* about 100 vertical scale rows versus 80 or fewer; *H. avius* shows reduced spination, with some spines which are normally found in the other species either poorly developed in *H. avius,* present as slight ridges, or absent; and *H. avius*, has the protuberance or dentigerous knob at the end of each premaxillary bone much better developed.

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TWO NEW SCORPIONFISHES (GENUS *SCORPAENODES*) FROM THE INDO-WEST PACIFIC, WITH COMMENTS ON *SCORPAENODES MUCIPARUS* (ALCOCK)

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Abstract: Two new scorpionfishes of the genus *Scorpaenodes* are described from the Indian Ocean. Additional comments are given on *Scorpaenodes muciparus* (Alcock). These three species are compared with each other and with *S. tribulosus* Eschmeyer, the fourth species of the genus *Scorpaenodes* known from offshore areas in the Indo-West Pacific.

Introduction

Eschmeyer (1969a) identified Indian Ocean specimens collected by the United States International Indian Ocean Expedition as *Scorpaenodes muciparus* (Alcock, 1889), offering a description and figures. Recently, we had the opportunity to examine two specimens of *S. muciparus* in the collection of the Zoological Survey of India, and one of us (W.N.E.) was also able to examine the specimen collected by the *Siboga* which was identified as *S. muciparus* by Weber (1913) and also by de Beaufort (Weber and de Beaufort, 1962). It was then apparent that the specimens identified by Eschmeyer (1969a) as *S. muciparus* were not specimens of that species but represented a new species, a species which one of us (K.V.R.R.) was in the process of describing as part of current studies on the scorpionfishes of India. Examination of scorpionfishes in other museums has resulted in location of yet another closely related species, the description of which we include in this paper. These three species, along with *S. tribulosus* (Eschmeyer, 1969a), live in offshore level-bottom areas, while other members of the genus are shallow-water rock or reef inhabitants.

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The senior author acknowledges the support of National Science Foundation Grant GB-15811, which permitted him to examine scorpionfishes in most of the major fish collections. The following museums contained specimens used in this study, and we wish to thank the curators and staffs listed for courtesies extended during his visits to their museums: BMNH, British Museum of Natural History (N. B. Marshall, G. Palmer, A. Wheeler, P. Whitehead); CAS, California Academy of Sciences (L. Dempster, P. Sonoda); NMS, National Museum of Singapore (E. Alfred); USNM, United States National Museum (N. Gamblin, V. Springer); ZMA, Zoological Museum, Amsterdam (H. Nijssen); ZMC, Zoological Museum, Copenhagen (J. Nielsen); ZSI, Zoological Survey of India (A. G. K. Menon).

Lillian Dempster, Pearl Sonoda, Kathy Smith, Terry Arambula, and Maurice Giles of the California Academy of Sciences, assisted in the study. We are grateful for comments on the manuscript made by Lillian Dempster and A. G. K. Menon.

METHODS

Counts, measurements, and terminology of head spines are as used by Eschmeyer (1969b, pp. 4–6).

SPECIES ACCOUNTS

The limits of the genus *Scorpaenodes* have been discussed recently (Eschmeyer, 1969a). Within the subfamily Scorpaeninae, the genus is characterized by the following combination of characters: normally thirteen dorsal spines, spinous procurrent caudal fin rays, and no palatine teeth. The genus contains species which are primarily tropical, shallow-water forms, and species of the genus are found in all warm oceans.

The four species of *Scorpaenodes* treated in the present paper are the only ones of the genus occurring in offshore Indo-Pacific waters below a depth of about 20 fathoms. These four species may be separated as follows:

1. Vertical scale rows (above lateral line from first lateral line scale to end of hypural) 70 or more .... *S. muciparus*
1. Vertical scale rows about 50 or fewer 2

2. Soft dorsal rays 8½, scales strongly ctenoid with long ctenii, underside of head covered with ctenoid scales .... *S. tribulosus*

2. Soft dorsal rays usually 9½, scales ctenoid, underside of head naked or with cycloid scales 3

3. Pectoral rays usually 17–18; rear of the buccal cavity pallid .... *S. smithi*, new species
3. Pectoral rays usually 19 (18–20); rear of the buccal cavity dusky .... *S. investigatoris*, new species

REMARKS. A new species, *Scorpaenodes steinitzi,* was described recently by Klausewitz and Frøiland (1970) from the Red Sea. Seventy-five additional specimens of this species are available to us. Two of the major differentiating characters used by these authors were that the dorsal and anal soft ray counts were 1 higher in *S. steinitzi* than in the other species, but this results from the fact that Klausewitz and Frøiland counted the last double ray as 2 rays, while recent authors count this as 1 or 1½ rays. Despite this, *Scorpaenodes steinitzi* appears to be a valid species which is distinguishable from other species most easily by its coloration. We mention this because readers may wonder if *S. steinitzi* might not be one of the species treated here by us. *Scorpaenodes steinitzi* is a pale-colored species with some brown pigment on the sides and it usually has a dark spot near the posterior end of the spinous dorsal fin, but *S. steinitzi* does not have the lateralis canal head pores well developed and it is a shallow-living species. In *S. steinitzi* the spots on the caudal fin when present are arranged in rows while they are more scattered in *S. smithi*; and the dark pigment on the sides in *S. steinitzi* is not arranged in definite bars as in *S. smithi, S. investigatoris,* and *S. muciparus.*

Scorpaenodes investigatoris Eschmeyer and Rama Rao, new species.

Scorpaenodes muciparus, ESCHMEYER, 1969a, pp. 4–8, figs. 1a, b, table 1 (description; these specimens now referred to this new species, not *S. muciparus* (Alcock, 1889).

Scorpaenodes varipinnis, SMITH, 1957, p. 65 (in part; only the 50 mm. specimen taken from the stomach of a specimen of *Pristipomoides microlepis* Bleeker collected in 110 fathoms off Memba and tentatively referred to *S. varipinnis*).

REMARKS. The specimens wrongly identified by Eschmeyer (1969a) as *S. muciparus* (Alcock) are designated as the types of this new species along with two specimens from the collection of the Zoological Survey of India. The holotype (CAS 24264) and one paratype (CAS 24265) were figured by Eschmeyer (1969a, fig. 1a, b).

TYPE MATERIAL. *Holotype.* CAS 24264 (1, 71.2 mm. S.L.), West Pakistan, 24°13′ N., 65°52′ E., in 93 fathoms, *Anton Bruun* Cruise 4B, station 267B, 9 December 1963.

Paratypes. CAS 24266 (1, 87.4 mm. S.L.), West Pakistan, 25°02′ N., 56°52′ E., in 159 fathoms, *Anton Bruun* Cruise 4B, station 264A, 2 December 1963; CAS 24265 (2, 45.8–48.9 mm. S.L.), off western India, 22°32′ N., 68°07′

E., in 31.5 fathoms, *Anton Bruun* Cruise 4B, station 221A, 18 November 1963; USNM 204030 (1, 72.4 mm. S.L.), off western India, 17°25′ N., 71°39′ E., in 52.5 fathoms, *Anton Bruun* Cruise 4B, station 202A, 13 November 1963; ZSI 916/1 (1, 86 mm. S.L.) and ZSI 917/1 (1, 67 mm. S.L.), Arabian Sea, off Ratnagiri Coast, 17°27′ N., 71°41′ E., 56–58 fathoms, bottom of fine sand, Agassiz trawl haul, *Investigator* station 242, 11 October 1898. (Smith's specimen mentioned above in the Synonymy is regarded only as an additional specimen and not a type.)

DESCRIPTION. See Eschmeyer (1969a, pp. 4–8, figs. 1a and 1b, table 1) for a complete description of this species. The two ZSI specimens have the following counts: Dorsal rays XIII, 9½ anal rays III, 5½–6½; pectoral rays 19. The vertical scale rows in the two specimens number 45–48, and the gill rakers number 5–6 plus 12–13. Except for the specimen with 6½ soft anal rays, the counts fall within those given by Eschmeyer (1969a, table 1).

DISTRIBUTION. *Scorpaenodes investigatoris* is known from the Gulf of Oman and in the Arabian Sea off western India and West Pakistan. The specimen reported by Smith (1957, p. 65) was taken off Memba, Mozambique. Depths of capture range from 31 to 159 fathoms.

COMPARISONS. This species very closely resembles *Scorpaenodes smithi* in scalation, counts, and coloration. *Scorpaenodes investigatoris* and *S. smithi* may be easily separated from the other two offshore species of *Scorpaenodes*: *S. muciparus* has over 70 vertical scale rows as opposed to about 50 in *S. investigatoris* and *S. smithi,* and *S. tribulosus* has strongly ctenoid scales on the underside of the head while the other species have the underside of the head mostly naked or with cycloid scales. The descriptions of *S. investigatoris* and *S. smithi* are almost identical. The two characters which may be used to separate them are pectoral rays and the coloration of the rear of the buccal cavity. In *S. investigatoris* the pectoral rays are usually 19 (18–20) while they usually number 17 or 18 (16–19) in *S. smithi*. In *S. investigatoris* the rear of the mouth, including the pharyngeal bones and the areas adjacent to them, is dusky in coloration while this area is pallid in *S. smithi*. No other clear-cut differences were noted. *Scorpaenodes investigatoris* appears to live at deeper depths than *S. smithi.*

ETYMOLOGY. The name is based on the Royal Marine Survey Steamer *Investigator,* which made important collections in the Indian Seas during the years 1884–1926; the name "*investigatoris*" was used by one of us (K.V.R.R.) for this species in his unpublished thesis on Indian Ocean scorpionfishes.

Scorpaenodes muciparus (Alcock).

Sebastes muciparus ALCOCK, 1889, pp. 298–299, fig. 3 on pl. 22 (original description; type locality Bay of Bengal, 26 miles N. by E. of Gopalpur, in 45 fathoms). ALCOCK, 1898, pl. 18, fig. 5 (good illustration). WEBER, 1913, p. 491 (brief description; one from *Siboga* station 306, Solor Straits, 8°27′S., 122°54′W., in 247 meters).

Scorpaenodes muciparus, de Beaufort *in* Weber and de Beaufort, 1962, pp. 34–35 (redescription of *Siboga* specimen described by Weber).

Material examined. ZSI 1179/1 (1, 80 mm. S.L.) Gulf of Martaban, 14°46′N., 95°52′E., in 61 fathoms, on soft, green muddy and sandy bottom, Agassiz trawl haul, *Investigator* station 328, 7 March 1904; ZSI 12432 (1, 73 mm. S.L.) Bay of Bengal, Ganjam coast, 19°24′N., 85°E., in 23 fathoms, muddy bottom, Blake trawl haul, *Investigator* station 42, 7 March 1889; ZMA 110.246 (1, 146 mm. S.L.) Indonesia, Solor Straits, 8°27′S., 122°54′E., in 135 fathoms, *Siboga* station 306, 8 Feb. 1900.

Remarks. The reader is referred to the references listed above for a more complete description of this species. The holotype of this species, which was originally in the ZSI collection, has been lost. If a neotype is ever needed, we suggest that the specimen listed above from *Investigator* station 42 (ZSI 12432) would make the best neotype, as it is from the same general locality as the type and was identified as *S. muciparus* by Alcock. *Scorpaenodes muciparus* is characterized by a dorsal ray count of 13 spines and 9½ soft rays, pectoral rays of 18–19, and vertical scale rows of over 70. The other three species treated in this paper have a scale count of 50 or fewer. De Beaufort (in Weber and de Beaufort, 1962, p. 35) gives a scale count of 45–58 for the *Siboga* specimen. Re-examination shows that the specimen has a vertical scale row count of about 70–73 when the scale rows are counted above the lateral line from the supracleithral spine to the end of the hypural plate.

Scorpaenodes tribulosus Eschmeyer.

Scorpaenodes tribulosus Eschmeyer, 1969a, pp. 8–10, fig. 1c, table 1 (original description; type locality East Africa, off Kenya, 02°42′S., 40°53′E., in 77 fathoms and off the Somali Republic, 11°24′N., 51°35′E., in 40–96 fathoms).

Remarks. The species is still known only from the western Indian Ocean, from the holotype (CAS 24267, off Kenya) and one paratype (USNM 204031, off the Somali Republic) as given above. The reader is referred to Eschmeyer (1969a) for a description of this species. This species is characterized by a dorsal ray count of 13 spines and 8½ soft rays, pectoral rays 19, and vertical scale rows under 50. *Scorpaenodes tribulosus* is most easily distinguished from the other species by the presence of strongly ctenoid scales on the underside of the head; the other three species have this area covered with cycloid scales or mostly naked.

Scorpaenodes smithi Eschmeyer and Rama Rao, new species.

(Figure 1.)

Type material. *Holotype.* BMNH 1929.6.12.6 (52.2 mm. S.L.), Andaman Sea, off western Malaya, 5°45′N., 98°20′E., in 40 fathoms, Madras- Penang Cable Survey, Cable ship *Patrol,* 16 March 1929.

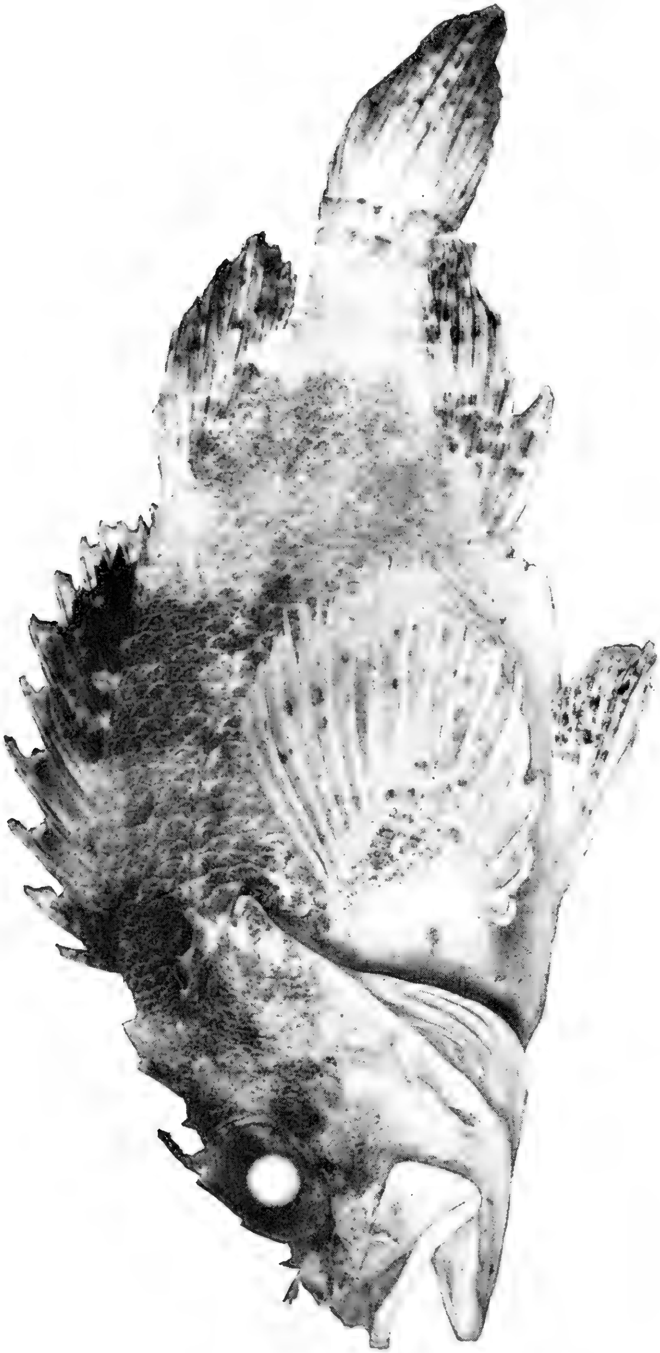

FIGURE 1. *Scorpaenodes smithi* Eschmeyer and Rama Rao, new species; holotype, BMNH 1929.6.12.6, 52.2 mm. S.L., from the Andaman Sea.

Paratypes. BMNH1929.6.12.7–15 (12, 21.5–47.0 mm. S.L.), and CAS 13616 (4, 23.2–52.1 mm. S.L.) and ZSI F6254/2 (1, 46.0 mm. S.L.), formerly in BMNH 1929.6.12.6–15, taken with the holotype; BMNH 1932.2.15.15–20 (6, 24.5–48.3 mm. S.L.), Andaman Sea, west of Malaya, 6°01′20″N., 99°03′05″E., in 46 fathoms, mud bottom, Madras-Penang Cable Survey, no date; BMNH 1972.1.17.1–9 (9, 22.0–51.3 mm. S.L.) and USNM 206501 (4, 22.4–45.6 mm. S.L.) west of Malaya, 80 miles south of Penang, in 24 fathoms, entangled in coelenterates found on cable, cable ship *Patrol*, May 1923; BMNH 1933.8.11.4 (1, 35.6 mm. S.L.), Arafura Sea, 11°59′30″S., 126°38′E., in 60 fathoms, E. and A. Telegraph Company, collected in or before 1933; ZMC P7982–83 (2, 56.5 mm. S.L.), Gulf of Tonkin, 20°26′N., 108°09′E., in 28 fathoms, collected by Schønau in or before 1895; ZMC P7978–81 (4, 46.2–60.8 mm. S.L.), China Seas, collected by E. Svenson, in or before 1893; ZMC P79100–112 (13, 34.0–62.4 mm. S.L.), southwest of Hong Kong, 26°10′N., 121°00′E., in 44 fathoms, collected by H. Christiansen, 31 May 1912; ZMC P79113–132 (20, 28.7–46.8 mm. S.L.), off western Malaya, 5°09′08″N., 99°48′10″E., in 32 fathoms, sandy mud bottom, collected by Store Nordiske, 24 Dec. 1935; ZMC P7991–92 (2, 32.1–58.8 mm. S.L.), Formosa Strait, "Namoa" Island, collected by Capt. Svenson, in or before 1912; NMS uncataloged (10, 15.5–54.4 mm. S.L.), near Singapore 5°59′06″N., 99°08′33″E., in 40 fathoms, collected by Tweedie. A total of 89 specimens.

DESCRIPTION. Measurements and counts summarized in table 1; body shape and coloration in figure 1.

Dorsal fin rays normally XIII, 9½, rarely 8½ or 10½. Anal fin rays normally III, 5½. Pectoral rays usually 17 or 18 (16–19), rays 2 or 3 through 7 to 9 branched in larger specimens; smaller specimens with fewer branched rays; the branching of pectoral rays begins at about 25–30 mm. S.L. Spines on head well developed. Preorbital bone with second and third lobes (Matsubara's, 1943, terminology) each as a broad spinous point extending over the maxillary, third lobe usually with additional spinous points; suborbital ridge with one row of spinous points, usually one and sometimes several spines on the lateral face of the preorbital bone in line with three or more spinous points on the suborbital bones, the posterior one frequently double. Tympanic spines present; coronal spines usually absent, sometimes present only on one side, rarely present on both sides. Interorbital ridges rarely ending in spines. Small spines (postfrontal spines of Smith, 1957) near midline between tympanic spines sometimes present. Supplemental preopercular spine present. First preopercular spine long, second usually small, third present, fourth usually present, points ventrally, and fifth points down (sometimes virtually absent). Preocular, supraocular, and postocular spines well developed. Small spine below parietal spine usually absent. Other spines present include the nasal, parietal, nuchal, sphenotic, pterotic, upper (some-

Table 1. *Counts*[1] *and measurements of type specimens of* Scorpaenodes smithi.
(Measurements are in millimeters; numbers in parentheses are percentages of standard length.)

	BMNH 1929.6.12.6	*CAS 13616*				*P7982-3*	
Standard length	52.2	52.1	48.7	44.2	23.2	56.5	56.5
Dorsal fin rays [1]	XIII+8½	XIII+9½	XIII+9½	XIII+9½	XIII+9½	XIII+9½	XIII+8½
Anal fin rays [1]	III+5½	III+5½	III +5½	III+5½	III+5½	III+6½	III+5½
Pectoral fin rays [1]	17+18	18+17	18+18	18+18	18+18	18+18	18+18
Head length	22.6(43)	23.3(45)	21.2(44)	19.1(43)	10.7(46)	24.3(43)	22.0(39)
Snout length	6.1(12)	6.5(12)	6.2(13)	5.2(12)	2.7(12)	6.5(12)	6.2(11)
Orbit diameter	6.8(13)	6.8(13)	6.7(14)	5.9(13)	3.2(14)	6.2(11)	6.7(12)
Interorbital width	3.3(06)	3.0(06)	2.8(06)	2.9(06)	1.7(07)	3.8(07)	3.2(06)
Upper jaw length	11.9(23)	13.0(25)	11.6(24)	9.7(22)	5.3(23)	12.4(22)	12.2(22)
Predorsal-fin length	20.7(40)	21.4(41)	20.0(41)	18.3(41)	10.3(44)	21.0(37)	20.4(36)
Body depth	22.2(43)	21.5(41)	19.6(40)	17.0(38)	9.9(43)	22.7(40)	22.0(39)
Pectoral fin length	17.2(33)	19.1(37)	16.5(34)	15.8(36)	7.4(32)	19.2(34)	21.5(38)
Pelvic fin length	13.9(27)	13.7(26)	12.6(26)	11.5(26)	5.7(24)	14.2(25)	14.8(26)
Caudal fin length	14.8(28)	14.4(28)	13.6(28)	12.3(28)	7.0(30)	14.8(26)	15.3(27)

	ZSI F6254/2	*BMNH 1932.2.15.15-20*					
Standard length	46.0	48.3	46.6	48.1	47.8	32.2	24.5
Dorsal fin rays	XIII+9½	XII+10½	XIII+9½	XIII+9½	XIII+9½	XIII+9½	XIII+9½
Anal fin rays	III+5½	III+5½	III+5½	III+5½	III+5½	III+5½	III+5½
Pectoral fin rays	17+18	17+17	18+18	17+17	17+17	18+18	18+18
Head length	19.8(43)	21.5(44)	20.3(44)	19.8(41)	19.7(41)	14.2(44)	11.4(46)
Snout length	5.2(11)	5.7(12)	5.2(11)	5.5(11)	5.4(11)	4.2(13)	3.1(13)

(Table 1 Continued)

	ZSI F6254/2	*BMNH 1932.2.15.15-20*					
Orbit diameter	5.7(12)	6.0(12)	5.7(12)	5.9(12)	6.0(12)	4.1(13)	3.6(15)
Interorbital width	2.7(06)	3.2(07)	2.8(06)	3.0(06)	3.2(07)	2.2(07)	1.8(07)
Upper jaw length	10.0(22)	11.0(23)	10.5(22)	10.4(22)	10.3(22)	7.5(23)	6.2(25)
Predorsal fin length	18.8(41)	19.1(40)	18.6(40)	19.4(40)	19.0(40)	14.2(44)	11.2(46)
Body depth	19.0(41)	18.8(39)	18.8(40)	19.8(41)	20.0(42)	13.2(41)	10.6(43)
Pectoral fin length	14.6(32)	14.5(30)	14.4(31)	14.0(29)	14.4(30)	9.0(28)	7.7(31)
Pelvic fin length	12.2(26)	12.0(25)	12.5(27)	12.5(27)	11.5(24)	8.0(25)	7.0(28)
Caudal fin length	13.0(28)	12.4(26)	12.8(27)	12.9(27)	12.6(26)	8.6(27)	7.1(29)

times absent) and lower posttemporal, two opercular, cleithral, and supracleithral (double). Fourth suborbital bone isolated, bearing a few small spines (Ginsburg's, 1953, postorbital spines). Tentacles and other fleshy appendages associated with most head spines. Supraocular tentacle about ⅓ to ½ of orbit diameter, sometimes reduced, with branches distally. A few tabs on upper part of eye, two usually larger than the others. Scales on flanks ctenoid; vertical scale rows about 40 to 50, usually in middle forties; lateral-line scales usually 23 plus 1 or 2 on caudal fin. Bases of fins with a few scales. Scales on chest and pectoral fin base mostly cycloid. Dorsal parts of head scaled; underside of head unscaled or with cycloid scales; snout unscaled. Gill rakers including rudiments 15–17; upper arch with 5–6 short spiny rakers; lower arch with 9–10 rakers on ceratobranchial and usually 2 rudiments on hypobranchial. Small slit present behind fourth gill arch. Head pores well developed. Color pattern as in figure 1. Most conspicuous feature is the black spot on the posterior part of the spinous dorsal fin. Body usually with four broad bands, first under anterior dorsal spines, second under posterior spinous dorsal fin, third between soft dorsal fin and anal fin, fourth at base of caudal fin. All fins with brown or black spots. Three brown bars radiating from eye; first extends forward across preorbital bone, second below eye, and third extends down and back from posterior ventral part of eye.

DISTRIBUTION. *Scorpaenodes smithi* seems to be widespread in the area of

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[1] Counts of 63 additional specimens give the following totals (12 small specimens not counted): Dorsal fin rays XIII+9½(70 specimens), XIII+8½(2), XIII+9(1), XII+10½(1), XIII+10½(2), and XIII+5½(1, abnormal); Anal fin rays III+5½(75 specimens), III+6½(1), I+6½(1, abnormal); Pectoral fin rays 16+17(1 specimen), 17+17(22), 17+18(6), 18+17(7), 18+18(37), 18+19(1), 19+18(2), 19+19(1).

the South China Sea and through the Straits of Malacca into the Andaman Sea. A wider distribution in the Indo-Australian Archipelago is expected. Depths of capture range from 24 to 60 fathoms, and the bottom type appears to be mud or sand.

COMPARISONS. See the Comparisons section under the account of *Scorpaenodes investigatoris*.

ETYMOLOGY. We name this species in honor of the late Professor J. L. B. Smith for his noteworthy contributions to the knowledge of Indian Ocean scorpionfishes.

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NEW BARNACLE RECORDS (CIRRIPEDIA, THORACICA)

By

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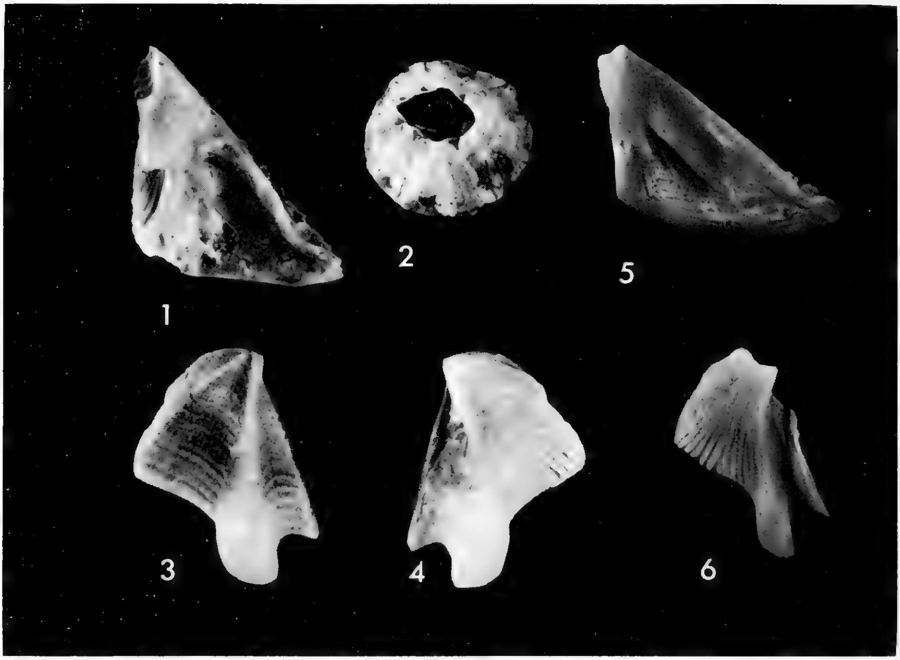
Balanus amphitrite amphitrite Darwin, 1854.

(Figures 1–4.)

In discussing the introduction of *Balanus improvisus* Darwin to the Pacific Coast of North America, Carlton and Zullo (1969) noted that although this species was relatively common in collections dating back to 1853, no specimens of *B. amphitrite amphitrite* were found in collections made prior to 1939, when it was first observed by F. L. Rogers in San Francisco Bay (Henry, 1942). The establishment of *B. improvisus* on the Pacific Coast appears to be tied to the commercial importation of the North American East Coast oyster, *Crassostrea virginica* (Gmelin). Both barnacles are frequent epizooites of this oyster, but as *B. amphitrite amphitrite* is a relatively recent addition to the fauna of the East Coast as well, Carlton and Zullo concluded that its absence in early Pacific Coast collections reflected a similar absence on the East Coast. However, further inquiry into the history of the Pacific Coast oyster industry has revealed that all importations of *Crassostrea virginica* were from areas north of Cape Hatteras, North Carolina (the northern range limit of *B. amphitrite amphitrite*), thus virtually eliminating this oyster as a vehicle of introduction for *B. amphitrite amphitrite*.

While processing miscellaneous collections of barnacles for the Academy of Natural Sciences of Philadelphia (ANSP), two lots of *B. amphitrite amphitrite* were found that had been obtained from the California coast prior to 1939. This material, collected by Charles R. Orcutt and originally identified by Henry A. Pilsbry, consists of four specimens with opercular valves from La Jolla, California, and of a single, large (20 millimeter basal diameter) specimen from San Diego Bay, California. Both lots bear the number "158/428", but no date of



FIGURES 1–4. *Balanus amphitrite amphitrite* Darwin. Figure 1, scutum, height 4 mm.; figure 2, shell, greatest diameter 20 mm.; figures 3–4, terga, height 4 mm. (Figures 1, 3, 4, La Jolla, California; figure 2, San Diego Bay, California). FIGURES 5–6. Opercular valves of *Balanus improvisus* Darwin, CAS locality 41227, Delta Mendota Canal, California, height of scutum and tergum 3.8 mm.

collection. Dr. Robert Robertson and Nancy Rulen of the Philadelphia Academy were kind enough to search their records, and were able to provide the following data:

> ANSP no. 2257. La Jolla, California, C. R. Orcutt collector, donated by the U. S. National Museum and cataloged December 6, 1921.
>
> ANSP no. 2426. San Diego, California, C. R. Orcutt collector, December 9, 1927.

The apparent establishment of *B. amphitrite amphitrite* in southern California by at least the early 1920's and in the late 1930's in northern California is likely attributable to transport by ships. Its occurrence may eventually be placed considerably earlier than this, for it had already arrived in Hawaii by the early 1900's (Pilsbry, 1907, p. 190). *Balanus amphitrite amphitrite* is restricted to certain estuarine parts of the San Francisco Bay complex where mean annual temperatures are highest, but even in these areas Newman (1967) has noted that the temperature regime is clearly suboptimal for this subspecies. If the establishment of *B. amphitrite amphitrite* in San Francisco Bay was indeed later than in southern California, the delay may be explained by the paucity of suitable environments for successful colonization.

Balanus eburneus Gould, 1841.

(Figures 8–15.)

Balanus eburneus, whose natural range includes the Atlantic coasts of North America and northern South America, the Caribbean Sea, and the Gulf of Mexico, has been introduced by shipping to various parts of the world. Known introductions, emphasizing those in the Pacific Ocean, were summarized by Matsui *et al.* (1964) and Utinomi (1966). Definite Pacific localities include Balboa, in the Bay of Panama, eastern Pacific, the Hawaiian Islands, and the Japan Sea coast of central Japan. Weltner (1897) reported *B. eburneus* on *Fasciolaria* with *B. amphitrite* from Manila in the Philippines, but this identification has not been corroborated.

A sample in the collection of the Department of Invertebrate Zoology of the California Academy of Sciences (CAS) taken by Mr. Vern Brock in July, 1967, from between Ansala and Vera islands in Eniwetok Atoll in the Marshall Islands was found to contain several individuals of *B. eburneus* in association with *B. amphitrite amphitrite.* These specimens represent the first record of *B. eburneus* from islands of the central West Pacific, and no doubt reflect the heavy traffic in American shipping to that area since the Second World War. The occurrence of this Atlantic American species at Eniwetok suggests that other highly frequented ports in the central Pacific islands might also harbor successfully introduced populations of *B. eburneus.*

This species was also discovered recently at another, albeit more likely, locality in the western Atlantic. Mrs. Joleen Gordon, in the course of an ecologic study of Bermuda barnacles during the summer of 1967, found *B. eburneus* to be a common member of that fauna in association with *B. amphitrite amphitrite* and *Chthamalus stellatus thompsoni* Henry.

The barnacle fauna of the Bermudas was investigated most recently by Henry (1958) on the basis of collections made by T. A. and Anne Stephenson in the early 1950's. *Balanus amphitrite hawaiiensis* Broch (= *B. amphitrite amphitrite*) and *Chthamalus stellatus thompsoni* were reported there for the first time, but *Balanus eburneus* was not found. Judging from the abundance of *B. eburneus* and its association with the above-mentioned subspecies as seen in 1967, it is possible that this species has been introduced to the Bermuda fauna since the date of the Stephensons' survey.

Balanus improvisus Darwin, 1854.

(Figures 5–7.)

A living population of *B. improvisus* was discovered in December, 1962, on the concrete lining of a section of the Delta-Mendota fresh water irrigation

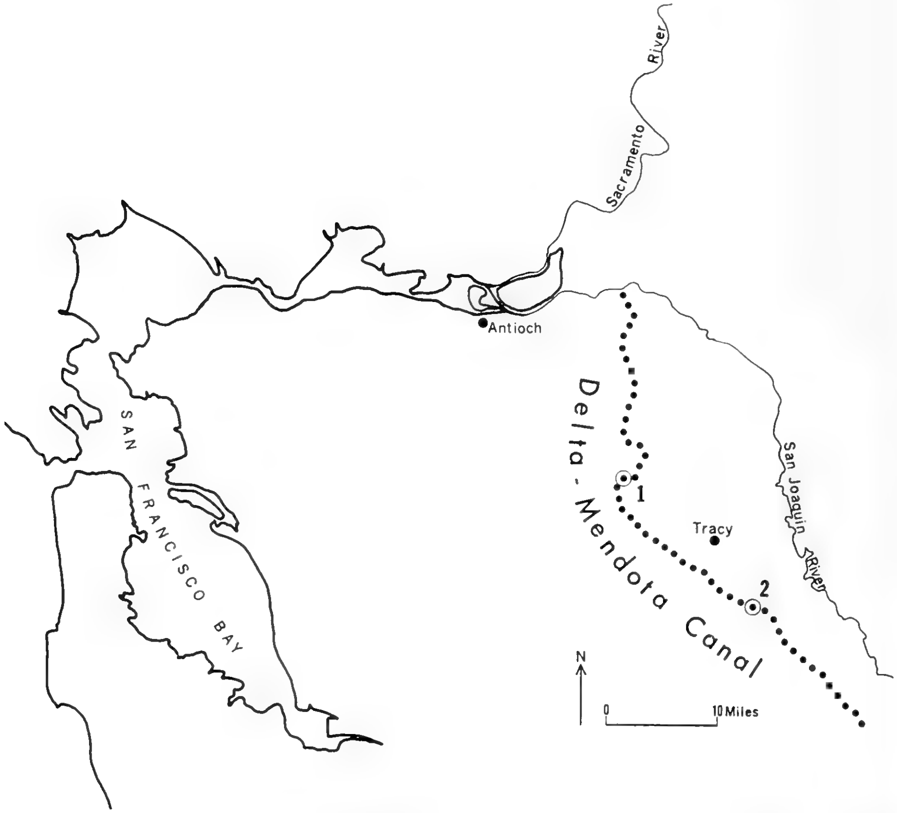


Figure 7. Relationship of Delta-Mendota Canal system to the San Francisco Bay-Delta area. Numbers indicate Tracy Pumping Plant (1) and collection site of *Balanus improvisus* (2).

canal in central California. The barnacles, collected by G Dallas Hanna and Allyn G. Smith of the California Academy of Sciences (CAS locality 41227), were taken at mile post 20.62, or more than 20 miles downstream from the Tracy Pumping Plant, which is about 9 miles northwest of Tracy, San Joaquin County, California (figure 7). This section of the canal was discussed previously by Hanna (1966, p. 40, figs. 30–31) with respect to the phenomenal infestation of the Asiatic fresh water clam *Corbicula manilensis* (Philippi). The occurrence of barnacles in the canal was noted by Prokopovich (1968, p. 53, photograph 48).

Irrigation water is pumped into the Delta-Mendota Canal by the Tracy Plant via a 2.3-mile-long canal from the Old River Channel of the San Joaquin River. This intake is well over 25 miles from the established salt water barrier of the Sacramento-San Joaquin estuary in the vicinity of Antioch, California.

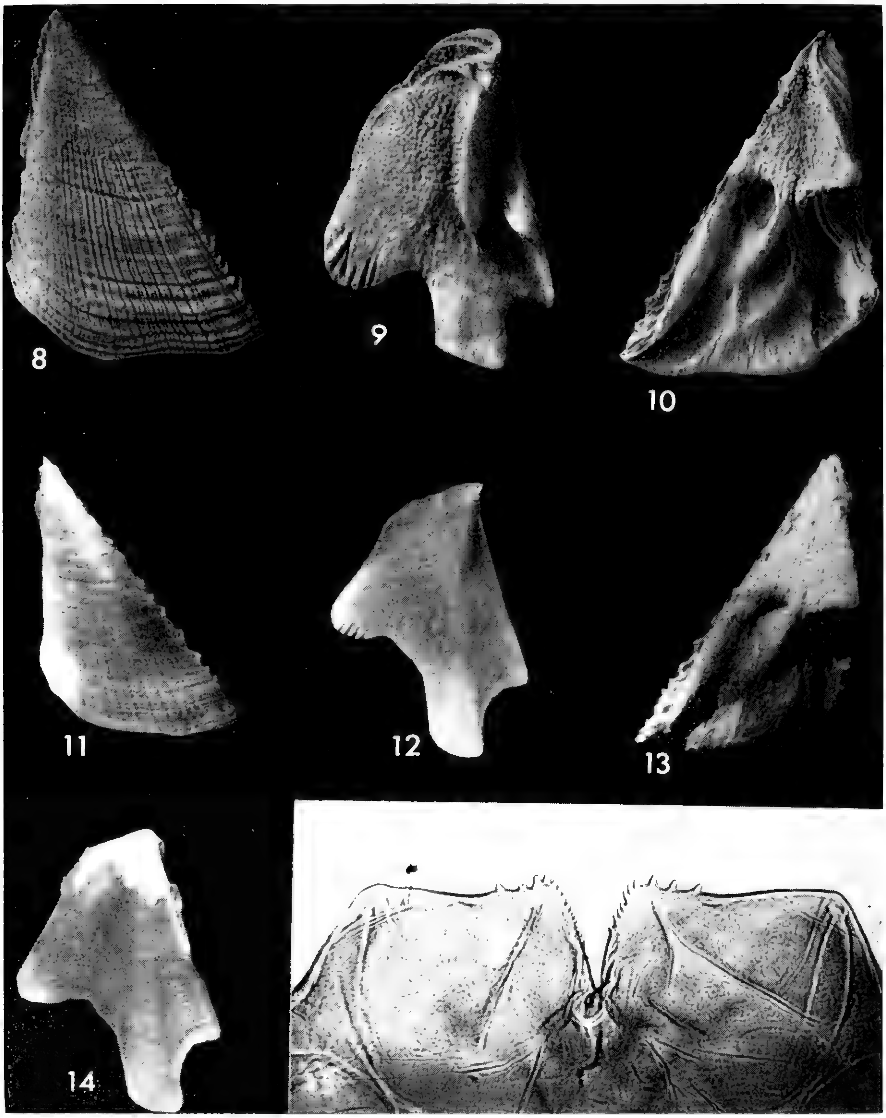
Continuing water quality analyses made at the pumping plant indicate that total dissolved solids do not exceed 500 parts per million (0.5 parts per thousand) at the canal intake.

Although a few species of barnacles are known to live in river estuaries where salinities are negligible for most of the year, there has been only one other report of an apparent occurrence in totally fresh water (Shatoury, 1958; *B. amphitrite* in a cement irrigation holding tank 64 kilometers south of the mouth of the Nile Delta). On the basis of observational and experimental data, it has been assumed that euryhaline barnacles, such as *B. improvisus* and *B. eburneus,* can exist in fresh water as adults provided that higher salinities prevail in the area during larval spawning and settlement. These outlying populations are apparently unable to reproduce, and must rely, therefore, on larval recruitment from breeding populations in higher salinities downstream. The larvae can be transported upstream in the encroaching salt wedge during the dry season, provided that this season (usually summer months) corresponds to spawning season.

Laboratory studies of the salinity tolerances of stage I and II nauplii of *B. balanoides* (Linnaeus), *B. balanus* (Linnaeus), and *B. crenatus* Bruguière were made by Barnes (1953), and Crisp and Costlow (1963) investigated the effects of varying salinities on the developing eggs and early naupliar stages of *B. amphitrite amphitrite* Darwin, *B. eburneus,* and *Chelonibia patula* Ranzani. The results from these two studies agree rather closely. Cytolysis of eggs was observed in all three species examined by Crisp and Costlow at salinities of 10 parts per thousand or less, regardless of temperature. Early stage nauplii of both studies died in salinities of 5 parts per thousand or less after only slight exposure, and could not withstand prolonged exposure to salinities below 10 parts per thousand. There was, however, some indication that larvae hatched from embryos developed at lowered salinities were better adapted to brackish conditions.

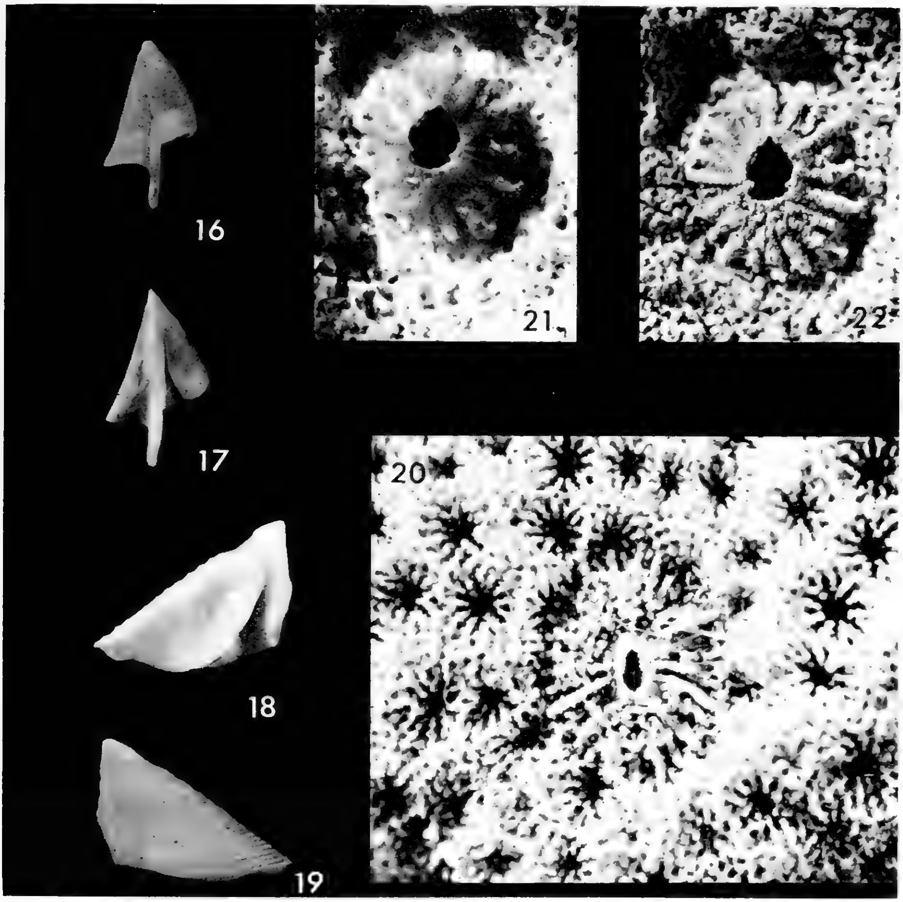
The survival ability of *B. improvisus* larvae in lowered salinities may be greater than that of other estuarine barnacles. Mohammad (1962), in a field and laboratory study of the distribution of barnacle larvae in Newport River, North Carolina, indicated that *B. improvisus* larvae could tolerate salinity as low as 0 parts per thousand, whereas the lower limit for those of *B. eburneus* was about 8 parts per thousand. If larval salinity tolerance were the limiting factor in the distribution of barnacles in estuaries, then *B. improvisus* should be expected in fresh water. However, this is not the case under natural conditions, suggesting that other factors are also limiting.

The only readily apparent physical difference between the two fresh water localities cited here and natural estuarine habitats is direction of current flow. Under natural conditions, larvae must counteract river current once outside the encroaching salt wedge, and Crisp and Costlow (1963) have noted that



FIGURES 8–10. Opercular valves of *Balanus eburneus* Gould, CAS locality 42617, St. Georges Island, Bermuda, height of scuta and tergum 7.5 mm. FIGURES 11–15. *Balanus eburneus* Gould, CAS locality 42618, Eniwetok, Marshall Islands. Figures 11 and 13, scutum, height 4 mm.; figures 12 and 14, terga, height 4 mm.; figure 15, labrum, ×100.

larval swimming ability is greatly decreased in lowered salinity. In pumped irrigation systems, however, weak swimming larvae can be swept up from river channels and carried into normally unattainable environments. Whether



Figures 16–20. *Creusia domingensis* Des Moulins, CAS locality 42616, Bermuda. Figures 16–17, terga, height 2.5 mm., and figures 18–19, scutum, height 2.5 mm.; figure 20, shell in *Porites astreoides,* greatest diameter of orifice 0.9 mm. Figures 21–22. Shell of *Hexacreusia durhami* (Zullo), CAS locality 27229, Panama, greatest diameter 3.5 mm. Figure 21, uncoated shell showing radii; figure 22, shell coated with ammonium chloride to show external sculpture (apex of rostrum is damaged).

or not flow reversal is an adequate explanation for these unusual occurrences, the possibility remains that barnacles may pose serious fouling problems in irrigation systems.

Creusia domingensis Des Moulins, 1866.

(Figures 16–20.)

A coral-inhabiting barnacle of the genus *Creusia* Leach was also found by Mrs. Gordon in Bermuda in 1967. The specimens are in two small heads of the coral *Porites astreoides* (Lamarck). The larger coral fragment, measuring about seven centimeters in greatest diameter, contains eleven barnacles, and the smaller, measuring about four centimeters, harbors three individuals.

These barnacles were identified through the kindness of Mr. Arnold Ross of the Natural History Museum, San Diego, who is presently preparing a monographic study of coral-inhabiting balanids. He indicated that they probably represent *Creusia domingensis*; a species originally described in *P. astreoides* from Port-au-Prince, Haiti (Des Moulins, 1866), but which has gone unnoticed since that time. Further examination of specimens of *P. astreoides* in the collections of the California Academy of Sciences (CAS) and of the University of California Museum of Paleontology, Berkeley (UCMP) disclosed additional localities for *C. domingensis* from the vicinity of Biscayne Bay, on the east coast of Florida (CAS locality no. 42265) and from the Dry Tortugas, off southern Florida in the Gulf of Mexico (UCMP locality nos. A-8146, A-8149, B-3717).

Previously, coral barnacles have been reported from the eastern Gulf of Mexico and the West Indies in the Tropical Atlantic region. The discovery of *C. domingensis* in the Bermudas and in southern Florida thus significantly increases the known range both of this little known species and of coralophilous balanids as a group.

Hexacreusia durhami (Zullo, 1961).

(Figures 21–22.)

This six plated coral barnacle was originally described as a species of *Balanus* Da Costa and placed in a new subgenus, *Hexacreusia* Zullo (Zullo, 1961). It was found in late Pliocene, Pleistocene, and Recent specimens of the coral *Porites californica* Verrill from various localities in the Gulf of California, and was later reported in extant specimens of the same coral from the Tres Marias Islands, Mexico, just south of the Gulf of California by Ross (1962).

Although *Hexacreusia* is related to *Balanus*, and especially to the subgenus *Armatobalanus* Hoek, it is more closely allied to the genera *Creusia* Leach and *Pyrgoma* Gray, with which it shares a cup-formed basis, "creusioid" rather than "balanoid" opercular valves, and an obligate coralophilous habitat. For these reasons, *Hexacreusia* is removed from the genus *Balanus* and raised to generic rank.

It was noted earlier (Zullo, 1967) that certain specimens included by Darwin (1854) in his original description of the Australasian species *Balanus allium* were, in fact, *Hexacreusia durhami*. These barnacles were in a coral from Hugh Cuming's collection purported to be from Australia, but which is most probably *Porites californica* from the Pacific Coast of tropical America. As Cuming had spent some time in Central America, but had never traveled north of the Gulf of Fonseca, Honduras, it was suggested that Darwin's specimens came from an area south of its present-known range.

Confirmation of the presence of *Hexacreusia durhami* in Central America is based on the recent acquisition of two lots from Panama. A beachworn piece of *Porites californica* collected by Dr. Leo G. Hertlein of the California Academy of Sciences on December 22, 1931, at Bahía Honda, Veragua, Panama (CAS-Geology locality no. 27229) contains three shells of *Hexacreusia durhami* without opercular valves. The second lot, made available by Professor J. Wyatt Durham of the University of California Museum of Paleontology (UCMP), consists of about two dozen specimens in a large fragment of a *Porites* questionably identified as *P. lobata* (Dana). The coral was collected by Dr. Peter W. Glynn of the Smithsonian Tropical Research Institute (Canal Zone, Panama) from depths between 10 and 20 feet off the Las Secas Islands, Golfo de Chiriquí, Panama (UCMP locality no. D-4138). These barnacles were alive when taken and still retain opercular valves and bodies, although the latter are unsuitable for dissection because of bleaching and drying during processing of the coral.

Hexacreusia durhami is probably present in *Porites* throughout the Panamic Province, but apparently is absent from the faunas of offshore Eastern Pacific islands. Extensive examination of hermatypic corals from the Galápagos Archipelago, Cocos Island (Costa Rica), and Clipperton Island has failed to yield coral barnacles, although a second species, to be described at a later date, has been discovered in ahermatypic corals from deeper water (90 meters) in the Galápagos.

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A KEY, BASED ON SCALES, TO THE FAMILIES OF NATIVE CALIFORNIA FRESHWATER FISHES

By

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Abstract: Much interdisciplinary interest has been shown with regard to fish scales in addition to their use in fisheries biology. To aid future workers, a key to the scales of the native California freshwater fish families is presented along with photomicrographs of scales from each group.

Introduction

Fish scales have been used in fisheries biology and systematic ichthyology for many years. Within fisheries studies, emphasis has been placed upon the use of scales in age and growth studies (Cable, 1956; Cating, 1954; Chugunova, 1959; Cooper, 1951, 1952; Fry, 1943; Hile, 1936; Hogman, 1970; Jensen and Wise, 1961; Miller, 1955; Phillips, 1948; Rush, 1952; Schuck, 1949; Taylor, 1916; Whitney and Carlander, 1956; Meehean, 1935). Various keys, based upon the morphology of scales, have been published dealing with species identification within families and with the identification of families comprising regional fish faunas (Batts, 1964; Lagler, 1947; Koo, 1962).

Fish scales have been used in palaeontological work (David, 1944, 1946a, 1946b), sediment analysis (Lagler and Vallentyne, 1956; Pennington and Frost, 1961; Soutar and Isaacs, 1969), and archaeology (Follett, 1967a, 1967b; Hubbs and Miller, 1948). Even within fisheries work, scales have been encountered during analysis of the stomach contents of various fishes (Greenfield, Ross, and Deckert, 1970; Kimsey, 1954). Based upon this evidently wide interdisciplinary interest in and use of fish scales, it is felt that a scale-based key to the families of native freshwater fishes of California would be a useful aid.

TABLE 1. *Species examined.*

Species	Source
Thaleichthys pacificus	CAS[1]
Oncorhynchus tshawytscha	UCD[2]
O. kisutch	CAS, UCD
Salmo gairdnerii	UCD
S. g. gairdnerii	UCD
S. g. stonei	UCD
S. g. gilberti	CAS
S. g. aquilarum	CAS
S. clarkii clarkii	CAS
S. c. henshawi	CAS
S. c. seleniris	CAS
S. aguabonita aguabonita	CAS
S. a. whitei	CAS
Salvelinus malma parkei	CAS
Prosopium williamsoni	CAS
Xyrauchen texanus	CAS
Catostomus luxatus	CAS
C. platyrhynchus	CAS
C. santaanae	CAS
C. rimiculus	CAS
C. latipinnis	CAS
C. occidentalis occidentalis	UCD
C. o. humboldtianus	CAS
C. mniotiltus	CAS
C. tahoensis	CAS
Rhinichthys osculus klamathensis	CAS
Mylopharodon conocephalus	CAS, UCD
Orthodon microlepidotus	UCD
Pogonichthys macrolepidotus	UCD
Lavinia exilicauda exilicauda	UCD
L. e. harengus	CAS
Ptychocheilus grandis	UCD
Hesperoleucas symmetricus symmetricus	UCD
H. s. subditus	CAS
H. s. venustus	CAS, UCD
H. navarroensis	CAS
H. parvipinnis	CAS
Gila bicolor bicolor	CAS
G. b. obesa	CAS, UCD
G. b. pectinifera	CAS
G. mohavensis	CAS
G. crassicauda	CAS
G. orcutti	CAS

[1] CAS = specimens from California Academy of Sciences, San Francisco.

[2] UCD = specimens from the author's personal collection, presently at University of California, Davis.

Table 1. (*continued*)

Species	Source
G. elegans	CAS
Richardsonius balteatus egregius	CAS
Cyprinodon macularius californiensis	CAS
C. nevadensis nevadensis	CAS
C. n. calidae	CAS
C. n. shoshone	CAS
C. salinus	CAS
Fundulus parvipinnis	CAS
Mugil cephalis	CAS
Archoplites interruptus	UCD
Hysterocarpus traskii	CAS, UCD

For the purposes of this paper, native freshwater fishes will refer to those fishes which occur exclusively in freshwater or spend a significant portion of their life-cycle in freshwater and which occurred in California prior to the known introduction of exotic species during and after the nineteenth century (Kimsey and Fisk, 1960; Shapovalov, Dill, and Cordone, 1959; Walford, 1931). The only exception has been the inclusion of the Mugilidae because of their importance in the Colorado River.

Methods and Materials

The scales studied come from 54 species of native fishes (table 1) and represent specimens collected by the author or by members of the California Department of Fish and Game, and specimens from the California Academy of

Table 2. *Scale sampling locations.*

A. Row anterior to dorsal fin.
B. Right side, below dorsal fin, above lateral line.
C. Left side, below dorsal fin, above lateral line.
D. Right side, below dorsal fin, below lateral line.
E. Left side, below dorsal fin, below lateral line.
F. Right side, caudal penduncle, above lateral line.
G. Left side, caudal penduncle, above lateral line.
H. Right side, caudal penduncle, below lateral line.
I. Left side, caudal penduncle, below lateral line.
J. Row posterior to dorsal fin.

TABLE 3. *Scale characteristics of California freshwater fish families.*

Family	Ctenoid Scales	Cycloid Scales	Scutes	Neither
Petromyzonidae				X
Acipenseridae			X	
Osmeridae		X		
Salmonidae		X		
Catostomidae		X		
Cyprinidae		X		
Gasterosteidae			X	
Cyprinodontidae	X	X[3]		
Mugilidae	X			
Centrarchidae	X			
Embiotocidae		X[3]		
Cottidae				X

[3] Scales of these families, while being cycloid, should be oriented as shown for ctenoid scales in figure 1 b.

Sciences, San Francisco. Table III indicates the general scale characteristics of the fishes in this study.

The fish were sampled for scales from ten different body locations (table 2) on the author's specimens. For reasons of future use, the specimens from the California Academy of Sciences could only be sampled from six locations on the right-hand side of the fish. Wherever possible, samples were taken from several individuals of different sizes within a species in order to allow for ontogenetic variations. All scale samples were mounted in glycerine jelly on microscope slides (Weesner, 1960) and examined under a dissecting microscope at between ten and thirty magnifications.

DEFINITIONS

The terms used here to describe the surface features of scales are taken from Lagler (1947, pp. 150–151) and are illustrated in figure 1.

Circuli — "Elevated markings on the outer surface; usually appearing as lines which more or less follow the outline shape of the scale."

Focus — "First part of scale to appear in growth; often central."

Radii — "Grooves, usually more or less radiating from focus to one or more margins."

Primary Radii — "Radii that extend from focus to margin."

Secondary Radii — "Radii that begin outward from, not at, focus."

Ctenii — "Tooth-like structures on posterior portion of scale."

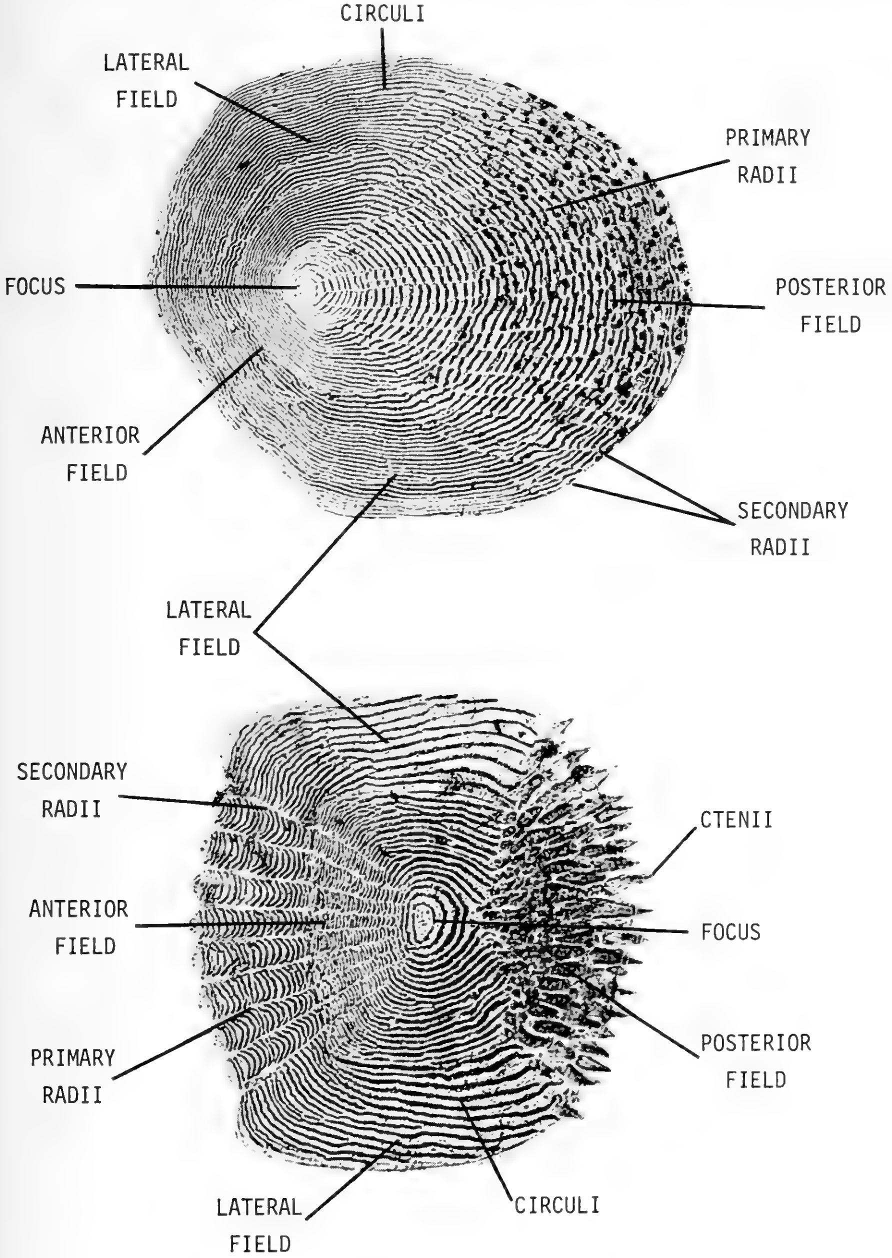

Figure 1. Top. Cycloid Scale. *Cyprinidae*. *Mylopharodon conocephalus*. UCD 5040 C. Bottom. Ctenoid Scale. Centrarchidae. *Archoplites interruptus*. UCD 5021 E.

Figure 2. a. Cyprinodontidae. *Cyprinodon macularius californiensis.* UCD 5063 G. b. Centrarchidae. *Archoplites interruptus.* UCD 5021 E. c. Mugilidae. *Mugil cephalus.* UCD 5056 I.

Fields — "Areas of the outer surface of the scale, either real as delimited by angulation of the ridges (circuli) at levels of the four principal corners or imaginary if the corners or configuration of the circuli are wanting. Adjectives of direction applied to fields are based on their positions when the scales are normally situated on the side of the fish."

Anterior Field — "Bounded by imaginary lines connecting the anterolateral corners, or their equivalent points on scales which are rounded (dorsal and ventral) with the focus."

Posterior Field — "Bounded by imaginary lines connecting the posterolateral corners (dorsal and ventral) with the focus."

Lateral Fields — "Dorsal and ventral fields remaining after delimitation of anterior and posterior ones."

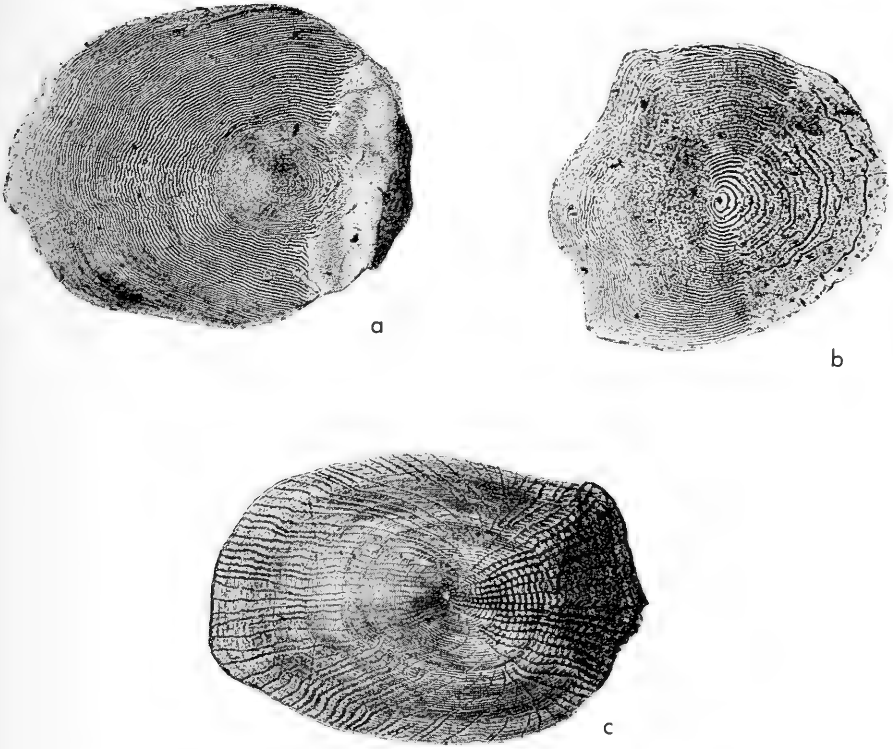

Figure 3. a. Salmonidae. *Salmo gairdnerii gairdnerii.* UCD 5002 D. b. Salmonidae. *Prosopium williamsoni.* UCD 5016 C. c. Catostomidae. *Catostomus occidentalis occidentalis.* UCD 5026 C.

Scale-based Key to the Families of California Freshwater Fishes

The following is a key to the family level with the exception of *Prosopium williamsoni* which is identified to species.

The Cyprinodontidae are characterized by both ctenoid and cycloid scales in the same individual. Lagler (1947, pp. 156–157) classified the Cyprinodontidae of the Great Lakes as having cycloid scales and the same appears true of the genus *Fundulus* in California. However, the other members of this family may also possess ctenoid scales (Lagler, Bardach, and Miller, 1962, p. 114). For this reason the key identifies this family twice, once on the basis of ctenoid scales and again on the basis of cycloid scales. This same case appears true of the Centrarchidae (Lagler, Bardach, and Miller, 1962, p. 114). Based upon data from my collections, however, I find cycloid scales to occur only once in 32 samples and

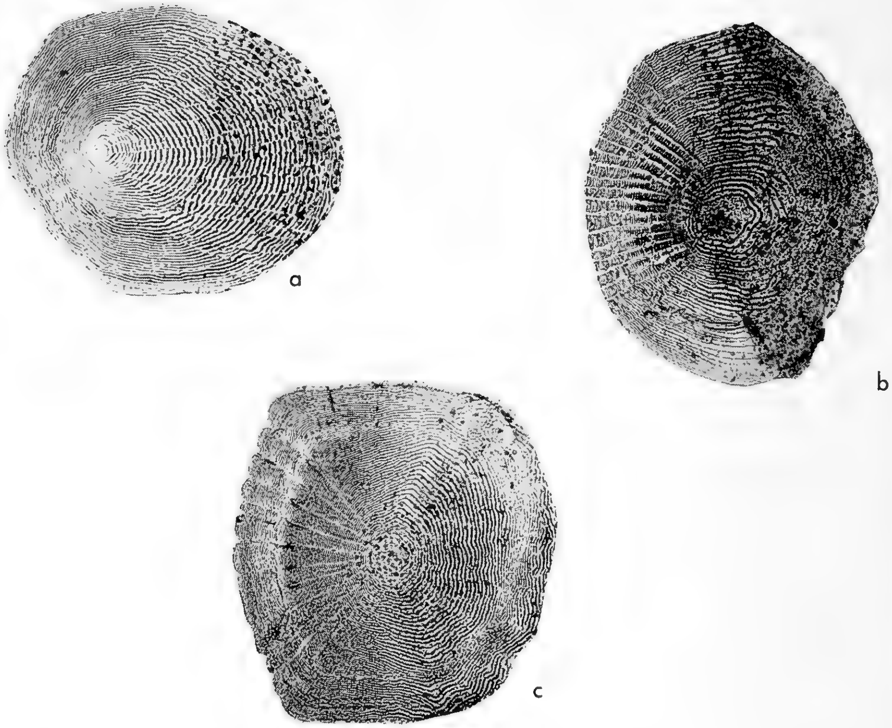

Figure 4. a. Cyprinidae. *Mylopharodon conocephalus.* UCD 5040 C. b. Cyprinodontidae. *Cyprinodon macularius californiensis.* UCD 5063 A. c. Embiotocidae. *Hysterocarpus traskii.* UCD 5099 C.

then only from restricted areas of the body in centrarchids (table 2, A). This is a rather low frequency and if one considers the total number of scales over a fish's body, it appears that occurrence of cycloid scales in *Archoplites interruptus* will be even more rare. I agree, therefore, that "These fishes may still be considered as predominantly ctenoid in their squamation but the degree and extent of development of the ctenii varies from place to place on the body" (Lagler, Bardach, and Miller, 1962, p. 114). In the rare event that a cycloid scale from this family should present itself in isolation it will key out as representing the Embiotocidae instead of the Centrarchidae.

Figures 2, 3, and 4 illustrate each of the families or species separated by the key. Each illustration is oriented with the anterior field to the observer's left.

1\. a) Ctenii present on posterior field 2
   b) Ctenii absent on posterior field 4
2\. a) Ctenii numerous and evenly spaced 3

b) Ctenii not numerous and irregularly spaced .... Cyprinodontidae
(figure 2, a)
3. a) Radii converge toward focus .... Centrarchidae
(specifically *Archoplites interruptus*; figure 2, b)
b) Radii roughly parallel .... Mugilidae
(specifically *Mugil cephalus*; figure 2, c)
4. a) Scale cycloid without radii 5
b) Scale cycloid with radii 6
5. a) Scale with anterior and posterior fields only or without fields .... Osmeridae and Salmonidae
(figure 3, a)
b) Scale with four fields; focus centrally located .... *Prosopium williamsoni*
(figure 3, b)
6. a) Primary radii on both posterior and anterior fields .... Catostomidae
(also includes the cyprinid genera *Rhinichthys* and *Orthodon*; figure 3, c)
b) Primary radii absent on either anterior or posterior field 7
7. a) Primary radii present on anterior field, but absent on posterior field 8
b) Primary radii absent on anterior field, but present on posterior field .... Cyprinidae
(figure 4, a)
8. a) Far fewer circuli in lateral than in anterior field .... Cyprinodontidae
(figure 4, b)
b) Number of circuli in lateral field approximately equal to number in anterior field .... *Embiotocidae*
(specifically *Hysterocarpus traskii*; figure 4, c)

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THE LYGAEIDAE OF THE GALÁPAGOS ISLANDS (Hemiptera:Heteroptera)

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With the publication of this paper, reports on the Heteroptera of the Galápagos International Scientific Project are nearly complete. Published papers cover the Anthocoridae (Herring, 1966), the Tingidae (Drake and Froeschner, 1967), the Saldidae and Veliidae (Polhemus, 1968a, b), the Cydnidae (Froeschner, 1968), the Nabidae (Kerzhner, 1968), the Miridae (Carvalho and Gagné, 1968), and the emesine Reduviidae (Villiers, 1970). The families Pentatomidae, Coreidae, Rhopalidae, Stenocephalidae, Berytidae, Pyrrhocoridae, Reduviidae, Gerridae, and Corixidae also are found in the Galápagos Islands, and members of the expedition collected all but Pyrrhocoridae and Stenocephalidae. Hopefully, the many new island records in these families will be summarized in another contribution. The collections of only the Rhopalidae may still prove to contain new species.

Before the expedition, Dr. Usinger and I had hopes of greatly increasing the number of Lygaeidae recorded from the islands, especially in the subfamily Orsillinae, a group well known for its ability to colonize islands. Only four species of Lygaeidae, including two orsillines, had previously been recorded from the Galápagos (Linsley and Usinger, 1966). Herein I am able to report only nine species of lygaeids—five are orsillines—of which two, including one of the orsillines, are possibly introduced by man. While more lygaeids may be found in the archipelago, I seriously doubt that the known endemic fauna of the group will double again. Because the lygaeid fauna of Hawaii contains forty percent of the world orsillines, the sparse fauna of the Galápagos deserves some explanation.

MacArthur and Wilson (1967) discuss the factors that determine the introduction and extinction rates of island faunas as they develop the concept of an island colonization rate. Further, they postulate that each island or archipelago has a fairly fixed capacity for numbers of species. Among islands populated from American sources, the Galápagos have a far better chance of receiving introductions than do most other islands of the eastern Pacific, primarily because they form an archipelago. The Hawaiian Islands, a larger archipelago, would have received fewer introductions because of its great isolation.

Some examples will illustrate the point. The smallest orsilline faunas are those of Guadelupe Island, 180 miles off Baja California, and San Felix, 550 miles west of Chile, each having a single undescribed endemic species (belonging to *Ortholomus* and *Nysius*, respectively). The Juan Fernandez Islands, two islands about 450 miles off the coast of Chile, have two endemic orsillines, *Nysius baeckstroemi* and *Robinsonocoris tingitoides*, the latter an endemic genus. The Galápagos Islands have five species, resulting from four introductions, including the endemic genus *Darwinysius* with two species. The Hawaiian fauna by contrast is rich. Of the 92 species of Orsillinae, the tribe Metrargini [probably of American origin (Ashlock, 1967)] contains 58 species (in six endemic genera) resulting from but two introductions. The remaining Hawaiian species (in *Nysius* and the endemic *Nesomartis*, a probable derivative of *Nysius*) are of unknown origin. Clearly, the Galápagos have a much higher introduction rate than Hawaii, but the larger, more hospitable Hawaiian Islands have a lower extinction rate than the dryer and smaller Galápagos.

Thus, possible ecological situations on the Galápagos are nearly saturated by naturally introduced orsillines. Hawaii's isolation has allowed few introductions, but its low extinction rate, combined with the large number of ecological situations, permitted explosive radiation.

Linsley and Usinger (1966) acknowledge those that made the G.I.S.P. expedition possible. I must add my own thanks to the late R. L. Usinger, who made my participation possible. Much of the work on this paper was done at the B. P. Bishop Museum, Honolulu, with financial help from two NSF grants (GB–3105 and GB–5860). Types of new species are deposited in the California Academy of Sciences, San Francisco, and specimens upon which the study was based will be found in that institution and in the Bishop Museum; the U. S. National Museum; the California Insect Survey, Berkeley; and the collections of J. A. Slater, G. G. E. Scudder, M. H. Sweet, and myself. All measurements are in millimeters, and the year of collection is 1964 unless otherwise noted.

Key to Galápagos genera of Lygaeidae

1. Suture between abdominal segments IV and V (second visible suture) curving anteriorly, not reaching lateral margin of abdomen .... Rhyparochrominae: Myodochini 2
Suture between segments IV and V not curving anteriorly, clearly reaching lateral margin of abdomen 3

2. Head constricted behind eye; eye removed from base of head by a distance greater than length of an eye .... *Heraeus*
   Head not constricted behind eye; eye removed from base of head by a distance less than length of an eye .... *Pachybrachius*
3. Scutellum bifid apically; clavus basally opaque, apically hyaline .... Cyminae: Ninini .... *Cymoninus*
   Scutellum not bifid apically; clavus not divided into distinct opaque and hyaline areas .... Orsillinae 4
4. Costal margin of corium straight, exposing connexivum of abdomen laterally .... Orsillini .... *Ortholomus*
   Costal margin of corium straight at most for a distance less than length of scutellum, then arcuately curved to apex; connexivum of abdomen completely covered 5
5. Buccula not punctate; lateral margin of abdomen and corium without cross-striated stridulitra .... Nysiini .... *Nysius*
   Either buccula punctate or lateral margin of abdomen and corium with cross-striated stridulitra .... Metrargini 6
6. Buccula punctate, not tapering, ending abruptly at base of head; antenniferous tubercle acutely produced; abdomen and corium without stridulatory structures .... *Darwinysius*
   Buccula impunctate, tapering to a low carina well before base of head; antenniferous tubercle not acutely produced; abdomen and corium laterally with cross-striated stridulatory structure .... *Xyonysius*

Genus **Nysius** Dallas

Nysius Dallas, 1852, p. 551.

Although two species from the Galápagos were originally described in the cosmopolitan genus *Nysius*, both have since been placed in other orsilline genera in the tribe Metrargini. *Nysius* (*Ortholomus*) *naso* Van Duzee is placed in *Xyonysius* (Ashlock and Lattin, 1963) and *Nysius* (?) *marginalis* Dallas is placed in *Darwinysius* (Ashlock, 1967). The following is the first true *Nysius* to be reported from the Islands.

Nysius usitatus Ashlock, new species.

(Figures 1, 3.)

Head nearly flat between eyes, densely punctate, sparsely clothed with appressed pale hairs, length 0.66, width 0.88, anteocular length 0.27, eye length 0.29, eye width 0.19, interocular space 0.48; buccula widest anteriorly, tapering posteriorly, and ending abruptly just before base of head; labium extending to between hind coxae, first segment not reaching base of head but just exceeding buccula, segment lengths from base 0.39, 0.39, 0.37, 0.29; antenna with first segment exceeding clypeus by nearly half its length, segment lengths from base 0.26, 0.60, 0.49, 0.49.

Pronotum moderately clothed with fine curved subappressed hairs, disk densely punctate, distance between punctures from one-half to one diameter of a puncture, sides nearly straight; length 0.59, width 1.02. Scutellum

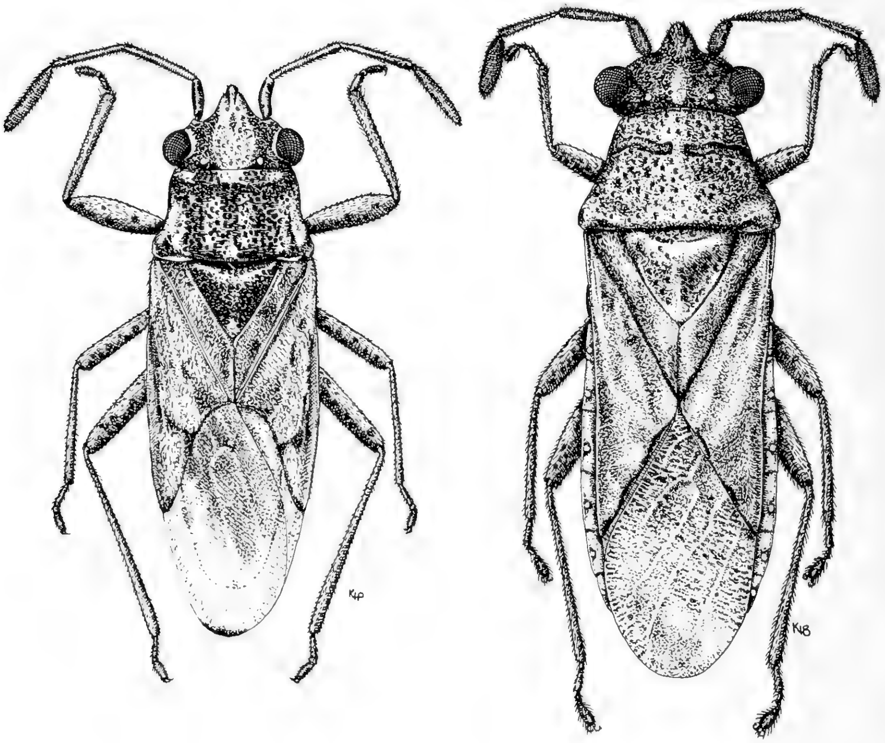


FIGURE 1. Dorsal views of (left) *Nysius usitatus* and (right) *Ortholomus usingeri.*

with vestiture and punctation similar to those of pronotum; Y-shaped carina appearing as a tumid pyramid; length 0.48, width 0.58.

Hemelytron exceeding abdomen, clavus and corium with surface almost dull, moderately clothed with subappressed curved hairs, with additional hairs projecting laterally along base of costal margin, clavus obscurely punctate only at base of claval suture, costal margins subparallel and paralleling vein R+M to level of apical two-thirds of scutellum, then gently becoming divergent and arcuate to apex of corium, veins evident but not prominent; length of claval commissure 0.34; length of corium 1.50; membrane normal with veins evident but not distinct, basal length to level of corial apex 0.65, apical length from corial apex 0.77.

Color. Light reddish brown, with broad stripe passing through each ocellus, margins of clypeus, three spots at base of clypeus, ventor except buccula, and spot below eye black. Buccula, labium, and antenna yellowish brown, first segment of antenna a little darker. Pronotum light yellowish brown, with partial indistinct median stripe, broad complete stripe behind each ocellus, and narrow lateral stripe dark brown, callosities black. Scutellum black or nearly so, apex white. Hemelytra light yellowish brown with indistinct brown spots on veins and apical margin. Membrane hyaline, embrowned medially except veins obscurely opaque white, ventor black except anterior and posterior margins of propleura, acetabula, scent gland area, metapleural plate, and spots laterally and apically on abdomen pale. Legs pale yellowish brown, with usual brown spots on femur, tibia with a brown knee band.

HOLOTYPE. ♂, Santa Cruz Island, 1.5 mi. north of Academy Bay, 13 February, under *Portulaca* (P. D. Ashlock).

PARATYPES. Santa Cruz Island, 9 ♂, 10 ♀, same data as holotype; 1 ♀, same data but 11 February; 32 ♂, 17 ♀, same data but 15 February; 3 ♂, 5 ♀, same data but 25 February; 3 ♀, Horneman Farm, 220 m., 2 April (D. Q. Cavagnaro).

Most specimens of this species were collected at the foot of the barranca (cliff) on the new trail from Academy Bay, Santa Cruz Island, under *Portulaca* and in company with *Darwinysius marginalis*. Since *Nysius usitatus* was collected only near Academy Bay on Santa Cruz and not at all from the *Portulaca* habitat on all other islands visited, it may be a recent introduction to the Galápagos. Specimens fit Dallas' (1852, p. 553) description of *N. nubilis* from Colombia fairly well, but the *N. nubilis* type is not extant. Dr. Usinger searched in vain for it at the British Museum in 1964, and found (correspondence) that the British Museum copy of the Dallas description has a note: "type missing." I have a short series of *Nysius* from Guayaquil, Ecuador, and another from Palmira, Colombia, that also fit Dallas' description, but the spermathecae differ substantially from that of *N. usitatus* (fig. 3). Since there is only slight evidence that *N. usitatus* is introduced, and its identity with *N. nubilis* is open to question, I have described the Galápagos form as new. The problem of the identity of *N. nubilis* can best be solved by the judicious choice of a neotype when adequate series of *Nysius* are available from northwestern South America.

Genus **Ortholomus** Stål

Nysius (*Ortholomus*) STÅL, 1872, p. 43.
Ortholomus Stål, BAKER, 1906, p. 134.

Ortholomus usingeri Ashlock, new species.

(Figures 1, 3.)

Head flattened between eyes, obscurely punctate, densely covered with flattened appressed hairs, vertex carina straight, eye prominent, slightly raised above vertex; length 0.85, width 1.11, anteocular length 0.44, eye length 0.22, eye width 0.29, interocular space 0.61; buccula widest anteriorly,

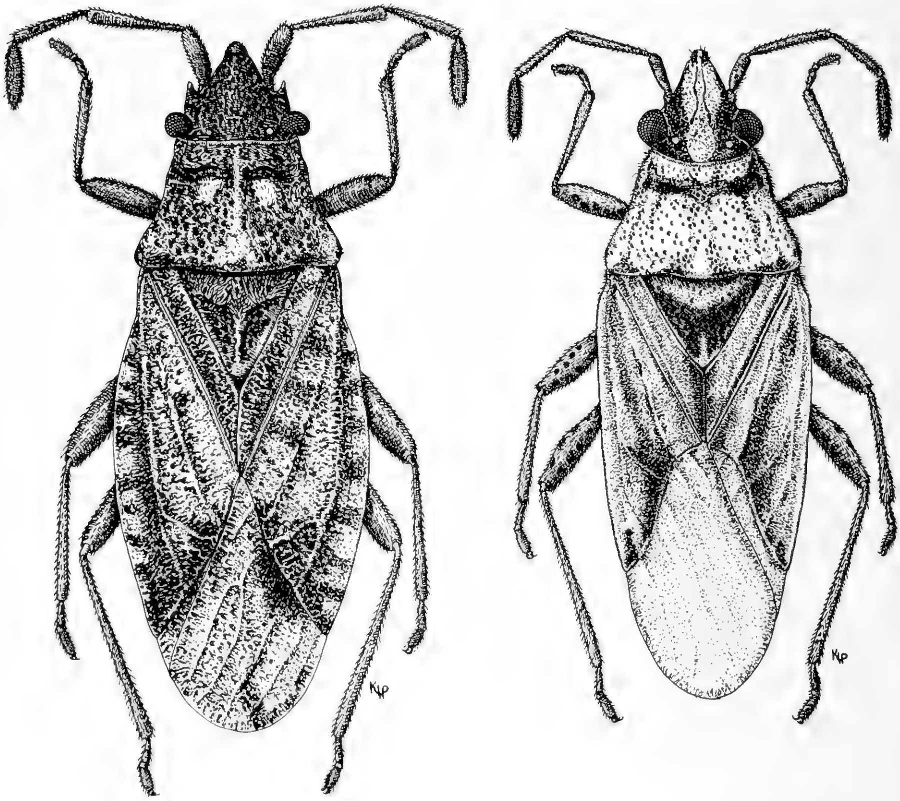


Figure 2. Dorsal views of (left) *Darwinysius wenmanensis* and (right) *Xyonysius naso.*

gradually narrowing posteriorly to mid eye level without abrupt change in width; labium reaching between posterior coxae, first segment exceeding buccula, not reaching base of head, segment lengths from base 0.46, 0.43, 0.46, 0.39; antenna with fine erect pubescence, first segment slightly exceeding clypeus, segment lengths from base 0.29, 0.46, 0.44, 0.49.

Pronotum clothed with appressed flattened somewhat silky hairs, with occasional short erect hairs, moderately punctate, distance between punctures from one-half to one diameter of a puncture, sides straight, slightly swollen, length 0.78, width 1.28. Scutellum with vestiture and punctation like those of pronotum, Y-shaped carina swollen on upper arms, stem not prominent, length 0.54, width 0.75.

Hemelytron slightly exceeding abdomen, clavus and corium moderately clothed with short silky appressed hairs, with a few short erect hairs projecting laterally along base of costal margin; veins evident but not prominent; length of claval commissure 0.49; length of corium 1.80; membrane irregularly wrinkled transversely; veins distinct, basal length to level of corial apex 0.77, apical length from corial apex 0.78.

Abdomen with connexival spiracles raised, very prominent.

Color. Head very dark brown, clypeus, median stripe on posterior half of vertex, buccula, labium, and antenna paler except antennal segment IV very dark brown. Pronotum and scutellum reddish brown, callosities and punctures a little darker. Hemelytron pale yellowish brown, darkened apically on clavus and corium and on obscure spots on veins; vestiture nearly white, silky. Connexival segments pale, darker around pale spiracles. Legs yellowish brown, femur with obscure, slightly darker spots. Ventor reddish brown, acetabula and scent gland paler.

Holotype. ♂, Santa Cruz Island, grassland, 1,800 ft., north of Academy Bay, 20 February, on *Hypericum pratense* (P. D. Ashlock).

Paratypes. Santa Cruz Island, 6 ♂, 12 ♀, 4 nymphs, same data as holotype; 4 ♂, 1 ♀, same data but 2,100 ft.; 1 ♂, 1 ♀, Bella Vista, 26 February (R. L. Usinger); 15 ♂, 15 ♀, Table Mountain, 440 m., 16 April (D. Q. Cavagnero). Floriana Island, 1 ♂, 1 ♀, 15 February, *Verbena* (R. L. Usinger); 57 ♂, 48 ♀, Whitmer's Farm, 15 February, *Verbena* (R. L. Usinger); 1 ♂, 2 ♀, same data but *Cordia* species; 1 ♂, 1 ♀, moist forest 200 m. above Black Beach, 15 February, *Cordia* tree with yellow flowers (R. L. Usinger); 7 ♂, 10 ♀, 18 February (R. L. Usinger). San Cristobal Island, 3 ♂, 4 ♀, Progresso, 23 February, *Verbena* (R. L. Usinger).

Ortholomus usingeri is less elongate than most of the described species in the genus, and the connexivum is more broadly exposed, being approached only by *O. gibbus* (Berg) in this respect. The spiracles are more prominent and enlarged than in any other species. All series of the species are variable in color, ranging from the pale form illustrated (fig. 1), to specimens that are highly maculated on the corium, clavus, and membrane. Some specimens have a very dark, contrasting claval apex. None of these variations are correlated with island of origin or with host plant. The new species of *Ortholomus* from Guadelupe Island (see Introduction) may be very closely related to *O. usingeri.*

It is with devoted appreciation that I dedicate this Galápagos orsilline to R. L. Usinger, who was the leading authority in the Orsillinae, and whose leadership of the G. I. S. P. expedition he considered the high point of his life.

Genus **Darwinysius** Ashlock

Darwinysius Ashlock, 1967, p. 42.

Darwinysius is the only endemic genus of Lygaeidae—and one of the very few in the Heteroptera—found in the Galápagos. It is closely related to

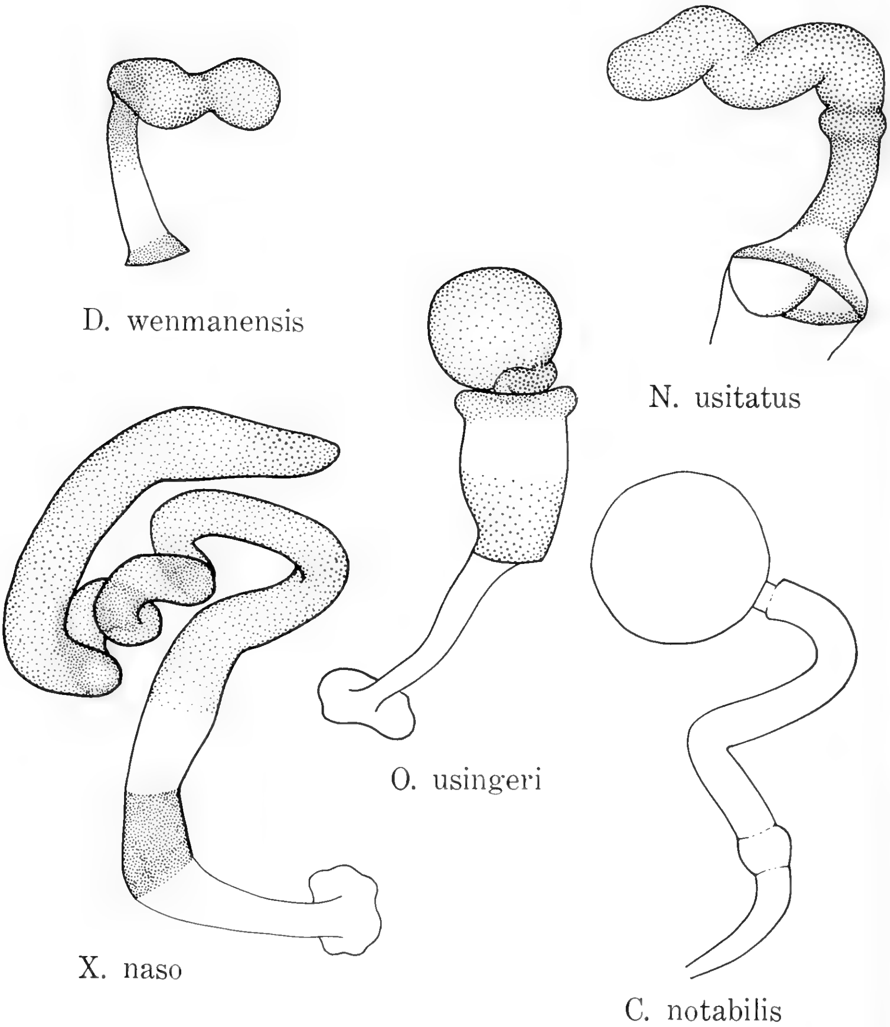


Figure 3. Spermathecae of the named species.

Robinsonocoris in the Juan Fernandez Islands, differing principally in features correlated with the flightlessness of *Robinsonocoris*. At the time of the original description of *Darwinysius* for *Nysius* (?) *marginalis* Dallas, it was mentioned that a second species had been found on the Galápagos.

Key to Galápagos species of Darwinysius

Larger species, male more than 3.2 long, female more than 3.8 long; clothed above with short, appressed hairs; vertex of head raised above level of top of eye; Wolf Island .... *D. wenmanensis* Ashlock, new species

Smaller species, male less than 3.1 long, female less than 3.5 long; clothed above with mixed erect and appressed hairs; vertex of head not raised above level of top of eye; main islands .... *D. marginalis* (Dallas)

Darwinysius marginalis (Dallas).

Nysius (?) *marginalis* DALLAS, 1852, p. 556.
Cymus galapagensis STÅL, 1959, p. 252 (synonymy by Butler, 1877).
Darwinysius marginalis (Dallas), ASHLOCK, 1967, p. 42.

In the summer of 1964, Dr. R. L. Usinger checked the types of *Cymus galapagensis* Stål and *Nysius* (?) *marginalis* Dallas at my request. In Stockholm he confirmed Butler's (1877) synonymy of Stål's species with that of Dallas, but in London, he found Dallas' series of eight specimens to contain two species: four of the eight belonged to *Xyonysius naso* (Van Duzee). Since Dallas did not select a holotype, and no lectotype had since been chosen, Usinger selected the best specimen of the remaining four as a lectotype. He wrote that the lectotype "is rather broad and well marked and has no antennae." The specimen is numbered 77–2 (as were the *X. naso*) and is from Charles Island (Floreana). The remaining specimens were from James Island (Santiago) and "were very poor and not suitable to be made a lectotype." The Charles Island specimen (no. 77–2) is here formally selected as the lectotype of *Nysius* (?) *marginalis* Dallas.

Published records of *Darwinysius marginalis* are from three islands: Floreana, Santiago, and Daphne Major. Members of the G. I. S. P. expedition collected well over 300 specimens and can add five islands to the list: Isabella, Fernandina, Rabida, Pinzon, and Santa Cruz. Almost all of my specimens were collected under *Portulaca*, where they were feeding on fallen seeds of the plant. Dr. Usinger collected 55 specimens on *Euphorbia viminea* at Black Beach, Floreana.

Darwinysius marginalis is generally similar to *D. wenmanensis*; differentiating characters can be found in the key to species. A dorsal view of *D. marginalis*, a side view of the head, and drawings of the aedeagus and spermatheca are given in Ashlock (1967).

Darwinysius wenmanensis Ashlock, new species.

(Figures 2, 3.)

Head elevated above eye about one-third height of eye, sparsely clothed with flattened appressed hairs, length 0.71, width 0.80, anteocular length 0.46, eye length 0.20, eye width 0.15, interocular space 0.48, buccula widest anteriorly, narrow, but not tapering to base of head, slightly projecting past posterior point of attachment, not reaching base of head, densely punctate; labium just reaching posterior coxae, first segment not reaching posterior end of buccula, segment lengths from base 0.46, 0.43, 0.44, 0.32; antenna with flattened subappressed hairs on first segment, semierect fine hairs on fourth segment, second and third segments intermediate, first segment exceeding clypeus by nearly half its length; segment lengths from base 0.39, 0.56, 0.48, 0.41.

Pronotum with flattened appressed hairs, deeply and densely punctate, cicatrices depressed, area anterior to cicatrices somewhat inflated; length 0.78, width 1.19. Scutellum with vestiture and punctation similar to those of pronotum, with a strongly elevated Y-shaped carina, length 0.51, width 0.68.

Hemelytron exceeding abdomen, clavus and corium moderately dotted with appressed hairs, without erect hairs at base of lateral margin, surface overall ridged, punctate on both sides of claval suture and outer edge of vein R+M for entire length, all veins prominent and elevated, length of claval commissure 0.54, length of corium 2.04, apex attaining abdominal segment VII; membrane with surface irregularly ridged transversely, veins prominent, basal length to level of corial apex 0.90, apical length from corial apex 0.54.

Color. Head, labium, antenna very dark brown, apices of first to third antennal segments and lower edge of buccula pale. Pronotum, scutelum, and hemelytron mottled dark and yellowish brown; pronotum with a patch of white flattened hairs behind cicatrix, corium with lateral margin alternately light and dark, apical margin beyond intersection of vein Cu very dark brown, membrane including veins mottled brown and transparent. Ventor dark brown except acetabula, posterior lobe of propleura, mesothoracic scent gland, and lateral posterior angle of metapleuron pale, legs with femur very dark brown, apex pale, tibia and tarsi pale with dark band dorsally and subapically on tibia.

HOLOTYPE. ♂, Wolf Island (Wenman). 31 January, under *Portulaca* (P. D. Ashlock).

PARATYPES. Wolf Island, 15 ♂, 15 ♀, same data as holotype; 1 ♂, 24 September 1906 (F. X. Williams).

Darwinysius wenmanensis is abundantly distinct from the type species of the genus as indicated by characters in the key. Both species are variable in color pattern, ranging from nearly immaculate on the clavus and corium to quite dark with few pale maculations, but in general *D. wenmanensis* tends to be darker. Such features of both species as the spotted costal margin, the acute antenniferous tubercles, the general body shape, and, in *D. wenmanensis*, the raised vertex of the head, make both look very much like miniature *Nesoclimacias* (Hawaiian Islands). This similarity was noted earlier (Ashlock, 1967, p. 35); however, I now think these similarities—of *Robinsonocoris* and *Darwinysius* with the Hawaiian *Metrarga*, *Nesoclimacias*, and *Nesocryptias*—represent parallelisms rather than a monophyletic origin.

Specimens of *D. wenmanensis* from Wenman Island were the first members of the genus I collected, and it was on Wenman that the "under *Portulaca*" habitat of *Darwinysius* was discovered. Unfortunately, it was then too late to search the *Portulaca* on Darwin Island (Culpepper), the most remote of the archipelago.

Genus **Xyonysius** Ashlock and Lattin

Xyonysius Ashlock and Lattin, 1963, p. 702.

Xyonysius naso (Van Duzee).

(Figures 2, 3.)

Nysius (Ortholomus) naso Van Duzee, 1933, p. 27.
Ortholomus naso (Van Duzee), Barber, 1934, p. 285.
Nysius naso Van Duzee, Usinger, 1941, p. 131.
Xyonysius naso (Van Duzee), Ashlock and Lattin, 1963, p. 702.

Xyonysius is a New World genus of metragine Orsillinae whose species are found from Canada to Argentina and Chile. The endemic Galápagos species *X. naso* is one of the more variable ones, ranging from forms with immaculate hemelytra to forms with three irregular dark brown longitudinal stripes on the corium, the middle one continuing onto the membrane, and dark brown claval apices. Figure 1 shows a specimen with intermediate coloration. This variation was found in all series of the species collected, and does not appear to be correlated with island or host plant. Unlike *X. californicus* (Stål), a wide-spread North American species found on many composites, *X. naso* seems to be confined to species of the endemic composite genus *Scalesia*. The species was described from a single specimen taken on Floreana (Charles Island). Dr. Usinger and I collected 59 specimens on the following islands and host plants: Santa Cruz (*S. affinis*, *S. helleri*), Fernandina (*Scalesia* species), Barrington (*S. helleri*), Isabella (*S. affinis*, *S. gummifera*), and Floreana (*S. affinis*). Nowhere was the species abundant.

Genus **Cymoninus** Breddin

Cymoninus Breddin, 1907, p. 38.

Cymoninus notabilis (Distant).

(Figures 3, 4.)

Ninus notabilis Distant, 1882, p. 191.
Cymoninus notabilis (Distant), Van Duzee, 1917, p. 163.

This species is here reported from the Galápagos for the first time. Wide-spread, it ranges from the southern United States through Central America and the Antilles south to Argentina and Brazil. I collected 55 specimens on Santa Cruz Island on the trail north of Academy Bay and Bella Vista at about 1,300 feet on a sedge identified by Ira Wiggins as *Cyperus confertus* Swartz. D. Q. Cavagnaro also collected a few specimens on Santa Cruz at the Horneman Ranch, just north of Bella Vista. This species may be a recent introduction to the Galápagos. I collected two specimens in the harbor at Guayaquil, Ecuador, at light, on board ship.

Genus **Pachybrachius** Hahn

Pachybrachius HAHN, 1826, p. 18.
Orthaea DALLAS, 1852, p. 580.

KEY TO GALÁPAGOS SPECIES OF PACHYBRACHIUS

Smaller species, less than 4 long; usually brachypterous; corium with long erect hairs and an oval white spot near inner angle .... *P. nesovinctus* Ashlock, new species

Larger species, more than 4 long; never brachypterous, fully winged; corium with short appressed hairs and without an oval white spot near inner angle .... *P. insularis* Barber

Pachybrachius insularis (Barber).

(Figure 5.)

Orthaea insularis BARBER, 1925, p. 246.
Pachybrachius insularis (Barber), SLATER, 1964, p. 1127.

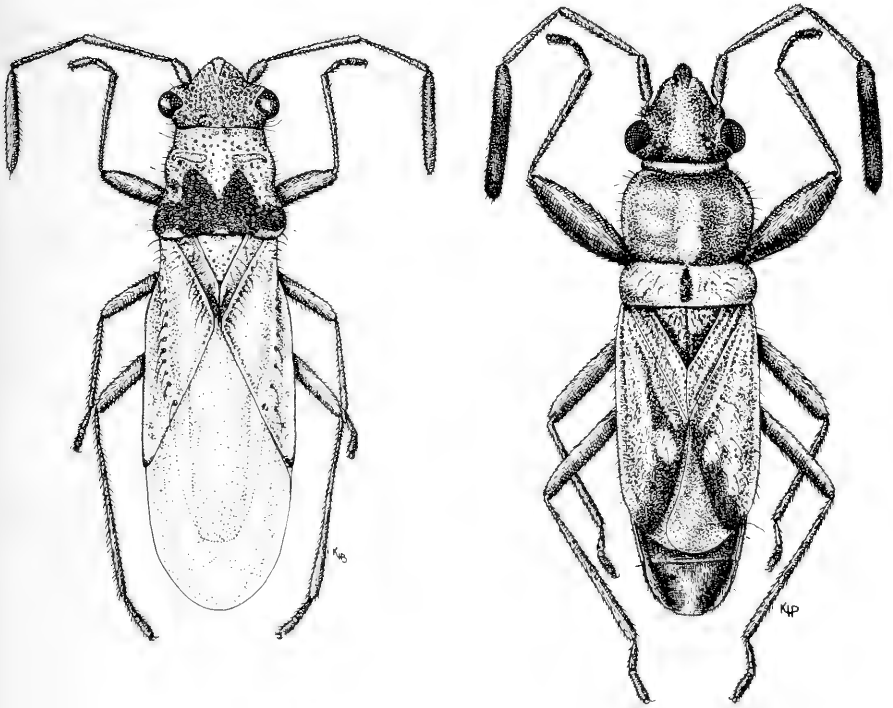
Barber's Galápagos *Pachybrachius* has been recorded from Isabella, Santiago, Baltra, and Santa Cruz Islands. Members of the expedition collected the species from all of these but Isabella and Baltra, but also collected it on Fernandina and Floreana. Most of the material was collected from lights, though occasional specimens were collected from the forest floor. The two specimens from Floreana, both females (Kuschel and Usinger, collectors) were unusual, since both had the labium extending onto the abdomen. Barber (1925) described the labium as "reaching just past intermediate coxae." However, labial length in a 36-specimen sample varied as follows: past front but not to mid coxae, 5 ♂, 0 ♀; between mid coxae, 14 ♂, 7 ♀; past mid but not to hind coxae, 3 ♂, 4 ♀; between hind coxae, 0 ♂, 1 ♀; behind hind coxae onto abdomen, 0 ♂, 2 ♀. This character is clearly variable, and females tend to have the longer labia. Although the two females with the longest labia came from the same island, there was no other correlation of labial length with island of origin.

Pachybrachius nesovinctus Ashlock, new species.

(Figures 4, 5.)

Head slightly elevated between eyes, densely but shallowly punctate, sparsely dotted with inconspicuous subappressed and long erect hairs, length 0.71, width 0.75, anteocular length 0.37, eye length 0.17, interocular space 0.44; buccula high, short, bucculae joined as a single low carina at level of antenniferous tubercle; labium not quite reaching mid coxae, first segment not reaching base of head, segment lengths from base 0.44, 0.44, 0.27, 0.29; antenna with first segment exceeding clypeus by nearly half its length, segment lengths from base 0.34, 0.63, 0.49, 0.94 (fourth segment drawn too thick in figure 3).

Pronotum with sparse short subappressed hairs and long erect fine hairs, with a single transverse row of widely spaced shallow small punctures on collar,



Cymoninus notabilis Pachybrachius nesovinctus

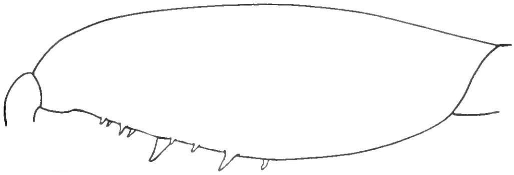


Figure 4. Dorsal views of the named species, and anterior view of fore femur of the holotype of *P. nesovinctus.*

and similar punctures scattered over posterior lobe, length 0.83, collar length 0.09, width 0.56, anterior lobe length 0.29, width 0.88; divisions between collar and two lobes very distinct, anterior lobe globular. Scutellum with vestiture and punctation like those of hind lobe of pronotum; length 0.46, width 0.46.

Brachypterous, hemelytron reaching midway onto abdominal segment VI, clavus and corium with surface subshining, vestiture as in pronotum and scutellum, clavus with three linear rows of punctures and a confused fourth row between medial and scutellar rows, corium with two linear rows of punctures

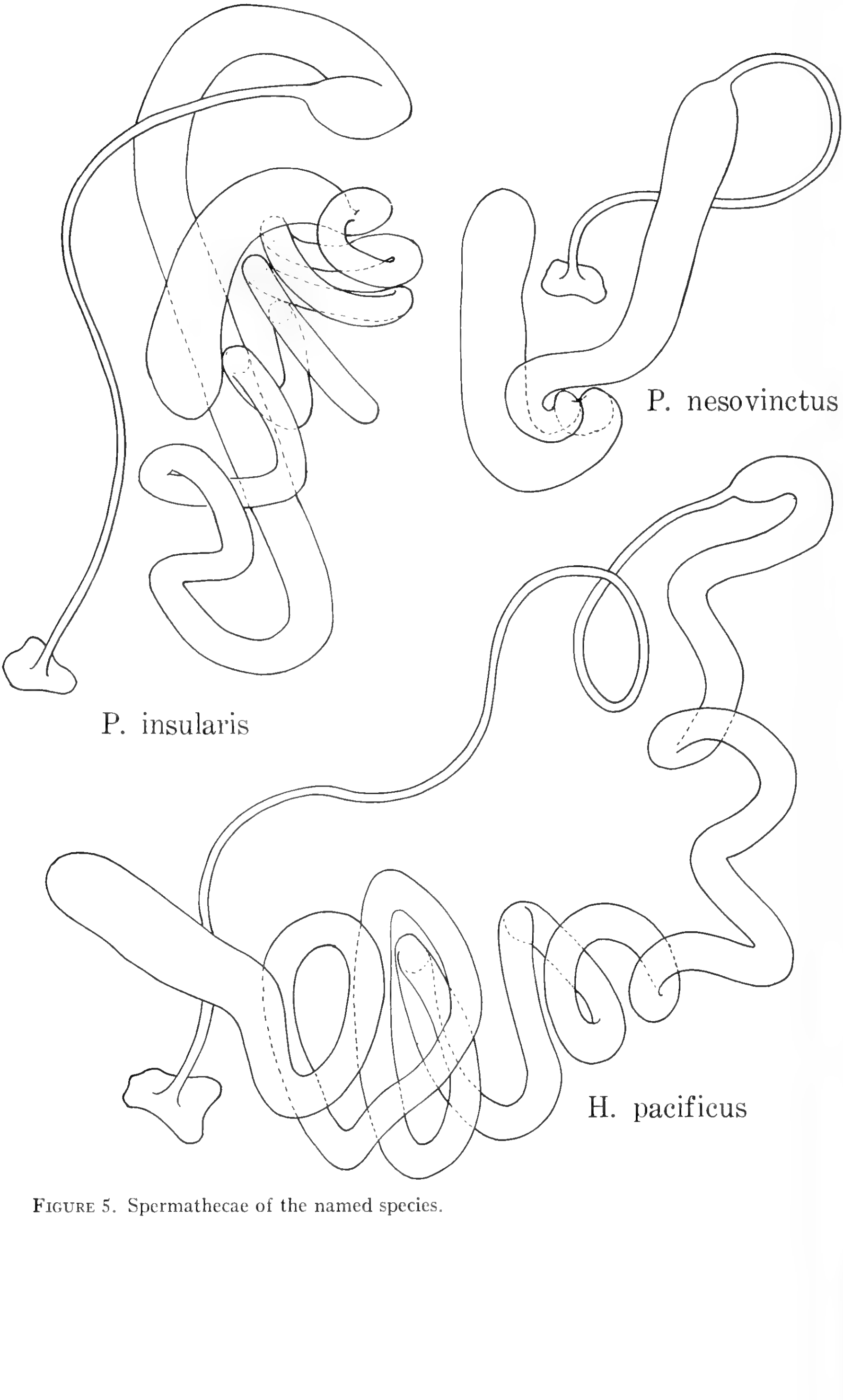


FIGURE 5. Spermathecae of the named species.

paralleling claval suture, randomly punctate laterally, with a few punctures posterior to level of apex of clavus; length of claval commissure 0.31, length of corium 1.36; membrane dull, veins not visible, basal length to level of corial apex 0.63, apical length from corial apex 0.07.

Fore femur armed beneath with spines in two ranks as figured (fig. 4); fore tibia unarmed, slightly curved.

Color. Head black, clypeus and juga dark reddish brown, antenna, buccula, and labium light yellowish brown. Pronotum black, collar anteriorly pale, posterior lobe reddish brown with dark median line. Hemelytron with clavus and corium light yellowish brown, punctures reddish brown, corium with white spot in inner angle and the black apical margin of *P. vinctus* group. Venter dark with anterior and posterior margins of propleuron, acetabula, scent gland auricle, and metapleural plate pale. Abdomen ventrally and dorsally dark reddish brown. Legs light yellowish brown, fore femur dark brown except apically.

HOLOTYPE. ♂, Santa Cruz Island, grassland, 2,100 ft., north of Academy Bay, 20 February (P. D. Ashlock).

PARATYPES. Santa Cruz Island, 10 ♂, 12 ♀, same data as holotype; 1 ♀ (macropterous), Table Mountain, 440 m., 16 April (D. Q. Cavagnaro). Fernandina Island, 1 ♀, southwest side, 1,000 ft., 4 February (P. D. Ashlock).

This description adds another species to the confusing *Pachybrachius vinctus* complex, which badly needs revision. The new species is distinct in having long erect hairs on the dorsum. The New World *P. vinctus* (Say) and the closely related Pacific *P. pacificus* (Stål) both have small, inconspicuous appressed hairs on the dorsum. *Pachybrachius nesovinctus* is usually found in the brachypterous state (only one macropterous specimen has been collected), as are many populations of *P. pacificus* from the western and central Pacific. Brachypterous forms are less common in the Western Hemisphere species *P. vinctus*. The Galápagos species show more brown on the hemelytron than do specimens of *P. vinctus* from the North and South American mainlands.

Genus **Heraeus** Stål

Heraeus STÅL, 1862, p. 315.

Heraeus pacificus Barber.

(Figure 5.)

Heraeus pacificus BARBER, 1925, p. 21.

Barber described this species from Santiago, and it has previously been recorded only from this island. Members of the expedition collected it in large numbers from Santa Cruz, and a single specimen was collected from Floreana. Many of the specimens were collected at light between Academy Bay and the Horneman Ranch on Santa Cruz, and I collected a large series in the so-called grassland area of the island at 1,800 feet under *Jaegeria hirta*.

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A NEW LIZARD OF THE GENUS *EMOIA* (SCINCIDAE) FROM THE MARIANAS ISLANDS

By

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and

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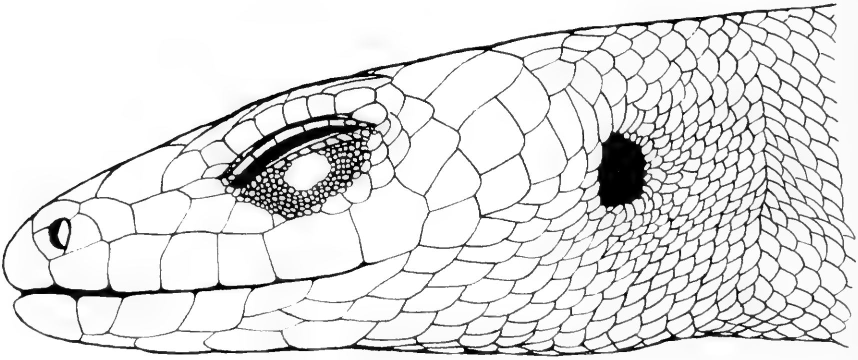
INTRODUCTION

Brown (1956) recognized eight species of the Papuan-Oriental genus of lizards, *Emoia*, as occurring in Micronesia. Two were noted as apparently undescribed, of which one, a moderate-sized species, was represented by only four specimens from the Marianas Islands in the northwestern part of Micronesia. One of us (the junior author) has recently obtained a large series of the species from the same island group, and this larger sample permits a more adequate diagnosis of the species. It apparently has its closest affinities with *Emoia boettgeri* (Sternfeld) from central and eastern Micronesia and with *Emoia arnoensis* Brown and Marshall from the Marshall Islands in eastern Micronesia. *Emoia atrocostata* (Lesson), a widely distributed species-complex in the western Pacific basin; *Emoia flavigularis* Schmidt from the Solomon Islands to the south; and the very large *Emoia nigra* Jacquinot and Guichenot, the range of which extends from the Solomon to the Tonga Islands in the southern Island chain, are also representatives of the same evolutionary group.

Measurements were made with a caliper to the nearest 0.1 mm. Middorsal scale rows were counted between the parietals and a point opposite the vent;



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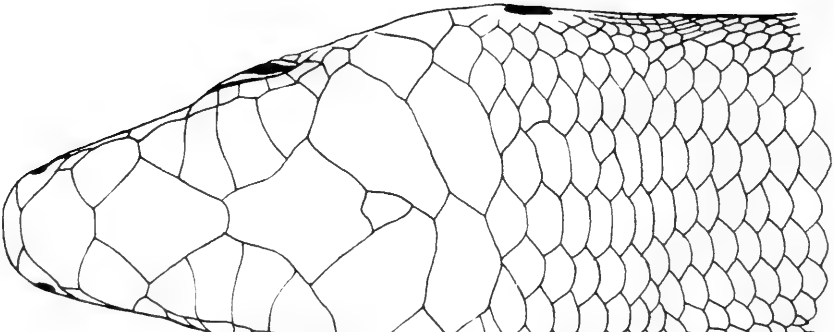

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midbody scale rows at a point approximately equidistant between the fore and hind limbs; fourth-toe lamellae from that proximal rounded lamella which is at least two-thirds the breadth of the toe to the most distal ventral scale inclusive.

Emoia slevini Brown and Falanruw, new species.

HOLOTYPE. United States National Museum no. 192781, Cocos Island (a small island off the southern end of Guam), Marianas Islands, collected by M. V. C. Falanruw.

PARATYPES. United States National Museum nos. 122645–122646, Rota Island; 122470, Ritidain Point, Guam Island, collected by L. P. McElroy; 128028, Mt. Lasso, Tinian Islands, collected by H. K. Townes, Jr.; University of Guam nos. 547–552, 1305–1306, 1393–1395, 1448, 1450–1451; California Academy of Sciences nos. 129138–129143; Museum of Comparative Zoology, Harvard University no. 128164; Field Museum of Natural History no. 171832; and British Museum of Natural History no. 1971.1027, from the same locality as the holotype.

DIAGNOSIS. An *Emoia* species of moderately large size, 58–85 mm. in snout-vent length for 18 mature specimens; length of hind limb less than 50 percent of the snout-vent length; simply rounded lamellae on under surface of digits, numbering 30–37 beneath the longest toe; 34–38 midbody scale rows and 61–74 dorsal scale rows between parietals and base of tail (for a sample of 27 specimens); prefrontals separated by the frontal; frontoparietals distinct; interparietal moderate in size; ground color (in life) of dorsum and upper lateral surfaces light to dark brown with variable scattered dark and light flecks.

DESCRIPTION. An *Emoia* species of moderate size; snout-vent length of 6 mature females 63–75 mm., of 12 males 69–84 mm.; snout round-pointed, of moderate length (36–44 percent of head length); supranasals much broader anteriorly than posteriorly, in contact with the anterior loreal which is shorter and broader than the posterior; prefrontals not in contact (separated by the frontal which is in contact with the rostral); length of the frontal about equal to that of the fused frontoparietals; interparietal of moderate size, length about equal to breadth at the base to nearly one and one-half times as great; 4 or 5 supralabials anterior to the enlarged one beneath orbit; 4 supraoculars plus a small one posteriorly; a single pair of large nuchals (fig. 1), dorsal scales smooth; midbody scale rows 34–38 for twenty-eight specimens; transverse rows along the middorsal line from parietals to base of tail 61–74; number of rows across the nape from ear to ear 12; 30–37 smooth, rounded lamellae

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FIGURE 1. *Emoia slevini.* a. Lateral view of head of paratype; b. Dorsal view of head of paratype, CAS.

Table 1. *Scale counts and pertinent measurements for species related to* Emoia slevini (*R = range, M = mean, N = number of specimens*)

Characters		*E. arnoensis*	*E. atrocostata*	*E. b. boettgeri*	*E. b. orientalis*	*E. flavigularis*	*E. nigra*	*E. slevini*
Midbody scale rows	R	36–42	39–40	36–40	35–40	35–40	32–40	34–38
	M	38.3	39.9	38.4	38.5	37.9	37.1	36.5
	N	21	7	9	23	8	23	27
Fourth-toe lamellae	R	35–41	31–38	45–52	39–45	38–44	31–38	30–37
	M	39	33.6	47.1	42.6	41.3	34.5	33.1
	N	21	7	9	23	9	23	27
Scale rows from parietals to base of tail	R	67–74	64–70	65–74	65–77	56–62	60–66	61–74
	M	71.8	66.3	68.8	67.9	58.0	63.1	66.3
	N	21	7	8	22	9	23	27
Snout-vent length (mm.) of mature specimens	R	67–85	64–88	60–65	55–72	58–71	75–114	58–85
	N	17	4	6	23	6	50	18
Length of hind limb/snout-vent length	R	0.435–0.512	0.458–0.515	0.497–0.550	0.476–0.557			0.403–0.481
	M	0.480	0.489	0.523	0.523			0.440
	N	18	6	8	20			23

beneath the fourth toe for 27 specimens; limbs rather well developed, but hind limb less than 50 percent of the snout-vent length (table 1) and usually slightly less than distance from axilla to groin.

Color. The ground color dorsally (in life) is irridescent medium brown to dark brown with some darker flecks and occasionally light flecks, limbs, especially the hind limbs, often lighter with more numerous flecks; venter whitish to gray or cream anteriorly, more yellow posteriorly, sometimes orange about the vent; in recently preserved specimens the ground color is brown or somewhat reddish brown with scattered darker markings, in some specimens forming a vague pattern of narrow, broken, transverse bands. The yellow and orange of the venter fade rapidly in preservative.

Etymology. The species is named for Mr. Joseph R. Slevin, former Curator of Amphibians and Reptiles at the California Academy of Sciences.

Comparisons. *Emoia slevini* is probably most closely related to *Emoia boettgeri* which occurs in the Caroline Islands. The two species are very similar in color pattern, but *E. slevini* differs from the latter primarily in the much lower number of subdigital lamellae, 31–38 (mean = 33) for 27 specimens, instead of 45–52 (mean = 47) for 6 specimens of *Emoia b. boettgeri* from the Caroline Islands, and the somewhat shorter hind limbs relative to snout-vent length, less than 50 percent (usually greater than 50 percent for *E. boettgeri*). *Emoia arnoensis* and *E. flavigularis* are also readily distinguished from *E. slevini* not only on the basis of very different color patterns, but also by the higher subdigital lamellar counts; for *E. flavigularis* the number of scale rows between the parietals and the base of the tail is usually less than 65, whereas it is usually greater than 65 for *E. slevini*; and the interparietal is usually fused with the parietals in *E. flavigularis*, or, if distinct, relatively small.

Of the group of related species noted in the Introduction, only *E. atrocostata* is sympatric with *E. slevini*. Populations of both species are represented in collections from Cocos Island, with 23 examples of *E. slevini* and two of *E. atrocostata*. Unfortunately this widespread species, described by Lesson (1830) on the basis of a unique specimen from Oualan (= Kusaie) Island in the eastern Carolines, is still poorly represented in collections from most islands of Micronesia and probably does not occur in the Marshall Islands, at least in the eastern part. The data for *E. atrocostata* presented in this paper are based upon two examples from Cocos Island and several specimens from Ulithi Atoll and the Palau Islands. Using the limited data from these two small samples of *E. atrocostata*, aside from totally unlike color patterns, *E. atrocostata* would appear to be most readily distinguished from *E. slevini* on the basis of the slightly greater number of midbody scale rows (table 1); the longer, narrower interparietal (length one and one-half to two times its basal breadth); and the posteriorly more broadly truncate rostral.

HABITAT. Based on observations of the population on Cocos Island, *E. slevini* is a forest species. The forest on this island is predominantly tall *Casuarina* trees with some scattered coconut and other broadleaf trees. The understory growth is sparse and the canopy permits only diffuse sunlight to mottle the forest floor. The forested area is bordered toward the lagoon by *Scaevola* shrubs. Most of the lizards observed were active on the forest floor. Occasionally specimens were seen in low hollows of tree trunks with only their heads protruding. Two were observed on the lower part of the trunk of *Casuarina* trees. In most instances escape was attempted by hiding under material on the forest floor. A few specimens were observed at the edges of the *Scaevola* shrubs.

Emoia atrocostata on Cocos Island, as elsewhere (Brown and Alcala, 1967), occupies the various marginal beach areas or the open, often sparsely grassy or shrub-dotted areas adjacent to the beaches.

KEY TO THE SPECIES OF EMOIA IN THE MARIANAS

1. Lamellae beneath the fourth toe greatly thinned, more than 50 .... *E. cyanura*
   Lamellae rounded, not thinned, less than 50 2
2. Midscale rows between the parietals and the base of tail less than 60; maturity attained at 45 mm. or less in snout-vent length .... *E. caeruleocauda*
   Middorsal scale rows between the parietals and the base of tail greater than 60; maturity not attained at less than 45 mm., rarely less than 50 mm., in snout-vent length 3
3. Midbody scale rows 38 to 40; rostral broadly truncate posteriorly; dorsum grayish, greenish, or tan with black or dark brown spots; upper lateral surface marked by irregular black or dark brown band .... *E. atrocostata*
   Midbody scale rows 34 to 38; rostral rounded or narowly truncate posteriorly; dorsal and upper lateral surfaces brownish with scattered darker markings occasionally forming a vague pattern of narrow, broken, transverse bands .... *E. slevini*

ACKNOWLEDGMENTS

This study is part of the senior author's program concerned with the herpetofauna of the Pacific Islands with emphasis on the Philippines. The latter program is currently supported by National Science Foundation Grant GB-16972. Illustrations were prepared by Mr. Walter Zawojski, Stanford University.

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TWO NEW GENERA AND TWO NEW SPECIES OF WESTERN PACIFIC SNAKE-EELS (APODES: OPHICHTHIDAE)

By

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Abstract. Two new species representing two new genera of ophichthid eels, subfamily Ophichthinae, are described from the western Pacific Ocean. *Evips percinctus*, from Palau, and *Allips concolor*, from Thailand, are described and figured.

Introduction

Examination of the extensive collections of Indo-Pacific fishes deposited at the California Academy of Sciences has disclosed the presence of two new species of ophichthid eels, subfamily Ophichthinae, each of which is distinctly different from any member of a known genus. Difficulty in obtaining specimens of sand-dwelling eels has been noted in recent works (McCosker and Rosenblatt, 1972), yet the two individuals upon which this report is based represent but a small fraction of the numerous ophichthids, moringuids, and xenocongrids collected by the George Vanderbilt and Naga expeditions to the central and western Pacific Ocean. It is the author's intent in this study to make these generic names available in preparation for his more thorough osteological comparison of genera within the family Ophichthidae.

Measurements are straight-line, made either with a 300 mm. ruler with

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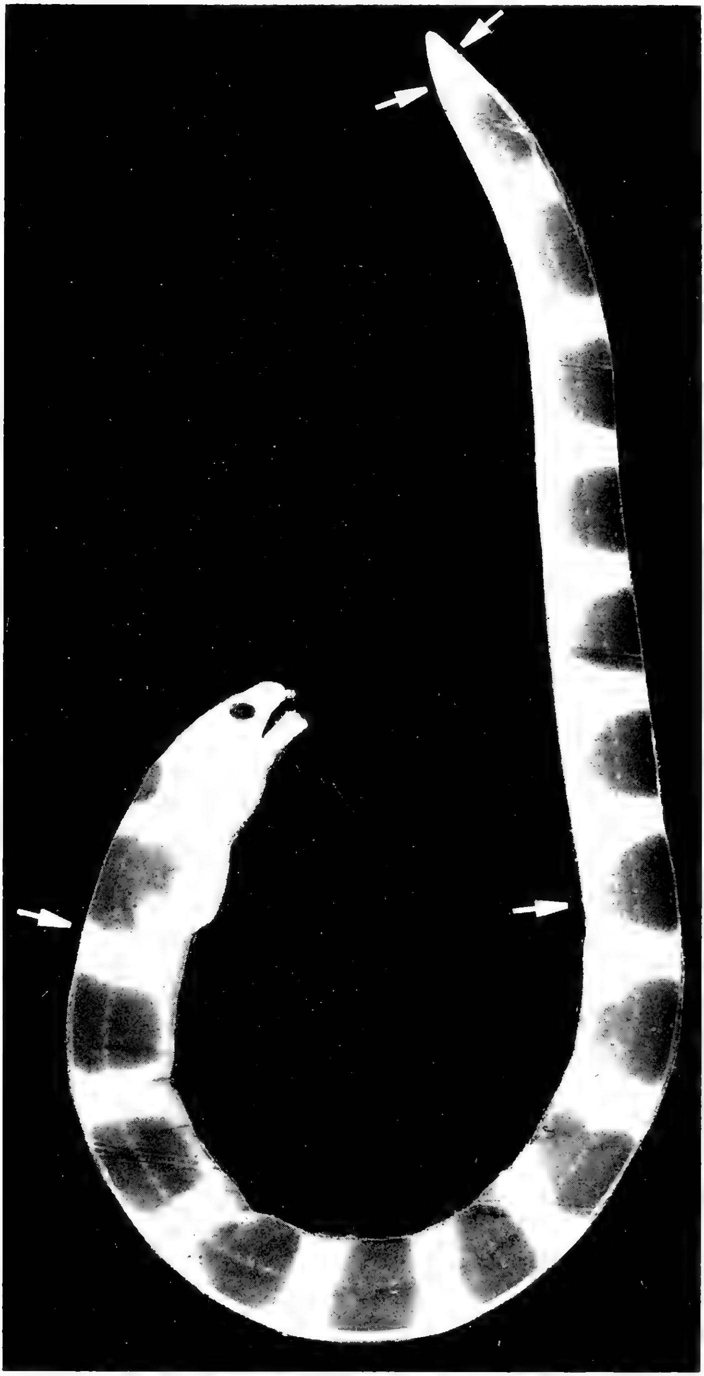
[1] Contribution from the Scripps Institution of Oceanography, University of California, San Diego.



0.5 mm. gradations (for total length, trunk length, and tail length) and recorded to the nearest 0.5 mm., or with dial calipers (all other measurements) and recorded to the nearest 0.1 mm. Head length is measured from the snout tip to the posterodorsal margin of the gill opening; trunk length is taken from the end of the head to mid-anus; body depth does not include the fin. Branchiostegal and vertebral counts (which include the hypural) were made using radiographs. Gill arches were prepared by means of the Taylor (1967) trypsin technique. Material used in this study is housed in the California Academy of Sciences (CAS) or the Marine Vertebrates Collection of the Scripps Institution of Oceanography.

I thank Richard H. Rosenblatt for reading this manuscript critically, Carl L. Hubbs for suggestions, and William N. Eschmeyer of the California Academy of Sciences for permission to utilize specimens in his care.

TAXONOMY

Evips McCosker, new genus

Diagnosis. Body nearly cylindrical, head and trunk longer than tail. Dorsal and anal low, ending before pointed tail tip; dorsal origin above and slightly behind gill openings. Pectoral rudimentary and less than eye diameter, its base in upper corner of gill opening. Gill openings lateral and shorter than isthmus breadth. Underside of snout not grooved. Anterior nostril tubular, posterior nostrils open into mouth. Teeth pointed; intermaxillary teeth largest and depressible, vomerine teeth smaller and fixed. Eye large. Other characters those of the single species.

Type species. *Evips percinctus* McCosker, new species.

Etymology. From the Greek εὖ (eu, latinized to ev for euphony before a vowel), good, and ἴψ (ips, masculine), a worm, in reference to the general appearance of this charming eel.

Relationships. *Evips percinctus* appears most closely related to the more generalized ophichthines such as species of *Ophichthus*, *Microdonophis*, and *Pogonophis*. Similarities among these genera include the retention of the pectoral and median fins, the lateral slightly restricted gill opening, the posterior nostril and head pore conditions, and the generally bold coloration. Osteologically, *E. percinctus* also appears similar to them in its pectoral girdle and hyoid arch conditions (viewed from radiographs and cleared and stained specimens) and in the condition of the gill arches, primarily the retention of the fifth ceratobranchial and the separation of UP$_3$ and UP$_4$

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Figure 1. *Evips percinctus* McCosker, new species, CAS no. 13966, holotype, 125.5 mm. TL. Arrows indicate the origin and termination of the median fins.

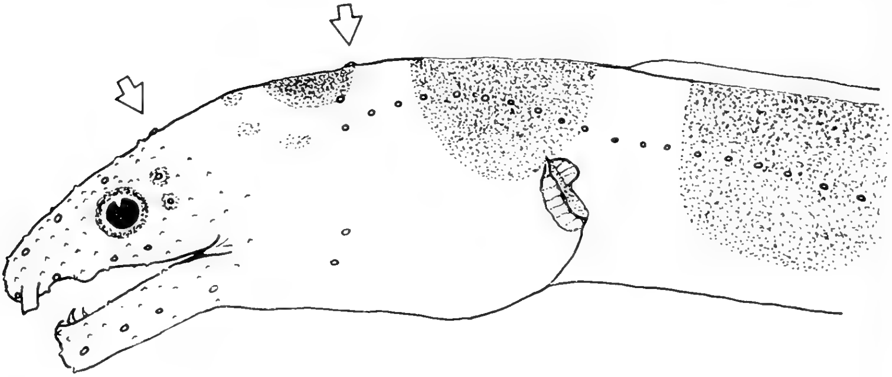

FIGURE 2. *Evips percinctus* McCosker, new species, CAS no. 13966, holotype. Arrows indicate location of median interorbital and temporal pores.

(Nelson, 1966; personal observation). The new genus is separable from these and other ophichthines on the basis of its rudimentary pectoral fin, robust body, and short tail.

Evips percinctus McCosker, new species.
(Figures 1–3.)

Holotype and only known specimen, CAS no. 13966, a 125.5 mm. juvenile from Kayangel Island, Palau Islands, Southern Caroline Archipelago (8°02′18″N., 134°43′21″E.), collected in shallow water (0–4″) by H. A. Fehlmann and party during the George Vanderbilt Foundation 1956 Palau Islands Expedition, on 8 October 1956.

DESCRIPTION. (Measurements are in millimeters.) Total length 125.5, head 14.0, trunk 60.0, tail 51.5, predorsal 17.2, body depth behind gill opening 5.2, at anus 4.5, snout length 2.8, upper jaw 4.8, eye diameter 1.4, interorbital width 1.5, gill opening height 0.9, isthmus width 3.1. Vertebrae 132; 69 to anal fin origin.

Body stout (not exceedingly elongate as in many ophichthids) and nearly cylindrical. Depth behind gill openings 24 times in total length, and at anus 28; width behind gill openings 31 times in total length, and at anus 34. Snout blunt. Lower jaw included, its tip beneath a line drawn from anterior nostril base. Eye large, about 3.4 times in upper jaw, its center opposite midpoint of upper jaw. Anterior nostrils tubular, about 1.5 in eye diameter. Posterior nostrils open into mouth and lie ahead of anterior margin of eye. Tongue adnate. Branchial basket expanded and supported by numerous branchiostegals and jugostegalia which broadly overlap along the ventral midline. Numerous papillae on snout, beneath eye, and on anterolateral flanges of upper lip (fig. 2). Dorsal origin above and slightly behind gill

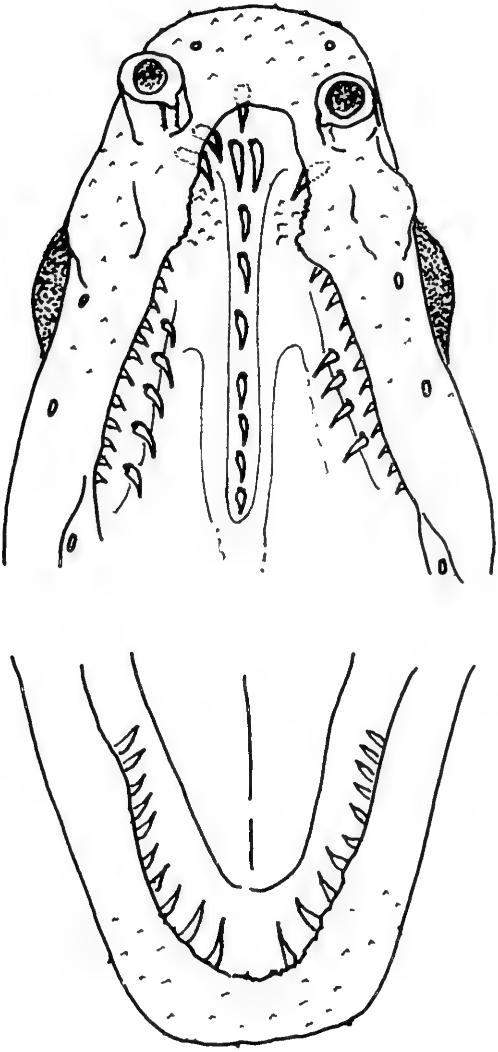

FIGURE 3. Dentition of holotype of *Evips percinctus* McCosker, new species.

opening. Pectoral fin rudimentary, a small semicircular flap, about equal in length to anterior nostril and attached above midpoint of gill opening. Dorsal and anal low, disappearing in advance of tail tip. Caudal rays lacking.

Head pores conspicuous; preoperculomandibular, temporal, suborbital, postorbital, and supraorbital series present (fig. 2). A single median interorbital and temporal pore. Two postocular pores, lying within faintly pigmented spots. Left lateral line pores 125; 9 before gill opening and 73 before the anus, terminating 0.3 head length before tail tip.

Teeth pointed and depressible (fig. 3). Four anterior peripheral intermaxillary teeth covered by skin folds, flanking a median intermaxillary pair, followed by seven uniserial vomerine teeth. Maxillary teeth biserial, the outer row covered by a skin fold and larger anteriorly, the inner 4 prominent. Mandibular teeth uniserial, about 10 on each side and grading smaller posteriorly.

Gill arches removed, and cleared and stained. First basibranchial ossified, second cartilaginous, third rudimentary, fourth absent. Hypobranchials 1 and 2 ossified, 3 cartilaginous. Ceratobranchials 1–5 ossified, the fifth a slender filament. Second and third infrapharyngobranchials ossified. Lower pharyngeal tooth plate slender with about 25 conical biserial teeth. Upper pharyngeal tooth plate (UP_3 and UP_4 of Nelson, 1966) separate (unfused) and subrectangular, with about 15 conical teeth.

Color in isopropanol yellow, overlain dorsally with 16 brown saddles. First saddle just behind occiput, does not reach sides of head; remaining 15 extend below lateral midline but do not meet ventrally. The type has retained traces of larval pigmentation, visible as 9 minute black pigment patches evenly spaced along the ventral midline of the trunk. Median fins unpigmented.

ETYMOLOGY. From Latin, signifying banded throughout.

Allips McCosker, new genus

DIAGNOSIS. Body very elongate, nearly cylindrical for most of its length; head and trunk longer than tail. Dorsal and anal low and lying within a shallow groove, ending before bluntly pointed tail tip; dorsal origin well behind gill openings. Pectoral rudimentary, a tiny flap in upper rear corner of gill opening. Gill openings lateral and low on sides, separated by an isthmus wider than their length. Underside of snout grooved. Jaw teeth and vomerine teeth small and pointed. Eye minute. Other characters those of the single species.

TYPE SPECIES. *Allips concolor* McCosker, new species.

ETYMOLOGY. From the Greek ἄλλος (allos), another, and ἴψ (ips, masculine), a worm.

RELATIONSHIPS. *Allips concolor* appears most similar to extant species of *Bascanichthys*, *Phaenomonas*, and *Gordiichthys*. The last is a poorly known ophichthid excluded from the recent generic treatment of Rosenblatt and McCosker (1970). It will be redescribed on the basis of new material by James E. Böhlke (personal communication). *Allips* differs from *Bascanichthys* in having a more posterior dorsal fin origin, a more rounded snout, and a more cylindrical trunk and tail. The two genera are quite similar in having

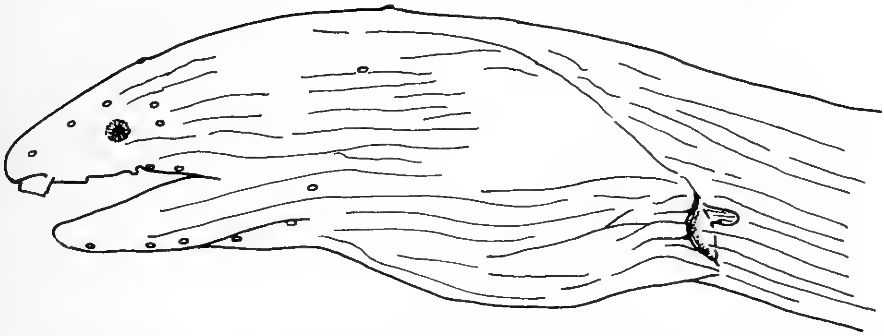

FIGURE 4. Head of holotype of *Allips concolor* McCosker, new species, CAS 13967, 375 mm. TL.

small nearly fixed teeth, comparable gill arch configurations (although the fifth ceratobranchial, absent in *Allips*, is very reduced but retained in certain species of *Bascanichthys*), low crescentic gill openings, rudimentary pectoral fins, a grooved snout, reduced eyes, highly rugose skin regions, a nearly uniform coloration (although certain species of *Bascanichthys* are often darkly pigmented dorsally), and similar head and body shapes and proportions. *Phaenomonas* differs in its extreme dorsal fin reduction, complete loss of the pectoral and anal fins, smaller eye, and the elongation of the trunk region.

Allips concolor McCosker, new species.

(Figures 4–5.)

Holotype and only known specimen, CAS no. 13967, a 375 mm. specimen from Goh Phi, Ranong Province, Thailand (10°57′42″N., 98°35′18″E.), north of Ban Parknam Ranong. Collected in shallow water (0–3″) at the mouth of Pakehan river by H. A. Fehlmann and party during the 1959–1961 Naga Expedition, on 1 June 1960.

DESCRIPTION. (Measurements are in millimeters.) Total length 375, head 21.0, trunk 205, tail 149, predorsal 48, body depth behind gill openings 5.6, at anus 5.0, snout length 3.0, upper jaw 5.2, eye diameter 0.6, interorbital width 2.6, gill opening height 1.7, isthmus width 2.6. Vertebrae 174; 96 to anal fin origin.

Body elongate and nearly cylindrical, becoming laterally compressed only near tail tip. Depth behind gill openings 67 times in total length, and at anus 75; width behind gill openings 83 times in total length, and at anus 86. Snout subconical, rounded at tip. Lower jaw included, its tip behind anterior nostrils. Eye small, 8.5 in upper jaw, and faintly visible under skin; its midpoint closer to corner of mouth than snout tip. Anterior

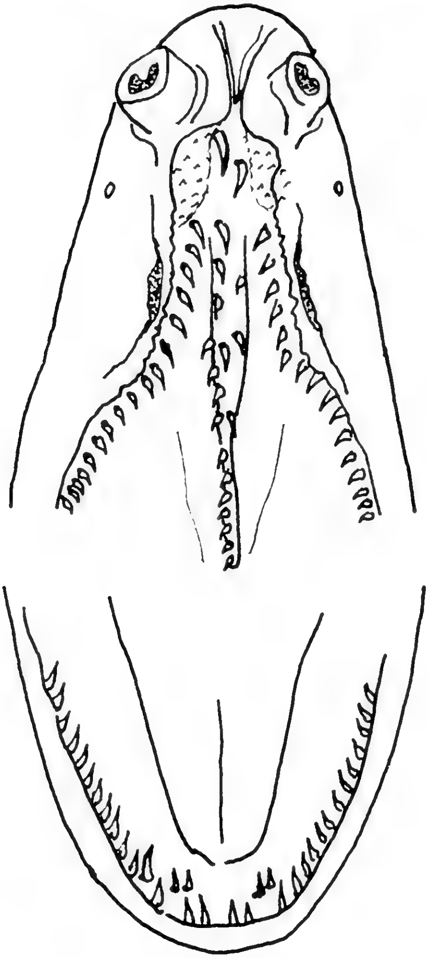

Figure 5. Dentition of holotype of *Allips concolor* McCosker, new species.

nostrils in a short tube; posterior nostrils open into mouth beneath eye. Tongue adnate. Branchial basket expanded and supported by 21 pairs of branchiostegals and jugostegalia which broadly overlap along ventral midline. Sides of head, throat, chin, and body flanks markedly rugose. Dorsal fin origin well behind gill openings. Pectoral fin rudimentary, a small flap attached to upper rear margin of gill opening. Dorsal and anal fins low, lying within a groove and disappearing 0.85 head length before finless caudal tip. The median and posterior caudal edges are covered with a band of numerous small papillae.

Head pores reduced, but preoperculomandibular, temporal, suborbital, postorbital, and supraorbital series present (fig. 4). A single median interorbital and temporal pore. Lateral line canal and pores present, but impossible to discern because of their reduced state and a waxy precipitate which has formed in preservation.

Teeth small, pointed, and close set (fig. 5). Jaw teeth and posterior vomerine teeth uniserial.

Gill arches removed, and cleared and stained. First basibranchial ossified, second cartilaginous, third absent, fourth cartilaginous but rudimentary. Hypobranchials 1 and 2 ossified, 3 cartilaginous. Ceratobranchials 1–4 ossified, 5 absent. Second and third infrapharyngobranchials ossified. Upper and lower pharyngeal tooth plates are subrectangular patches with conical teeth; UP_3 and UP_4 separate.

Color in isopropanol nearly uniform brown although slightly darker on upper half due to small dark punctations.

ETYMOLOGY. From Latin, in reference to the nearly uniform coloration.

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FIVE NEW INDO-PACIFIC PIPEFISHES

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During the 1946 fish investigations at Bikini Atoll in the Marshall Islands, V. E. Brock and Herald carried out the first moderate-depth rotenone stations for the collection of fishes. Since this was before the development of scuba, the diving gear consisted of Brock's modified Monson lung rebreather with other divers receiving air supplied through a standard dive line attached to a small compressor. It was soon evident from these collections that an important break occurred in the vertical distribution of the fishes. Many were confined to the intertidal zone or a few feet below; others were common in water of about 15 feet or greater and rarely, if ever, were seen in shallow water. The Syngnathidae provided a good example of this faunal break. Of the ten species of pipefishes (47 specimens from 26 stations) which were collected in the Marshall Islands, five were found only at depths below 15 feet, and three of those were undescribed.

With the exception of *Dentirostrum janssi*, the other four species of pipefishes described as new herein appear to belong to the deeper water group, being taken at depths ranging from 20 to 160 feet. One species was collected in the Hawaiian Islands, one in the Marianas, the third in the

Table 1. *Meristic comparisons for the* Dunckerocampus *complex.*

	Number of Specimens	Trunk Rings			Tail Rings								Dorsal Fin Rays					
		15	16	17	16	17	18	19	20	21	22	23	20	21	22	23	24	25/30
Dunckerocampus multiannulatus[1]	9[1]		7	2[1]			1	7[1]		1[1]			1[1]	5[1]	3			
D. pessuliferus	1			1					1									1
D. c. caulleryi	1		1					1									1	
D. c. chapmani	3	1	2		1	2											1	2
D. dactyliophorus	59	1	58				10	37	10	2			2	13	18	14	8	5
D. baldwini	20		20					1	12	6	1		1	5	12	2		
Dentirostrum janssi	34		34						1	4	26	3		1	3	16	14	

[1] Includes literature holotype data for *D. multiannulatus* and *D. ben-tuviae.* It is probable that trunk ring counts for these two types should be recorded as 16 rather than 17.

Ryukyus, and the fourth at Easter and Pitcairn islands. These are island groups in which considerable fish collecting has been carried out in shallow water in recent years.

The following abbreviations are used for institutions in this paper: AMS (Australian Museum-Sydney); ANSP (Academy of Natural Sciences of Philadelphia); BM(NH) [British Museum (Natural History)]; BPBM (Bernice P. Bishop Museum); CAS (California Academy of Sciences); LACM (Los Angeles County Museum of Natural History); SMF (Senckenberg Museum); and USNM (United States National Museum).

Technical assistance in making counts and measurements has been provided by Mr. D. Anderson.

THE *DUNCKEROCAMPUS* COMPLEX

Seven long-nosed species of very spiny belly-pouch Indo-Pacific pipefishes are members of the *Dunckerocampus* complex. All of these including the related *Doryrhamphus* and *Oostethus* pipefishes have a first trunk ring, i.e., the one bearing the pectoral fins, that is twice as long as any of the remaining trunk rings. Although it is actually double, it is counted as a single ring. In meristic characters these species are very similar (table 1). Based on pigment patterns or the absence thereof, members of the *Dunckerocampus* complex fall into four categories: the first is the narrow-banded group whose two members usually have 4 or 5 very narrow pigment bands on the opercle, two or more on each trunk ring and sometimes on each tail ring. *Dunckerocampus multiannulatus* (Regan) 1903, was described from Mauritius and was characterized by a lack of banding on the snout.

Dunckerocampus ben-tuviae Fowler and Steinitz 1956, described from the Red Sea had the same meristic characters but did have banding on the snout. Dr. Eugenie Clark advises us that Red Sea pipefishes of the *D. multiannulatus/D. ben-tuviae* group have a wide range of snout banding variability so that *D. ben-tuviae* will need to be considered a synonym of *D. multiannulatus*.

The remaining species in the narrow-banded group, *Dunckerocampus pessuliferous*, is distinct from other *Dunckerocampus* in having a high dorsal fin count of 30 as compared with a normal range of 20–25. It is known from the holotype taken by dredge at a depth of 144 feet at Sulade Island in the southern Philippines.

The two species in the wide-band group usually have a single pigment ring for each trunk and tail ring. The most common species is the central and western Pacific *D. dactyliophorus*; it has a single ring around the opercle which differentiates it from the twin opercular rings of *D. caulleryi* Chabanaud known only from Amboina and New Caledonia. This latter species has two subspecies: *D. c. caulleryi* with 19 tail rings, and *D. c. chapmani* Herald with 16 or 17 tail rings. More material is needed to determine the status of these two.

The third category is represented by the striped Hawaiian endemic described as new herein: *Dunckerocampus baldwini*. This species extends the generic range from the Austral Islands northward to the Hawaiian region, a distance of about 2800 miles. And, finally, the fourth category is that group of pipefishes that, unlike *Dunckerocampus*, developed the brood pouch folds; the new genus and species for this is *Dentirostrum janssi* described as follows:

Dentirostrum Herald and Randall, new genus

DIAGNOSIS. Spiny, long-snouted Doryrhamphine pipefish with abdominal brood area protected by lateral membranous folds but without protecting plates. Lateral trunk ridge continuous with inferior tail ridge at anal ring; superior trunk and tail ridges discontinuous at end of dorsal fin; lateral tail ridge ending free at anal ring. Tail non-prehensile. Dorsal fin rays 21–24, anal 4, pectoral 19–21, caudal 10; trunk rings 16; tail rings 20–23. Named *Dentirostrum* in reference to the magnificent spines present on the median snout ridge of males and to a lesser extent on females.

DISCUSSION. *Dentirostrum* is most closely related to *Dunckerocampus* from which it differs, (1) in having brood pouch flaps rather than having the eggs nakedly attached to the abdomen, (2) in its extremely spinose nose ridge, and (3) in the presence of a secondary spine behind the primary spine at the ring juncture of the superior and inferior trunk ridges. *Dentirostrum* and *Doryrhamphus* are similar in that both have brood-pouch folds, but the latter differs in its small size and its short snout.

The type species of *Dentirostrum*, *D. janssi*, is new and is the only known member of the genus. The description of *D. janssi* based on 34 specimens (14 males 61–126 mm. SL and 20 females 52–110 mm. SL) from 19 localities in the Indo-Malayan region is as follows:

Dentirostrum janssi Herald and Randall, new species.
(Figure 1.)

From the Palau Islands: 13 types, 6 localities.

Holotype. CAS 14139, male 125 mm. SL, with 126 brood patch sockets–a few with eggs; Arappu Point of Koror to Ho Island, south side of reef; 0–50 feet; H. DeWitt; November 19, 1957 (GVF 1442).

Paratypes. CAS 14140, male 123 mm. SL; same data as holotype. CAS 14141, male 105 mm. SL; south entrance to small bay on west side of Ngalab Point, Koror Island; 0–50 feet; H. DeWitt; November 21, 1957 (GVF 1445). CAS 14142, female 89 mm. SL; Iwayama Bay, off Kaibakku Island; 0–45 feet; H. DeWitt; October 3, 1957 (GVF 1408). AMS 16144-001, male 103 mm. SL; female 105 mm. SL; LACM 32123-1, male 105 mm. SL; SMF 11425, male 111 mm. SL; channel between Sanryo Island and Ngatkumer Island, Iwayama Bay; 0–50 feet; H. DeWitt; October 31, 1957 (GVF 1433). CAS 14143, 3 females, 53 mm., 97 mm., 103 mm. SL; channel between Sanryo Island and Kamori Island, Iwayama Bay; 0–42 feet; H. DeWitt; November 18, 1957 (GVF 1439). BPBM 11937, male 102 mm. SL; female 83 mm. SL; western tip of Ngargol Island; 20–40 feet, coral; J. E. Randall, E. S. Helfman, O. Custer; June 8, 1968.

From Thailand: 16 paratypes, 9 localities.

BPBM 11938, female 91 mm. SL; NW. side of Koh Kroi Island about 5.5 miles ESE. of Ban Pae Fisheries Training Center, Rayong Province; 0–4 meters; H. A. Fehlmann; April 30, 1960 (GVF 2183). CAS 14146, male 77 mm. SL; NW. side of Goh Samet Island, Rayong Province; 0–2 meters; B. Bronson; April 29, 1960 (GVF 2180). CAS 14147, 3 females, 62 mm., 64 mm., 83 mm. SL; NW. side of Goh Raed about 1.5 miles ESE. of Prachuap Khiri Khan town, Prachuap Khiri Khan Province; 0–15 feet (photo 3-79 a-c); H. A. Fehlmann; June 19, 1961 (GVF 2651). USNM 206654, male 126 mm. SL; female 78.5 mm. SL; CAS 14148, 2 males 80 mm. and 61 mm. SL; female 59 mm. SL; W. side of Goh Luem ca. 3 miles SE. of Prachuap Khiri Khan Town, Prachuap Khiri Khan Province; 0–15 feet; H. A. Fehlmann; June 18, 1961 (GVF 2648). CAS 14149, 2 females 95 mm. and 102 mm. SL; W. side of Goh Luem, Prachuap Khiri Khan Province; 0–15 feet; H. A. Fehlmann; June 17, 1961 (GVF 2646). CAS 14150, female 111 mm. SL; on fringing reef at head of Gulf of Siam, Goh Sak Island, about 35 miles NE. of Prachuap Khiri Khan town, Prachuap

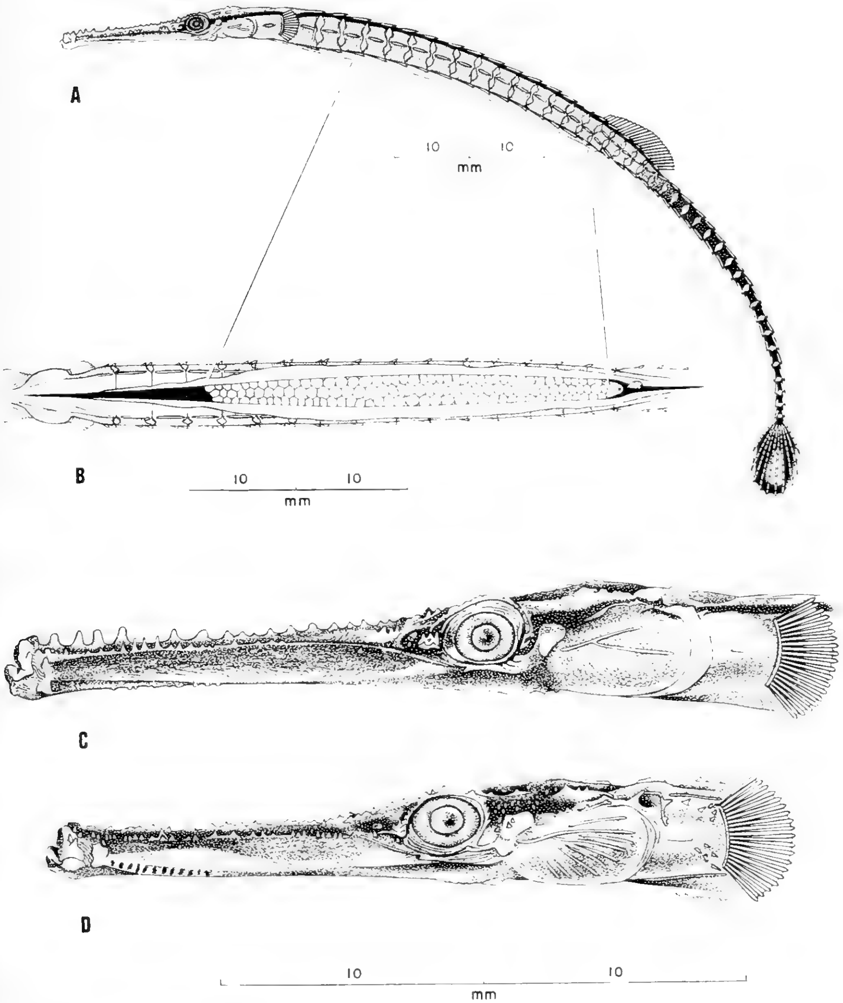

Figure 1. *Dentirostrum janssi* Herald and Randall, Holotype; male 125 mm. SL (CAS 14139); (a) lateral view; (b) expanded ventral view of brood patch area; (c) head detail male holotype compared with (d) head detail female 111 mm. SL paratype (CAS 14150). Drawing by H. Hamman.

Khiri Khan Province; 0–20 feet; H. A. Fehlmann and R. Rofen; October 24, 1957 (GVF 1460). CAS 14151, female 58 mm. SL; SW. point on Goh Chorakhay, Chumphon Province; 0–16 feet; B. Bronson; May 25, 1960 (GVF 2199). CAS 14152, male 91 mm. SL; fringing reef on NW. side of Goh Maprao, Chumphon Province; 0–12 feet; H. A. Fehlmann; May 18, 1960 (GVF 2186). CAS 14153, male 105 mm. SL; Prond Bay at SW.

corner of Goh Samed, ca. 100 meters from shore, Chumphon Province; 0–10 feet; H. A. Fehlmann; May 17, 1960 (GVF 2185).

From OTHER LOCALITIES[2]: 5 paratypes.

CAS 14145, 2 females 96 mm. and 107 mm. SL; Bay of Nhatrang SW. of Hon Long, Vietnam, South China Sea; 1–15 meters; R. Bolin; March 14, 1960 (GVF 2116). BPBM 11939, female 93 mm. SL; Bay of Nhatrang, Hon Long, Ving Damlon, Vietnam, South China Sea; 1–6 meters; R. Bolin; February 23, 1960 (GVF 2072). CAS 14144, male 93 mm. SL; Surabaja, Java, Indonesia; Hilmi Oesman; February 1961. ANSP 119933, female 99 mm. SL; Little Hope Island, NE. end, Queensland, Australia; 5–8 meters; J. Tyler, C. L. Smith, and G. Bettle; January 3, 1969.

It will be noted that the distribution of *Dentirostrum janssi* does not include the Philippines although it is known from west, east, and south of that area. It is probable that it will be found there when rotenone collecting is conducted by diving methods using scuba.

DIAGNOSIS. Dorsal fin rays 21–24, usually 23–24; dorsal covering a total of 5–6½ rings of which 1–2 are trunk rings and 4–5 are tail rings; usual count: 1 + 5. Trunk rings 16, tail rings 20–23, usually 22; pectoral 19–21, usually 20; anal 4, caudal 10. Head-in-standard length 4.2–5.0; snout-in-head 1.5–1.9; dorsal-base-in-head 1.9–2.8; brood pouch folds extending from second trunk ring to anal ring, and occasionally as far as 4th tail ring. Eggs large, about .75 mm. diameter; largest number in belly brood patch: 195 (105 mm. male). Ridge system and brood patch folds typical of *Dentirostrum*.

DESCRIPTION. Nearly all ridges of head, trunk, and tail are spinose. The median snout ridge of the males has 15–21 large spines, and on each side there is a lateral ridge with smaller spines. The spines on females are less accentuated. The supranasal ridge is present. The anterior ocular ridge is lacking, and the posterior ridge is smooth. The orbit is ringed with small spines. The opercle has a smooth median ridge over its entire length, and beneath it may have 5–7 additional radiating ridges (compare figs. 1c and 1d). The pectoral cover plate has 1 or 2 spines on its upper anterior edge, and a single spine in the center. Superior and inferior trunk ridges have double spines at each ring juncture, but on the tail only a single spine at each ring. The lateral trunk ridge has double spines for the first 5–7 rings, and then a single spine for the next 9–11 rings.

Between 62 and 80 mm. the future brood patch folds show their presence by a pair of darkly pigmented lines on the abdominal surface of the male. Among the 14 males only two had eggs attached to the brood patch: the

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[2] A new male *Dentirostrum janssi* (106 mm. SL) has just arrived; it is a depth record (100 feet) captured at Kranket I., Madang, New Guinea; G. R. Allen, May 15, 1972.

125 mm. male holotype (126 brood patch sockets, a few with eggs) and a 103 mm. male (21 eggs and 135 empty sockets = 156). These were collected in October and November in the Palaus. Another male of 111 mm. collected at the same time and place showed 156 empty egg sockets. Two males, 91 and 105 mm. from Chumphon Province, Gulf of Thailand (May collection), showed 106 and 195 empty sockets. All 33 specimens had 16 trunk rings, and the male brood patch folds usually cover 15 of the 16. However, five of the 14 males had the folds extending upon the tail, the furthest distance being 3½ tail rings. Although the range of brood pouch coverage was 15 to 19½ rings there was no indication of vascularity on the tail portion of the pouches. It is probable that this small tail section is not used as a brood area.

The overall color of *Dentirostrum janssi* is light brown with two pairs of dark brown lines extending from the head to the dorsal fin with one on each side of each superior trunk ridge. The first pair extends from above the eye dorsally on the inside edge of the superior trunk ridge, whereas the second pair extends from the center part of the eye over the opercle and along the upper lateral side of the superior trunk ridge. The tail fin has a clear center section surrounded by a dark reddish black area. The junior author's field notes on two males collected in the Palaus at Ngargol Island indicate that the body is blackish anteriorly and posteriorly with orange in the middle. Also, the pigment around the tail fin shows a small amount of white on the outer edge.

Discussion. From the upper west side of the Gulf of Siam (GVF 64: BanAangtong Bay; CAS 14155), we have three small specimens (33, 33.5, and 42 mm. SL) that have all of the characteristics of *D. janssi* except that they have a single spine on each ring of trunk and tail and are lacking the double spines of the trunk of *D. janssi.* Our smallest specimen of the latter species is 58 mm. SL (CAS 14151), and it has the physical characteristics of the adults. Among the syngnathids, spines are usually lost with growth, not added. Because of the lack of spines on these three specimens, we are faced with the possibility of another species of *Dentirostrum* existing in this area. However, we will not describe these as new at this time, but will await the collection of adult material from the same area.

At this same GVF station 64, juvenile representatives of two additional species of syngnathids were collected: 8 specimens (average length 44 mm.) of *Corythoichthys* species (CAS 14318) and a 61 mm. specimen tentatively identified as *Syngnathus maxweberi* (CAS 14317).

Named '*janssi*' in honor of Mr. Edwin Janss, Jr., whose keen interest in tropical marine biology has resulted in important field investigations in many regions.

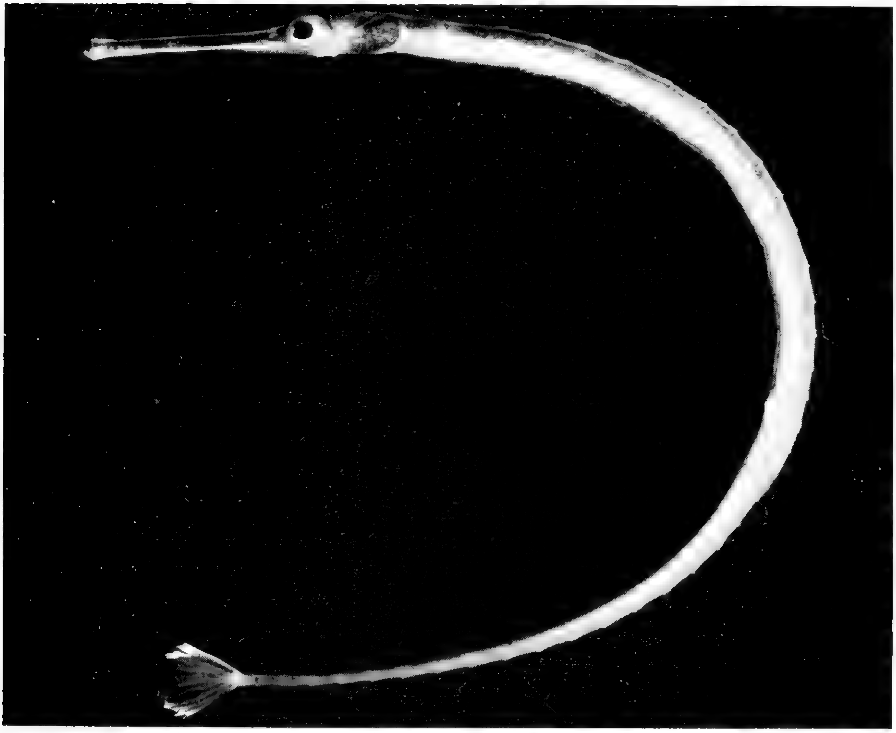

FIGURE 2. *Dunckerocampus baldwini* Herald and Randall, Holotype; male 125 mm. SL (CAS 24734); cave SE. of Pokai Bay, Waianae coast, Oahu; 70 feet. Photograph by J. E. Randall.

Dunckerocampus baldwini Herald and Randall, new species.
(Figure 2.)

Twenty type specimens from the Hawaiian Islands: Oahu (17), Hawaii (2), and Maui (1). Capture methods: by hand, quinaldine, and chemfish ichthyocide. Depth range 20–160 feet; size range 63–131 mm. SL.

HOLOTYPE. CAS 24734, male 120.5 mm. SL (125.5 mm. total length); cave SE. of Pokai Bay, Waianae coast, Oahu; 70 feet; J. E. Randall and S. Swerdloff; July 20, 1969.

PARATYPES. CAS 24735, female 125 mm. SL; same data as holotype. LACM 32126-1, female 126 mm. SL; CAS 14138, 2 males 106.5 and 129 mm. SL; 3 females 129, 131, and 131 mm. SL; Waianae coast off Makaha Shores Condominium, Oahu; 45 feet; J. E. Randall and A. R. Emery; April 26, 1970. BPBM 11941, 2 females 63 and 128 mm. SL; Waianae coast off Lahilahi Point, Oahu; 40 feet; J. E. Randall and P. M. Allen; July 11, 1970. SMF 11426, female 128 mm. SL; Kawaihoa Point, Maunalua

Bay, Oahu; 35 feet, lava caves; Jane Culp; November 15, 1971. AMS 15607-001, female 123.5 mm. SL; CAS 14137, female 134 mm. SL; Kawaihoa Point, Maunalua Bay, Oahu; 35 feet, lava caves; Jane Culp and James Moore; December 18, 1971. USNM 204683, female 92 mm. SL; off north side at base of dropoff, Moku Manu, Oahu; 160 feet; J. E. Randall, T. Stark, W. Baldwin; October 9, 1969. BM(NH) 970.1.26:1, female (?) 72 mm. SL, Moku Manu, Oahu; 85 feet; J. E. Randall and W. Baldwin; October 6, 1969. BPBM 7783, male 124 mm. SL; female 125 mm. SL; Kanoehe Bay at channel entrance, Oahu; 95 feet; J. E. Randall, D. Chave, W. Hashimoto; October 10, 1969. BPBM 11940, male 102 mm. SL (tail broken at 11th ring; caudal regenerated); north end of Honaunau Bay, Kona coast, Hawaii; 150 feet; J. E. Randall, E. S. Hobson, J. R. Chess; August 16, 1969. BPBM 11942, male 130 mm. SL; first point north of Hanakahau Boat Harbor, Kona Coast, Hawaii; 100 feet; J. E. Randall; August 18, 1970. CAS 14979, female 117 mm. SL; 1½ miles north of Lahina, Maui, Hawaii; 20 feet; Steinhart Divers; June 29, 1972.

Diagnosis. Holotype belly brood area covering ½ 12 ½ trunk rings with 143 egg sockets—73 on right and 70 on left. Dorsal fin rays 21–23; pectoral 19–21; anal 4; caudal 10; dorsal fin covering ⅓–1 trunk ring and 3¾ tail rings; usually ¾ + 3; total rings covered by dorsal 3¾–4¼; trunk rings 16; tail rings 20–21; head-in-standard length 4.5–5.2; snout-in-head 1.5–1.7; dorsal fin base-in-head 2.9–3.5. Ridge system typical of *Dunckerocampus*, i.e., lateral trunk ridge continuous with inferior tail ridge; median tail ridge extending forward to anal ring. Tail fin long, 5–7 mm. in adults of 100 mm. or larger. General appearance except color similar to other members of genus *Dunckerocampus*. Color in life reddish, fading to dark with preservation. Red stripe along upper part of body from snout to tail. Edges of caudal fin white.

Description. Median snout ridge with many serrations; orbital, opercular, nuchal, and pectoral cover plate crests faintly visible. Eye very large, the orbit diameter contained almost two times in minimum snout depth or ¾ length of opercle. Intermedial scutella between rings small and equal in width to one-half distance between scutella. Body ridges well developed with sharp spine projecting at posterior edge of juncture of each ring.

The following color description was made from 102 mm. Honaunau Bay male shortly after capture:

> "light pinkish gray with broad dorso-lateral bright orange-red stripe becoming blackish red and narrower on snout; also a broad orange-red stripe midventrally extending forward on snout as red and blackish red. Snout yellowish, white dorsally and yellow between lateral and ventral blackish red stripes; tail nearly entirely red (red stripes close together); caudal fin red with a narrow white edge at sides, and a black area distally on 2 upper central interradial membranes; dorsal colorless."

In preservative the males apparently retain the color stripe along the head and trunk much better than do the females. The 125 mm. female from Kaneohe Bay (BPBM 7783) has a conspicuous blackish tip on the outer margin of the last five rays of the dorsal fin. Other specimens did not show this character.

DISCUSSION. Capture data and dive observation records indicate that specimens of *Dunckerocampus baldwini* are often found in pairs. In captivity longevity has been short, usually no more than 2 months. This compares with about three months longevity for the banded pipefish, *D. dactyliophorus*. In recent years this latter species has often been imported into the United States from the Philippines.

Cleaning activity by *Dunckerocampus baldwini* has been observed by Dr. Edith Chave. While diving at Milolii, Hawaii (August 4, 1970), in a cave at a depth of 75 feet, she watched an adult redstripe pipefish clean a cardinal fish, *Apogon evermanni*, then a moray eel, *Gymnothorax* species, and finally the pipefish attempted to clean Dr. Chave's wrist.

Only two other species of pipefishes are known to act as cleaners. Randall (1962) reported D. P. Wilson's observations at the Plymouth Aquarium of a John Dory being cleaned by the snake pipefish, *Entelurus aequoreus*. The junior author has also observed the flagtail pipefish, *Doryrhamphus melanopleura*, cleaning reef fishes, specifically a moray and a cardinal (Randall and Helfman, 1972).

In recognition of his study of Pacific fishes, the redstripe pipefish, *Dunckerocampus baldwini*, is named in honor of Wayne J. Baldwin who with the junior author collected the first specimens of this new species.

Dunckerocampus dactyliophorus (Bleeker) 1853.

Banded Pipefish.

Syngnathus dactyliophorus Bleeker, Nat. Tijdschr. Nederl. Indiee, vol. 4, p. 506, 1853 (type locality, Onrust Island, Djakarta [Batavia], Java).

Herald (1953, p. 252) studied geographic variability of meristic characters in a small series of *Dunckerocampus dactyliophorus*. He postulated sexual dimorphism in the trunk color ring pattern with females having a greater number than males. Tables 2 and 3 present data on the 62 specimens from 22 localities now available. Unfortunately, there does not appear to be any recognizable pattern that can be correlated with sex or area. It will be noted that the trunk ring count is remarkably constant at 16 with only one of 62 having a different count, i.e., 15. Size range for the 62 specimens was 41 to 159 mm. SL. The smallest mature male showing egg sockets on the brood patch area was 90 mm.

The banded pipefish has some interesting color ring variations. The typical

TABLE 2. *Geographic variation of* Dunckerocampus dactyliophorus.

	Trunk Rings			Tail Rings						Dorsal Fin Rays					
	15	16	17	18	19	20	21	22	23	20	21	22	23	24	25
Australs		2			2							2			
Marshalls		6			1	5				1	3	2			
Kapingamarangi		1			1					1					
Guam		1					1				1				
Ulithi		2			2							2			
Palaus	1	29		9	21						9	12	7	2	
Philippines		6			1	4	1						1	3	2
Solomons		2			1	1							1		1
Celebes		6		1	5							3	2		1
Java		1			1									1	
New Guinea		5			5								3	2	
Totals (62)	1	61		10	40	10	2			2	13	21	14	8	4

pattern shows about 5 rings on the snout (range 4–7), 1 over, under, and rarely through the eye, another around the opercle, 1 at the pectoral fins, then (table 3) 6–13 on the trunk, and 7–14 on the tail. The pattern for any given specimen is recorded as 5-1-1-1-7-9 = 24. The width of the individual color band is usually ½ to ¾ of an individual ring. However, the two Ulithi specimens (BPBM 8746) have remarkably narrow color bands; in width they are only equal to about ⅓ to ½ of a trunk or tail ring. Another extreme is shown by a 91 mm. specimen from Urukthapel in the Palaus (BPBM 7352); the color bands were very wide, 1 to 1¼ rings in width.

Dunckerocampus dactyliophorus ranges through the western and central Pacific. The type locality, Djakarta, is the westernmost point in the distributional pattern, and until recently the easternmost was 4300 miles away at Rongelap Atoll in the Marshall Islands. However, in 1971 the junior author diving at a depth of 185 feet collected two specimens at Rurutu (lat. 24° S.) in the Austral Islands. This extended the range westward for another 2700 miles and southward for 900 miles from the latitude of the Solomons (lat. 9° S.). The northernmost locality is Guam (lat. 12° N.).

Recently Dr. Eugenie Clark advised us that she has examined *Dunckerocampus dactyliophorus* from the Red Sea (Eilat, Gulf of Aqaba) which is some 8800 miles (by water) from Djakarta. This break in distribution is similar to that which occurs in *Corythoichthys flavofasciatus* with the subspecies of *C. f. flavofasciatus* in the Red Sea and *C. f. conspicillatus* many miles away in the Central Pacific (Herald, 1953, p. 275).

Table 3. *Geographic variation of* Dunckerocampus dactyliophorus.

	Trunk Color Bands								Tail Color Bands						
	6	7	8	9	10	11	12	13	7	8	9	10	11	12	13
Australs	1	1							1		1				
Marshalls			3	1	2					1		2	2		1
Kapingamarangi			1								1				
Guam		1								1					
Ulithi				1	1								1		1
Palaus	4	15	6	4	1				5	14	9	2			
Philippines			1	2	2	1					1			3	2
Solomons					2							2			
Celebes			1	2	2			1			3	2		1	
Java				1							1				
New Guinea		1		4							2	3			
Totals (62)	5	18	12	15	10	1	0	1	6	16	18	11	3	4	4

The specific collection localities for *Dunckerocampus dactyliophorus* listed for the general areas of tables 2 and 3 are as follows: Marshall Islands: Rongelap, Bikini, and Eniwetok atolls; Palaus: Koror, Auluptagel, Babelthaup, Urukthapel, and Arakabesan islands; Solomons: New Georgia and Florida islands; Philippines: Cebu, Jolo, Pandanan Island, and Sibutu. Although the Philippine localities are all from the southern section, we have been advised by Mr. Earl Kennedy, who is the major Manila live fish jobber, that the species is fairly well distributed throughout the islands; most of his specimens come from Luzon (Batangas), Mindoro, and Palawan. Amboina is the only recorded locality from which we have not examined specimens.

THE PIPEFISH OF EASTER AND PITCAIRN ISLANDS

On the map of the world, Easter Island is a small dot in the eastern south Pacific some 2000 miles west of Caldera, Chile, and about 1100 miles east of Pitcairn, the nearest inhabited island. This isolated volcanic outcrop has a total area of 46 square miles, being about 14 miles long and 7 miles wide (27° 05′ S. Lat. and 109° 20′ W. Long.). Although the island is internationally famed because of the giant stone statues, the published record of its ichthyological fauna and relationships is less well known (Randall, 1970). In recent years three field parties of biologists (1958, 1965, and 1969) have made collections at various sites around the island. All have used ichthyocides, and among them they have taken ten specimens from three localities of the first syngnathid to be collected in the area. In December 1971 the junior author visited Pitcairn Island and was able to collect three additional specimens. The type series consists of 13 specimens: 5 males (69–85.5 mm. SL) and 8 females (67–95 mm. SL).

Several years ago Dr. David K. Caldwell studied the Ramsey Parks 1958 series of 6 specimens at the Los Angeles County Museum of Natural History. He tentatively determined that they represented an undescribed species. This we are now able to verify, and we name this species in his honor.

Syngnathus caldwelli Herald and Randall, new species.

(Figure 3.)

HOLOTYPE. LACM 6560-3, 76 mm. standard length male with eggs in pouch. Anakena Cove, Easter Island; Ramsey Parks, Yacht *Chiriqui*; boulders and brown algae, rotenone to 4.6 m.; October 1, 1958.

PARATYPES. (5 from same collection as holotype): LACM 6560-41, 69 mm. male and 82 mm. female; CAS 24202: 71 mm. male and 65.5 mm. female; and USNM 203409, 79 mm. female. Another collection made at type locality 6½ years later—BC 65440, 84 mm. male (pouch empty); closed tidepools, depth ½ to 8 m., rotenone; Ian E. Efford and Jack A. Mathias, Jan. 15, 1964. Ten days later at nearby Vinapu on southwest side—BC 65449, 2 females 93 and 93.5 mm.; large boulders and rocks; depth 2–3 m., rotenone, also Efford and Mathias, Jan. 25, 1965. Finally, 10½ years after first colection—BPBM 6596, 95 mm. female (fig. 2); southwest coast between Hanga-Roa and Hanga-piko, inshore; depth 61 cm.; boulder bottom with brown algae; chemfish; J. E. Randall and G. R. Allen; January 26, 1969. BPBM 10856, 82 mm. male and 80 mm. female. Pitcairn Island, off "the Rope" 20 ft., large boulders with brown algae, sand and small rocks in low places; J. E. Randall, Dean B. Cannoy, Steve Christian, and Noggie Young; December 23, 1970. CAS 13922, 75 mm. female, same data as BPBM 10856.

DIAGNOSIS. Dorsal fin: 28–31; 7 specimens with 28 rays; 3 with 29; 2, 30; and 1, 31; pectoral 14–16; usually 14; anal 3; caudal 10; dorsal fin covering 6¾–7½ rings, i.e., ½–1 trunk ring and 6–6½ tail rings usually 1 + 6; trunk rings 16–17; tail rings 34–36; head-in-standard length 8.5–9.2; snout-in-head 2.2–2.6; head-in-dorsal fin base 1.06–1.15; dorsal fin base-in-head .87–.95. Lateral body ridges typical for genus *Syngnathus*: i.e., lateral trunk ridge interrupted at anal ring, then subcontinuous with lateral tail ridge (65.5 mm. female has the two ridges continuous on one side only). Brood pouch covering first 13–15 tail rings; eggs large, 1 mm. diameter, arranged in 3–4 single rows across pouch (holotype) or 2 rows wide and 2 rows deep (69 mm. male). Holotype egg count 88; for 69 mm. male: 19

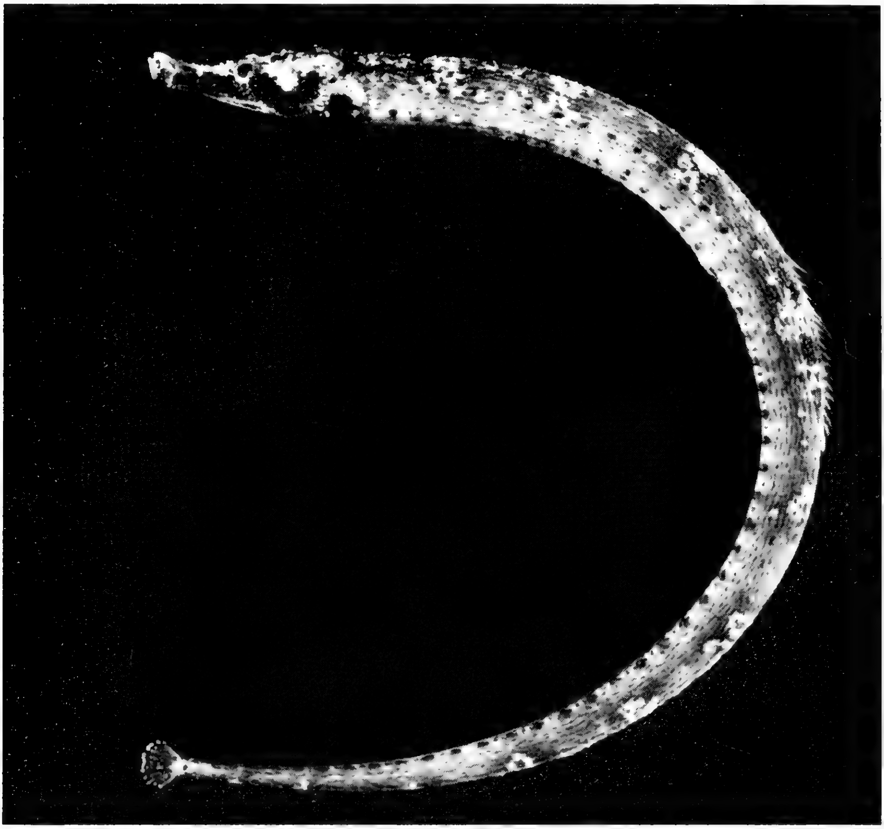

FIGURE 3. *Syngnathus caldwelli* Herald and Randall, Paratype; female 93 mm. SL (BPBM 6596); Easter Island between Hanga-Roa and Hanga-piko. Photograph by J. E. Randall.

and 21 eggs for dorsal rows and 14–14 for ventral rows or about 68 for total pouch count. Brood pouch folds almost in contact but without overlap or indentation, merely slightly thickened at free end of individual flap (modified Open Brood Pouch Closure: O-BPC). Color in preservative, brownish sometimes with many narrow dark lines running length of body. Eye may have dark band extending obliquely postero-ventrally over opercle. Dark spots sometimes present at juncture point between rings on inferior trunk ridge, and to lesser extent on lateral trunk ridge. Spots on Pitcairn pipefishes, larger and very pronounced; also with wide whitish areas on upper surface: about 4 on trunk and 7 on tail.

DESCRIPTION. Median snout ridge smooth, extending forward from interorbital area for about half snout length. Superior ocular ridge extends posteriorly for distance equal to eye width but is absent anteriorly. Eye very large, in diameter about equal to 2½ of snout length. Nuchal plates bilobed, indistinct. Upper and lower pectoral ridge plates evident but not pronounced; opercular ridge extends over ½ to ¾ length of opercle. Body ridges evident, smooth, and not strongly pronounced. Lateral flanges of brood pouch slightly developed.

Field Notes. The junior author and G. R. Allen collected the most recent Easter Island paratype and also made color and black and white photographs at the time of capture. From field notes the near-living color of *Syngnathus caldwelli* from Easter Island is:

> "light brown with row of red dots along anterior lateral ridge and full length of ventral flange; a small red spot at front and at rear of dorsal fin; ventral part of body light yellowish with a midventral row of red dots along trunk; large irregular light gray blotches on back and upper side; a dark brown band running from snout through lower half of eye where it broadens on lower opercle and continues as a broad zone on chest; caudal fin yellowish with brown rays; dorsal fin clear."

Any distinctive marks on the 1958 specimens have been largely lost following preservation. The two 1965 specimens from Vinapu are the only ones to show clearly the narrow lines on the body, about 12 on the top of the trunk and approximately 10 on the trunk sides. The 1965 Anakena specimen is very dark and its markings are suggestive of the 1969 specimen whose near-life colors are described above.

Comparisons. In the Indo-Pacific from Africa to the Americas there are about 34 members of the genus *Syngnathus*, excluding *Corythoichthys* and *Bombonia*. None of these approach *Syngnathus caldwelli* in their numerical or other characteristics. The nearest relative is probably *Syngnathus balli* of Hawaii. However, the latter is a smaller species (58 mm.) with fewer tail rings (32 vs. 35–36) and fewer dorsal fin rays (21–23 vs. 28–31).

Syngnathus banneri Herald and Randall, new species.

(Figure 4.)

Holotypes. BPBM 8695, 39 mm. SL (40 mm. TL) undet. sex; Ryukyu Islands, Ishigaki; reef about ½ mile off harbor of Ishigaki City; depth 20–35 feet; chemfish ichthyocide; J. E. Randall and A. H. Banner, May 22, 1968.

Paratype. CAS 14375, 26.5 mm. SL (27.3 mm. TL) immature; Marshall Islands, Eniwetok Atoll, lagoon off Eniwetok Island; 25 feet, coral and rubble patch; quinaldine; J. E. Randall, March 31, 1972.

Diagnosis. Dorsal fin rays 16–18 located on a total of 3½–4 rings (¼–1 trunk and 3–3¼ tail rings); pectoral 11; anal 2; caudal 10. Trunk rings

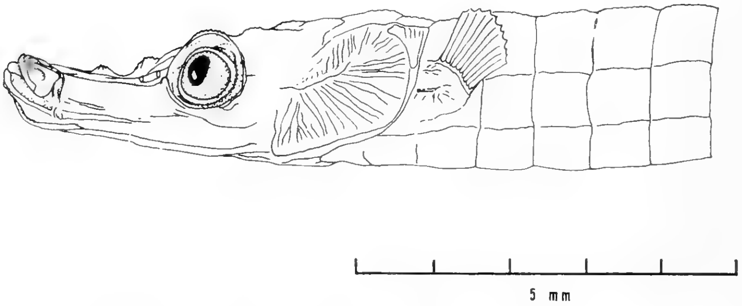

Figure 4. *Syngnathus banneri* Herald and Randall, Holotype; imm. 39 mm. SL (BPBM 8695); reef near Ishigaki City, Ryukyus. Drawing by L. Sabre.

15; tail rings 27. Head-in-standard length 7.3–7.8; snout-in-head 2.5–3.2; dorsal fin base-in-head 1.7–1.8. Body ridge pattern typical of *Syngnathus*, i.e., lateral trunk ridge discontinuous with lateral tail ridge at end of anal ring; inferior trunk and tail ridges continuous and superior trunk and tail ridges discontinuous at end of dorsal fin. Brood pouch unknown.

Description. Holotype median snout ridge with two triangular flanges just anterior to nostrils; orbital ridge markedly extended dorsally; prenuchal-nuchal ridges present but not accentuated. Opercular ridge extending over one-half (paratype three-quarters) of opercle. Superior and inferior pectoral cover plate ridges sharply pronounced. Trunk and tail ridges slightly raised and indented between individual rings so that ridges have moderately scalloped profile. Paratype ridges for the most part less accentuated than holotype. Holotype color light tan with exception of dark brown spot pattern on anterior trunk; beginning behind pectoral, 6 spots on lower trunk ridge and 5 on lateral trunk ridge on left side; spots on right side less distinct; on dorsal surface 9 dark brown bars, one-half ring in width: 3 extending between superior trunk ridges and 6 between superior tail ridges. Paratype color whitish with dark area on lower sides of gill cover extending underneath pectoral fins.

Discussion. *Syngnathus banneri* is a remarkable species for it has the lowest dorsal fin count of any member of the genus (16–18 as compared with a normal range of about 19–45), and with this is combined a very low tail ring count of 27. When egg-bearing males are available for examination, this species will probably prove to be a member of the subgenus *Microsyngnathus* Herald 1953. These are small Syngnathine pipefishes usually less than 100 mm. in length that have overlapping brood pouch closures (O-BPC).

Named '*banneri*' in honor of Dr. A. H. Banner whose welcome field efforts resulted in the capture of the holotype of this species.

Minyichthys Herald and Randall, new subgenus of **Micrognathus** Duncker 1915

TYPE SPECIES. *Micrognathus brachyrhinus* Herald 1953.

DIAGNOSIS. Differentiated from other members of *Micrognathus* by increased number of trunk rings (19–21 rather than 13–17), very short snout, and small size (mature at less than 50 mm.). Named *Minyichthys*, small fish, from the Greek "miny" meaning small.

DISCUSSION. Pipefishes of the genus *Micrognathus* have the lateral trunk ridge continuous with the inferior tail ridge and the lateral tail ridge is present. The tail brood pouch has everted type closure in which the outer lip of one flap is turned back upon itself, and the other flap overlaps it (Herald, 1959). There are three subgenera: (1) *Anarchopterus* Hubbs 1935, characterized by smooth body ridges and absence of the anal fin, has two species limited to the Gulf of Mexico and Caribbean; (2) *Minyichthys*, defined above, has two Pacific species; and (3) the type subgenus *Micrognathus* with its typical sharp body ridges, has two Atlantic American species and nine Pacific species.

Micrognathus (Minyichthys) myersi Herald and Randall, new species.

(Figures 5 and 6.)

HOLOTYPE. CAS 13918, 42.5 mm. SL mature male (43.5 mm. TL); Guam, NW. Cocos Island, outside of reef, 70–100 feet depth; rotenone; June 30, 1969; J. E. Randall, *et al.*

PARATYPE. BPBM 8759, 41 mm. SL female (43 mm. TL); Guam; south of Uruno Point, about 10 mi. NE. of Agana; depth 60–90 feet; reef edge adjacent to sand; June 27, 1968; J. E. Randall and H. Kami.

DIAGNOSIS. Dorsal fin rays 29–31 covering 9–10½ rings, i.e., 2½–3 trunk rings and 6½–7½ tail rings; trunk rings 19, tail rings 40–41; pectoral 11–12; anal 2, caudal 8; head-in-standard length 7.2–8.92; snout-in-head 2.36–2.7; dorsal fin base-in-head .75–.93; pectoral base-in-pectoral length 1.6. Lateral ridge pattern typical of *Micrognathus*, i.e., median trunk ridge continuous with inferior tail ridge; lateral tail ridge extended forward onto 2 trunk rings (holotype) or 2½ (paratype); superior trunk and superior tail ridges interrupted at posterior edge of dorsal fin. Distinctive spike on dorsomedian snout ridge just ahead of nostrils. Brood pouch covering first 13 tail rings with embryos to 10th ring; 7 large embryo sockets; pouch protecting plates slightly developed with pouch closure of everted type (E-BPC). Mouth extremely vertical.

DESCRIPTION. With exception of internasal spike, all head and body ridges faint. Orbital ridge mildly accentuated with pronounced spine on anterior border (holotype) or moderate (paratype). Opercular ridge extending

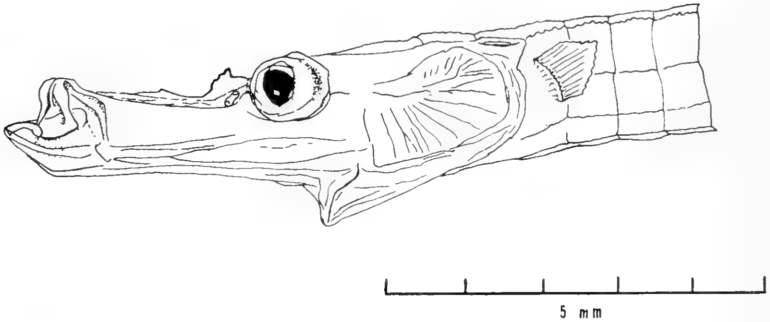

FIGURE 5. *Micrognathus myersi* Herald and Randall, Holotype; male 42.5 mm. SL (CAS 13918); NW. Cocos Island, Guam. Drawing by L. Sabre.

over half of opercle. Pectoral cover plate with faint superior and inferior ridges. Trunk and tail ridges with indentation between rings, and ridges with finely toothed edge. Base of dorsal fin resting in slight 'V.' Color light tan: holotype with indication of 4 pigment streaks extending downward from opercle and dark area on side of snout just anterior to eye. Paratype with indication of color bands formed by occasional dark spots: 7 bands or bars on trunk and 17 on tail.

DISCUSSION. Although the two type specimens are almost the same size, the holotype snout length is much greater than that of the paratype, with snout-in-head values being 2.36 and 2.7. If the other characters were not so similar, one would be tempted to consider them as closely related but separate species.

Short snouts are the mark of the subgenus *Minyichthys* as is shown even better by the two known specimens of the genotype *M.* (*Minyichthys*) *brachyrhinus* (snout-in-head 3.17). A comparison between the two species of *Minyichthys* follows:

	M. (M.) brachyrhinus	*M. (M.) myersi*
Dorsal fin rays	23–25	29–31
Rings covered by dorsal	1½ – 1¾ + 5¾ – 6½ = 7¼ – 8¼	2½ – 3 + 6½ – 7½ = 9 – 10½
Trunk rings	19–21	19
Tail rings	37–39	40–41
Snout-in-head	3.17–3.18	2.3–2.7
Max. known size	31 mm.	42.5 mm.
Distribution	Oahu; Ticao I. Philippines	Guam

This new species is named in honor of Stanford faculty member Dr. George Myers (retired) who has been the major professor for many of today's ichthyologists.

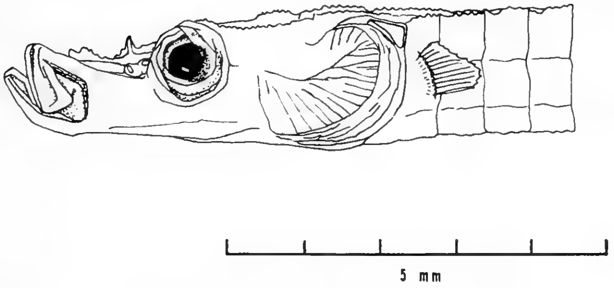

Figure 6. *Micrognathus myersi* Herald and Randall, Paratype; female 41 mm. SL (BPBM 7579); south of Uruno Point, Guam. Drawing by L. Sabre.

Comments on other *Micrognathus*

Since the senior author's *Micrognathus* study of 1953, there have been two additional new species, one in the Atlantic and one in the Pacific. In 1964 Gilbert Whitley described *Micrognathus boothae* from Australia's Lord Howe Island (off New South Wales). This species is closely related to *M. brocki* discovered at Bikini Atoll in the Marshall Islands, about 2570 miles north of Lord Howe. The two species differ mainly in the shorter snout of *M. boothae* along with its 42 rather than 37 tail rings. Three specimens are known for the two species: the female holotypes of each plus a second specimen of *M. brocki* captured by the junior author in 1968 at Ishigaki in the Ryukyu Islands. This 82 mm. female (BPBM 8755; 20–70 feet) represents a westward range extension of about 2800 miles. When more material is available of both species, it is possible that the two may prove identical.

In April and May 1971 the junior author collected four heavily-banded specimens of *Micrognathus edmonsoni* in the Marquesas. Three were taken at Nuka Hiva at a depth of 70 feet (BPBM 10857, 71 and 70 mm. SL, and CAS 13977, 62 mm.) and one was captured at 115 feet in Vaitahu Bay at Tahuata (BPBM 11936, 72 mm. SL). This is startling because previously this species had been considered a rare Hawaiian endemic. Although it was described more than 42 years ago (1930) only 7 other specimens are known from 3 localities on Oahu and Maui. This new locality extends the range about 2500 miles southward from the Hawaiian archipelago. It is entirely possible that this species is one of the deeper water syngnathids, and thus has escaped collections made by non-diving ichthyologists.

Another problem deals with a pipefish originally described as *Ichthyocampus annulatus* Macleay 1878. The two type specimens are actually *Micrognathus brevirostris* as shown by reexamination in 1971 by Dr. John R. Paxton at the Australian Museum. Unfortunately the artist used a specimen of *Yozia* species to make the illustration for the original description, and in some unknown way this fact escaped the notice of the author.

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THE GENUS *MECAS* LECONTE (COLEOPTERA: CERAMBYCIDAE)

By

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The genus *Mecas* is a group of lamiines generally distributed from Guatemala to southcentral Canada. A single species occurs in North America west of the Rocky Mountains, but none are known from northeastern North America. Based upon present knowledge, most of the species are associated with weedy composites. A few of them are also lampyrid and/or cantharid and lycid mimics. Although the genus has been recently revised (Breuning, 1955), available information and material have necessitated a further reclassification of the group.

CLASSIFICATION AND NOMENCLATURE

The first named species of *Mecas* as currently recognized (*M. pergrata*, *M. cana*, *M. cinerea*) were assigned by their authors to the genus *Saperda* Fabricius (Say, 1824; Newman, 1840). LeConte (1852, 1859a) transferred *S. pergrata* to *Stenostola* Mulsant, a generic name he also used for his '*saturnina*' (LeConte, 1859a), but left '*cana*', which he did not know, in *Saperda* (he had no reason to refer to '*cinerea*' which was from Mexico). In 1847, Haldemen described '*femoralis*' in the genus *Phytoecia* Mulsant, which LeConte (1852) made the monobasic type of his genus *Mecas*. Twenty-one years later, LeConte (1873a) added a second species, *M. marginella*, and defined the genus (1873b) in such a manner that all of the above species could be included, although he did not mention them by name. Unfortunately, Lacordaire (1872) overlooked *Mecas* which would have fallen in his Tribe IV (Phytoecides), although he included the related *Dylobolus* Thomson (which Bates later regarded as a synonym of *Mecas*) in his Groupe IV (Arenicides) and *Pannychis* Thomson (which we regard as a subgenus of *Mecas*) in his Groupe III (Amphionychides). LeConte's expanded concept of the genus was first applied to the North American species by Horn (1878) and to the Mexican species by Bates (1881). Casey (1913) provided a key to the species in his collection and Breuning (1955) published a revision of the genus. However, this revision is incomplete, since three of the species, *M. inornata* of authors, *M. cineracea* Casey, and *M. bicallosa* Martin were omitted. These were incorrectly transferred by Breuning to the genus *Saperda*, although their published characters (including the cleft or toothed claws in both sexes) and recorded host plants (weedy composites) are typical of the species currently and historically referred to *Mecas* (the species of *Saperda* are wood borers).

Although the evolution of the generic concept of *Mecas* until the revision by Breuning was fairly straightforward, there has been considerable uncertainty regarding the identity of some of the species. The most serious confusion involves the name '*Saperda inornata*' described from Missouri Territory by Say (1824), who used the broad concept of *Saperda* current in his time. LeConte (1852), not knowing what species Say had before him, included it in his treatment of *Saperda*, quoting from Say's description as he did for other species which he had not identified. Obviously uncertain, he speculated that it might be the male of his *S. concolor* from Sante Fe, New Mexico, which he described in the same paper (LeConte, 1852). However, he apparently decided later that '*inornata* Say' belonged to the genus *Mecas*, and the specimens standing under that name in his collection belong to this genus. Further, the name '*inornata* Say' does not appear in his key to the species of *Saperda* (LeConte, 1873a). Horn (1878), in his key to the species of *Mecas*, included the name '*inornata*,' applying it to the species previously described by LeConte as '*saturnina*,' which Horn regarded as a synonym of '*inornata*.' However, Blanchard (1887) found two species differing in claw structure standing under the name '*saturnina*' in his collection. These had not been differentiated in Horn's Key. This discovery prompted Horn (1888) to apply the name '*saturnina*' LeConte to the species with the claws moderately deeply cleft with the inner division lobe-like. On this basis of distinction Gahan (1888) placed *Saperda cinerea* Newman and *Mecas senescens* Bates as synonyms of *Mecas inornata* (Say) and *Mecas saturnina* (LeConte) as a synonym of *Mecas cana* (Newman). We agree that *M. saturnina* and *M. cana* are conspecific, although in the material before us the two appear to be allopatric. *Mecas cinerea* (Newman) and *M. senescens* Bates also appear to be conspecific, but are not closely related to any species from the United States and thus could not under any circumstances be called '*inornata* Say.' Although various species of *Mecas* have been treated taxonomically in the intervening years as '*M. inornata* Say' (see synonymical bibiographies), the species which most closely fits Say's very brief description is *M. confusa* (described below) or, possibly, *M. cineracea* Casey.

In 1924, Martin named a species *M. bicallosa* on the assumption that '*inornata* Say' was *Saperda* in the modern sense and a senior synonym of *S. concolor* LeConte (see above), although the arguments advanced for this decision were not conclusive (Martin also assumed that he was formally naming the species that previously had been called *M. inornata*; however, the species before him was from the Great Basin and the ranges accorded to *M. inornata* by Horn and Blanchard are to the east of this area). Martin's placement of *S. concolor* LeConte as a synonym of *S. inornata* Say was accepted by Breuning (1952) and Nord and Knight (1970). These latter appealed to the International Commission on Zoological Nomenclature to use its plenary powers to designate as neotype of *Saperda inornata* Say the type of *Saperda concolor unicolor* Felt and Joutel, and place '*inornata*' on the Official List of Specific Names in Zoology. While such an action would eliminate some nomenclatural confusion in the genus *Mecas*, its impact on the literature of the North American *Saperda* will be unfortunate. Proposing to relegate the name '*inornata* Say' to the list of *nomina dubia* might have been a preferable solution to the problem.

Distribution

The known species of *Mecas* occur in the area from western Canada to southeastern United States, Mexico, and Guatemala. Of the 15 species recognized by us, five are restricted to northern and central Mexico and another ranges into Guatemala; six occur in both the United States and Mexico and three are thus far known only from the United States.

A single species, *M. bicallosa*, is found west of the Rocky Mountains, occupying the Great Basin and extending into British Columbia and northern Baja California. Most of the species occurring in the United States are found in either the southeastern and/or southwestern portions of the country. Only three species, *M. femoralis, M. marginella,* and *M. confusa*, are not yet known from Mexico but probably only *M. femoralis* does not occur there. The most widely distributed species, *M. rotundicollis*, ranges from Costa Rica to Kansas and Arizona. Of the remaining four species common to both countries, *M. cana saturnina, M. pergrata,* and *M. cineracea* apparently occur only in northeastern Mexico but are more widely distributed in the United States. The other species, *M. menthae*, ranges from Distrito Federal north along the western slope of the Sierra Madre to Arizona and New Mexico. Five of the six Mexican species, *M. sericea, M. humeralis, M. cinerea, M. cirrosa,* and *M. ambigena* are apparently largely restricted to central Mexico from Chihuahua and San Luis Potosi to Puebla. The sixth, *M. obereoides*, extends into Guatemala.

In many respects the distribution of *Mecas* is comparable to that of *Elytroleptus* (Linsley, 1962; Chemsak and Linsley, 1965). Of the 17 species of *Elytroleptus*, 9 are known only from Mexico, 7 from the United States and Mexico, and one from the United States only. The majority of the species, as in *Mecas*, are found in central and northern Mexico and southwestern United States. Since nothing is known of the biology of the species of *Elytroleptus*, the significance of the distributional similarity, if any, is not evident.

FORM AND COLORATION

Most of the species of *Mecas* are concolorous with the integument black and densely clothed with pale recumbent pubescence. A few of the species, *M. femoralis*, *M. pergrata*, and *M. cinerea* frequently or always possess reddish femora and the latter two often have the elytra and/or pronotum partly reddish. Some of the members of the genus are distinctive by the narrow, densely pubescent white bands on the suture and epipleurae of the elytra.

The most striking divergence from the typical appearance is to be found in *M. sericea*, *M. rotundicollis*, and *M. obereoides*. The first of these, *M. sericea*, is definitely lycid-like in aspect usually possessing two lateral dark bands at the base and apex of the elytra. The basal band may be reduced or absent and occasionally both bands are lacking. Since this species is mimetic, the variation in color is probably an expression of resemblance to different lycid models within the range of the species. *Lycus sallei* Gorham is a possible model with two dark elytral bands and we have another similarly marked *Lycus* from Sinaloa and Colima.

Mecas rotundicollis is unquestionably a lampyrid mimic throughout most of its range, although in some areas a cantharid may be the model. As is the case in *M. sericea*, *M. rotundicollis* apparently mimics different species of models in different parts of its range. Variation is expressed primarily by the presence or absence of yellow pubescence on the apical abdominal sternites and yellow pubescent bands on the suture and epipleurae of the elytra. We have been unable to find a geographical trend in these characteristics but most of the available specimens from Arizona lack the yellow pubescence.

The third species, *M. obereoides*, may be involved in a mimetic ring with a cantharid model. Very little variation in color is expressed in this species but it is one of the most distinctive in the genus. Field studies will be necessary to confirm involvement with mimicry.

The remaining species of *Mecas* are all quite similar in form and coloration. Differences between species involve such characteristics as tarsal claw structure, number of glabrous calluses on the pronotum, and relative lengths of antennal segments.

BIOLOGY

Little has been recorded on the biology of species of *Mecas*. The most complete accounts known to us are those of Baerg (1921) and Stride and Warwick (1962). Baerg's report describes injury to Jerusalem artichokes in Arkansas and probably refers to *M. cana saturnina* (LeConte) or the species named below as *Mecas confusa,* new species. Baerg's account, under the name "*Mecas inornata* Say" is as follows:

> This beetle, half an inch long, of a light gray color, is a girdler that attacks artichoke (*Helianthus tuberosus*). The beetles begin ovipositing early in July. The females when laying eggs girdle the main stem about six inches from the top. Two girdles are made, about 1–1¼ inches apart. Immediately above the lower girdle is the egg puncture. This is exactly similar to the method followed by the Raspberry cane girdler (*Oberea bimaculata*). The girdles are not clean cuts such as we find in woody plants, but rather a series of holes encircling the stem. Apparently one female will deposit in a large number of plants. In spite of the fact that only a few beetles could be located, practically all the plants in the field were attacked in the course of a few days.
>
> As a result of the injury, the leader in the plant dies and the plant develops a bushy type of branching.
>
> The young larvae upon hatching begin to feed between the girdles and later proceed towards the base of the plant. They confine their injury largely to the pith. Apparently under certain weather conditions the artichoke is not well fitted as a host plant. In only one out of four or five plants showing egg punctures was there a full grown larva. In most of the other plants the larva had begun to feed and some time later died, presumably it had been injured by the growing stalk.
>
> The larvae attain full growth, that is about seven-eights of an inch in length, some time in November. At this time the larvae are found at the very base of the stalk, about two inches below the surface of the ground, in an enlargement of the tunnel which has been padded with fine bits of pulp.
>
> The pupal stage has not been observed but since the adults appear early in July, the larvae will presumably pupate some time in May or early in June.
>
> It seems reasonable to assume that this species will attack most of the species in the genus *Helianthus*. None of these were near the artichokes, and no data have been secured. The only host plant other than artichoke that could be located is the common ragweed (*Ambrosia artemisiifolia*).

The observations of Stride and Warwick were made on *M. saturnina* in Australia where that species had been introduced as a biological control agent for *Xanthium* (Wilson, 1960). The habits as they reported are almost identical with Baerg's account and an additional observation was the plugging of the oviposition hole with a gummy substance after the single egg had been laid. Stride and Warwick advance a hypothesis whereby the double-girdling behavior of *M. saturnina* may be regarded as a device originally evolved to permit the use of succulent green shoots of otherwise woody plants as food for cerambycid larvae. Presumably, it has been retained in *M. saturnina* because it promotes advantageous changes in the herbaceous host plant attacked, possibly increased pithiness.

Earlier reports also refer to stem- and root-boring habits of *Mecas* (Riley, 1880; Beutenmuller, 1896; Leng and Hamilton, 1896). Most aspects of adult behavior are lacking from the older literature but Townsend (1884) reported that

'*Mecas inornata*' takes wing and flies away when it observes someone approaching, but drops to the ground and feigns death when unexpectedly disturbed.

Adults of *M. menthae*, new species were found in numbers by their collectors on the upper leaves of the mint, *Agastache*, during the day.

HOST RELATIONSHIPS

Precise host data for most species of *Mecas* are lacking. In part this results from uncertainty regarding the identity of the species of *Mecas* associated with published host records and in part from the fact that most records, both published and unpublished, are based upon collections of adults from plants and not upon reared material. Nevertheless, there is an interesting consistency among the records that are available. With very few exceptions the plants involved are weedy, herbaceous composites which have special chemical characteristics expressed in terms of aromatic, medicinal, irritant, or toxic properties. The list of known or suspected hosts based upon field collections, with notations of some of their properties as reported by Blake (1951) and Kingsbury (1967) is as follows:

COMPOSITAE

Ambrosia (Ragweed).
  A. artemisiifolia Linnaeus (Common Ragweed). One of the most widespread causes of hayfever.
Artemisia (Sagebrush).
  A. tridentata Nuttall (Big Sage). Used medicinally by Indians and early white settlers in the West; a hay fever plant; toxic to livestock if eaten in excess.
Aster (Aster).
  A. tanacetifolius Humboldt, Bonpland, & Kunth (Tansyleaf Aster). Used medicinally by the Indians; some species of aster absorb Selenium and become toxic.
Baileya (Baileya).
  B. multiradiata Harvey & Gray (Desert Marigold). Causes mortality in sheep, particularly, but not exclusively, on over-grazed land.
Gaillardia (Blanket-flower).
  G. pulchella Fougeroux de Bondaroy. A related species, *G. pinnatifida* Torrey. was used by the Hopi Indians as a diuretic.
Guardiola (Guardiola).
  G. tulocarpus Gray.
Helenium (Sneezeweed).
  H. hoopesii Gray (Orange Sneezeweed). Contains a toxic glucoside (dugaldin) which causes spewing sickness in sheep.
  H. microcephalum DeCandolle (Sneezeweed). Toxic to livestock.
  H. tenuifolium Nuttall (Bitter Sneezeweed). Toxic to livestock and suspected of poisoning humans.
Helianthus (Sunflower).
  H. annuus Linnaeus (Common Sunflower). Toxic to cattle in large amounts; the seeds are edible.
  H. tuberosus Linnaeus (Jerusalem Artichoke). Roots edible.

Verbesina (Crown-beard).

V. encelioides (Cavanilles) Bentham & Hooker (Golden Crownbeard). Used by Indians and White pioneers in the West for treatment of boils and skin disease; Hopis reported to bathe in water in which plant has been soaked to relieve pain of spider bites.

Xanthium (Cocklebur).

X. spinosum Linnaeus (Spiny Cocklebur). Seeds and seedlings contain a glucoside (Xanthostrumarin) poisonous to swine and poultry.

LABIATAE

Agastache (Giant-hyssop)

A. species (Horsemint).

Genus **Mecas** LeConte

Mecas LECONTE, 1852, Jour. Acad. Sci. Philadelphia, vol. 2, no. 2, p. 155; 1873, Smithsonian Misc. Coll., no. 265, p. 347; HORN, 1878, Trans. American Ent. Soc., vol. 7, p. 44; BATES. 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 203; LECONTE and HORN, 1883, Smithsonian Misc. Coll., vol. 507, p. 332; LENG and HAMILTON, 1896, Trans. American Ent. Soc., vol. 23, pp. 151, 152; CASEY, 1913, Memoirs on the Coleoptera, vol. 4, p. 360; BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 138.

Form elongate, usually parallel. Head with front convex, interantennal area usually concave; mandibles rather short, apices curved, acute; palpi slender, maxillary pair longer than labial; eyes rather small, finely faceted, deeply emarginate, upper lobe small; antennae usually slender, sparsely or densely fringed with long hairs beneath, particularly on basal segments; third segment usually longer than first, fourth subequal to or shorter than third, outer segments short or long. Pronotum wider than long, sides usually rounded; disk variably pubescent, often with glabrous calluses; prosternum short, intercoxal process narrow, expanded at apex, coxal cavities closed behind; mesosternum with coxal cavities open; metasternum with episternum broad in front, narrowing behind. Legs short; intermediate tibiae with a dorsal sinus; tarsal claws bifid. Abdomen normally segmented; last sternite deeply impressed in the male, linearly impressed in the female.

TYPE SPECIES. *Phytoecia femoralis* Haldeman (monobasic).

This genus is distinctive from others in its tribe by the proportions of the antennal segments, the frequent presence of dorsal calluses on the pronotum, the shape of the metepisternum, and by the nature of the impressions of the last abdominal sternite, which are concave in the male and linear in the female. Many of the species resemble *Saperda* but the bifid claws will readily separate them.

There are at present 15 known species of *Mecas* assignable to three subgenera, all occurring in the New World.

Key to the known species of the genus *Mecas*

1. Pronotum with sides rounded or subparallel; elytra not expanded apically behind middle; appearance not lyciform 2

Pronotum with sides obtusely produced at middle; elytra expanding slightly toward apices; integument yellow and black; appearance lycid-like. *Mecas* (*Pannychis*). 14–20 mm. Chihuahua to Veracruz .... *M. sericea*

2(1). Pronotum not densely fringed with short, erect, golden pubescence, erect hairs moderately long; elytral apices broadly rounded or rotundate-truncate; abdomen with pubescence of sternites unicolorous. *Mecas,* sensu stricto. 3

Pronotum densely fringed with short, erect, golden pubescence with scattered long setae intermixed, dorsal surface with a pair of longitudinal vittae on each side of middle composed of short, appressed, golden pubescence; integument usually concolorous golden yellow, less commonly mottled or vittate with black, rarely wholly black; elytral apices angulate, obliquely truncate or emarginate; abdomen often with last three sternites margined laterally with longitudinal bands of yellowish-white pubescence suggesting luminescent organs of a lampyrid. *Mecas* (*Dylobolus*). 8–14 mm. Southwestern United States to Costa Rica. .... *M. rotundicollis*

3(2). Pronotal pubescence dense, appressed, obscuring surface, intact or broken by well defined black polished callosites and usually also a median impunctate area on disk. 4

Pronotal pubescence very sparse, erect, not obscuring surface which has five tubercles, one median, two antemedian, and two lateral, the surface red to yellow, concolorous or margined laterally with black and/or with black spots on the median or median and lateral tubercles. 8–10 mm. Sinaloa and San Luis Potosi to Guatemala .... *M. obereoides*

4(3). Pronotum with pubescence intact, not interrupted by polished black callosities. 5

Pronotum with at least two polished black callosities and usually a median elongate impunctate area on disk. 8

5(4). Pronotum and elytra with concolorous pubescence which obscures the surface; sternum uniformly, densely pubescent. 6

Pronotum and elytra with longitudinal bands of dense, appressed, often yellowish pubescence at middle and sides, remaining pubescence not completely obscuring surface; sternum margined with a row of dense, appressed, yellowish pubescence. Length, 6.5–8 mm. Southeastern United States to New Mexico. .... *M. marginella*

6(5). Tarsal claws with inner tooth much smaller than outer one. Smaller species, 6–11 mm. in length (fig. 1b). 7

Tarsal claws with inner tooth almost as long as outer one. Length, 10–14 mm. Kansas to Texas (fig. 1a). .... *M. confusa*

7(6). Femora always reddish; pubescence finer, not completely obscuring surface. Length, 6–8 mm. Southeastern United States. .... *M. femoralis*

Femora always black; pubescence thick, obscuring surface. Length, 6–11 mm. Southeastern United States to Arizona, Colorado, and northeastern Mexico. .... *M. cineracea*

8(4). Pronotum with four rounded glabrous calluses in addition to median impunctate area. 9

Pronotum with two rounded glabrous calluses in addition to elongate median impunctate area. 10

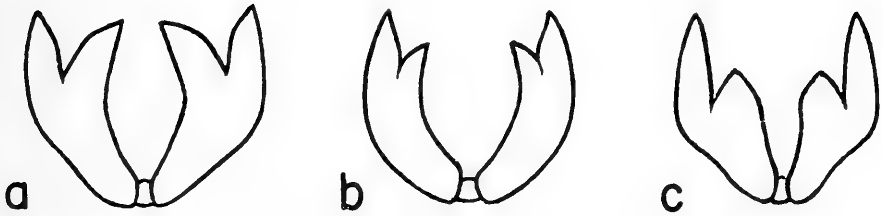

Figure 1. Some variations in the form of the tarsal claws in the genus *Mecas.*

9(8). Form elongate, elytra about 3 times as long as broad; antennae at least as long as body; elytra uniformly pubescent, margins and suture not distinctly pubescent. Length, 8–13 mm. San Luis Potosi to Morelos and Nayarit. ...... *M. cinerea*

Form rather stout, short, elytra about 2½ times as long as broad; antennae shorter than body; elytra with margins and suture densely pale pubescent. Length, 6–12 mm. Great Plains to southeastern United States, New Mexico, and northeastern Mexico. ...... *M. pergrata*

10(8). Tarsal claws with inner tooth short, obtuse, lobe-like (fig. 1c). 11

Tarsal claws with inner tooth acute, spine-like. 12

11(10). Antennae shorter than body, densely clothed beneath with long curved hairs, segments robust, flattened; elytra uniformly gray pubescent. Length, 10.5–13 mm. Guanajuato and Queretero. ...... *M. cirrosa*

Antennae longer than body, sparsely clothed beneath with long erect hairs, segments slender; elytra broadly clothed with brownish pubescence along epipleurae; humeri glabrous. Length, 10.5–13 mm. Jalisco. ...... *M. humeralis*

12(10). Antennae much shorter than body, outer segments short. 13

Antennae at least as long as body, outer segments elongate. 14

13(12). Appressed pubescence gray, uniform on elytra; pronotum irregularly, separately punctate; elytra lacking long erect dark hairs over apical one half. Length, 10–15 mm. Washington to northern Baja California and Colorado. ...... *M. bicallosa*

Appressed pubescence brownish, denser on margins and suture of elytra; pronotum coarsely, confluently punctate; elytra densely clothed with dark erect hairs over apical one half. Length, 9–10 mm. Durango to Mexico. ...... *M. ambigena*

14(12). Elytra sparsely, separately punctate, lacking long erect hairs; pronotal calluses small, median impunctate area vague. 15

Elytra coarsely, contiguously punctate, densely clothed with long erect hairs; pronotal calluses large, median impunctate area distinct. Length, 8–13 mm. Arizona to Nayarit and Distrito Federal. ...... *M. menthae*

15(14). Elytra with distinct longitudinal pubescent bands along margins and suture. Length, 10–16 mm. Florida. ...... *M. cana cana*

Elytra uniformly grayish or yellowish pubescent, suture and margins without pubescent bands. Length, 10–16 mm. Eastern United States to South Dakota and northeastern Mexico. ...... *M. cana saturnina*

Subgenus **Pannychis** Thomson

Pannychis Thomson, 1864, Systema cerambycidarum, p. 127;1868, Physis, vol. 2, p. 197; Lacordaire, 1872, Genera des coléoptères, vol. 9, pp. 882, 889; Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 205; Gilmour, 1962, Rev. Biol. Trop., vol. 10, pp. 125, 137.

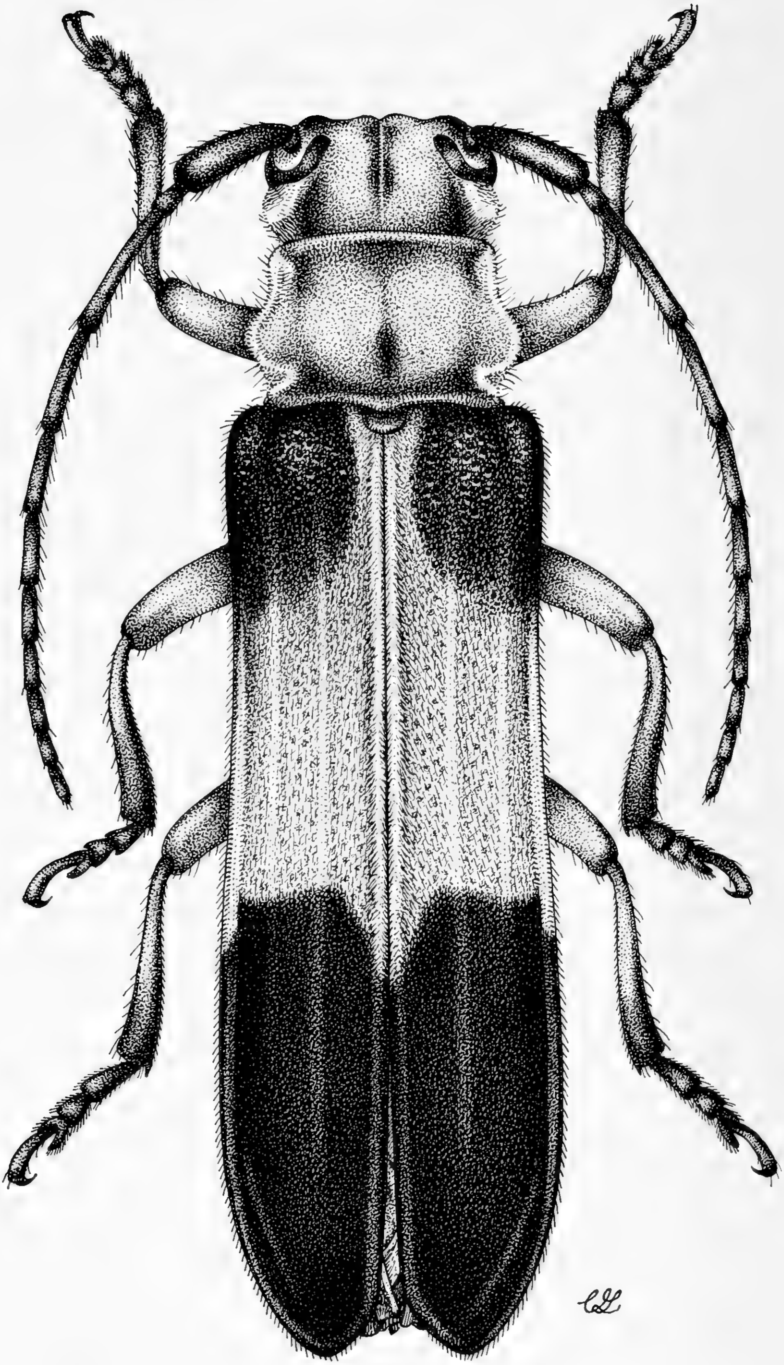

FIGURE 2. *Mecas (Pannychis) sericea* (Thomson), ♀.

Form moderate to large, lycid-like. Antennae short, not extending beyond third abdominal segment, segments not gray pubescent. Pronotum broader than long, sides obtusely produced at middle; disk convex, sparsely punctate, pubescence not obscuring surface. Elytra slightly expanded behind middle, disk costate, pubescence bicolored. Legs with tarsal claws with long inner tooth. Abdomen with last sternite impressed at apex in females.

Type species. *Pannychis sericeus* Thomson (monobasic).

The lycid-like form and coloration and the obtusely produced pronotal sides make this subgenus very distinctive. A single species is known from Mexico.

Mecas (Pannychis) sericea (Thomson).

(Figures 2, 3.)

Pannychis sericeus Thomson, 1864, Systema cerambycidarum, p. 127; 1868, Physis, vol. 2, p. 197; Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 205; Gilmour, 1962, Rev. Biol. Trop., vol. 10, p. 137.

Pannychis ducalis Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 205; Gilmour, 1962, Rev. Biol. Trop., vol. 10, p. 137. New synonymy.

Male. Form moderate sized to rather large, elytra slightly expanding toward apices; integument yellowish, antennae black, legs variable, tibiae usually black, femora often partially black, head usually with 3 black bands over vertex and behind eyes, pronotum usually with 3 longitudinal bands joining at base and broad black bands at sides beneath, elytra yellow or with basal and broad apical black bands, basal bands often reduced or lacking, beneath variably colored. Head with front convex, coarsely, shallowly punctate; interantennal area concave, median line deep; vertex shallowly punctate; pubescence dense, appressed on cheeks, sparse, short, and suberect on front; antennae extending to about third abdominal segment, segments all clothed with very short, dark, depressed pubescence, basal segments with a few long erect setae beneath, third segment subequal in length to first, fourth shorter than third, remaining segments gradually decreasing in length, eleventh appendiculate, segments from fifth with vague longitudinal poriferous areas. Pronotum broader than long, sides obtusely produced at middle; disk convex, almost impunctate; pubescence dense, golden, appressed at sides, a little sparser on disk with a few long, erect hairs interspersed; prosternum sparsely pubescent; meso- and metasternum moderately densely pubescent, distinctly punctate at sides. Elytra about 3 times as long as broad, slightly expanding behind middle; each elytron lightly bicostate, epipleurae vertical; punctures at base coarse, dense, becoming fine and sparser toward apex; pubescence short, dense, subdepressed, colored as integument, longer suberect hairs present basally; apices rounded. Legs finely pubescent; tarsal claws with inner tooth slightly shorter than outer. Abdomen finely moderately pubescent; last sternite deeply impressed for most of its length. Length, 14–19 mm.

Female. Form more robust, elytra slightly more expanded behind middle.

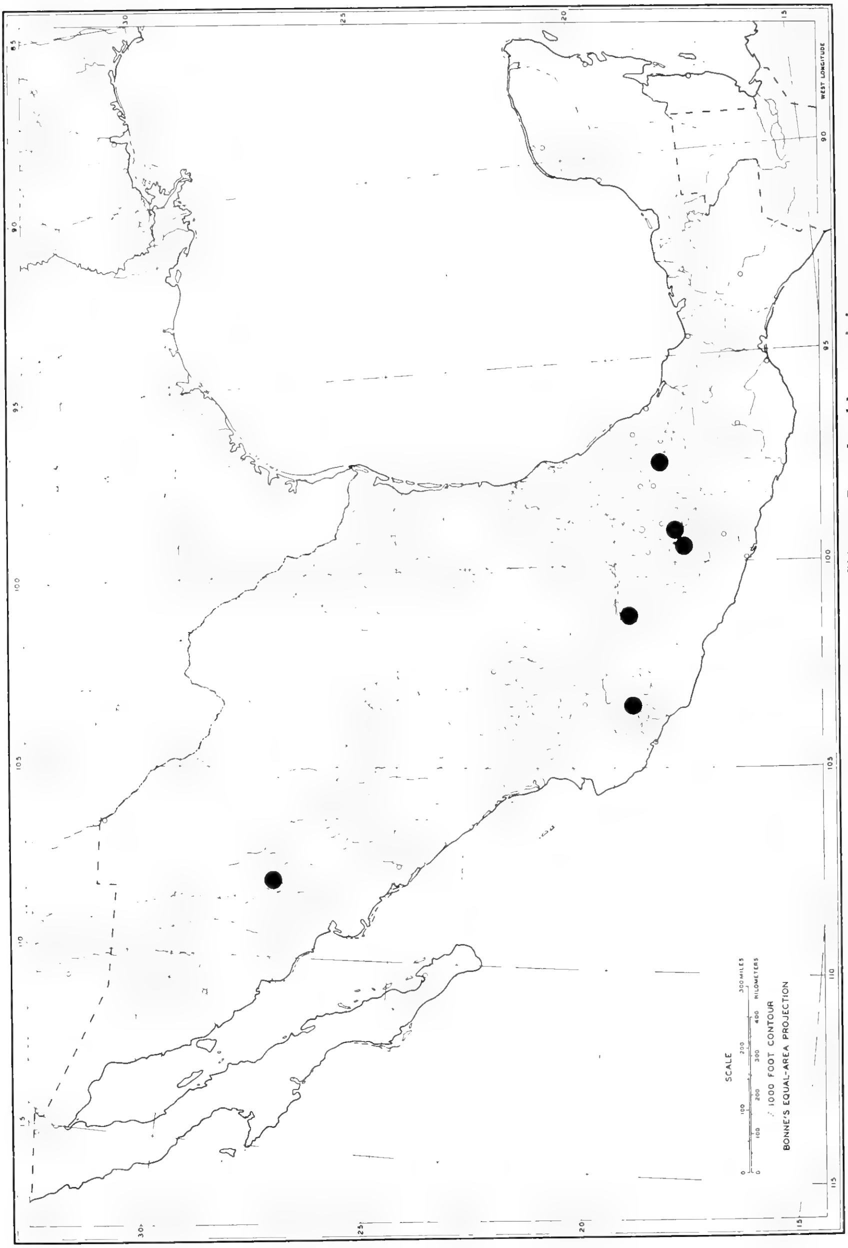

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Figure 3. Known occurrence of *Mecas* (*Pannychis*) *sericea* (Thomson).

Antennae extending to about first abdominal segment. Abdomen with last sternite linearly impressed, concave at apex, apex broadly V-shaped. Length, 14–20 mm.

Type locality. Of '*sericeus*,' Mexico; '*ducalis*,' Orizaba, Mexico.

Range. Chihuahua, Mexico to Veracruz (fig. 3).

Flight period. July to October.

Remarks. This striking species undoubtedly is one of the lycid mimics. It is variable in coloration and, as is found among members of *Elytroleptus* (Chemsak and Linsley, 1965), all yellow individuals occur as well as ones with only the apices of the elytra black or with both the apices and base black. It would not be surprising to encounter individuals with all black elytra.

Material examined. MEXICO. Chihuahua: 1 ♀, 3 miles SE. of Temoris, VII-25-69 (R. C. Gardner, C. S. Glaser, T. A. Sears); Jalisco: 1 ♂, 10 miles SW. of Tecalitlan, X-10-64 (A. E. Michelbacher); 1 ♂, Cuidad Guzman, Jalisco, IX-15-63 (M. C. Colorado); Morelos: 1 ♂, Tequesquitengo, VII-15-61 (R. & K. Dreisbach); Michoacan: 1 ♀, near Morelia, IX-5-52 (G. H. Dieke); Guerrero: 1 ♀, Iguala, VII-21-62 (H. E. Milliron); 1 ♀, 10 miles N. of Mercula. VIII-26-58 (E. L. Mockford); 1 ♂, Thaxmalac, IX-22-42 (W. F. Fosberg); Puebla: 1 ♂, 19 miles NW. of Cacaloapan, VII-30-65 (W. A. Foster).

Subgenus **Dylobolus** Thomson

Dylobolus Thomson, 1868, Physis, vol. 2, p. 195; Lacordaire, 1872, Genera des coléoptères, vol. 9, pp. 897, 900.

Form slender, elongate. Antennae slender, third segment slightly curved. Pronotum with sides rounded, disk densely fringed with short, erect, golden pubescence. Elytra with apices angulate, usually obliquely emarginate. Legs with tarsal claws with inner tooth almost as long as outer one. Abdomen frequently with yellowish appressed pubescence at sides of apical sternites.

Type species. *Dylobolus rotundicollis* Thomson (monobasic).

This subgenus differs from the others by the pubescence of the pronotum and emarginate or truncate elytral apices. The single known species is a lampyrid mimic.

Mecas (Dylobolus) rotundicollis (Thomson).

(Figures 4, 5, 6.)

Dylobolus rotundicollis Thomson, 1868, Physis, vol. 2, p. 196.

Mecas rotundicollis, Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 205; Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 148.

Mecas ruficollis Horn, 1878, Trans. American Ent. Soc., vol. 7, p. 44; Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 205; Leng and Hamilton 1896, Trans. American Ent. Soc., vol. 23, pp. 152; Casey, 1913, Memoirs on the Coleoptera, vol. 4, p. 362.

Mecas ruficollis morpha *mediomaculata* Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 149. New synonymy.

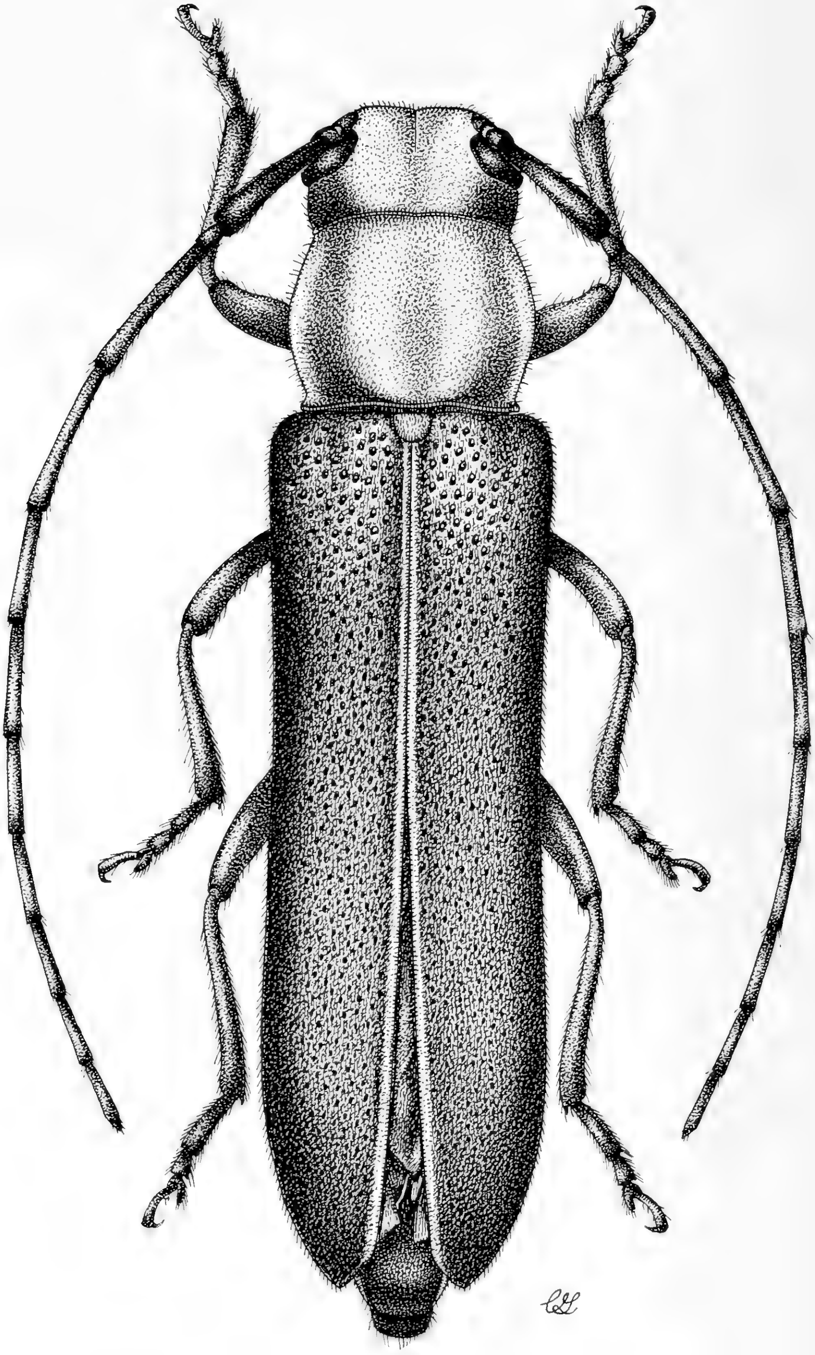

FIGURE 4. *Mecas* (*Dylobolus*) *rotundicollis* (Thomson), ♂.

Mecas rotundicollis morpha *ruficollis*, Breuning, 1955, Mem. Soc. Roy. Belgique, vol. 27, p. 149.

Mecas laticeps Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 204; Breuning, 1955; Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 151. New synonymy.

Mecas laticeps morpha *sutureflava* Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 151. New synonymy.

Mecas laticeps morpha *mediopunctata* Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 151. New synonymy.

Mecas mexicana Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 204.

Mecas rotundicollis morpha *mexicana*, Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 149.

Mecas vitticollis Casey, 1913, Memoirs on the Coleoptera, vol. 4, p. 362.

Mecas laticeps morpha *vitticollis*, Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 152.

Male. Form moderate sized, elongate, sides parallel; color black, head and pronotum orange, usually with dark spots or bands, legs often orange, thoracic sterna often orange, abdomen usually with broad bands of yellow appressed pubescence at sides of last three sternites, elytra frequently with narrow bands of appressed yellowish pubescence down suture and epipleurae. Head rather small; front convex, median line extending from clypeus to neck; interantennal area concave; vertex moderately coarsely, densely punctate; pubescence dense, yellowish, appressed with short, dark, erect hairs numerously interspersed; antennae shorter than body, scape finely, very densely punctate, third segment longer than first, fourth shorter than third, fifth subequal to first, segments from sixth gradually decreasing in length, scape rather densely clothed with short subdepressed hairs, underside of segments densely clothed with short, pale, appressed pubescence, basal segments with a few long erect hairs beneath. Pronotum usually broader than long, sides rounded; disk convex, sparsely to rather densely punctate; pubescence usually dense, consisting of short, dense, subappressed, longitudinal bands, one on each side of middle and at lateral margins, longer erect hairs numerously interspersed; prosternum densely pubescent; meso- and metasternum finely, densely punctate at middle, coarsely at sides, pubescence dense. Elytra over three times longer than broad; suture and epipleurae usually with narrow bands of appressed yellow pubescence; punctures rather coarse, dense, becoming finer and sparser toward apex; surface clothed with fine appressed pubescence, short, recurved hairs numerously interspersed, apices obliquely truncate. Legs finely, densely pubescent; tarsal claws with inner tooth almost as long as outer. Abdomen elongate, densely pubescent; last three sternites usually clothed with broad yellow bands at sides; last sternite deeply impressed for most of its length. Length, 9–16 mm.

Female. Form similar, more robust. Antennae slightly shorter than in male. Abdomen with last sternite linearly impressed for its entire length; last tergite strongly, obtusely conical at apex. Length, 10–19 mm.

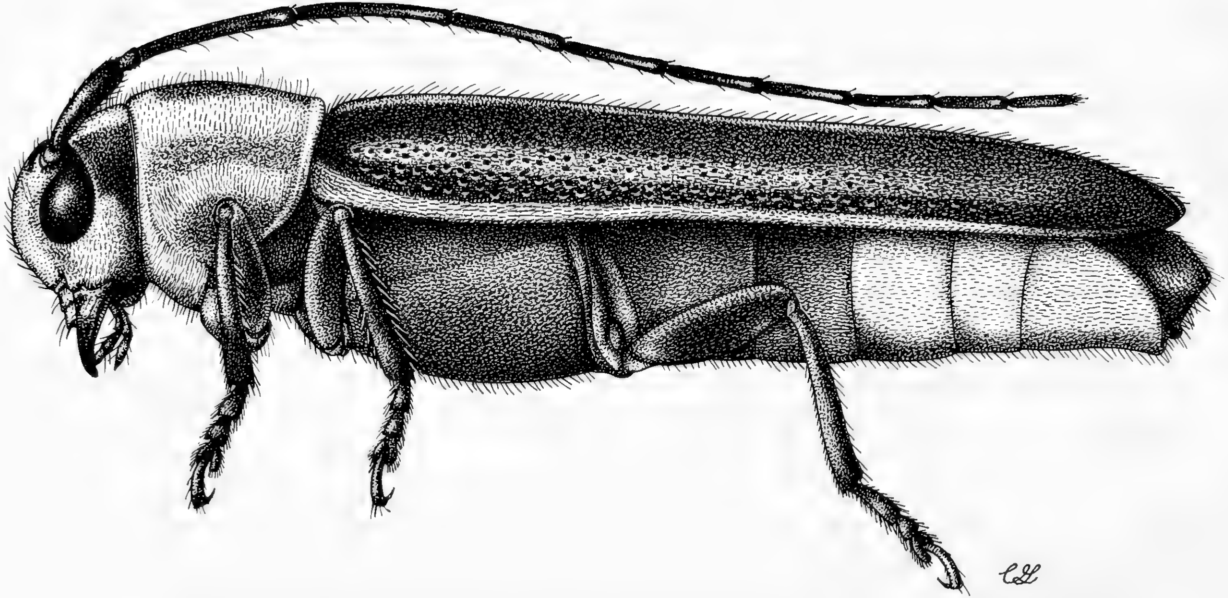

FIGURE 5. *Mecas* (*Dylobolus*) *rotundicollis* (Thomson), ♀. Lateral view illustrating the yellow pubescent lampyrid-like apical abdominal sternites.

TYPE LOCALITY. Of *'rotundicollis,'* Mexico; *'ruficollis,'* Texas; *'laticeps,'* Guanajuato, Mexico; *'mexicana,'* Izucar, Mexico; *'vitticollis,'* Durango City; *'mediomaculata,'* Guerrero; *'sutureflava,'* Temax, Yucatan; *'mediopunctata,'* Mexico.

RANGE. Oklahoma to Arizona, Texas, and south to Costa Rica (fig. 6).

FLIGHT PERIOD. May to December.

HOST PLANTS. Adults have been collected on flowers of *Guardiola tulocarpa* (Compositae) and on *Eysenhardtia polystachya* (Leguminosae).

REMARKS. This species is a lampyrid mimic, resembling different models in different parts of its range, as is evident by the polychromatism expressed in the specimens at hand. These color differences are expressed especially in the presence or absence of yellowish longitudinal sutural and epipleural bands on the elytra and in the yellowish apical sternites of the abdomen. There are varying combinations of these characters but we have been unable to correlate them geographically, although this might be possible with larger series of specimens and model-mimic associations over the entire range.

In addition to the above differences, individuals also vary considerably in size, color of head, pronotum, sternum, and legs.

MATERIAL EXAMINED. UNITED STATES. Oklahoma: 1 ♂, 1 ♀, Edmond, VII-9-57 (D. Alexander); Arizona: 2 ♂♂, Dry Canyon, Sands Ranch, SE. end Whetstone Mts., Cochise Co., VII-10-52 (H. B. Leech, J. W. Green); 1 ♀, Tombstone, VIII-13-40 (E. S. Ross); 1 ♀, Madera Canyon, Pima Co., IX-1-54 (Menke & Stange); 1 ♂, 5 mi. W. Portal, Chiricahua Mts., VIII-12-58 (P. Opler). Texas: 1 ♂, New Braunfels; 1 ♂, 1 ♀, San Antonio, May, VI-11-36 (C. D. Orchard); 1 ♂, 13 mi. W. of San Marcos, Comal Co., VI-24-25-61 (R. L. Westcott); 1 ♂, Brownsville; 1 ♂, Van Horn, V-23-32 (E. G. Linsley). MEXICO. Tamaulipas: 1 ♂, Ciudad Victoria, VI-8-51 (P. D. Hurd); 1 ♂, Rio Corona, 21.3 mi. N. of Cuidad Victoria, X-25-65 (G. E. Ball, D. R. Whitehead). Nuevo Leon: 1 ♂, 2 ♀♀, Monterrey, XI-30-65, X-12-52. San Luis Potosi: 1 ♀, El Huizache, VIII-22-61 (R. & K. Dreisbach). Veracruz: 3 ♂♂, 1 ♀, Veracruz, XI-1-57, IX-24-61 (R. & K. Dreisbach). Chihuahua: 1 ♂, 3 mi. E. of Temoris, VIII-26-69 (Sears, Gardner, Glaser). Durango: 1 ♀, Encino, VII-27-47, 6200 ft. (Schramel); 1 ♂, 11 mi. W. of Durango, VIII-2-64, 7000 ft. (L. Kelton); 1 ♂, 7 mi. W. of Durango, VII-23-64 (W. R. M. Mason); 1 ♂, 25 mi. S. of Durango, VII-24-64 (L. Kelton); 1 ♂, 2 ♀♀, 8 mi. S. of Canutillo, VIII-9-51, on flowers of *Guardiola tulocarpa* (P. D. Hurd). Hidalgo: 1 ♂, Ajacuba, VI-21-37 (M. A. Embury); 2 ♂♂, 2 ♀♀, Pachuca, VI-15-35, VII-10-37 (Embury), VII-31-35 (Embury); 1 ♀, Zimapan, VII-14-68 (M. Wasbauer, J. Slansky). Distrito Federal: 2 ♀♀, Temascaltepec, 1931 (G. B. Hinton). Nayarit: 6 ♂♂, 5 ♀♀, Tepic, IX-13-57 (R. & K. Dreisbach), IX-15-17-53 (B. Malkin), IX-24-47 (B. Malkin); 1 ♀, Campostella, IX-16-57 (R. & K. Dreisbach). Jalisco: 1 ♀, 13

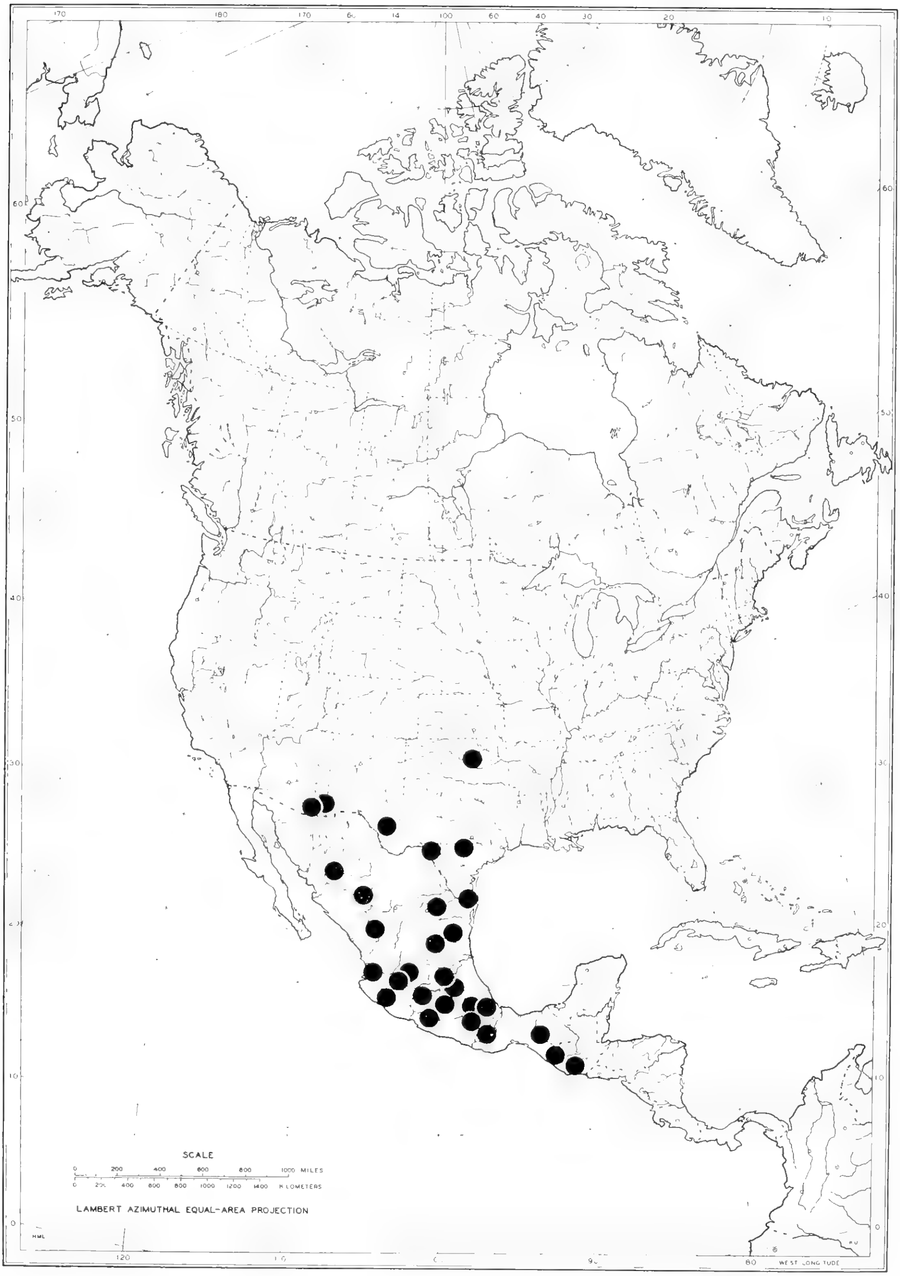

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Figure 6. Known occurrence of *Mecas* (*Dylobolus*) *rotundicollis* (Thomson).

mi. N. of Chapala, VIII-1-63 (P. J. Spangler); 1 ♂, San Juan Lagos, VII-27-51, on *Eysenhardtia polystachya* (P. D. Hurd); 1 ♀, Tlaquepaque, VI-28-45 (N. C. H. Krauss); 1 ♀, Ajijic, VII-28-54 (Cazier, Gertsch, Bradts); 1 ♂, 17 mi. SSW. of Guadalajara, VIII-22-70 (M. & J. Wasbauer). Colima: 1 ♀, Pine zone, SE. Slope Mt. Colima, XII-48 (E. S. Ross). Michoacan: 1 ♂, 5 km. W. of Zacapu, VII-13-51 (H. E. Evans); 1 ♂, Morelia, IX-30-45; 1 ♂, 6 mi. NW. of Quiroga, VII-11-63 (Parker, Stange); 1 ♂, 1 ♀, Quiroga, VII-15-56 (R. & K. Dreisbach); 2 ♂♂, 1 ♀, Tuxpan, IX-6-03 (McClendon), IX-18-57 (Scullen). Morelos: 2 ♂♂, 1 ♀, Hujintlan, VIII-22-56 (R. & K. Dreisbach); 1 ♀, Lake Tequesquitengo, IX-13-57 (Schullen); 2 ♂♂, Cuernavaca, X-02, X-29-57 (Dreisbach); 1 ♀, Morelos, Oct. Guerrero: 1 ♀, Rio Balsas (Wickham). Puebla: 1 ♂, 3 mi. N. of Petalcingo, VIII-21-63 (Parker, Stange); 1 ♂, 55 mi. S. of Acatlan, VII-30-63 (J. Doyen); 1 ♂, Tehuacan, VI-23-51 (Evans); 1 ♂, 19 mi. NW. of Cacaloapan, VII-30-63 (Foster). Oaxaca: 8 ♂♂, 1 ♀, Oaxaca, VII-20-37 (Embury); 2 ♂♂, 1 ♀, Oaxaca, IX-13-20-47 (Malkin); 1 ♂, 1 ♀, Monte Alban, VIII-3-54 (P. & C. Vaurie), X-12-63 (A. E. Michelbacher); 2 ♀♀, 18 mi. NW. of Totolapan, VII-28-63 (Doyen, Foster); 1 ♀, Temescal, VII-5-65 (G. H. Nelson). Chiapas: 1 ♀, Jct. Hwys. 190–195, VI-6-69 (H. F. Howden); 3 ♂♂, 2 ♀♀, San Jeronimo, Volcan Tacana, X-1-10-70, XI-7-70 (E. C. Welling). GUATEMALA. 1 ♀, El Salto, Escuintla, 1934 (F. A. Bianchi). COSTA RICA. 1 ♂, La Pacifica, 4 km. NW. of Canas, Guanacaste, XI-17-71 (P. A. Opler).

Subgenus **Mecas** *sensu stricto*

Mecas LeConte, 1852, Jour. Acad. Nat. Sci. Philadelphia, (2) vol. 2, p. 155; 1873, Smithsonian Misc. Coll., vol. 11, no. 265, p. 347; Blatchley, 1910, Coleoptera—in Indiana, p. 1090; Knull, 1946, Ohio Biol. Survey, Bull. vol. 39, p. 274.

Form moderate sized, parallel; body usually densely clothed with appressed pubescence. Pronotum with or without dorsal calluses, sides broadly to narrowly rounded. Elytra parallel, apices rounded, disk not costate. Legs with tarsal claws variable, inner tooth long or short.

Type species. *Phytoecia femoralis* Haldemen (monobasic).

The members of this subgenus are easily recognizable by the densely pubescent body, subcylindrical and usually densely pubescent pronotum which frequently has glabrous dorsal calluses.

Thirteen species are presently known.

Mecas obereoides Bates.

(Figure 7.)

Mecas obereoides Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 204, pl. 15, fig. 16; Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 150.

Mecas laminata Bates, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 204; Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 150.

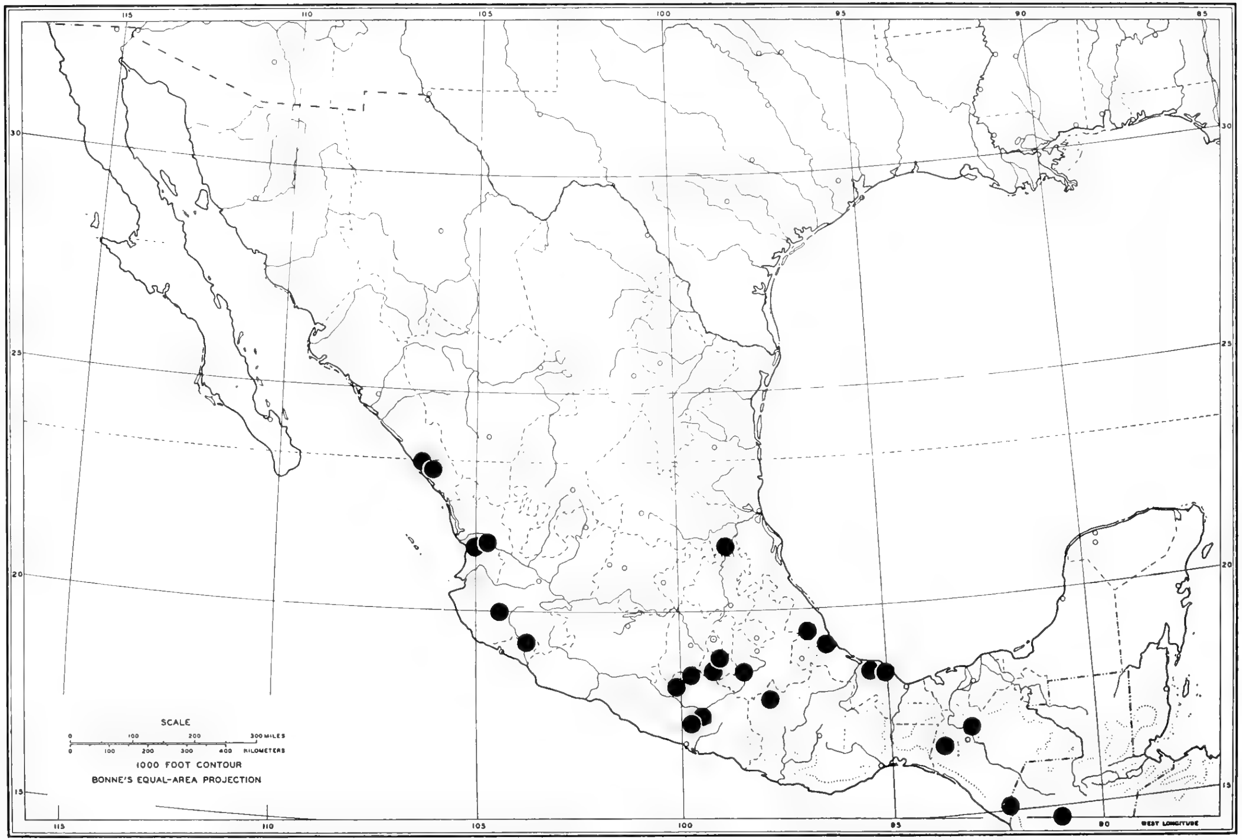

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Figure 7. Known occurrence of *Mecas obereoides* Bates.

Mecas laminata morpha *rufobasalis* BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 150. New synonymy.

Mecas laminata morpha *discopunctata* BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 150. New synonymy.

Mecas laminata morpha *discoimpunctata* BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 150. New synonymy.

MALE. Form moderate sized, elongate, sides parallel; color black, vertex of head and pronotum orange, pronotum usually with three black spots, one median and two lateral. Head with front convex, densely clothed with gray appressed pubescence which covers basal half of mandibles, erect dark hairs numerous on front; interantennal area convex; vertex moderately coarsely punctate; antennae slightly longer than body, densely gray pubescent beneath with a few long erect hairs present on basal segments, scape slightly shorter than third segment, fourth equal to third, fifth shorter than first, segments six to nine subequal, remaining two segments shorter. Pronotum usually a little broader than long, sides narrowly rounded; disk convex, middle with a usually black glabrous callus, frequently a vague callus present on each side of middle anterior to median one, two black glabrous spots present laterally; punctation irregular, moderately coarse; pubescence sparse, fine with a few long erect hairs present at sides; prosternum densely clothed with gray recumbent pubescence; meso- and metasternum densely clothed with gray recumbent pubescence, sides moderately coarsely punctate. Elytra about three times as long as broad; each elytron costate down middle, area between costae and suture impressed; punctures coarse, dense, becoming finer toward apex; pubescence short, dense, appressed, with longer suberect hairs numerously interspersed; apices rounded. Legs densely pubescent; tarsal claws with inner tooth slightly smaller than outer. Abdomen densely clothed with gray appressed pubescence; last sternite shallowly impressed for most of its length. Length, 10–14 mm.

FEMALE. Form similar, slightly more robust. Antennae about as long as body. Abdomen with last sternite linearly impressed for its entire length, shallowly concave at middle at apex. Length, 10–15 mm.

TYPE LOCALITY. Of '*obereoides*,' Cuernavaca, Mexico; '*laminata*,' not restricted; '*rufobasalis*,' Mexico; '*discopunctata*,' Mexico; '*discoimpunctata*,' Mexico.

RANGE. San Luis Potosi and Sinaloa, Mexico to Guatemala (fig. 7).

FLIGHT PERIOD. June to December.

HOST PLANTS. Unknown.

REMARKS. The sparsely pubescent orange pronotum and the dark pronotal spots will readily separate this species from other known species of *Mecas*. The coloration is almost constant in the series at hand. However, specimens from the eastern parts of Mexico tend to have dark appressed elytral pubescence while in those from the western portions to Guatemala this tends to be grayish.

MATERIAL EXAMINED. MEXICO. San Luis Potosi: 1 ♀, 30 mi. N. of

Tamazunchale, X-6-57 (H. A. Scullen). Veracruz: 2 ♂♂, 3 ♀♀, Veracruz, VIII-1-6-61 (R. & K. Dreisbach); 1 ♀, Jalapa, IX-28 to X-3-61 (R. & K. Dreisbach); 1 ♂, 1 ♀, Puente Nacional, VIII-3-56 (R. & K. Dreisbach), VII-23-24-65 (Flint & Ortiz); 2 ♀♀, San Andreas Tuxtla, X-25-57 (R. & K. Dreisbach); 1 ♂, 1♀, Hueyapan, X-30-57 (R. & K. Dreisbach); 1 ♂, Cerro Venado, Los Tuxtlas Range, XII-29-62 (Edmonds, Robinson). Sinaloa: 1 ♂, Venedillo, VII-31-18; 2 ♂♂, 20 mi. E. of Villa Union, VIII-19-64 (M. E. Irwin, E. I. Schlinger). Nayarit: 2 ♂♂, 1 ♀, 15 mi. N. of Tepic, VII-25-54 (Cazier, Gertsch, Bradts); 1 ♂, 1 ♀, 18 mi. N. of Tepic, VIII-16-60 (D. C. Rentz); 3 ♂♂, Tepic, IX-21-24-53 (B. Malkin), IX-13-57 (R. & K. Dreisbach); 1 ♂, 14 mi. E. of San Blas, VII-21-54 (Schlinger). Colima: 1 ♂, Colima (Conradt). Jalisco: 1 ♀, Puerto Los Mazos, 9 mi. NW. of Autlan, VIII-28-70 (M. & J. Wasbauer). Guerrero: 2 ♂♂, 1 ♀, Teloloapan, VIII-15-21-57 (D. Douglas); 1 ♂, 1 ♀, 3 mi. S. of Acahuizlotla, XI-17-46 (E. C. Van Dyke); 1 ♂, Taxco, VIII-16-18-56 (A. E. Lewis); 1 ♂, Highway 95, 23 mi. N. of Acapulco. VII-30-65 (Cornell U. Mex. field party); 1 ♂, 5 mi. W. of Mex. 92, Cacahuamilpa Caves, VIII-16-18-56 (A. E. Lewis). Morelos: 6 ♂♂, 2 ♀♀, Hujintlan, VII-22-56 (R. & K. Dreisbach); 1 ♀, Lake Tequesquitengo, IX-13-57 (H. A. Scullen); 1 ♂, Tequesquitengo, VII-15-61 (Dreisbach); 1 ♂, Xochicalco, VII-13-61 (Dreisbach); 5 ♂♂, 1 ♀, Cuernavaca, VII-15-52 (G. M. Boush), VIII-9-13-38 (L. Lipovsky), VIII-1-6-21 Sept. (Barrett), IX-8-90 (D. Delong); 1 ♂, 1 ♀, 22 mi. S. of Cuernavaca, IX-10-57 (Scullen); 1 ♂, 45 mi. S. of Cuernavaca, IX-12-57 (Scullen). Puebla: 1 ♂, 5 mi. S. of Izucar de Matamoros, VIII-1-63 (Parker, Stange). Oaxaca: 1 ♂, 10 mi. NE. of Huajuapan de Leon, VI-27-65 (Doyen). Chiapas: 1 ♀, Santo Domingo, 15 mi. SE. of Simojovel, VII-8-15-58 (J. A. Chemsak); 6 ♂♂, 9 ♀♀, San Jeronimo, Volcan Tacana, VIII-10 to X-12-70 (E. C. Welling). GUATEMALA. 1 ♀, El Salto, Escuintla, 1934 (F. Bianchi).

Mecas marginella LeConte.

Mecas marginella LECONTE, 1873, Smithsonian Misc. Coll., vol. 11, no. 264, p. 239; HORN, 1878, Trans. American Ent. Soc., vol. 23, p. 152; BLATCHLEY, 1910, Coleoptera—in Indiana, p. 1090; CASEY, 1913, Mem. Coleoptera, vol. 4, p. 361; BREUNING, 1955, Mem. Soc. Roy. Belgique, vol. 27, p. 147.

MALE. Form small, subparallel; color black, pronotum with three longitudinal bands of yellowish to whitish appressed pubescence, elytra with narrow bands of pale pubescence down suture and lateral margins. Head with front convex, deeply punctate, densely clothed with appressed pale pubescence, long erect hairs numerous; interantennal area broadly concave; vertex coarsely, densely punctate; antennae a little longer than body, very sparsely gray pubescent beneath, long erect hairs numerous on basal segments, third segment longer than scape, fourth subequal to third, fifth shorter than fourth. Pronotum broader than long, sides subparallel; punctures moderately coarse, dense, calluses absent; pubescence dense, appressed, lateral bands broad, yellowish, median band narrower, usually whitish, remainder of surface finely pubescent, long, erect hairs numerous; prosternum densely pubescent; meso- and metasternum densely pubescent, rather coarsely punctate at sides, metepisternum yellow pubescent over posterior half. Elytra over twice as long as broad; punctures coarse, close, becoming finer toward apex; pubescence between longitudinal bands fine, appressed, with longer erect hairs numerously interspersed; apices rounded. Legs finely, densely pubescent; tarsal claws with teeth subequal in length. Abdomen densely pubescent, narrowly yellow at sides of apical sternites; last sternite deeply impressed for its entire length. Length, 6.5–8 mm.

Female. Form and size similar. Antennae about as long as body. Abdomen with last sternite shallowly impressed near apex. Length, 6.5–8 mm.

Type locality. Western States and Texas.

Range. Southeastern United States to New Mexico.

Flight period. March to July.

Host plants. Unknown. One specimen was collected on *Colubrina texensis* (Rhamnaceae) in Texas, but it is very unlikely that this shrub is a host.

Remarks. The absence of pronotal calluses and the distinctive pubescent bands make this species easily recognizable. Breuning (1955) states that the head, pronotum, and elytra are densely and very finely punctate but this is an illusion produced by the pubescence. Actually, they are coarsely punctate, the elytra less so apically.

Material examined. Twenty-one specimens from South Carolina, Alabama, Texas, and New Mexico.

Mecas confusa Chemsak and Linsley, new species.

(Figure 8.)

Mecas inornata (not Say), Blanchard, 1887, Ent. Amer., vol. 3, p. 86; Horn, 1888, Trans. Amer. Ent. Soc., vol. 15, p. 301; Leng and Hamilton, 1896, Trans. Amer. Ent. Soc., vol. 23, p. 152; Blatchley, 1910, Coleoptera—in Indiana, p. 1090.

Male. Form moderate sized, subparallel; color black, body densely clothed with thick, grayish, recumbent pubescence which obscures the surface. Head with front convex, finely densely punctate, darker suberect hairs short, about half as long as second antennal segment; interantennal area very shallowly concave; vertex sparsely punctate, large punctures well separated; antennae about as long as body, scape finely gray pubescent, remaining segments to ninth gray pubescent beneath, third segment longer than scape, fourth shorter than third, fifth shorter than first, remaining segments gradually decreasing in length. Pronotum broader than long, sides rounded, base impressed; disk convex, calluses absent; large deep punctures irregular, well separated, each

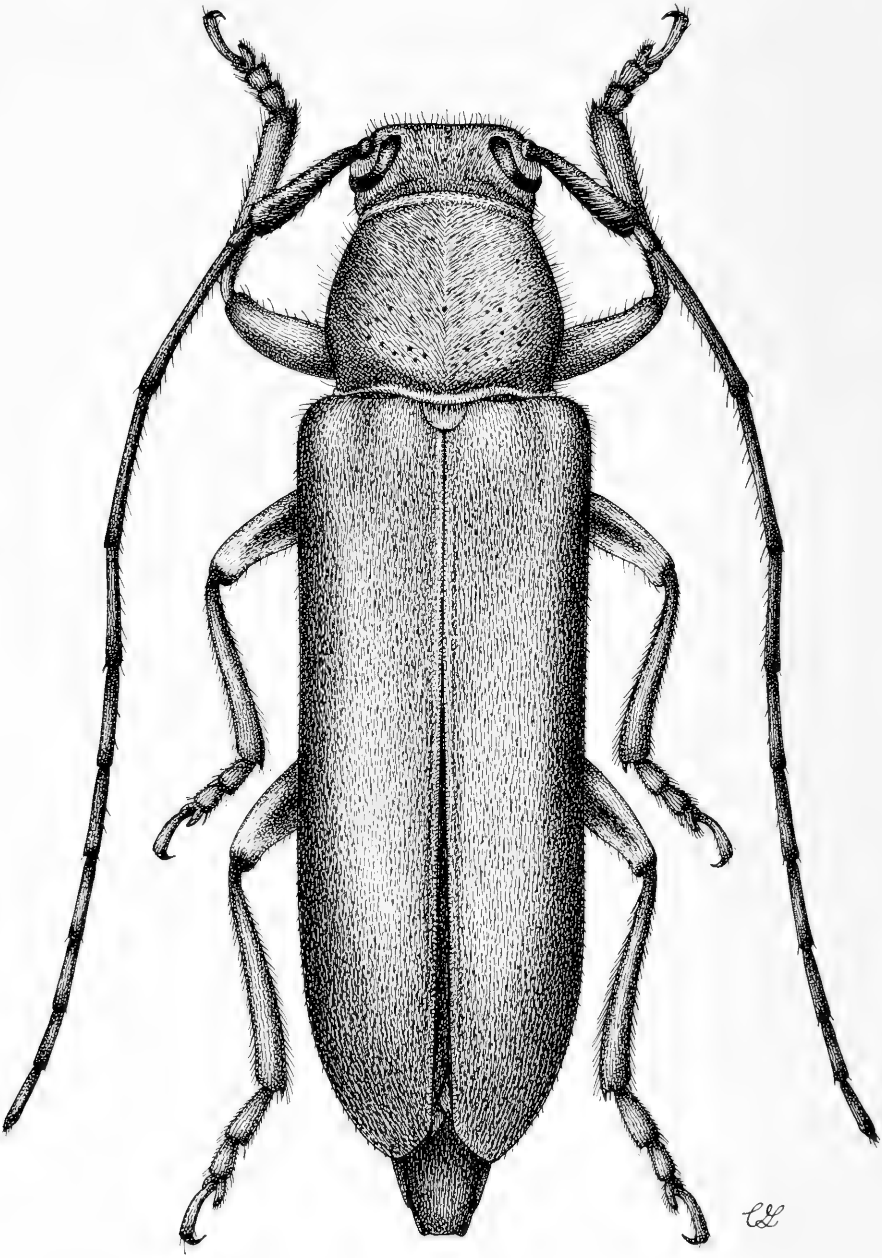

FIGURE 8. *Mecas confusa* Chemsak and Linsley, ♂.

puncture bearing a long erect hair; pro-, meso- and metasterna densely clothed with recumbent pubescence which obscures the surface. Elytra less than 2½ times as long as broad; punctures coarse, close, linearly arranged, becoming obsolete at apex; recumbent pubescence completely obscuring surface, base with numerous rather short suberect hairs, these becoming shorter and recurved toward apex; apices obliquely subtruncate. Legs very densely pubescent; tarsal claws with inner tooth almost as long as outer. Abdomen very densely pubescent; last sternite impressed for its entire length. Length, 10–13 mm.

Female. Similar in form and size. Abdomen with last sternite linearly impressed, apex broadly V-shaped. Length, 10–14 mm.

Material examined. Holotype male (California Academy of Sciences) from Luling, Gonzales Co., Texas, V-3-53 (B. J. Adelson). Allotype from Gonzales, Gonzales Co., Texas, V-2-53 (M. Wasbauer). Paratypes as follows: 2 ♂♂, same data as holotype; 1 ♂, 1 ♀, same data as allotype; 1 ♀, Ft. Sam Houston, Texas (C. Grant); 1 ♀, Corpus Christi, Texas, VI-28-42 (E. S. Ross); 2 ♂♂, 1 ♀, Palmetto State Park, Gonzales Co., Texas, IV-11-53 (M. Wasbauer), V-10-53 (B. J. Adelson); 1 ♂, Lee Co., Texas, May (R. Oertel); 1 ♀, Hidalgo Co., Texas, VI-22-33 (S. Bromley). Other material, not paratypical includes: 1 ♀, Texas (F. Blanchard collection); 1 ♀, Lee Co., Texas, June; 1 ♀, 49 mi. N. of Raymondville, Kenedy Co., Texas, VI-30-61 (R. L. Westcott); 1 ♂, 5 ♀♀, Lake Texoma, 2 mi. E. of Willis, Oklahoma, June, July, 1965 (R. M. Bohart); 2 ♀♀, Clark Co., Kansas, June (F. H. Snow).

This species closely resembles *M. cineracea* but may be separated by its larger size, denser overall pubescence, shorter erect hairs on the front of the head, and by the structure of the tarsal claws. In *M. confusa* the inner tooth of the claws is elongate and almost as long as the outer one; in *M. cineracea* the tooth is very small. The two species are sympatric, at least in parts of Texas, but it is not now known whether they infest the same or different host plants.

Mecas femoralis (Haldeman).

Phytoecia femoralis Haldeman, 1847, Trans. American Philos. Soc., vol. (2)10, p. 59.
Mecas femoralis, LeConte, 1852, Jour. Acad. Philadelphia vol. (2)2, p. 155; Horn, 1878, Trans. American Ent. Soc., vol. 7, p. 44; Leng and Hamilton, 1896, Trans. American Ent. Soc., vol. 23, pp. 152, 153; Casey, 1913, Memoirs on the Coleoptera, vol. 4, p. 360 (fn.); Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 143.

Male. Size small, subparallel; color black, femora reddish; pubescence grayish. Head with front convex, densely punctate, densely clothed with appressed pubescence and numerous suberect, dark hairs; vertex rather coarsely, closely punctate, densely pubescent; antennae about as long as body, basal segments sparsely gray pubescent beneath, long, erect hairs sparse, third segment longer than first, fourth shorter than third, fifth shorter than fourth. Pronotum about as long as broad; sides almost subparallel; disk convex, rather coarsely, closely punctate; pubescence dense, short, appressed, long, erect hairs numerous; prosternum densely pubescent; meso- and metasternum densely clothed with recumbent pubescence, sides more coarsely punctate. Elytra about 2½ times as long as broad; punctures coarse, dense, becoming finer toward apex; pubescence dense, appressed, with longer erect hairs numerously interspersed; apices rounded. Legs moderately densely pubescent; tarsal claws with inner tooth very short. Abdomen densely pubescent; last sternite shallowly impressed over most of its length. Length, 6–8 mm.

FEMALE. Very similar in size and shape. Abdomen with last sternite impressed over apical one-half. Length, 6–8 mm.

TYPE LOCALITY. Not given.

RANGE. Southeastern United States.

FLIGHT PERIOD. May to July.

HOST PLANTS. Unknown.

REMARKS. *Mecas femoralis* can be recognized by its small size, rather uniform pubescence, lack of pronotal calluses, and reddish femora. This species appears to be rare in collections. The eleven specimens we have seen vary very little.

MATERIAL EXAMINED. Eleven individuals from North Carolina to Florida have been seen.

Mecas cineracea Casey.

Mecas cineracea CASEY, 1913, Memoirs on the Coleoptera, vol. 4, p. 360; VOGT, 1949, Pan-Pacific Ent., vol. 25, p. 184. (record)

Saperda cineracea, BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 139.

Saperda bicallosa BREUNING (not Martin), 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 140.

MALE. Form rather small, parallel; color black, body densely clothed with gray recumbent pubescence. Head with front convex, appressed pubescence obscuring punctures, longer erect hairs numerous; interantennal area almost plane; vertex moderately coarsely, separately punctate; antennae about as long as body, basal segments finely gray pubescent beneath, long erect hairs decreasing in number toward apex, third segment longer than first, fourth shorter than third, fifth a little shorter than first, remaining segments gradually decreasing in length. Pronotum broader than long, sides almost parallel, shallowly impressed at base; disk convex, without calluses, punctures coarse, separated; appressed pubescence obscuring surface, long erect hairs numerous; prosternum densely pubescent; meso- and metasternum densely pubescent, coarsely punctured at sides. Elytra about 2½ times as long as broad; punctures coarse, contiguous, becoming finer toward apex; pubescence obscuring surface, long suberect hairs numerous near base; apices obliquely truncate. Legs very densely pubescent; tarsal claws with inner tooth small. Abdomen densely pubescent; last sternite shallowly impressed for its entire length. Length, 6–10 mm.

FEMALE. Similar in form and size. Antennae shorter than body. Abdomen with last sternite linearly impressed. Length, 7–11 mm.

TYPE LOCALITY. Harris Co., Texas.

RANGE. Southeastern United States to Arizona and Colorado and northeastern Mexico.

FLIGHT PERIOD. April to August.

HOST PLANTS. *Helenium microcephalum*, *Baileya multiradiata.*

REMARKS. This species may be recognized by its small size, lack of pronotal calluses, uniform coloration and pubescence, and by the small inner tooth of the tarsal claws. It was incorrectly transferred to *Saperda* by Breuning (1955).

A series of specimens from western New Mexico and Arizona have thicker pubescence than the Texas examples. However, there appears to be a gradient in this character from east to west as is apparent in the material at hand.

MATERIAL EXAMINED. More than 200 specimens from South Carolina to Florida, to Arizona and Colorado.

Mecas cinerea (Newman).

(Figure 9.)

Saperda cinerea NEWMAN, 1840, Entomologist vol. 1, p. 13.

Mecas cinerea, GAHAN, 1888, Trans. American Ent. Soc., vol. 15, p. 300.

Mecas senescens BATES, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 203; CASEY, 1913, Memoirs on the Coleoptera, vol. 4, p. 360.

Mecas rubripes BATES, 1881, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 203; BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 140, 143. New synonymy.

Mecas rubripes morpha *callosoreducta* BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 140, 143. New synonymy.

Mecas inornata GAHAN, 1888 (not Say), Trans. Amer. Ent. Soc. vol. 15, p. 300.

MALE. Form moderate sized, elongate, slender, parallel; color black, femora and/or elytra often reddish, pronotum occasionally with a median longitudinal reddish band; pubescence gray to yellowish, dense, appressed, long erect hairs fairly numerous. Head with front convex, finely separately punctate; interantennal area slightly concave; vertex deeply, separately punctate; pubescence dense, obscuring surface, long erect hairs moderately numerous; antennae slightly longer than body, segments gray pubescent beneath, basal segments with a few long erect hairs beneath, third segment longer than first, fourth subequal to third, fifth equal to first, remaining segments gradually decreasing in length, eleventh subacute at apex. Pronotum slightly broader than long, cylindrical; disk with two small glabrous calluses on each side of basal median elongate callus; punctures moderately coarse, separated at middle and subconfluent at sides; appressed pubescence obscuring surface,

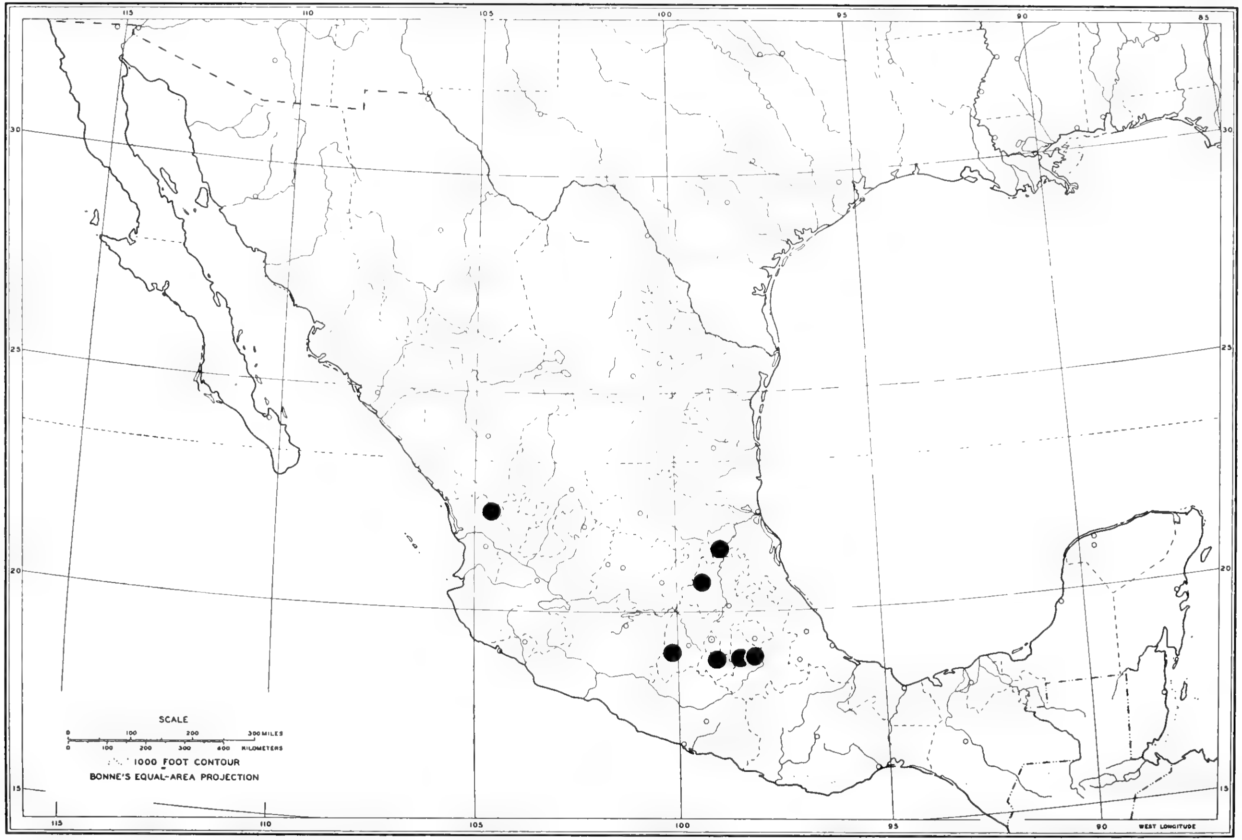

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Figure 9. Known occurrence of *Mecas cinerea* (Newman).

denser at middle and forming a vague longitudinal band, long erect hairs fairly sparse, shorter erect hairs more numerous; prosternum densely pubescent; meso- and metasternum densely pubescent, rather densely punctate at sides. Elytra usually about 3 times as long as broad; punctures coarse and contiguous basally, becoming finer and sparser toward apex; pubescence short, dense, appressed, long erect hairs numerous basally, becoming shorter and suberect toward apex; apices rounded. Legs moderately densely pubescent; tarsal claws with inner tooth slightly shorter than outer. Abdomen densely pubescent; last sternite rather shallowly impressed for its entire length. Length, 8–11 mm.

FEMALE. Form similar. Antennae about as long as elytra. Pronotum more transverse, distinctly broader than long. Abdomen with last sternite linearly impressed. Length, 8–13 mm.

TYPE LOCALITY. Of '*cinerea,*' Mexico; '*senescens,*' Puebla; '*rubripes,*' Mexico; '*callosoreducta,*' Mexico.

RANGE. San Luis Potosi to Morelos and Nayarit (fig. 9).

FLIGHT PERIOD. June to September.

REMARKS. The number of calluses on the pronotum, elongate body form, and the length of the antennae distinguish this species from the other Mexican species of *Mecas.* The body and antennal length, and different tarsal claws separate it from *M. pergrata.* It is difficult to detect a definite geographical variational trend from the material available for study. The more northern individuals are all black while most of the southern specimens possess reddish femora and often, reddish elytra. Two individuals from Nayarit have a reddish longitudinal band on the pronotum and yellowish epipleurae.

MATERIAL EXAMINED. MEXICO. San Luis Potosi: 2 ♂♂, 17 miles W. of Xilitla, 4700 ft., VII-22-54 (Univ. Kansas Mex. Exped.); Hidalgo: 1 ♂, 2 ♀♀, 7 miles NE. of Zimapan, VIII-15-58 (H. F. Howden); Distrito Federal: 5 ♂♂, 7 ♀♀, Temascaltepec, 1931 (G. B. Hinton); 1 ♂, 2 ♀♀, Real de Arriba, Temascaltepec, VII-32 (H. E. Hinton), VII-33 (Hinton and Usinger); 2 ♂♂, 5 ♀♀, Tejupilco, Temascaltepec, VI-VII-33 (Hinton and Usinger); Puebla: 1 ♀, 15 miles S. of Puebla, 6200 ft., IX-6-57 (H. A. Scullen); 1 ♂, Atlixco, VII-23-56 (R. & K. Dreisbach); Mexico: 1 ♂, 1 ♀, 3 miles N. of Valle de Bravo, VI-28-29-65 (G. H. Nelson); Morelos: 7 ♂♂, Cuernavaca VII-6-38, VII-29-61, 7000 ft. (R. & K. Dreisbach); 1 ♂, 1 ♀, Cuernavaca-Acapulco Road, VIII-22-36 (Ball & Stone); 1 ♂, 4 miles E. of Cuernavaca, 6000 ft., VI-25-59 (H. E. Evans); 1 ♂, 7 km. E. of Cuernavaca, 5700 ft., VIII-11-62 (Evans); Nayarit: 1 ♂, 1 ♀, La Mesa de Nayarit, VII-21-55 (B. Malkin).

Mecas pergrata (Say).

Saperda pergrata SAY, 1824, Jour. Acad. Philadelphia, vol. 3, p. 407; HALDEMAN, 1847, Trans. American Philos. Soc., vol. (2)10, p. 55; LECONTE, 1859, Complete Writings of Thomas Say, vol. 2, p. 190.

Stenostola pergrata, HALDEMAN, 1847, Proc. American Philos. Soc., vol. 4, p. 373; LECONTE, 1852, Jour. Acad. Nat. Sci. Philadelphia, vol. (2)2, p. 154.

Mecas pergrata, HORN, 1878, Trans. American Ent. Soc., vol. 7, p. 44; LENG and HAMILTON, 1896, Trans. American Ent. Soc., vol. 23, pp. 152, 153; BLATCHLEY, 1910, Coleoptera—in Indiana, pp. 1090, 1091; CASEY, 1913, Memoirs on the Coleoptera, vol. 4, p. 361; CRAIGHEAD, 1923, Dom. Canada Agr. Bull., vol. 27, p. 138; KNULL, 1946, Ohio Bio. Survey, Bull. vol. 39, pp. 274, 275, pl. 22, fig. 86; BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 140, 144, fig. 1.

Mecas pergrata morpha *semiruficollis* BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 140, 145. New synonymy.

Stenostola gentilis LECONTE, 1852, Jour. Acad. Nat. Sci. Philadelphia, vol. (2)2, p. 154.

Mecas discovittata BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 140, 143. New synonymy.

MALE. Form moderate sized, parallel; color black, femora pale reddish, elytra occasionally partly reddish; pubescence dense, short, recumbent, grayish. Head with front convex, punctures rather fine, well separated; pubescence dense, appressed, long dark erect hairs numerously interspersed; appressed pubescence thicker around eyes; vertex rather densely punctate; antennae shorter than body, segments gray pubescent beneath, outer segments annulate, third segment longer than first, fourth subequal to first, remaining segments gradually decreasing in length. Pronotum broader than long, sides slightly rounded; disk convex, four glabrous calluses present in addition to median callus; punctures rather sparse, scattered; apex and base usually with a narrow band of dense yellowish pubescence, remaining surface partially obscured, long, erect hairs numerously interspersed; prosternum densely pubescent; meso- and metasternum densely pubescent, densely punctate at sides. Scutellum densely clothed with yellowish recumbent pubescence. Elytra about 2½ times as long as broad; punctures rather coarse, contiguous at base, becoming finer toward apex; pubescence short, recumbent, partially obscuring surface, longer suberect hairs numerous, suture and lateral margins narrowly clothed with dense, yellowish, appressed pubescence; apices rounded. Legs finely, densely pubescent; femora reddish; tarsal claws with inner tooth small. Abdomen densely pubescent; last sternite shallowly impressed over most of its length. Length, 6–11 mm.

FEMALE. Similar in form and size. Antennae extending to about second abdominal segment. Abdomen with last sternite linearly impressed. Length, 6–12 mm.

TYPE LOCALITY. Of '*pergrata*,' Platte River, Nebraska; '*gentilis*,' Missouri Territory; '*semiruficollis*,' Texas; '*discovittata*,' Colorado.

RANGE. Great Plains to southeastern United States, New Mexico, and northeastern Mexico.

FLIGHT PERIOD. April to July.

HOST PLANTS. *Aster* (roots), *Helianthus.*

REMARKS. The five glabrous spots of the pronotum, reddish femora, and the densely pubescent lines on the suture and lateral margins of the elytra will readily distinguish this species. In certain parts of the range, the elytra tend to be reddish down the disk and frequently the pronotum is also partially reddish.

Habits. According to Craighead (1923) larvae feed in the stems of *Aster* and down into the roots, completely hollowing the latter. Subsequently that portion of the stem of the plant breaks off at the surface of the ground. Small heaps of frass are exuded about the base of the plant. Only one larva is found in each stem.

Mecas cirrosa Chemsak and Linsley, new species.

Male. Form moderate sized, robust; color black; pubescence dense, gray, recumbent. Head with front convex, rather finely, irregularly punctate; interantennal area rather deeply impressed; vertex coarsely, separately punctate; pubescence dense, appressed, long erect hairs numerous, pale and dark colored; antennae slightly shorter than body, segments robust, somewhat flattened, all segments gray pubescent beneath, dark brown above, segments from second densely fringed with long curved hairs beneath, third segment slightly longer than first, fourth a little shorter than third, fifth shorter than first, remaining segments gradually decreasing in length. Pronotum broader than long, sides broadly rounded; disk convex, each side with a small glabrous, premedian callus, narrow median callus extending almost length of disk; punctures moderately coarse, irregular, subconfluent; pubescence fine, appressed, long, pale, erect hairs numerous; prosternum densely pubescent; meso- and metasternum densely pubescent, minutely punctate. Elytra more than 2½ times as long as broad; basal punctures moderately coarse, well separated, punctures becoming fine and quite sparse toward apex; pubescence fine, dense, appressed, basal margin with a few long, erect, pale hairs, remainder of surface with very short, suberect, dark hairs; apices rounded. Legs densely pubescent; tarsal claws with inner tooth short, obtuse, lobe-like. Abdomen densely pubescent; last sternite deeply impressed. Length, 13 mm.

Female. Form similar. Antennae shorter than body, curved hairs less numerous beneath. Abdomen with last sternite linearly impressed. Length, 10.5 mm.

Type material. Holotype male (California Academy of Sciences) from 5 miles N. of Guanajuato, Guanajuato, Mexico, VII-25-54 (E. I. Schlinger). The specimen that we consider as the female of this species differs in several respects. The pubescence appears thicker and the antennae have a much sparser fringe. This individual is from Km. 320, near Hacienda Balvanera, Queretero, Mexico, VII-13-55.

Remarks. Although the tarsal claws are uniquely different from other species of *Mecas,* we consider them to be bifid and the other morphological characteristics are similar enough to place '*cirrosa*' in the genus.

Mecas humeralis Chemsak and Linsley, new species.

Male. Form moderate sized, parallel; color black; pubescence dense, grayish and brownish. Head with front convex, rather finely, separately punctate; interantennal area impressed; vertex rather finely, separately punctate; pubescence dense, appressed, long, dark, erect hairs numerous; antennae about as long as body, outer segments slightly flattened, all segments gray pubescent beneath, dark brown above, long erect hairs sparse on basal segments, third segment much longer than first, fourth a little shorter than third, fifth equal to first, remaining segments gradually decreasing in length. Pronotum slightly broader than long, sides broadly rounded; disk convex, each side with a large glabrous callus before middle, median callus long, rather broad; punctures moderately coarse, subconfluent; pubescence dense, appressed, long erect hairs numerous; prosternum densely pubescent; meso- and metasternum densely pubescent, finely densely punctate at sides. Elytra about 3 times as long as broad; basal punctures coarse, contiguous, becoming finer and sparser toward apex; pubescence dense, recumbent, gray on disk, humeri glabrous, epipleurae and sides with a broad band of brown pubescence extending from under humeri almost to apex, long erect hairs abundant at base, becoming shorter and recurved toward apex; apices rounded. Legs densely pubescent; tarsal claws with inner tooth short, blunt, lobe-like. Abdomen densely pubescent, first three sternites with a narrow glabrous band at base; last sternite deeply impressed. Length, 13 mm.

Female. Form similar. Antennae about as long as body. Legs with tarsal claws having the short inner tooth slightly acute. Abdomen lacking glabrous lines on sternites, last sternite linearly impressed. Length, 10.5 mm.

Type material. Holotype male (California Academy of Sciences) from El Molino, Jalisco, Mexico, VII-10-56 (R. & K. Dreisbach); allotype from Guadalajara, Jalisco, VII-24-51 (P. D. Hurd).

Remarks. This species has tarsal claws similar to those of *M. cirrosa.* The different antennae and antennal pubescence will readily separate the two species. The glabrous humeri also make *M. humeralis* distinctive.

Mecas bicallosa Martin.

Mecas bicallosa Martin, 1924, Ent. News, vol. 35, p. 244; Hatch, 1971, Univ. Washington Publs. Biol., vol. 16, p. 155.

Saperda bicallosa, Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 139, 140.

Male. Form moderate sized, parallel, rather robust; color black, body densely clothed with short, appressed, grayish pubescence. Head with front convex, pubescence obscuring surface, long erect hairs very numerous; interantennal area plane, vertex deeply punctate; antennae extending to about third abdominal segment, segments through fourth gray pubescent, dark at apices, basal segments with numerous long, suberect hairs, segments from third with long hairs beneath, these decreasing in number toward apex, third segment longer than first, fourth subequal to first, remaining segments short, subequal in length. Pronotum broader than long, sides rounded; disk convex, with two glabrous calluses at middle and a smaller median one behind middle; punctures rather fine, deep, separated; pubescence obscuring surface, very long erect hairs numerous; prosternum densely pubescent, front coxal cavities narrowly open behind; meso- and metasternum densely clothed with recumbent and subdepressed pubescence. Elytra more than twice as long as broad; punctures at base coarse, dense, becoming finer toward apex; pubescence obscuring surface, long, suberect hairs abundant over basal half; apices rounded, often vaguely, obtusely toothed. Legs very densely pubescent; tarsal claws with inner tooth very small, short. Abdomen densely pubescent; last sternite shallowly, rather broadly impressed. Length, 10–13 mm.

FEMALE. Form similar. Antennae slightly shorter. Abdomen with last sternite narrowly linearly impressed, apex shallowly concave. Length, 10–15 mm.

TYPE LOCALITY. Martins Springs, Lassen Co., California.

RANGE. Washington to northern Baja California, to Colorado.

FLIGHT PERIOD. April to August.

HOST PLANTS. *Artemisia tridentata.*

REMARKS. The bicallused pronotum and abbreviated distal antennal segments characterize this species. Breuning (1955) incorrectly synonymized *M. bicallosa* with *M. cineracea* Casey and transferred both to *Saperda.*

MATERIAL EXAMINED. A total of 127 specimens were examined from Washington, Oregon, California, Nevada, Idaho, Utah, Colorado and Baja California.

Mecas ambigena Bates.

Mecas ambigenus BATES, 1881–1885, Biologia Centrali-Americana, Coleoptera, vol. 5, pp. 203, 426; BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 142, 147.

Mecas pseudambigena BREUNING, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, pp. 142, 147. New synonymy.

MALE. Form rather small, short, parallel; color black; pubescence dense, rather coarse, brownish, appressed, long dark erect hairs numerous. Head with front convex, finely densely punctate; interantennal area concave; vertex distinctly, separately punctate; pubescence short, appressed, front with numerous very long erect black hairs; antennae extending to about apical ½ of elytra, segments to tenth gray pubescent beneath, segments from fourth narrowly annulate at base, basal segments with a moderate number of suberect hairs beneath, scape robust, a little shorter than third segment, fourth subequal to first, remaining segments decreasing in length. Pronotum broader than long, sides broadly rounded; disk convex with a glabrous callus on each side before middle, elongate median basal callus often vague or absent; punctures coarse, confluent; pubescence short, appressed with numerous long erect hairs interspersed; prosternum densely pubescent; meso- and metasternum densely pubescent, finely densely punctate. Elytra less than 2½ times as long as broad; punctures coarse, contiguous, becoming finer toward apex; pubescence moderately densely appressed, suture narrowly lined with dense yellow-brown pubescence, long erect hairs numerous over basal ½, shorter and suberect toward apex; apices rounded. Legs densely pubescent; tarsal claws with inner tooth smaller than outer. Abdomen densely pubescent, finely punctate; last sternite deeply impressed for about ¾ its length. Length, 9 mm.

FEMALE. Similar in form and size. Antennae extending to about apical ¼ of elytra. Abdomen with last sternite lightly linearly impressed. Length, 10 mm.

TYPE LOCALITY. Of '*ambigena*,' Mexico; '*pseudambigena*,' Mexico.

RANGE. Durango to Mexico.

FLIGHT PERIOD. June and July.

REMARKS. The shorter form and short antennae will distinguish *M. ambigena* from other species of *Mecas*.

MATERIAL EXAMINED. MEXICO. Durango: 1 ♂, 25 miles W. of Durango, 7,500 ft., VI-23-64 (J. E. Martin); Zacatecas: 2 ♂♂, 4 miles W. of Monte Escobido, 7,800 ft., VII-19-20-54 (R. H. Brewer); Mexico: 1 ♀, Toluca (Wickham).

Mecas menthae Chemsak and Linsley, new species.

(Figures 10, 11.)

Mecas marginella, LINSLEY, KNULL, and STATHAM (not LeConte), 1961, Amer. Mus. Nov., no. 2050, p. 32.

MALE. Form moderate sized, subparallel; color black; pubescence dense, short, appressed, grayish to gray-brown, long erect dark hairs numerous. Head with front convex, rather finely, separately punctate; vertex deeply, separately punctate; pubescence dense, short, appressed, antennal tubercles dark pubescent above, long erect hairs numerous on front and vertex; antennae slightly longer than elytra, segments to tenth gray pubescent beneath, segments from fifth narrowly pale annulate at base, long erect hairs fairly numerous beneath on basal segments, third segment longer than first, fourth shorter than third but longer than first, fifth equal to first, remaining segments gradually decreasing in length. Pronotum broader than long, sides broadly rounded; disk convex, each side of middle with a rather large, glabrous callus, middle with an elongate

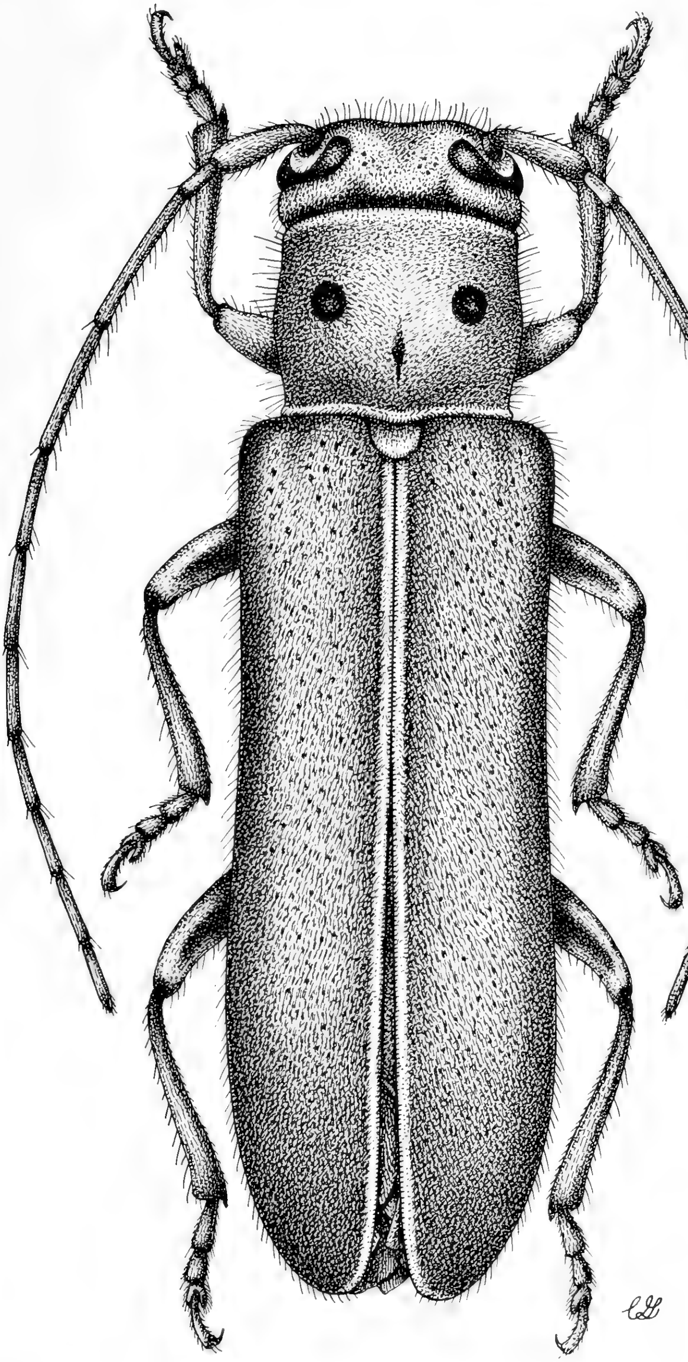

FIGURE 10. *Mecas menthae* Chemsak and Linsley, ♀.

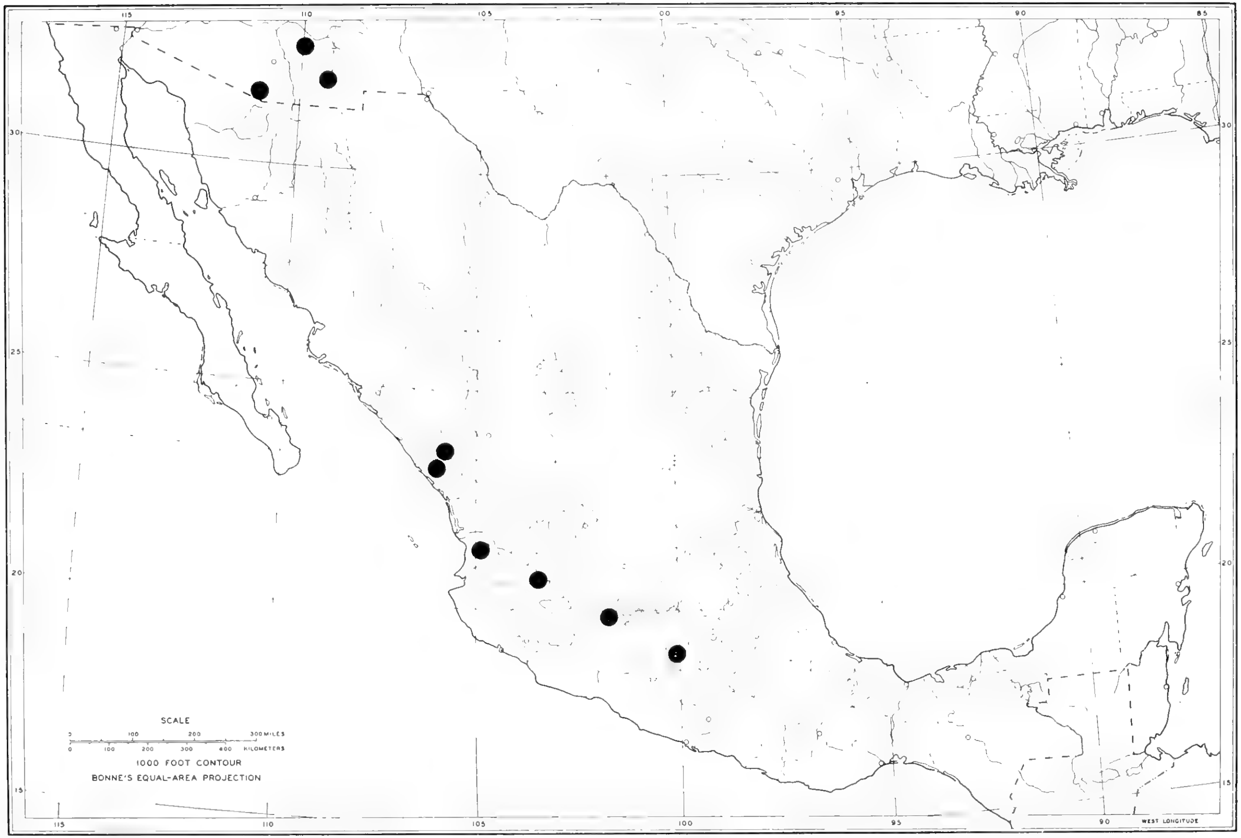

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Figure 11. Known occurrence of *Mecas menthae* Chemsak and Linsley.

callus toward base; punctures rather fine, separated; pubescence short, appressed, obscuring surface, long erect hairs numerous; prosternum densely pubescent; meso- and metasternum densely pubescent, finely densely punctate at sides. Scutellum densely clothed with appressed pubescence. Elytra more than 2½ times as long as broad; punctures coarse, contiguous to about apical ⅓, very fine at apex; pubescence dense, short appressed, lateral margins and suture with a narrow band of appressed pubescence, long erect hairs numerous basally, shorter toward apex; apices rounded. Legs densely pubescent; tarsal claws with inner tooth slightly shorter than outer. Abdomen densely pubescent; last sternite deeply impressed for about ¾ of its length. Length, 8–12 mm.

FEMALE. Similar in form, slightly more robust. Antennae about as long as elytra. Abdomen with last sternite linearly impressed. Length, 9–13 mm.

MATERIAL EXAMINED. Holotype male, allotype (California Academy of Sciences) and 99 paratypes (60 males, 39 females) from 8 miles W. of El Palmito, Sinaloa, Mexico, VII-19, 24, 29-64, VIII-5-64 on *Agastache* (J. A. Chemsak, J. A. Powell, H. F. Howden). Additional material not paratypical assignable to this species includes: 9 ♂♂, 5 ♀♀, 6.5 miles E. of Potrerillos, Hwy. 30, Sinaloa, VIII-20-21-64 (E. I. Schlinger, P. Rauch); 2 ♂♂, 20 miles E. of Villa Union, Sinaloa, VIII-20-64 (P. Rauch); 1 ♀, 63 miles E. of Jct. Hwy. 15 & 40 on Hwy. 40, Mexico, VIII-28-64 (D. C. & K. A. Rentz, J. A. Grant); 1 ♂, El Pichon, Nayarit, Mexico, VI-25-63 (J. Doyen); 1 ♂, Southwestern Research Station, Chiricahua Mts., Arizona, VIII-24-58 (P. D. Hurd); 1 ♂, 1 ♀, Yank's Spring, Sycamore Canyon, Tumacacori Mts., Santa Cruz Co., Arizona, VII-28-65 (H. B. Leech); 1 ♂, Oak Creek Canyon, 12 miles S. of Sedona, Arizona, VII-18-57 (C. W. O'Brien); 1 ♀, Swift Trail, between Ladybug Saddle and Shannon Park, Pinaleno Mountains, Graham County, Arizona, VI-27-58 (J. M. & S. N. Burns). Other specimens from Mexico tentatively assigned to *M. menthae*; 1 ♀, 2 miles S. of Tlaquepaque, Jalisco, VII-11-53 (C. & P. Vaurie); 1 ♀, 5 km. W. of Zacapu, Michoacan, VII-13-51 (H. E. Evans); 1 ♀, Real de Arriba, Distrito Federal, VII-32 (H. E. Hinton); 1 ♂, 2 ♀♀, Temescaltepec, Distrito Federal, 1931 (G. B. Hinton); 1 ♀, Tejupilco, Temescaltepec, VI-33 (H. E. Hinton, R. L. Usinger).

This species differs from *M. ambigena* by the much longer antennae, finer pubescence, and much less coarsely punctate pronotum.

The type series was collected during the day from the apical leaves of the mint *Agastache*. The adults were found resting in the curve of the smaller top leaves of the plant. Numerous individuals were mating and this plant is probably the larval host.

Mecas cana (Newman).

Saperda cana NEWMAN, 1840, Entomologist, vol. 1, p. 12; LECONTE, 1852, Jour. Acad. Nat. Sci. Philadelphia, vol. (2)2, p. 164.

Mecas cana, Gahan, 1888, Trans. American Ent. Soc., vol. 15, p. 300; Leng and Hamilton, 1896, Trans. American Ent. Soc., vol. 23, p. 152; Casey, 1913, Memoirs on the Coleoptera, vol. 4, p. 360; Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 148.

Male. Form moderate sized, subparallel; color black, body densely clothed with gray recumbent pubescence. Head with front convex, pubescence obscuring punctures, longer, dark, suberect hairs numerous; interantennal area almost plane;vertex finely, separately punctate; antennae slightly shorter than body, segments to sixth rather sparsely grey pubescent beneath, long erect hairs decreasing in number toward apex; third segment longer than scape, fourth shorter than third but longer than first, remaining segments gradually decreasing in length. Pronotum broader than long, sides rounded to subparallel; basal and apical margins narrowly margined; disk convex, each side with a flat glabrous callus before middle, middle usually with a vague linear callus near base; punctures moderately coarse, rather sparse, partially obscured by pubescence; longer erect hairs pale with dark setae interspersed mostly at sides; prosternum densely pubescent; meso- and metasternum densely pubescent; metasternum deeply rather densely punctate at sides. Elytra over 2½ times longer than broad; punctures moderately coarse, well separated, becoming finer and sparser toward apex; pubescence obscuring surface, longer suberect hairs numerous; apices obliquely subtruncate. Legs densely pubescent; tarsal claws with inner tooth small. Abdomen occasionally reddish, densely pubescent; last sternite moderately impressed for its entire length. Length, 9–15 mm.

Female. Form similar. Antennae shorter than body. Abdomen with last sternite linearly impressed. Length, 10–16 mm.

Type locality. St. John's Bluff, Florida.

Range. Southeastern United States to Texas, northeastern Mexico, and South Dakota.

Remarks. This species may be separated from *M. confusa* by the short inner tooth of the tarsal claws. The pronotal calluses readily distinguish it from *M. cineracea* and the elongate antennal segments from *M. bicallosa*.

Two subspecies can be recognized.

Mecas cana cana (Newman).

Saperda cana Newman, 1840, Entomologist, vol 1, p. 12; LeConte, 1852, Jour. Acad. Nat. Sci. Philadelphia, vol. (2)2, p. 164.

Mecas cana, Gahan, 1888, Trans. American Ent. Soc., vol. 15, p. 300; Casey, 1913, Memoirs on the Coleoptera, vol. 4, p. 360; Breuning, 1955, Mem. Soc. Roy. Nat. Belgique, vol. 27, p. 148.

Body densely grayish pubescent, elytra narrowly clothed at suture and lateral margins with bands of appressed pubescence. Length, 10–12.5 mm.

Type locality. St. John's Bluff, Florida.

Range. Florida.

Flight period. April to October.

Host plants. *Ambrosia, Flaveria linearis.*

Remarks. This subspecies appears to be restricted to Florida, primarily the southern portion. Although Breuning (1955) states that the type of *M. c. cana* appears to be lost, it is in the collection of the British Museum (Natural History).

Mecas cana saturnina (LeConte).

Stenostola saturnina LeConte, 1859, Smithsonian Contr. Knowledge, vol. 11, p. 21.

Mecas saturnina, Gahan, 1888, Trans. American Ent. Soc. vol. 15, p. 300; Horn, 1888, Trans. American Ent. Soc., vol. 15, p. 301; Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 146; Wilson, 1960, Comm. Inst. Biol. Control Tech. Comm. vol. 1, p. 62; Stride and Warwick, 1962, Anim. Behaviour, vol. 10, p. 112 (habits).

Mecas inornata (not Say), Horn, 1878, Trans. American Ent. Soc., vol. 7, p. 44; Knull, 1946, Ohio Biol. Surv. Bull. vol. 39, p. 274; Dillon and Dillon, 1961, Man. Common Beetles of Eastern North America, p. 652, pl. 65, no. 17.

Mecas brevicollis Casey, 1913, Memoirs on the Coleoptera, vol. 4, p. 362.

Similar in form and size to typical subspecies. Pubescence uniformly gray or yellowish, elytra without pubescent bands on margins and suture. Length, 9–16 mm.

Type locality. Of '*saturnina*,' Kansas; '*brevicollis*,' Kansas.

Range. Alabama to northeastern Mexico to South Dakota.

Flight period. May to August.

Host plants. *Ambrosia, Xanthium, Helianthus, Gaillarda.* Adults have also been taken on *Prosopis* and *Salvia* in Texas.

INCERTAE SEDIS

Mecas albovitticollis Breuning.

Mecas albovitticollis Breuning, 1955, Mem. Soc. Roy. Ent. Belgique, vol. 27, p. 146.

Mecas (?)————————(?) Bates, 1885, Biologia Centrali-Americana, Coleoptera, vol. 5, p. 427.

> "Antennae a little longer than the body. Lower lobes of the eyes obviously longer than the cheeks. Head and pronotum densely and very finely punctate. Pronotum transverse. Elytra slightly truncate at the apices, densely and finely punctate.
>
> "Black covered with light gray pubescence. Pronotum ornated with three straight, longitudinal, discal, whitish bands. Scutellum having whitish pubescence. Antennae faced with deep brown pubescence.
>
> "Length: 10 mm; width: 2½ mm.
>
> "Type: a male from Mexico in the British Museum."

We have been unable to place this species on the basis of the above original description and were unable to locate the type at the British Museum. However, we believe that this species was based on the single specimen cited by Bates in the Biologia Centrali-Americana. Since this reference stated: "One example of a distinct species, in bad condition, doubtfully belonging to this genus.", we will follow Bates and exclude it from the genus *Mecas.*

Mecas marmorata Gahan.

Mecas marmorata Gahan, 1892, Trans. Ent. Soc. London. 1892, p. 268, pl. 12, fig. 7; Breuning, 1955, Mem. Soc. Roy. Belgique, vol. 27, pp. 140, 152.

Male. Form elongate, slender; color black, pronotum and elytra suffused with pale reddish brown, antennal segments 2 to 10 reddish; pubescence dense, yellowish, appressed, arranged in patches on elytra, forming a longitudinal band down middle of pronotum. Pronotum cylindrical, as long as broad; mesosternal process slightly broadened. Elytra more than 3 times longer than broad; punctures coarse, irregular; apices produced, dentate. Legs short; mesotibiae with sinus; tarsal claws with inner tooth smaller than outer. Abdomen with last sternite deeply impressed.

Type locality. Guerrero, Mexico (not restricted further).

The elongate body, apically produced elytra, and cylindrical pronotum appear sufficient to exclude this species from *Mecas.* Since we have examined only the type in the British Museum (Natural History) and one other male from 17 miles south of Puebla, Puebla, IX-6-57 (H. A. Scullen) we have not attempted to clarify the generic status of '*marmorata*' at this time.

Acknowledgments

This study was made as part of a National Science Foundation sponsored monograph of North American Cerambycidae (Grant GB-31120-X). Although a large portion of the material we examined came from the California Academy of Sciences and the California Insect Survey, Berkeley, we wish to gratefully acknowledge the following institutions for the loan of specimens: American Museum of Natural History; Canadian National Collection, Ottawa; Cornell University; Field Museum of Natural History, Chicago; Los Angeles County Museum; Museum of Comparative Zoology, Harvard University; Instituto Tecnologico y de Estudios Superiores de Monterrey, Monterrey, Mexico; Ohio State University; Oregon State University; United States National Museum; University of California, Davis and Riverside, University of Kansas; collections of G. H. Nelson and R. L. Westcott.

We are deeply appreciative to Celeste Green for preparing the illustrations and to the authorities of the British Museum (Natural History) for permitting us to examine type specimens in their collection.

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COMPARATIVE REVISION OF *SCOMBEROIDES*, *OLIGOPLITES*, *PARONA*, AND *HYPACANTHUS* WITH COMMENTS ON THE PHYLOGENETIC POSITION OF *CAMPOGRAMMA* (PISCES: CARANGIDAE)[1]

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INTRODUCTION

This study evolved as a result of our efforts to unscramble the confused synonymies of Indo-Pacific carangids of the genus *Scomberoides*. The initial effort led us to review the species of *Oligoplites*, a New World genus closely related to *Scomberoides*, last treated by Schultz (1945). It soon became obvious that our paper would not be complete unless we included coverage of several monotypic Atlantic genera that are superficially similar to the 'leatherjackets' of American waters. Comparison of these three carangid genera is especially desirable because they, together with *Oligoplites*, are the only ones, of the 18 Atlantic genera that we currently recognize, which do not occur on both sides of the Atlantic. The combinations of characters exhibited by these genera have impressed us with the artificiality of the present subfamilial partitioning of the Carangidae. In discussing relationships of these genera it is necessary to emphasize some of the inadequacies of the present subfamilial classification of the Carangidae.

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We wish to thank the following individuals who assisted us in obtaining data for our study, either through hospitality at their institutions or by providing data on, or loans of, specimens (abbreviations refer to institutions and are explained in the methods section): Donn E. Rosen, AMNH; John R. Paxton, AMS; N. B. Marshall and Alwyne C. Wheeler, BMNH; William N. Eschmeyer and staff, CAS; M. L. Bauchot, MNHN; Carl L. Hubbs and Richard H. Rosenblatt, SIO; Warren C. Freihofer, SU; Frederick H. Berry, TABL; Boyd W. Walker, UCLA; C. Richard Robins, UMML; Victor G. Springer, Martin F. Gomon and Edgar E. Gramblin, USNM; Jørgen G. Nielsen, ZMC; R. J. McKay, WAM.

Special thanks are due J. R. Paxton and R. J. McKay for providing identifications and locality data for collections of *Scomberoides* housed in their respective institutions, thus confirming our tentative zoogeographical conclusions. Tomio Iwamoto examined MNHN types of *Scomberoides* (subsequently reexamined by us) that provided much of the impetus for initiation of the present paper.

Additional help came from various sources. James E. Böhlke and William N. Eschmeyer facilitated our study by making literature available. Phillip C. Heemstra called to our attention several pertinent references. William H. Hulet and Francisco J. Palacio assisted in translating Italian and Portuguese literature. Grady W. Reinert illustrated the specimens shown in figure 1. The manuscript was typed by Mrs. Kathie Jeffries.

Work space at the Southeast Fisheries Center Miami Laboratory, National Marine Fishery Service, where much of the material cited in this paper is housed, was generously provided by the Director, Mr. Harvey R. Bullis.

Frederick H. Berry and C. Richard Robins reviewed the manuscript and offered suggestions for improvement.

Major collections of *Scomberoides* critical to our study were obtained in Ceylon under Smithsonian Foreign Currency Grant 3818, C. Richard Robins and Frederick H. Berry, principal investigators. Field work in Ceylon was greatly facilitated by the cooperation of Mr. A. S. Mendis, Deputy Director (Research), Department of Fisheries, Ceylon. The second author was able to pursue this study through support of the National Geographic Society-University of Miami Deep-Sea Biology Program (University of Miami research account 8852R), Gilbert L. Voss, Principal Investigator. Partial support was also provided by a grant from the Tai Ping Foundation to Smith-Vaniz for study of Indian Ocean Carangidae.

Characters and Methods

Osteological terminology generally follows that of Suzuki (1962); a specific exception is the "postmaxillary process" which is here more appropriately termed a premaxillary spur since it is a posterior projection on the premaxilla that braces the maxilla. A basibranchial is defined (Nelson, 1969, p. 480) as the median part of the gill arch endoskeleton that lies between successively paired arch-elements. The number of the basibranchial refers to the paired arch-element behind it.

Rayless predorsal interneurals are termed predorsal bones (Smith and Bailey, 1961). All carangids have at least 3 predorsal bones; counting posteriorly, the fourth element, whether supporting a dorsal-fin spine or not, has a well developed spinelike projection on its anterodorsal margin. This structure, commonly termed a procumbent spine, may occasionally protrude through the skin. In the genera treated in this study, all anterior dorsal pterygiophores support a single fin spine. Thus, a shortening of the dorsal-fin base through loss of anterior spines results in a concomitant increase in number of predorsal bones. The first fin-ray (spine) is often greatly reduced, depressed posteriorly, and can easily be overlooked. In carangids there is a tendency for the number of external spines to decrease in large specimens due to absorption, as evidenced from examination of radiographs. In this study large specimens were not x-rayed or dissected; thus the frequency of specimens with the least number of dorsal spines may be slightly lower than indicated in tables 2 and 4.

The last dorsal- and anal-fin rays are split to the base, have a single pterygiophore, and were counted as one ray.

The first caudal vertebra has a well developed haemal spine which articulates with the first anal pterygiophore; the urostyle is regarded as the terminal caudal vertebra.

Counts of outer row dentary teeth in *Scomberoides* and *Oligoplites* are lateral counts (one side only). Counts were made on the dentary that appeared to have the most teeth. Broken teeth were counted but empty tooth sockets and teeth that had not attained a functional position in the outer row were excluded. Symphyseal dentary canines were also excluded in the case of *Scomberoides*.

Pectoral-fin ray counts are lateral counts (one side only). The dorsalmost fin-ray element is spinelike and was counted separately.

Gillraker counts are lateral counts and were usually made on the right side of each fish. Only gillrakers on the lateral side of the first arch were counted. The gillraker at the angle of the upper and lower limb has the major portion of its base on the ceratobranchial bone and was included in the count of the lower limb. Rudimentary gillrakers (with the width of raker greater than its length) were not included in the counts.

All measurements are straight line (point to point) measurements. Measurements smaller than 120 mm. were made with dial calipers. Measurements given in the material examined sections are fork length (FL), unless otherwise stated, and have been rounded off to the nearest millimeter. In large fishes with relatively rigid caudal fins, such as carangids, the end of the hypural plate is often difficult to determine precisely. In addition to being easier to determine than standard length, fork length is more familiar to fishery biologists, who should have the greatest need to identify carangids. The following measurements were used in this study:

Fork length (FL). Snout tip to tip of shortest median caudal-fin ray.
Standard length (SL). Snout tip to posterior end of hypural bones (caudal base).
Head length (HL). Snout tip to posterior margin of fleshy opercular flap.
Snout-postorbit length. Snout tip to anterior margin of posterior adipose eyelid.

Snout length. Snout tip to posterior margin of anterior adipose eyelid.
Upper jaw length. Snout tip to posterior margin of maxilla.
Body depth D_2 to A_2. Origin of terminal dorsal spine to origin of terminal anal spine.
Height of fin lobes. Origin of fin to tip of longest segmented ray.
Pectoral-fin length. Origin of spine to tip of longest ray.

Abbreviations of institutions cited are as follows:

AMNH	American Museum of Natural History, New York City
AMS	Australian Museum, Sydney
BMNH	British Museum (Natural History), London
CAS	California Academy of Sciences, San Francisco
FMNH	Field Museum of Natural History, Chicago
MNHN	Muséum National d'Histoire Naturelle, Paris
NFIS	Natur-Museum und Forschungs-Institut Senckenberg, Frankfurt
SIO	Scripps Institution of Oceanography, University of California, La Jolla
SU	Stanford University, Division of Systematic Biology (collection transferred to CAS)
TABL	Southeast Fisheries Research Center, National Marine Fishery Service, Miami (formerly Tropical Atlantic Biological Laboratory)
UCLA	University of California at Los Angeles
UMML	University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami
USNM	National Museum of Natural History, Division of Fishes, Washington, D. C.
ZMC	Zoological Museum, Copenhagen
WAM	Western Australian Museum, Perth.

Uncataloged California Academy of Sciences specimens collected under the auspices of the George Vanderbilt Foundation (GVF) are reported under their register or station numbers. Most collections from Ceylon are uncataloged and listed by station numbers. Abbreviations refer to the following collectors listed in chronological order of their visits to Ceylon: F. J. Schwartz; W. F. Smith-Vaniz; P. C. Heemstra; C. C. Koenig.

Localities in material examined sections are abbreviated. Summary statements of material examined include only specimens examined by the authors.

Scomberoides Lacépède, 1802

Scomberoides LACÉPÈDE, 1802, p. 50 (type-species: *Scomberoides commersonianus* LACÉPÈDE, 1802, by subsequent designation of JORDAN, 1917, p. 60).

Orcynus RAFINESQUE, 1815, p. 84 (*nomen nudum*; substitute name for *Scomberoides* LACÉPÈDE, 1802).

Chorinemus CUVIER *in* Cuvier and Valenciennes, 1831, p. 367 (type-species: *Scomberoides commersonianus* LACÉPÈDE, 1802, by subsequent designation of JORDAN, 1917, p. 137).

Rhaphiolepis FOWLER, 1905, p. 59 (as a subgenus of *Scomberoides*; type-species: *Chorinemus tol* CUVIER *in* Cuvier and Valenciennes, 1831, by original designation).

Eleria JORDAN and SEALE, 1905, p. 774 (type-species: *Eleria philippina* JORDAN and SEALE, 1905 = *Chorinemus tala* CUVIER *in* Cuvier and Valenciennes, 1831, by monotypy).

Palaeoscomber SMIRNOV, 1936, p. 49–59 (type-species: *Palaeoscomber spinosus* SMIRNOV, 1936, by original designation).

The carangid genus *Scomberoides* comprises four recent and one fossil species of tropical and subtropical marine fishes restricted to the Indian and western and central Pacific oceans. All recent species attain at least 45 cm. fork length. *Scomberoides commersonianus*, the largest species, occasionally exceeds 100 cm. and is a valued game fish. In some areas *S. commersonianus* supports a seasonal fishery of considerable importance. Major catches are obtained from drift nets set at depths of 15 to 18 m. in waters surrounding offshore islands (James, 1967). Depending on the region, scomberoides are considered excellent food fishes (Smith, 1949, p. 224) or they are mostly salted and not generally esteemed (Chan, 1968, p. 82).

Halstead *et al.* (1972) give a detailed description of the venom apparatus of *Scomberoides lysan*. Venom glands are associated with the first seven dorsal-fin spines and the first two anal spines. The anal spines, rather than the dorsal spines, are the most venomous. The anal spines are equipped with a frictional locking device which resembles that found in the fin spines of catfishes and balistid triggerfishes. *Scomberoides lysan* is capable of inflicting painful stings. The nearly identical morphology of these spines in the other species of *Scomberoides* and *Oligoplites* (see comments under *O. saurus*) suggest that all species of both genera are venomous.

The osteology of *Scomberoides* has received inadequate attention. The only species studied in detail (under the name *Chorinemus orientalis*) is *Scomberoides lysan* (Suzuki, 1962). The only known fossil species of *Scomberoides* was originally described as belonging to a new genus, *Palaeoscomber*, of Scombridae (Smirnov, 1936) and was subsequently redescribed as a species of *Oligoplites* (Danil'chenko, 1960).

The nomenclature of *Scomberoides* species has been greatly confused by a plethora of nominal species inadequately described by early workers. Differences ascribed to nominal species have frequently been based on unrecognized ontogenetic changes. Changes in dentition associated with growth led Jordan

TABLE 1. *Nominal species of* Scomberoides *recognized in selected publications with our present allocation.*

Authors	Species			
Present Study	*commersonianus*	*tala*	*lysan*	*tol*
Smith (1970)	*lysan*	—	*tolooparah*	*tala*
Williams (1958)	*lysan*	—	*sanctipetri*	—
Roxas and Agco (1941)	*lysan*	*tala*	*toloo parah*	*tol*
Weber and De Beaufort (1931)	*lysan*	*tala*	*toloo parah* *sanctipetri*	*tol*
Wakiya (1924)	*lysan*	—	*sanctipetri* *orientalis* *moadetta*	*formosanus*
Day (1878)	*lysan*	*tala* *toloo*	*sanctipetri*	*moadetta*

and Seale (1905, p. 774) to describe a new genus and species based on juveniles of *S. tala.* The failure of recent workers to critically read original descriptions and examine types adequately has resulted in the consistent misapplication of the name *Scomberoides lysan* (Forskål). Because of the confused nomenclature of *Scomberoides* species, we present in table 1 a list of the species recognized in several major papers with our present allocation of them. An annotated list of the nominal species of *Scomberoides* and *Oligoplites* is given in the appendix.

NOMENCLATURE. Considerable confusion exists as to whether *Scomberoides* Lacépède, 1802 was validly described and thereby has priority over *Chorinemus* Cuvier, 1831. Williams (1958) briefly discussed the problem and rejected *Scomberoides*, as did Weber and De Beaufort (1931) and Smith (1970). Rejection of *Scomberoides* as a valid generic name by several recent workers is probably attributable to the comments of Barnard (1927, p. 562) who credits the rejected name to Lacépède (1800), in which only a figure is given with the caption "Scomberoide commersonnien." Jordan (1917, p. 60) rightly credits *Scomberoides* to Lacépède (1802), in which "Les Scomberoides" was latinized to accommodate the description of three new species. *Caranx* and *Trachinotus*, widely accepted carangid generic names, originate from the same work and were described in the same manner as *Scomberoides*.

Williams (1958, p. 416) states that "the use of *Chorinemus* has been common and widespread since 1833 whilst *Scomberoides* has been restricted (except Wakiya, 1924) to American authors of the last 75 years." He further states "should *Scomberoides* be proved to have priority over *Chorinemus* C. V. . . . . , then a case exists for submission to the International Commission of Zoological Nomenclature for a suspension of the Rules, in that strict application of the Rules will clearly result in greater confusion than uniformity." In their review of the Philippine Carangidae Roxas and Agco (1941) used *Scomberoides* as did Oshima (1925) and McCulloch (1929). Except for Rofen (1963), American authors of the last 75 years, the most recent of which are Gosline and Brock (1965), have consistently used *Scomberoides* instead of *Chorinemus*. Although Williams apparently attaches little importance to this, it should be noted that American authors are responsible for a large portion of the literature treating these fishes.

Confusion also exists as to what constitutes the type-species of the genus. Several workers have recognized *Scomberoides noelii* as the type-species. Lacépède (1802) described three species in his new genus, listing them on page 50 with brief diagnoses (descriptions expanded on following pages) in the following order: (1) *Scomberoides noelii*; (2) *S. commersonianus*; (3) *S. saltator*. He did not, however, specifically designate a type-species. The first author to subsequently designate a type-species for *Scomberoides* in accordance with Article 69a of the International Code of Zoological Nomenclature was Jordan (1917, p. 60), who selected *S. commersonianus*. The published illustration of *S. commersonianus* (as "Scomberoide commersonnien") (Lacépède, 1800 pl. 20, Fig. 3) is sufficiently accurate for positive identification.

The possession of needlelike scales does distinguish the type-species of *Rhaphiolepis* from its congeners. However, the transition from oval-shaped to needlelike scales is obvious in *Scomberoides* (see figure 3), and we do not believe that recognition of subgenera in such a small group of closely related species is justified. The sole character mentioned in the original description to distinguish *Eleria* from *Scomberoides* was based on unrecognized ontogenetic changes in dentition (see discussion under *S. tala*). Reasons for referral of *Palaeoscomber* to the synonymy of *Scomberoides* are discussed under *S. spinosus*.

DESCRIPTION. Body moderately to strongly compressed. Adipose eyelids moderately to poorly developed. Body, except head, covered with embedded scales, broadly lanceolate to needlelike. Lateral-line scales not developed into scutes. Lateral line without side branches, straight except for slight curve over pectoral fin. Anterior rim of shoulder girdle smooth, without fleshy papillae or deep groove near isthmus. Premaxillae not protractile, connected anteriorly to snout at midline by a wide fleshy bridge. Swimbladder strongly bifid posteriorly, length of bifurcated portion of swimbladder equal to or greater than undivided part. Posterior dorsal- and anal-fin rays consisting of semidetached finlets, distal fourth to half of ray not connected by interradial membrane (unattached portion of rays increasing with growth); ultimate and penultimate rays more closely spaced than adjoining rays, fully connected by interradial membrane; none of dorsal- or anal-fin rays produced into long filaments. Pelvic fins relatively short, depressible into shallow abdominal grooves. Pectoral fins short, not falcate, 53 to 71 percent head length in adults. Maxilla extends posteriorly from middle of eye to well behind orbital rim, 43 to 65 percent head length, in adults.

Predorsal bones 3, rarely 4 (4 in one of 60 specimens); dorsal-fin rays VI or VII + I, 19–21; total dorsal-fin rays 27–29. Anal-fin rays II + I, 16–20. Pectoral-fin rays I, 16–18. Pelvic-fin rays I, 5. Vertebrae 10 + 16 = 26; epipleural ribs 9 or 10. Branchiostegal rays 3 + 5 (epihyal + ceratohyal). Upper gillrakers 0–8; lower gillrakers 7–20; total gillrakers 8–27.

Fronto-supraoccipital crest low; temporal crest extending forward to edge of cranium slightly in front of middle of orbit; preorbital region short. Epiotics broadly united along midline of cranium internally. Zygapophyses of exoccipital joined beneath foramen magnum. Parasphenoid not expanded into a broad, flattened plate posteriorly. Myodome with broad, posterior opening. Basioccipital without a pair of lateral processes on ventral surface. Ascending process of premaxilla short and triangular; maxilla long and slender, rather closely attached to premaxilla. Premaxillary spur absent. Small supramaxilla present. Interosseous space between dorsal arm of dentary and upper margin of articular greatly reduced. Well developed teeth on dentary, premaxilla, palatine, and vomer; two distinct rows of dentary teeth (see discussion under Zoogeography and Relationships Section); symphyseal premaxillary and dentary teeth of juveniles (except *S. lysan*) robust and caniniform. Mesopterygoids covered with firmly ankylosed, minute, granular teeth. Pharyngeals not noticeably enlarged, covered with sharp, pointed teeth.

Well developed suborbital shelf present; lower and posterior suborbitals not greatly expanded posteriorly. Basibranchials 1–2 with a pair of tooth plates, third basibranchial with two or more irregular tooth plates. Lower limb of posttemporal not noticeably short or thickened. Postcoracoid process absent. Interpelvic keel well developed; post pelvic process of each side coalesced entire length, not forming an apical fork. Inferior vertebral foramina absent. First anal pterygiophore and haemal spine of first caudal vertebra firmly attached to form a strong strut. Anal pterygiophore expanded anterolaterally to form roof over first two anal spines; first two anal spines articulated proximally with each other; second anal spine asymmetrical, with deep groove on one side of anterior face. Caudal skeleton with 2 epurals and 2 pairs of uroneurals.

Key to Recent Species of *Scomberoides*

Color pattern will readily separate most specimens of the four species. In large individuals and especially in small specimens that are not freshly caught the spots may fade or completely disappear; this is particularly true of fish market specimens.

1a. Gillrakers 8 to 15; dorsal-fin lobe uniformly pigmented 2
1b. Gillrakers 21 to 27; distal half of dorsal-fin lobe abruptly and heavily pigmented 3
2a. Large oval blotches above or touching lateral line; upper jaw extends well beyond posterior margin of eye, especially in adults (fig. 2a); snout 21 to 26 (mean 23.4)

percent HL; dentary teeth of inner and outer rows subequal in adults; specimen figure 1a .... *S. commersonianus*

2b. Vertically elongate blotches intersecting lateral line; upper jaw extends slightly beyond posterior margin of eye (fig. 2b); snout 26 to 30 (mean 28.2) percent HL; inner row dentary teeth distinctly larger than outer row teeth in adults; specimen figure 1b .... *S. tala*

3a. Double series of 6 to 8 dusky, roundish blotches above and below lateral line, occasionally connected by narrow isthmus; scales lanceolate (fig. 3b); specimen figure 1c .... *S. lysan*

3b. Oval or vertically oblong blotches, the first 4 or 5 intersecting lateral line; scales slender, needlelike (fig. 3d); specimen figure 1d .... *S. tol*

Scomberoides commersonianus Lacépède.

(Figures 1a, 2a, 3a, 4a, 5–7, 14c, 16b, 19, 23b, 25b; tables 2–3.)

Scomberoides commersonianus LACÉPÈDE, 1802, p. 50 (type locality Madagascar).

Scomber madagascariensis SHAW, 1803, p. 590, pl. 85 (type locality Madagascar).

Chorinemus exoletus EHRENBERG *in* Cuvier and Valenciennes, 1831, p. 379 (278) (based solely on an unpublished drawing by Ehrenberg of a fish from Lohaia, Red Sea).

Chorinemus delicatulus RICHARDSON, 1846, p. 269 (based solely on a drawing in the Reeves Collection of Chinese fish drawings).

Chorinemus leucopthalmus RICHARDSON, 1846, p. 269 (based solely on a drawing in the Reeves Collection of Chinese fish drawings).

NOMENCLATURE. The figure of *S. commersonianus* (as "Scombéroide commersonnien") and original description are sufficiently accurate for positive identification, and the name has consistently been applied to the correct species, although usually in synonymy (see nomenclature section under *S. lysan*). Although in the original description *S. commersonianus* was spelled with a double "n," we prefer the emended spelling with a single "n," which is correct.

The description of *Chorinemus exoletus* refers to a deep-bodied species with a long upper jaw. This together with the stated type locality is sufficient to confidently identify it as conspecific with *S. commersonianus.*

Whitehead (1969) has published the original drawings upon which the descriptions of *Chorinemus delicatulus* and *C. leucopthalmus* are based. These drawings and that of *Scomber madagascariensis* are reasonably diagnostic and are undoubtedly based on *S. commersonianus.* Although the large oval blotches characteristic of *S. commersonianus* are not shown on the sides of *Chorinemus delicatulus* and *C. leucopthalmus*, they rapidly fade and disappear in dead specimens.

DESCRIPTION. Characters given in the generic description are not repeated here. Frequency distributions of selected meristic characters are given in table 2. Dorsal-fin rays VI-VII + I, 19–21; anal-fin rays II + I, 16–19; pectoral-fin rays, I, 17–19. Gillrakers 0–3 + 7–12 = 8–15. Upper jaw extending well beyond posterior margin of eye, especially in adults (fig. 2a). Scales broadly lanceolate (fig. 3a). Inner and outer row of dentary teeth subequal in adults (fig. 4a); dentary typically with one or two pair of symphyseal canines, at least

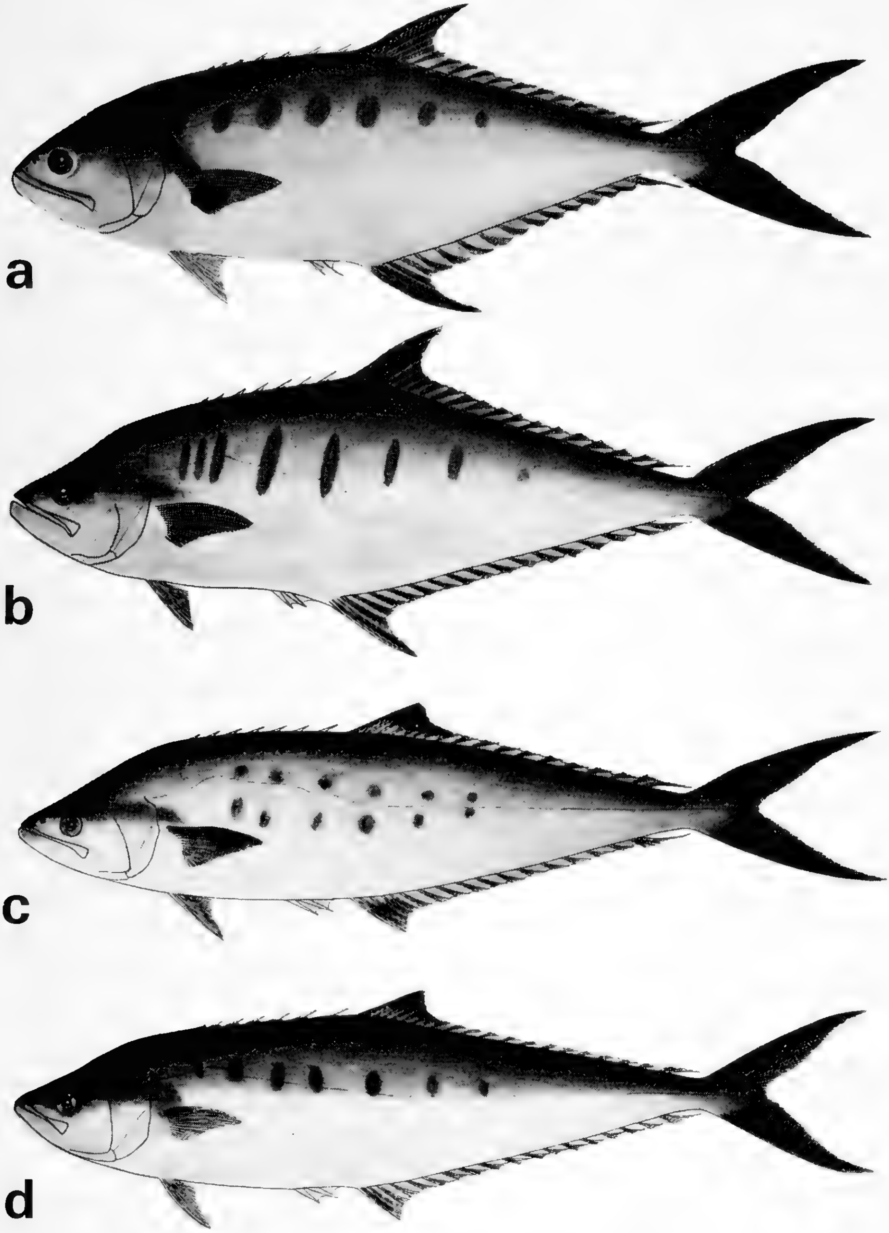

Figure 1. *Scomberoides* species: a, *S. commersonianus*, TABL 107366, 468 mm. FL; b, *S. tala*, TABL 107365, 464 mm. FL; c, *S. lysan*, TABL 107364, 523 mm. FL; d, *S. tol*, TABL 107363, 450 mm. FL.

TABLE 2. *Frequency distribution of meristic characters in* Scomberoides *species.*

	Dorsal-Fin Rays							Anal-Fin Rays						
	D_1 Spines		Segmented Rays					Segmented Rays						
Species	VI	VII	19	20	21	N	$\bar{x}$	16	17	18	19	20	N	$\bar{x}$
commersonianus	4	83	23	63	1	87	19.7	2	13	71	3	—	89	17.8
tala	6	84	11	73	6	90	19.9	—	3	80	6	—	89	18.0
lysan	8	86	3	83	8	94	20.0	—	5	83	7	—	95	18.0
tol	2	89	1	44	46	91	20.5	—	—	22	68	2	92	18.8

	Upper Gill Rakers											Lower Gill Rakers															
Species	0	1	2	3	4	5	6	7	8	N	$\bar{x}$	7	8	9	10	11	12	13	14	15	16	17	18	19	20	N	$\bar{x}$
commersonianus	10	30	31	18	—	—	—	—	—	89	1.6	1	10	26	36	15	1	—	—	—	—	—	—	—	—	89	9.6
tala	—	2	66	20	—	—	—	—	—	88	2.2	1	24	55	6	2	—	—	—	—	—	—	—	—	—	88	8.8
lysan	—	—	—	1	2	21	44	22	6	96	6.1	—	—	—	—	—	—	—	—	1	2	26	45	18	2	96	17.5
tol	—	—	—	—	1	24	55	11	—	91	5.6	—	—	—	—	—	—	—	—	—	—	12	31	41	7	91	18.5

	Total Gill Rakers																					
Species	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	N	$\bar{x}$
commersonianus	3	11	18	18	17	10	11	1	—	—	—	—	—	—	—	—	—	—	—	—	89	11.3
tala	—	—	—	1	20	46	18	3	—	—	—	—	—	—	—	—	—	—	—	—	88	12.0
lysan	—	—	—	—	—	—	—	—	—	—	—	—	—	3	14	22	29	12	11	5	96	23.9
tol	—	—	—	—	—	—	—	—	—	—	—	—	—	1	4	13	35	26	12	—	91	24.3

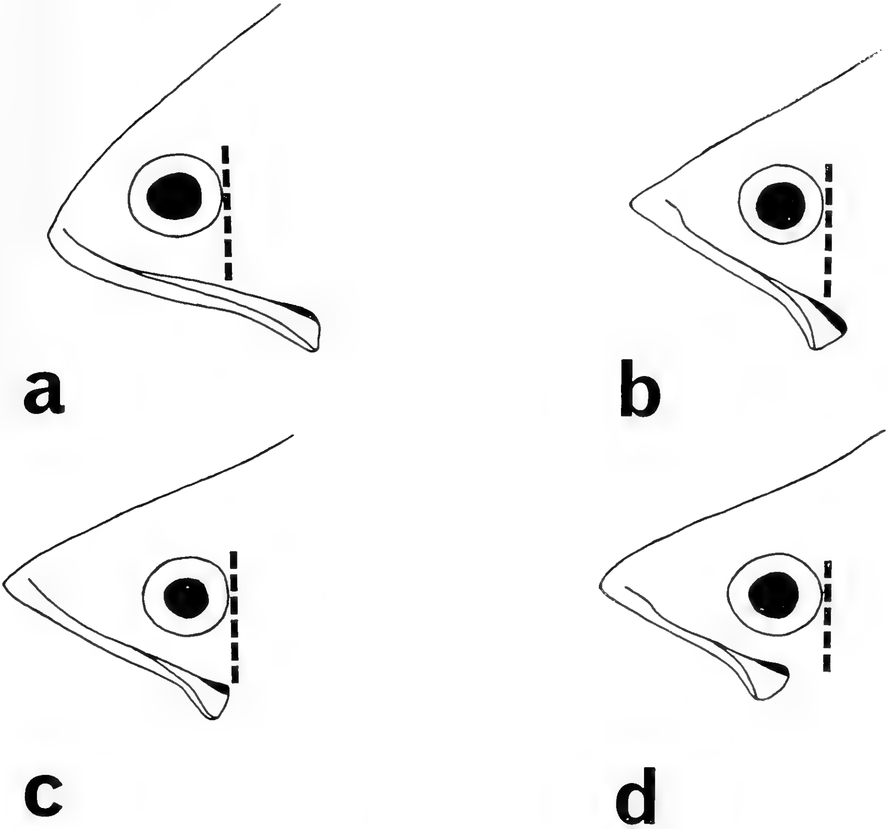

FIGURE 2. Upper jaw development of adult *Scomberoides* species: a, *S. commersonianus*, TABL 107192, 355 mm. FL; b, *S. tala*, TABL 107712, 351 mm. FL; c, *S. lysan*, TABL 107364, 412 mm. FL; d, *S. tol*, TABL 107714, 410 mm. FL. Maxilla shown in black.

in young; young with dentary teeth of outer row numerous and considerably more closely spaced than inner row teeth.

Proportional measurements apply only to specimens longer than 150 mm. FL, and are expressed as percent FL unless otherwise stated. Depth (origin D_2 to A_2) 25.7–36.2; height dorsal-fin lobe 14.4–19.8; height anal-fin lobe 13.5–18.5; upper jaw 55.9–64.6 percent head length; snout 20.6–26.0 percent head length.

PIGMENTATION. Sides with 5 to 8 large oval blotches above or touching lateral line, first two may intersect lateral line. Dorsal and anal fins uniformly pigmented. Pectoral fin of adults frequently with a dusky blotch ventrally. In life, body gray to silvery white ventrally, dusky green or bluish dorsally;

TABLE 3. *Comparison of several proportional measurements in* Scomberoides *species expressed as hundredths of head length.*

Species	<20 cm. Range FL	N	Upper Jaw Length		Snout Length	
			Range	$\bar{x}$	Range	$\bar{x}$
commersonianus	82–198	19	59–64	60.1	21–26	23.6
tala	71–199	23	53–61	58.2	26–30	28.3
lysan	45–189	20	51–56	53.9	28–31	29.0
tol	44–181	17	47–51	48.6	30–33	31.3

Species	>20 cm. Range FL	N	Upper Jaw Length		Snout Length	
			Range	$\bar{x}$	Range	$\bar{x}$
commersonianus	224–943	64	56–65	60.6	21–26	23.4
tala	201–571	58	54–61	57.8	26–30	28.2
lysan	201–585	65	50–54	51.6	28–32	30.0
tol	209–468	70	43–49	46.3	29–33	31.3

lateral blotches plumbeous gray. Large individuals often golden, especially ventrally. Annunziata and Cedrone (1972, p. 61) present a color photograph of a large specimen from Madagascar.

DISTRIBUTION. Widely distributed throughout the Indian Ocean and Indo-Australian Archipelago. The species has also been reliably reported from the Red Sea and Persian Gulf. *Scomberoides commersonianus* appears to be restricted to neritic waters and does not occur east of the New Guinea-Solomon Islands region. Records of the species (as *S. lysan*) from Tahiti and other central Pacific islands are based on misidentifications.

MATERIAL (96 specimens, 82–943 mm. FL, from 53 collections). KENYA: Mombasa Fish Market, TABL uncataloged *Anton Bruun* cruise 9 station, FT-2 (1: 398). WEST PAKISTAN: off Karachi, TABL uncataloged (3: 236–295). INDIA: Gulf of Kutch, TABL uncataloged (1: 203); Bombay, TABL 107190 (1: 384), 107350 (1: 158); Palk Strait, TABL 107292 (4: 127–288), TABL uncataloged FHB 66–36 (1: 766); Porto Novo, TABL 107303 (1: 198), TABL uncataloged (1: 190). CEYLON: TABL 107192 FJS 69–41 (9: 327–422), FJS 69–45 (6: 195–244), FJS 69–64 (1: 474), FJS 69–50 (1: 400), TABL 107366 S-V 69–77 (3: 303–476), S-V 69–86 (2: 224–254), S-V 69–126 (1: 335), S-V 69–151 (2: 754–762), PCH 69–183 (1: 617), PCH 69–185 (7: 123–158), TABL 107715 PCH 69–201 (3: 398–443), PCH 69–218 (10: 130–168), PCH 69–267 (1: 503), PCH 69–305 (1: 913), CCK 69–1 (1: 843), CCK 69–44 (1: 797), CCK 69–53 (1: 475), CCK 69–60 (7: 234–349), CCK 69–97 (2: 160–218). GULF OF THAILAND: GVF station 57–45 (2: 355–391), GVF station 57–92 (1: 520), GVF station 57–83 (2: 559–579), GVF station 60–113 (2:

849–943), GVF station 60–146 (2: 727–729), GVF-1548 (1: 133), GVF-1557 (2: 186–197), GVF-2195 (1: 93, cleared and stained), GVF-2513 (2: 727–739), GVF-2546 (1: 291), GVF-2547 (6: 243–612). HONG KONG: GVF station HK-111 (1: 829). PHILIPPINES: Luzon, USNM 72190 (1: 172), 83447 (1: 241), 168322 (1: 309), SU 20341 (2: 82–116); Samar, USNM 149810 (1: 129); Iloilo, USNM 72189 (1: 129), 149812 (1: 152); Palawan, USNM 149813 (1: 128), 149815 (1: 151). NORTH BORNEO: Sandakan, USNM 149814 (1: 172), 168323 (1: 234). JAVA: Djakarta, TABL 107300 (1: 266). AUSTRALIA: Western Australia, Exmouth Gulf, Onslow, WAM P.2772 (1: 302), P.15487 (1: 175); Port Hedland, WAM P.180 (1: 329); Broome, WAM P.555 (1: 95); Northern Territory, Charles Point, AMS IA.7781 (1: 164); Port Darwin, AMS I.9778 (1: 300), IA.4375 (1: 280); Darwin, AMS IB.3168 (1: 420), IB.3171 (1: 85); Bedwell Point, AMS IA.7678 (1: 356); Gulf of Carpentaria, Groote Eylandt, USNM 173954 (4 of 7: 240–345); 17°22′S., 149°45′E., AMS I.15557–118 (5: 87–172); Queensland, Burdekin River, USNM 47835 (1: 275), AMS A.18299–300 (2: 285–615); Lindeman Island, AMS IA.6279 (1: 297); Hayman Island, AMS IA.6104 (1: 460); New South Wales, Port Jackson, USNM 47910 (1: 357). NEW GUINEA: AMS A.12694 (1: 300); Port Moresby, AMS I.13357 (1: 565).

Scomberoides tala (Cuvier).

(Figures 1b, 2b, 3c, 4b, 5–7, 15b, 17, 19, 24b; tables 2–3.)

Chorinemus tala Cuvier *in* Cuvier and Valenciennes, 1831, p. 377 (type locality Malabar).

?*Chorinemus toloo* Cuvier *in* Cuvier and Valenciennes, 1831, p. 377 (description based on "toloo parah" Russell, 1803, p. 29, pl. 137, Vizagapatam).

Eleria philippina Jordan and Seale, 1905, p. 744, fig. 1 (type locality Negros Island, Philippines).

Chorinemus hainanensis Chu and Cheng, 1958, p. 317, fig. 2 (type localities Sanya, Kanchium, Kwonghoi, and Chinglan, China).

Nomenclature. In the Muséum National d'Histoire Naturelle there are two collections (A. 6587 and A. 6588) from Malabar, collected by Belanger, which are labeled syntypes of *Chorinemus tala* Cuvier. A. 6588, here designated lectotype of *C. tala*, is a single specimen 298 mm. SL. A. 6587 consists of two specimens of *S. tol* Cuvier. In his treatment of the western Indian Ocean species of *Scomberoides*, Smith (1970, p. 221) referred *S. tol* to the synonymy of *S. tala*. This erroneous action was based on his examination of one of the specimens of A.6587. Smith apparently was unaware of the existence of other material labeled as types of *S. tala*, and fortunately did not designate a lectotype.

Although Weber and De Beaufort (1931, p. 282) and Smith (1970, p. 219) considered the species insufficiently described for positive identification, the following statements given in the original description of *Chorinemus tala* leave no doubt as to its specific identity: (1) "*Chorinemus tala* differs [from the

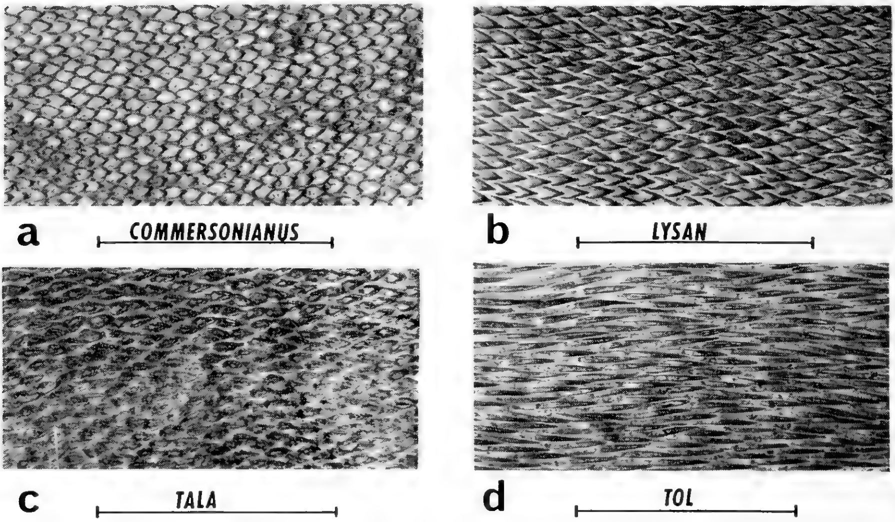

FIGURE 3. Scales of *Scomberoides* species (from area between anal-fin origin and lateral line): a, *S. commersonianus*, TABL 107715, 398 mm. FL; b, *S. lysan*, TABL 107364, 412 mm. FL; c, *S. tala*, TABL 107712, 370 mm. FL; d, *S. tol*, TABL 107714, 410 mm. FL. Scale, 20.0 mm.

preceding species, *C. commersonianus*] by a smaller gape, a maxillary that hardly extends beyond the posterior border of the orbit. (2) The maxillary is, in addition, covered by the suborbital and only shows its posterior third; it is enlarged more posteriorly and is cut off more squarely. (3) The teeth are stronger in proportion. (4) The curve of the snout is a little less straight . . . , but the shape of the body, the scales, the lateral line and the number of rays are as in the preceding species."

Statement 4 and the fact that *S. tala* was compared with *S. commersonianus*, suggest that the name *S. tala* applies to a deep-bodied species with high fin lobes. *Scomberoides tol* and *S. lysan* are both relatively slender species (fig. 6) and have shorter fin lobes (fig. 7) than do the other two species of *Scomberoides*. Statements 1 and 4 exclude *S. tol*, in which the maxilla does not reach the posterior border of the orbit and the scales are needle-shaped (fig. 3d). Statement 3 excludes *S. lysan* and *S. tol*, in which the teeth in both jaws are relatively small in adults and applies best to the species here recognized as *S. tala*, which has the largest teeth (fig. 4b). Statements 1 and 2 are sufficient to exclude *S. commersonianus* (compare figs. 2a and 2b).

The fact that Cuvier recognized *S. commersonianus* (and several of its synonyms) and described as new, from Malabar specimens, examples of the three remaining valid species of *Scomberoides* leaves no doubt that he was able

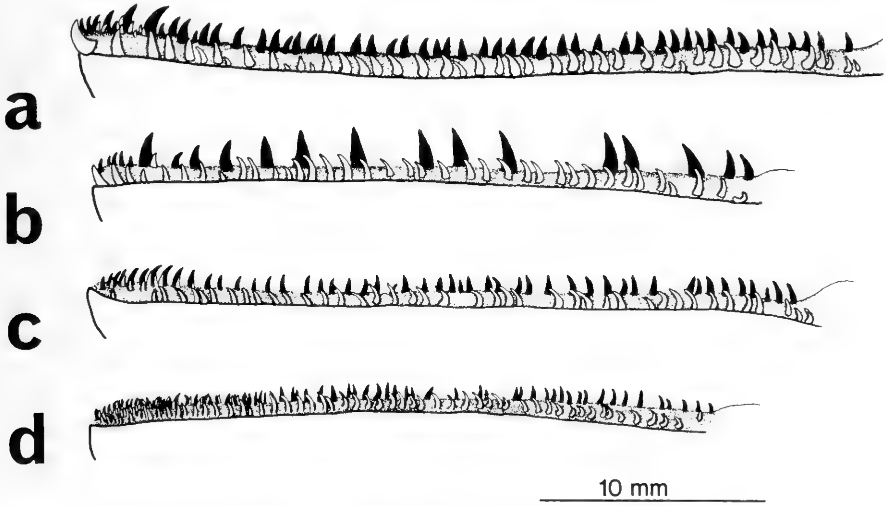

FIGURE 4. Dentary teeth of adult *Scomberoides* species: a, *S. commersonianus*; b, *S. tala*, c, *S. lysan*, d, *S. tol*. Data as in figure 2. Teeth of inner row shown in black.

to distinguish them. It is obvious from his description of *S. tala* that he would not have confused it with *S. tol*. At some time type labels or MNHN catalog numbers must have become inadvertently mixed. Since the description of *S. tol* was based in part on specimens from Malabar, the two specimens of that species labeled as types of *S. tala* are here designated putative paralectotypes of *Scomberoides tol* (Cuvier).

Russell's poor figure of "toloo parah," upon which the original description of *Chorinemus toloo* is based, cannot be positively identified as *S. tala*, although it most closely resembles that species. Weber and De Beaufort (1931) included *S. toloo* in their synonymy of *Scomberoides tala*; the figure of *Chorinemus toloo* published in Day's *Fishes of India* is clearly referable to *S. tala*.

Jordan and Seale distinguished their new genus and species, *Eleria philippina*, from *Scomberoides* solely on the basis of strong symphyseal canines on the lower jaw. They apparently were unaware that such canines are typically present in the young of *S. tala*.

The description and figure of *Chorinemus hainanensis* leave no doubt as to the identity of this nominal species. In their description, Chu and Cheng emphasized the absence of spots on side of body. Like a number of authors, they were not cognizant of the fact that these spots frequently fade completely.

DESCRIPTION. Characters given in the generic description are not repeated here. Frequency distributions of selected meristic characters are given in table 2. Dorsal-fin rays VI-VII + I, 19–21; anal-fin rays II + I, 17–19; pectoral-

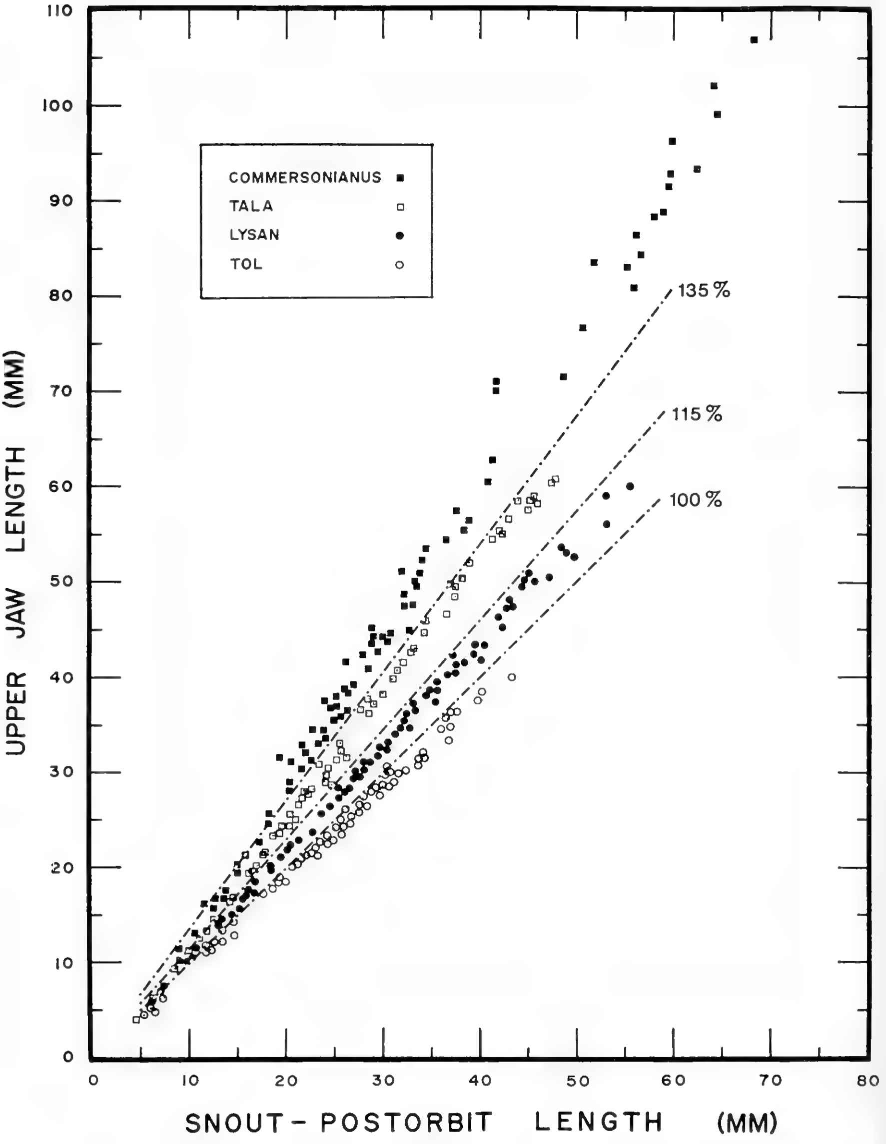

Figure 5. Relationship of upper jaw length to snout-postorbit length in *Scomberoides* species. Dashed lines represent upper jaw length as percent snout-postorbit length.

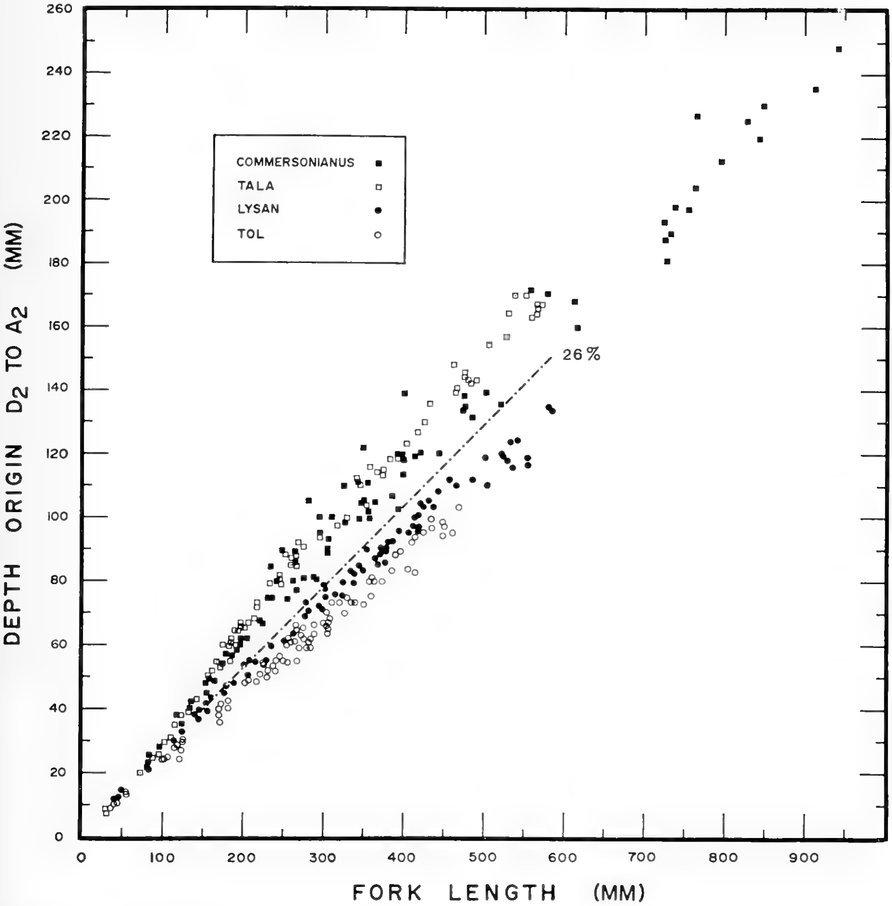

FIGURE 6. Relationship of body depth to fork length in *Scomberoides* species. Dashed line represents depth as percent fork length.

fin rays I, 16–17. Gillrakers 1–3 + 7–11 = 11–15. Upper jaw extending slightly beyond posterior margin of eye in adults (fig. 2b). Scales lanceolate (fig. 3c). Inner row of dentary teeth distinctly larger than outer row teeth in adults (fig. 4b); dentary typically with one or two pair of symphyseal canines in young; young with dentary teeth of outer row numerous and considerably more closely spaced than inner row teeth.

Proportional measurements apply only to specimens more than 150 mm. fork length (FL), and are in percent FL unless otherwise stated. Depth (origin D_2 to A_2) 29.0–34.9; height dorsal-fin lobe 14.6–18.0; height anal-fin lobe 13.1–16.2; upper jaw 54.3–61.6 percent head length; snout 26.1–30.1 percent head length.

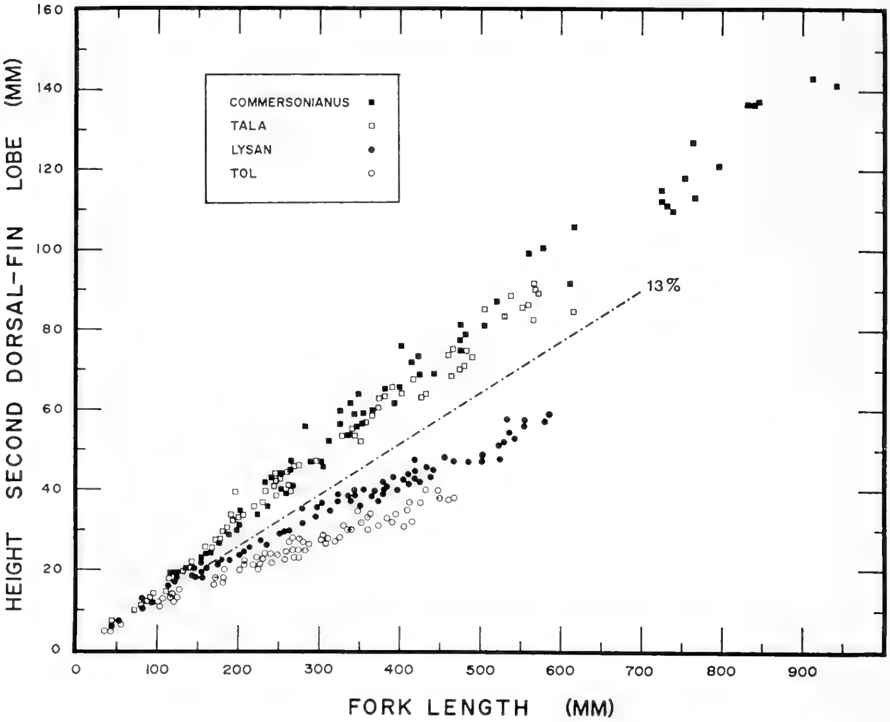

Figure 7. Relationship of dorsal-fin lobe height to fork length in *Scomberoides* species. Dashed line represents dorsal-fin lobe height as percent fork length.

Pigmentation. Sides with 4 to 8 vertically elongate blotches, most of them intersecting lateral line. Dorsal and anal fins uniformly pigmented. Life coloration not observed.

Distribution. Widely distributed throughout the Indo-Australian Archipelago, and the Bay of Bengal in the Indian Ocean. Although more collections are needed, the apparent absence of the species from the western Indian Ocean, Red Sea, and Persian Gulf appears to be real. *Scomberoides tala* is apparently restricted to neritic waters, and does not occur east of the New Guinea-Solomon Islands region.

Material (110 specimens, 31–615 mm. FL from 45 collections). CEYLON: TABL 107365 FJS 69–27 (2: 295–464), S-V 69–77 (1: 560), S-V 69–156 (1: 116, cleared and stained), TABL 107712 CCK 69–43 (12: 244–490), CCK 69–45 (3: 517–567), CCK 69–53 (4: 265–474), CCK 69–54 (2: 197–565), CCK 69–89 (8: 366–483), CCK 69–94 (1: 505), CCK 69–104 (2: 529–551), CCK 69–111 (1: 568). INDIA: Malabar, MNHN A. 6588 (315, lectotype of *Chorinemus tala*); Madras, AMS B. 8124 (1: 197); Calcutta, AMS B. 8093 (1: 115). BURMA: Maungmagan Island, SU 33635 (2: 91–95). ANDAMAN ISLAND: AMS I. 68 (1: 57). GULF OF THAILAND: GVF station 57–90 (1: 87), GVF station 57–99 (1: 167), GVF-1470 (4: 185–214), GVF-1503 (1: 176), TABL 107040 GVF-1512 (5: 190–219), GVF-2195 (1: 45), GVF-2197 (3: 31–71), GVF-2203 (1: 131), GVF-2222 (3: 183–198), GVF-2497 (2: 159–161), GVF-2540 (1: 345), GVF-2546 (12: 219–275). MALAYSIA: Penang, TABL 107266 FJS 69–79 m. (3: 168–183). PHILIPPINES: Luzon, USNM 65339 (1: 265), 149803 (3: 110–132), 149804 (1: 80); Batangas Prov., CAS uncataloged (6: 135–172); Manila Bay, CAS uncataloged (1: 165); Leyete, USNM 149805 (1: 178), 149811 (1: 178); Mindanao, USNM 55990 (1: 271); Matnog Bay, USNM 194913 (1: 218); Balabac Island, AMS I. 10478 (1: 220); Southern Negros, USNM 51945 (98, holotype of *Eleria philippina*), 75729 (1: 112), SU 9131 (2: 103–111). JAVA: USNM 72616 (2: 157–161), 72617 (1: 118), 72618 (1: 109), 72619 (1: 114). AUSTRALIA: Northern Territory, Port Darwin, AMS I. 5291–2 (2: 76–100), IA. 3639 (1: 67); Gulf of Carpentaria, Groote Eylandt, USNM 173957 (5: 317–339); Queensland, Cape York, BMNH 1879.5.14.282 (1: 381); Fitzory River Estuary, AMS IB. 1249 (1: 73). NEW BRITAIN: 4°19′S., 152°1′E., GVF station HK-130 (1: 615). SOLOMON ISLANDS: Bougainville, AMS IB. 1458 (1: 219).

Scomberoides lysan (Forskål).

(Figures 1c, 2c, 3b, 4c, 5–7, 19; tables 2–3.)

Scomber lysan FORSKÅL, 1775, p. 54 (type locality Djeddae and Lohajae, Red Sea).

Scomber forsteri BLOCH and SCHNEIDER, 1801, p. 26 (type locality Pacific Ocean [based on *Scomber maculatus* FORSTER MS]).

Lichia tolooparah RÜPPELL, 1828, p. 91 (type locality Massawa, Red Sea).

Chorinemus sanctipetri CUVIER *in* Cuvier and Valenciennes, 1831, p. 379 (279) (type locality Malabar coast).

Chorinemus moadetta EHRENBERG *in* Cuvier and Valenciennes, 1831, p. 382 (282) (based on an unpublished drawing by Ehrenberg of a fish from the Red Sea).

Chorinemus mauritianus CUVIER *in* Cuvier and Valenciennes, 1831, p. 382 (282) (type locality l'Isle-de-France [=Mauritius Island]).

Scomber maculatus FORSTER, 1844, p. 195 (type locality Tahiti).

Chorinemus orientalis TEMMINCK and SCHLEGEL, 1844, p. 106, pl. 57, fig. 1 (type locality Nagasaki, Japan).

Thynnus moluccensis GRONOVIUS *in* Gray, 1854, p. 121 (type locality Insulas Moluccenses).

Scomberoides formosanus OSHIMA (*non* Wakiya), 1925, p. 349, pl. 1, fig. 1 (type locality Tôkô, Formosa).

Scomberoides oshimae WHITLEY, 1951, p. 65 (replacement name for *Scomberoides formosanus* OSHIMA, 1925, preoccupied).

NOMENCLATURE. The description of *S. lysan* is inadequate for positive identification, but the following statements given by Forskål suggest that he did not have *S. commersonianus* (= '*lysan*' of recent workers): (1) scales lanceolate (in "*S. lysan*" they are usually referred to as ovate or broadly lanceolate); (2) "about the lateral line there are obsolete [?indistinct] dark spots"; (3) dentes [teeth] numerous, small. Rüppell (1828), who set out especially to clarify the identities of Forskål's Red Sea fishes, applied the name 'lysan' to *S. commersonianus*. His application of the name, however, was based on the fact that native fishermen referred to that species as "lysan." Smith (1968, p. 174) has clearly shown that native names of Red Sea fishes were often not specific. Cuvier and Valenciennes (1831) did not believe the description of *S. lysan* was sufficiently diagnostic for positive identification. They did, however, state that since Forskål's description contained no mention of a dark blotch in the second dorsal fin, they were hesitant to refer it to their *Chorinemus moadetta*. Günther (1860) and all subsequent workers have regarded *S. lysan* as a senior synonym of *S. commersonianus*.

Klausewitz and Nielsen (1965, pl. 25) have published an excellent photograph and radiograph of the 216 mm. SL lectotype (ZMC 44) of *Scomber lysan*, reproduced without comment in Smith (1970). The most distinctive feature of the lectotype is the position of the maxilla, which ends below the middle of the eye. It is also apparent from the radiograph that the snout has been pushed in on the dried skin, giving the snout an atypically blunt appearance. Since the maxilla extended well beyond the posterior margin of the orbit in all our specimens, we suspected that the *'lysan'* of recent authors was not the same species as the lectotype. Accordingly we wrote Dr. Jørgen Nielsen and asked him to examine the lectotype for us. The following information, largely provided by Dr. Nielsen, is sufficient to identify the lectotype as conspecific with *S. tolooparah* of recent workers: (1) Although there are no teeth left in the outer dentary row, judging from the sockets the missing teeth were the same size and number as those of the inner row, which excludes *S. tala* (see fig. 4); (2) comparison of the premaxillary teeth also excludes *S. tala*; (3) there are no symphyseal canines left. Symphyseal canines are never present in *S. lysan*, and usually are still retained in specimens of *S. commersonianus* and *S. tala* at this size; (4) the length of the upper jaw is 21 mm.; the dentary is 30 mm. The 1:1.5 ratio between the length of the upper jaw and dentary agrees fairly well with similar sized specimens of *S. tolooparah* and is sufficiently different to exclude *S. commersonianus*; (5) the scales of the paralectotype and the lectotype are the same size and form. Comparison of a small patch of skin (scales included) removed from the paralectotype just anterior to the spinous dorsal fin with scales from the same area of the four species of *Scomberoides* is sufficient to exclude *S. tol*, *S. commersonianus*, and, with less confidence, *S. tala*. The most diagnostic feature of these scales is their strongly lanceolate posterior margins (see fig. 3).

Unfortunately, the name *S. lysan* (applied to *S. commersonianus* by recent authors) must be retained as a senior synonym of the widely used *S. tolooparah*. It would be difficult to justify suppression of the name, however, since it is not simply an overlooked synonym of *S. tolooparah. Scomberoides forsteri* is also a senior synonym of *S. tolooparah*; and *S. sanctipetri*, a junior synonym, has frequently been recognized as a valid species. Although carangids are commercially important fishes, most genera have not been adequately revised, and consequently many of the names currently in use may eventually prove to be synonyms.

Although the descriptions of *Scomber forsteri* and *S. maculatus* are poor, they apply best to *S. lysan*. Since the type locality of *S. maculatus* (and thus that of *S. forsteri* as well) is Tahiti, an area from which only *S. lysan* is known, there can be little doubt as to the specific identity of either nominal species. The characters given for *Chorinemus moadetta*, and comparison of it in the original description with Forskål's *S. lysan*, leaves no doubt that it too is a junior synonym of *S. lysan*.

Smith (1970) presents photographs of the holotypes of *Lichia tolooparah* (NFIS 386) and *Chorinemus sanctipetri* (MNHN A. 6587). They are both clearly synonyms of *S. lysan*. Likewise, the original descriptions and figures of *Chorinemus orientalis* and *Scomberoides formosanus* agree well with *S. lysan*. The description and insular type locality of *Chorinemus mauritianus* are also sufficient to identify it as conspecific with *S. lysan*.

We have not examined the type of *Thynnus moluccensis*, but according to Wheeler (1958, p. 220) it is a synonym of *Chorinemus sanctipetri* (= *S. lysan*). The 142 mm. SL holotype bears the catalog number BMNH 1853. 11.12.29.

Description. Characters given in the generic description are not repeated here. Frequency distribution of selected meristic characters are given in table 2. Dorsal-fin rays VI-VII+I, 19–21, anal-fin rays II-I, 17–19; pectoral-fin rays I, 16–17. Gillrakers 3–8 + 15–20 = 21–27. Upper jaw extending to or slightly beyond (in large adults) posterior margin of eye (fig. 2c). Scales lanceolate (fig. 3b). Inner and outer row of dentary teeth subequal in adults (fig. 4c); dentary without symphyseal canines; young with dentary teeth of outer row numerous and considerably more closely spaced than inner row teeth.

Proportional measurements apply only to specimens more than 150 mm. fork length (FL), and are in percent FL unless otherwise stated. Depth (origin D_2 to A_2) 20.9–27.3; height dorsal-fin lobe 9.1–14.2; height anal-fin lobe 7.7–11.6; upper jaw 50.3–54.6 percent head length; snout 27.8–31.8 percent head length.

Pigmentation. Sides of adults with a double series of 6 to 8 dusky roundish blotches above and below lateral line, occasionally connected by narrow isthmus. Distal half of dorsal-fin lobe abruptly and heavily pigmented; anal-fin lobe white or pale yellow, often with interradial membranes of several anterior rays black, especially in large individuals. In life, body gray-green above, silvery gray to midline, silvery white below.

DISTRIBUTION. Widely distributed throughout the Red Sea, Indian Ocean, Indo-Australian Archipelago and central Pacific Ocean including Hawaii and the Marquesas Islands. *Scomberoides lysan* is the only species of *Scomberoides* that occurs east of the Solomon Islands and frequents entirely oceanic islands in the Indian Ocean, *e.g.*, Seychelles and Chagos Archipelago. The other species of *Scomberoides* are generally restricted to neritic habitats. This suggests a fundamental difference in the biology of *S. lysan*.

MATERIAL (276 specimens, 20–585 mm. FL from 109 collections). TANZANIA: Zanzibar, TABL 105602 (1: 281). MADAGASCAR: USNM 171034 (1: 336), TABL uncataloged station JR-68 (1: 54). MAURITIUS ISLAND: USNM 118407 (13: 256–403). COMORO ISLANDS: TABL uncataloged station FT-9 (2: 45–46), TABL uncataloged station HA-8 (1: 123), HA-10 (1: 52). ALDABRA ISLAND: TABL uncataloged station HA 67–56 (1: 385). CHAGOS ARCHIPELAGO: Diego Garcia Atoll, TABL uncataloged station HA 67–42 (2: 83–113), HA 67–43 (3: 146–154). INDIA: Malabar, MNHN A. 5893 (480, holotype of *Chorinemus sanctipetri*); Madras, AMS B. 8091 (3: 110–128). CEYLON: TABL 107364 FJS 69–27 (2: 412–523), S-V 69–123 (8: 177–303), S-V 69–128 (2: 123–161, cleared and stained), S-V 69–152 (9: 278–355), PCH 69–201 (1: 541), PCH 69–224 (1: 279), PCH 69–225 (1: 381), PCH 69–228 (1: 585), CCK 69–9 (1: 525), CCK 69–49 (4: 467–530), CCK 69–53 (1: 339), CCK 69–110 (1: 343), CCK 69–113 (2: 370–535), CCK 69–130 (1: 555). SOUTH CHINA SEA: Hainan Island, USNM 94780 (1: 178). TAIWAN: USNM 192563 (1: 194). OKINAWA ISLAND: USNM 72093 (2: 125–211). PHILIPPINES: Luzon, USNM 139573 (2: 33–38), 149797 (1: 47), 149800 (1: 31), 168276 (1: 215), 168277 (1: 220), 191855 (2: 29–48), 191888 (11: 45–73), 191889 (11: 83–103), 191891 (6: 76–116), 191894 (4: 44–100), 191896 (2: 200–213), 191907 (1: 76), 191913 (1: 54); Burias Island, USNM 194916 (1: 232); Busanga Island, USNM 191884 (3: 42–56); Linacapan Island, USNM 191893 (2: 66–92); Pandanon Island, USNM 191910 (2: 89–97); Mindoro, USNM 149799 (3: 66–79), 191902 (1: 73), 191908 (1: 96); Samar, USNM 191859 (4: 190–196); Leyete, USNM 191886 (11: 64–188); Palawan, USNM 191887 (19: 26–187), 191897 (4: 81–185), 191905 (1: 39); Cuyo Island, USNM 191911 (2: 67–81). BORNEO: Sandakan Bay, USNM 191901 (3: 83–109). AUSTRALIA: Northern Territory, Bedwell Point, AMS IA. 7679–80 (2: 136–200); Gulf of Carpentaria, Sir Edward Pellew Group, AMS IA. 1488 (1: 129), IA. 2559 (1: 144); Queensland, AMS A. 12495 (1: 141); Cape York, AMS I. 9712–4 (3: 206–217); Barrier Reef, USNM 176914 (6: 129–194); Townsville, AMS IA. 2324–5 (2: 150–164); Lindeman Island, AMS IA. 6288 (1: 290), IA. 6289–90 (2: 112–158), IA. 6647 (2: 110–128), IA.

7498–7501 (4: 51–75), IA. 7887 (1: 88); Hayman Island, AMS IA. 6126–7 (4: 35–132); Burdekin River, I. 5314–5 (2: 175–187), A. 18302 (1: 157); New South Wales, Sydney, MKT AMS IB. 4232 (1: 290), USNM uncataloged station BBC 1464 (1: 295); Gafton, AMS I. 15594–001 (1: 65). NEW GUINEA: Aroma, AMS IA. 5738 (3: 33–69); Hula Village, AMS IB. 1706 (1: 160); Bat Island, Purdy Archipelago, AMS IB. 1523 (1: 82). NEW BRITAIN: GVF station HK-29 (1: 297), GVF station HK-130 (1: 418). SOLOMON ISLANDS: Bougainville, TABL uncataloged *Te Vega* Expedition, Cruise 6, station 247 (1: 155); Ontonga Java Island, AMS IA. 3696 (1: 355). PALAU ISLAND: GVF-546 (1: 81), GVF-591 (1: 83), GVF-1971 (2: 189–205), GVF station 59–708 (11: 373–442), GVF station 59–710 (2: 369–410), GVF station 59–724 (2: 365–379). MARIANA ISLAND: Saipan, USNM 154647 (1: 54). MARSHALL ISLANDS: USNM 66022 (1: 40), 66024 (1: 37), 66025 (1: 30), 142040 (1: 580), 142041 (2: 30), 142042 (2: 28–32), 163134 (1: 26), 165648 (2: 78–80), 179433 (1: 63). GILBERT ISLANDS: USNM 66021 (1: 60); Onotoa, USNM 167428 (2: 380–415); Arorae, AMS IB. 6618 (1: 25); Nauru, AMS IA. 6999 (1: 375). ELLICE ISLAND: AMS IA. 5531 (1: 215); Funafuti, USNM 66020 (1: 96), AMS I. 3562 (1: 495). PHOENIX ISLANDS: Canton Island, USNM 115330 (1: 456). SAMOA ISLANDS: Apia, USNM 52361 (3: 219–240). NEW HEBRIDES ISLANDS: Malehuka, AMS I. 11294 (1: 162). FIJI ISLANDS: Suva, USNM 66023 (2: 176–177). TONGA ISLANDS: Vavau, USNM 66019 (1: 103); Tonga, TABL uncataloged, *Te Vega* Expedition, Cruise 8, station 308 (2: 215–227). SOCIETY ISLANDS: Tahiti, GVF-1155 (1: 324), GVF station 57–6 (1: 296). TUAMOTU ARCHIPELAGO: Rangiroa, USNM 66018 (2: 84–135); Takaroa, GVF station 56–?? (1: 299); Raroia, GVF-87 (3: 502–555). MARQUESAS ISLANDS: Nukahiva, USNM 66016 (1: 416), 66017 (3: 184–215); Hiva Oa, USNM 186329 (2: 33–38). LINE ISLANDS: Palmyra Island, GVF station 51–41 (5: 350–419), GVF station 51–44 (4: 140–157); Christmas Island, USNM 19238 (3: 402–415). JOHNSTON ISLAND: USNM 26825 (1: 440). HAWAIIAN ISLANDS: Hawaii, USNM 78073 (5: 26–69), 82818 (1: 279), 83429 (1: 227); Oahu, SU 3270 (5: 172–220), 7647 (3: 103–190), 53345 (1: 20), USNM 55082 (1: 357), 55371 (1: 141), 88161 (1: 166), 88162 (3: 172–255), 126691 (1: 174), 151615 (3: 191–260).

Scomberoides tol (Cuvier).

(Figures 1d, 2d, 3d, 4d, 5–7, 14d, 19, 20b, 21c, 22c; tables 2–3.)

Chorinemus tol Cuvier *in* Cuvier and Valenciennes, 1831, p. 385 (type localities Pondichery; Malabar coast; Amboine; Ile de Bourou).

Scomberoides formosanus Wakiya, 1924, p. 236, pl. 38, fig. 3 (type locality Kii, Formosa).

Nomenclature. The original description of *Chorinemus tol* is sufficiently diagnostic for positive identification (see also discussion under *S. tala*). Likewise the statement "scales linear, pointed at both ends" given in the description of *S. formosanus* could apply only to *S. tol* Cuvier. F. H. Berry has examined the 130 mm. SL holotype (FMNH 59499), and made his data available to us.

DESCRIPTION. Characters given in the generic description are not repeated here. Frequency distributions of selected meristic characters are given in table 2. Dorsal-fin rays VI-VII + I, 19–21; anal-fin rays II + I, 18–20; pectoral-fin rays I, 15–18. Gillrakers 4–7 + 17–20 = 21–26. Upper jaw does not extend to posterior margin of eye (fig. 2d). Scales slender, needlelike (fig. 3d). Inner and outer row of dentary teeth subequal in adults (fig. 4d); dentary typically with one or two pairs of symphyseal canines in young; young with dentary teeth of outer row only slightly more numerous and closely spaced than inner row teeth.

Proportional measurements apply only to specimens more than 150 mm. fork length (FL), and are in percent FL unless otherwise stated. Depth (origin D_2 to A_2) 20.0–24.7; height dorsal-fin lobe 7.7–11.2; height anal-fin lobe 6.3–8.8; upper jaw 42.6–49.3 percent head length; snout 29.1–32.8 percent head length.

PIGMENTATION. Sides of adults with 5 to 8 oval or vertically oblong blotches, the first 4 or 5 of which intersect lateral line. Distal half of dorsal-fin lobe abruptly and heavily pigmented; anal-fin lobe usually immaculate, white in life. In life, body white ventrally, bluish dorsally; lateral blotches black, faint or absent in young.

DISTRIBUTION. Widely distributed throughout the Indo-Australian Archipelago and Indian Ocean. Although we have not examined specimens, the species has been reliably reported from the Red Sea. *Scomberoides tol* is apparently restricted to neritic waters, and does not occur east of the New Guinea-Solomon Islands region.

TYPE MATERIAL. MNHN A. 6605 (150, here designated lectotype of *Chorinemus tol*) Malabar. Paralectotypes as follows: MNHN B. 2650 (2: 135–147, removed from A. 6605), B. 5542 (dried skin, not measured) Pondichery, A. 6585 (1: 170) Bourou Island, A. 6620 (1: 119) Amboine. MNHN A. 6587 (2: 296–302, putative paralectotypes) Malabar (see discussion under *S. tala*). FMNH 59499 (130 mm. SL, holotype of *S. formosanus*) Kii, Formosa.

OTHER MATERIAL (142 specimens, 20–468 mm. FL from 66 collections). SOUTH AFRICA: Durban, TABL uncataloged FJS 69–1 (7: 224–267). MOZAMBIQUE: Ponta Mabonl, TABL uncataloged FJS 69–5 (1: 173); Polana, TABL uncataloged FJS 69–12 (1: 208); Mecaneta, TABL uncataloged FJS 69–14 (3: 225–232). KENYA: Mombasa, TABL uncataloged *Anton Bruun* cruise 9, station FT-2 (2: 271–276). MADAGASCAR: USNM 171055 (1: 185), TABL uncataloged JR-27 (3: 171–173), JR-70 (1: 120), TABL uncataloged *Anton Bruun* cruise 7, Tulear Harbor, (1: 124). PERSIAN GULF: USNM 147819 (1: 20), 148074 (1: 323). INDIA: Bombay, TABL uncataloged FHB

66–1 (4: 37–55); Kerala State, Cochin, TABL uncataloged FHB 66–53 (1: 127); Madras State, AMS B. 8045 (1: 171); Cape Comorin, TABL uncataloged FHB 66–46 (1: 222), FHB 66–49 (2: 264–330); Porto Nova, TABL uncataloged FHB 66–17 (2: 282–284). CEYLON: FJS 69–14 (3: 225–232), TABL 107707 S-V 69–86 (4: 262–284), S-V 69–123 (8: 240–390), TABL 107363 S-V 69–126 (8: 268–450), S-V 69–128 (6: 107–131.5, 2 cleared and stained), PCH 69–180 (1: 326), PCH 69–185 (10: 102–107), PCH 69–202 (2: 108–126), PCH 69–237 (1: 310), PCH 69–266 (4: 358–373), PCH 69–292 (3: 146–154), CCK 69–9 (1: 340), CCK 69–43 (1: 181), CCK 69–73 (1: 395), CCK 69–91 (1: 242), CCK 69–94 (1: 468), CCK 69–113 (3: 410–426), CCK 69–129 (8: 351–460). MALAYSIA: Penang, TABL uncataloged FJS 69–74 m. (2: 209–219). GULF OF THAILAND: GVF station 13B-C (6: 209–246) GVF-1541 (7: 141–203), GVF-2546 (8: 269–320), GVF-2655 (2: 117–119). TAIWAN: USNM 76607 (8: 41–149), SU 7317 (1: 169), 20997 (2: 203–218). JAPAN: Kagoshima, SU 23774 (3: 86–117). PHILIPPINES: Luzon, USNM 56329 (5: 105–224), 168275 (1: 207), 168281 (1: 372), 168282 (1: 331), USNM uncataloged (out of USNM 191896) (1: 115), 191899 (1: 156), 191906 (1: 77), 191909 (1: 89), 191912 (1: 89), AMS I. 10539 (1: 215); Leyte, USNM 149796 (1: 38); Cebu, USNM 191900 (2: 123–134); Panay, USNM 149794 (1: 30), 191898 (1: 105); Mindanao, USNM 55995 (1: 244), 58011 (2: 143–144), 59004 (1: 149), 168283 (1: 348). JAVA: Batavia, USNM 726211 (2: 122–140), 72612 (1: 171), 72613 (1: 145), 72614 (1: 130), 72615 (2: 162–208). AUSTRALIA: Western Australia, Onslow, WAM P. 15488–90 (3: 110–174); Port Hedland, AMS IB. 1638 (1: 128); Gulf of Carpentaria, 16°53′S., 139°21′E., AMS I. 15557–118 (5: 87–172); Queensland, Barrier Reef, USNM uncataloged (out of USNM 176914) (1: 171); Palmers Island, AMS I. 2962–3 (2: 90–91); Hayman Island, AMS IA. 6373 (1: 221). NEW GUINEA: Sumarai District, AMS IA. 5740 (1: 235). SOLOMON ISLANDS: Bougainville, TABL uncataloged *Te Vega* Expedition, cruise 6, station 246 (2: 43–44); Malaita Island, AMS I. 15360–056 (1: 350).

Scomberoides spinosus (Smirnov).

(Figure 8.)

Palaeoscomber spinosus SMIRNOV, 1936, p. 49–59, pl. 7, figs. 31–32 (type locality Zuramakent Horizon of the Upper Maikop deposits, Northeastern Caucasus).

Danil'chenko (1960) has given a detailed redescription of *Palaeoscomber spinosus* and convincingly demonstrated that it is a species of carangid, although originally believed to represent a new genus and subfamily of Scombridae (Smirnov, 1936). In reassigning *P. spinosus* to *Oligoplites*, Danil'chenko emphasized the peculiar needlelike scales which he regarded as a "characteristic sign" of the genus. He did not compare it with *Scomberoides tol*, apparently

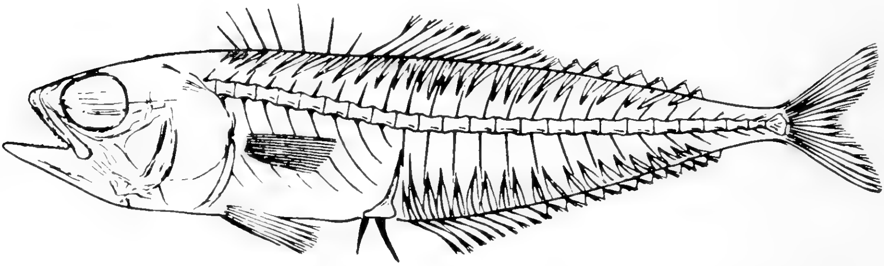

FIGURE 8. Diagrammatic sketch of *Palaeoscomber spinosus* Smirnov (after Danil'chenko, 1960).

unaware that its scales are identical to those of *Oligoplites*. Although we have not examined specimens of *P. spinosus*, and therefore do not include a description, we believe it is a species of *Scomberoides* closely related to *S. tol*. The number of dorsal-fin rays (VI-VII + I, 20) and predorsal bones (3) reported for *P. spinosus* apply best to a species of *Scomberoides*. Likewise, the relatively short upper jaw (47 to 48 percent HL) and general configuration of the maxilla suggest *S. tol* rather than a species of *Oligoplites* (compare figs. 2d and 8).

The four fossils upon which the description is based are from the Zuramakent Horizon of the Upper Maikop deposits (Lower Miocene) in the Northeastern Caucasus. According to Danil'chenko (1960), only 3 of 18 genera examined from this deposit do not represent recent genera. The recent species *Scomber japonicus* Houttuyn is also present. The characters of *Oligoplites* and its present distribution (western Atlantic and eastern Pacific) suggest that it evolved from a *Scomberoides*-like ancestor that reached the New World via the Pacific (see discussion under Relationships and Zoogeography Section). It seems more logical in view of the geographical location and recent nature of the Upper Maikop fauna that *P. spinosus* represents a genus present in the Indian Ocean rather than one that is restricted to the western Atlantic and eastern Pacific oceans.

Two characters mentioned in the redescription of *P. spinosus* require comment. (1) The supramaxilla is said to be absent. The small supramaxilla of *Scomberoides* could easily be lost or overlooked in a fossil. (2) The vertebral count is given as 10 + 15. In his discussion of methods Danil'chenko (1960) stated that the vertebrae were counted as in recent fishes (the urostyle is treated as a separate vertebra), yet his diagrammatic drawing of *P. spinosus* (here reproduced as fig. 8) clearly shows 10 + 16 vertebrae. We believe the count of 10 + 15 is an error. Berry (1968, p. 148) stated that the number of vertebrae is intraspecifically very constant in all Carangidae. One exception that he noted was one specimen of *Oligoplites saurus inornatus* Gill with 10 + 17 vertebrae;

19 others had 10 + 16. We have made numerous vertebral counts of all species of *Oligoplites* and *Scomberoides* and except for the specimen mentioned above, all have 10 + 16 vertebrae.

The available material of *Scomberoides spinosus* should be carefully compared with similar sized specimens of *S. tol.* We tentatively regard them as specifically distinct because several of the proportional measurements given for *S. spinosus* do not agree with our specimens of *S. tol.*

Oligoplites Gill, 1863

Oligoplites Gill, 1863, p. 166 (type species: *Scomber saurus* Bloch and Schneider, 1801, by subsequent designation of Jordan, 1917, p. 324).

Leptoligoplites Fowler, 1944, p. 226 (as a subgenus of *Oligoplites*; type-species: *Oligoplites refulgens* Gilbert and Starks, 1904, by original designation).

The carangid genus *Oligoplites* comprises five species of tropical and subtropical marine fishes restricted to the eastern Pacific and western Atlantic oceans. Only one species, *O. saurus*, occurs in both oceans. Parenthetically, it should be noted that in his excellent review of the zoogeographic relationships of tropical American marine shore fishes, Rosenblatt (1967, p. 590) has perpetuated a misconception by reporting *Oligoplites* from the eastern Atlantic. The genus is largely confined to inshore, neritic waters, and the young are sporadic invaders of coastal freshwater habitats (Gunter and Hall, 1963; Miller, 1966; Gilbert and Kelso, 1971). Breder (1942) has made the interesting observation that the young of *Oligoplites saurus* 27 to 34 mm. SL, which appear on the west coast of Florida during June and July, frequently drift passively at the surface head-down or twisted in a most unfishlike manner. He noted that their behavior and general appearance almost perfectly mimicked a floating dead leaf. The young of *Scomberoides lysan* have been observed exhibiting similar behavior (Major, 1973). The largest species of *Oligoplites* seldom, if ever, exceed 40 cm. fork length. In Central and South America they are commonly sold in fish markets. F. H. Berry *in* McClane (1965, p. 477) has reported *Oligoplites altus* (as *O. mundus*) to be an exceptionally strong and stubborn fighter on light tackle.

Oligoplites shows a striking external resemblance to the allopatric Indo-Pacific genus *Scomberoides*, and together they constitute the subfamily Scomberoidinae (=Chorineminae) of recent authors. Starks (1911) gives a detailed osteological comparison of these two genera. The adults of *Scomberoides* have a series of prominent spots or bars on the sides that is absent in *Oligoplites*, although faint bars may occasionally be present in *O. saurus*. The genus was last reviewed by Schultz (1945). Several junior synonyms overlooked in that work are included in our synonymies. The species that we recognize may be

Table 4. *Frequency distribution of meristic characters in* Oligoplites *species.*

	Upper Gill Rakers									Lower Gill Rakers																
Species	2	3	4	5	6	7	8	N	x̄	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	N	x̄
altus	2	23	31	9	—	—	—	65	3.7	1	9	14	17	10	14	—	—	—	—	—	—	—	—	—	65	11.0
palometa	—	1	14	22	—	—	—	37	4.7	—	—	—	8	16	12	1	—	—	—	—	—	—	—	—	37	12.2
saliens	—	—	2	12	26	1	—	41	5.6	—	—	—	—	—	—	—	—	—	3	9	23	6	—	—	41	18.8
refulgens	—	—	—	—	9	33	4	46	6.9	—	—	—	—	—	—	—	—	—	—	—	10	15	15	6	46	20.4
saurus saurus	—	4	8	10	13	—	—	35	4.9	—	—	—	—	—	7	24	4	—	—	—	—	—	—	—	35	13.9
saurus inornatus	—	—	—	13	8	4	—	25	5.6	—	—	—	—	—	—	6	9	9	—	1	—	—	—	—	25	15.2

	Total Gill Rakers																					First Dorsal Spines			
Species	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	N	x̄	IV	V	VI	N
altus	2	9	9	8	13	9	10	5	—	—	—	—	—	—	—	—	—	—	—	65	14.7	21	40	—	61
palometa	—	—	—	1	3	9	16	7	1	—	—	—	—	—	—	—	—	—	—	37	16.7	36	2	—	38
saliens	—	—	—	—	—	—	—	—	—	—	1	—	6	14	14	6	—	—	—	41	24.4	42	—	—	42
refulgens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	13	14	11	2	46	26.8	7	45	—	52
saurus saurus	—	—	—	—	—	—	7	6	8	13	1	—	—	—	—	—	—	—	—	35	18.8	1	34	2	37
saurus inornatus	—	—	—	—	—	—	—	—	—	4	8	7	5	—	1	—	—	—	—	25	21.7	—	24	1	26

Correlation of predorsal bones and pterygiophores of first dorsal spines
(predorsal bones + pterygiophores[1])

Species	4 + 5	4 + 6	5 + 4	5 + 5	6 + 4	N
altus	—	—	—	13	10	23
palometa	—	—	—	3	8	11
saliens	—	—	23	—	—	23
refulgens	1	—	—	33	1	35
saurus saurus	—	1	—	19	—	20
saurus inornatus	1	1	—	12	—	14

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[1] All dorsal pterygiophores bear a single spine.

Table 5. *Comparison of upper jaw length (expressed as percent HL) and body depth (expressed as percent FL) in* Oligoplites *species.*

Species	<150 mm. Range FL	N	Upper Jaw Length		N	Depth	
			Range	$\bar{x}$		Range	$\bar{x}$
altus	35–149	13	59–66	63.4	10	27–32	29.8
palometa	92–147	12	58–63	59.7	12	24–31	27.3
saliens	88–146	7	57–67	62.3	8	26–29	27.0
refulgens	44–148	35	41–46	43.6	36	18–22	19.9
saurus saurus	31–144	11	52–57	54.7	10	23–26	23.9
saurus inornatus	53–132	20	52–57	55.3	20	23–25	24.0

Species	>150 mm. Range FL	N	Upper Jaw Length		N	Depth	
			Range	$\bar{x}$		Range	$\bar{x}$
altus	154–379	65	58–70	64.3	47	27–38	32.0
palometa	160–392	26	59–64	61.6	26	26–34	29.2
saliens	165–390	34	62–68	65.3	33	27–31	28.8
refulgens	150–230	22	42–46	43.5	22	19–22	20.0
saurus saurus	165–285	26	52–57	54.3	26	24–27	25.2
saurus inornatus	200–257	7	52–57	54.6	7	25–28	26.8

identified by reference to the key and tables 4–5. We have not included segmented dorsal- and anal-fin ray counts because, as in *Scomberoides,* they are not useful in defining species.

Nomenclature. Schultz (1945) considered *O. inornatus* Gill the "genotype" of *Oligoplites,* however, no type-species designation was given in the original description. We believe that the action of Jordan (1917, p. 324) qualifies *Scomber saurus* Bloch and Schneider, 1801, as the type-species in accordance with provision (iv) of Article 68a of the International Code of Zoological Nomenclature (1964).

We concur with Schultz (1945, p. 330) that recognition of the subgenus *Leptoligoplites* on the basis of a few more gill rakers and elongate body is unjustified. Differences in dentition would be a much better basis upon which to establish subgenera if such were needed.

Description. Body moderately to strongly compressed. Adipose eyelids moderately to poorly developed. Body, except head, covered with needle-like embedded scales. Lateral-line scales not developed into scutes. Lateral line without side branches, straight except for slight curve over pectoral fin. Anterior rim of shoulder girdle smooth, without fleshy papillae or deep groove near isthmus. Premaxillae not protractile, connected anteriorly to snout at midline by a wide fleshy bridge. Swimbladder strongly bifid posteriorly, length of bifurcated portion of swimbladder equal to or greater than undivided part. Posterior dorsal- and anal-fin rays consisting of semidetached finlets, distal fourth to half of ray not connected by interradial membrane (unattached portion of rays increasing with growth); ultimate and penultimate rays more closely spaced than adjoining rays, fully connected by interradial membrane; none of dorsal- or anal-fin rays produced into long filaments. Pelvic fins relatively short, depressible into shallow abdominal grooves. Pectoral fins short, not falcate, 57 to 80 percent head length in adults. Upper jaw extends posteriorly from middle of eye to well behind orbital rim, 42 to 70 percent head length in adults.

Predorsal bones 4 to 6, rarely 4; dorsal-fin rays IV-VI (rarely VI) + I, 18 to 21; total dorsal-fin rays 23 to 27. Anal-fin rays II + I, 19 to 21. Pectoral-fin rays I, 15 to 17. Pelvic-fin rays I, 5. Vertebrae 10 + 16 to 17 (rarely 17) = 26; epipleural ribs 8–10. Branchiostegal rays 3 + 4 or $2\frac{1}{2} + 4\frac{1}{2}$ (epihyal + ceratohyal). Upper gillrakers 2 to 8; lower gillrakers 8 to 22; total gillrakers 11 to 29.

Fronto-supraoccipital crest low; temporal crest poorly developed, not extending forward to posterior rim of orbit and not reaching edge of cranium; preorbital region short. Epiotics broadly united along midline of cranium internally. Zygapophyses of exoccipital widely separated beneath foramen magnum. Parasphenoid not expanded into a broad, flattened plate posteriorly. Myodome with broad, posterior opening. Basioccipital without a pair of lateral processes on ventral surface. Ascending process of premaxilla short and triangular; maxilla long and slender, rather closely attached to premaxilla. Premaxillary spur absent. Supramaxilla absent. Interosseous space between dorsal arm of dentary and upper margin of articular minute or absent. Well developed teeth on dentary, premaxilla, palatines, and vomer; two distinct rows of dentary teeth (see discussion under Relationships and Zoogeography Section); symphyseal premaxillary and dentary teeth of juveniles not robust or caniniform. Mesopterygoids edentate. Pharyngeals not noticeably enlarged, covered with sharp, pointed teeth.

Suborbital shelf absent; lower and posterior suborbitals expanded posteriorly, especially in large specimens, thus covering a large portion of cheek. Basibranchials 1–3 usually each with a pair of large tooth plates. Lower limb of posttemporal not noticeably short or thickened. Postcoracoid process absent. Interpelvic keel well developed; postpelvic process of each side coalesced entire length, not forming an apical fork. Inferior vertebral foramina absent. First anal pterygiophore and haemal spine of first caudal vertebra firmly attached to form a strong strut. Anal pterygiophore expanded anterolaterally to form roof over first two anal spines; first two anal spines articulated proximally with each other; second anal spine asymmetrical, with deep groove on one side of anterior face. Caudal skeleton with 2 epurals and 2 pairs of uroneurals.

KEY TO SPECIES OF *Oligoplites*

1a. Upper jaw 41 to 46 percent HL; body depth 18 to 22 (mean 20.0) percent FL; head length usually equal to or greater than body depth; specimen figure 10a .... *O. refulgens* (Pacific)

1b. Upper jaw 52 to 70 percent HL; body depth 23 to 38 percent FL; head length less than body depth 2

2a. Ventral profile of dentary strongly convex (fig. 9c); premaxillary teeth in a single row, somewhat irregular in young; gillrakers of lower limb of first gill arch 17 to 20 (mean 18.8); first dorsal spines consistently 4; specimen figure 9c .... *O. saliens* (Atlantic)

2b. Ventral profile of dentary moderately convex; premaxilla with 2 distinct rows of teeth or a band of villiform teeth; gillrakers on lower limb of first gill arch 8 to 18 (11 to 15 in Atlantic species); first dorsal spines 4 to 6 3

3a. Upper jaw 52 to 57 (mean 54.7) percent HL; body depth 23 to 28 percent FL; gillrakers on lower limb of first gill arch 13 to 18; premaxillary teeth essentially in 2 distinct rows, an additional row of minute teeth may occur anteriorly; first dorsal spines typically 5; specimen figures 9a and 10b .... *O. saurus* (Atlantic and Pacific)

3b. Upper jaw 58 to 70 percent HL; body depth 24 to 38 percent FL; gillrakers on lower limb of first gill arch 8 to 14; premaxilla with a band of villiform teeth, wide anteriorly; first dorsal spines 4 or 5 4

4a. Top of head with numerous sensory pores, which are connected by network of tubes visible beneath skin; specimen figures 10c, d .... *O. altus* (Pacific)

4b. Sensory pores on top of head sparse, never as numerous as in specimens of *O. altus*; specimen figure 9b .... *O. palometa* (Atlantic)

Oligoplites refulgens Gilbert and Starks.

(Figures 10a, 11, 19; tables 4–5.)

Oligoplites refulgens GILBERT and STARKS, 1904, p. 73, pl. 11, fig. 19 (type locality Panama Bay).

This Eastern Pacific species is easily distinguished from its congeners by its short upper jaw and slender body (see table 5). From those species with which it occurs sympatrically, it is also distinguished by its higher number of gill rakers. On the basis of its premaxillary dentition, relationship of predorsal bones to first dorsal pterygiophores, and upper jaw development, it appears to be most closely related to *O. saurus*.

Oligoplites refulgens is the smallest species of the genus, rarely exceeding 250 mm. FL. It occurs in the Gulf of California north at least to Kino Bay, Sonora, Mexico and south to the Gulf of Guayaquil, Ecuador.

MATERIAL (61 specimens, 38–230 mm. FL, from 14 collections). GULF OF CALIFORNIA: TABL 103470 (1: 148.5), 103475 (2: 113–131, cleared and stained), 103477 (2: 162), SIO 59–245 (1: 170). GULF OF PANAMA: TABL 103473 (1: 117), 103474 (2: 186–189), 103476 (4: 116–132), 107711 (4: 164–175), USNM 81986 (10 of 36: 38–82). COLOMBIA: TABL 103472 (6: 89–102), 107708 (1: 230). ECUADOR: TABL 103471 (1: 209), TABL 103478 (15 of 38: 115–137). PERU: Zorritos, TABL 107710 (11: 150–196).

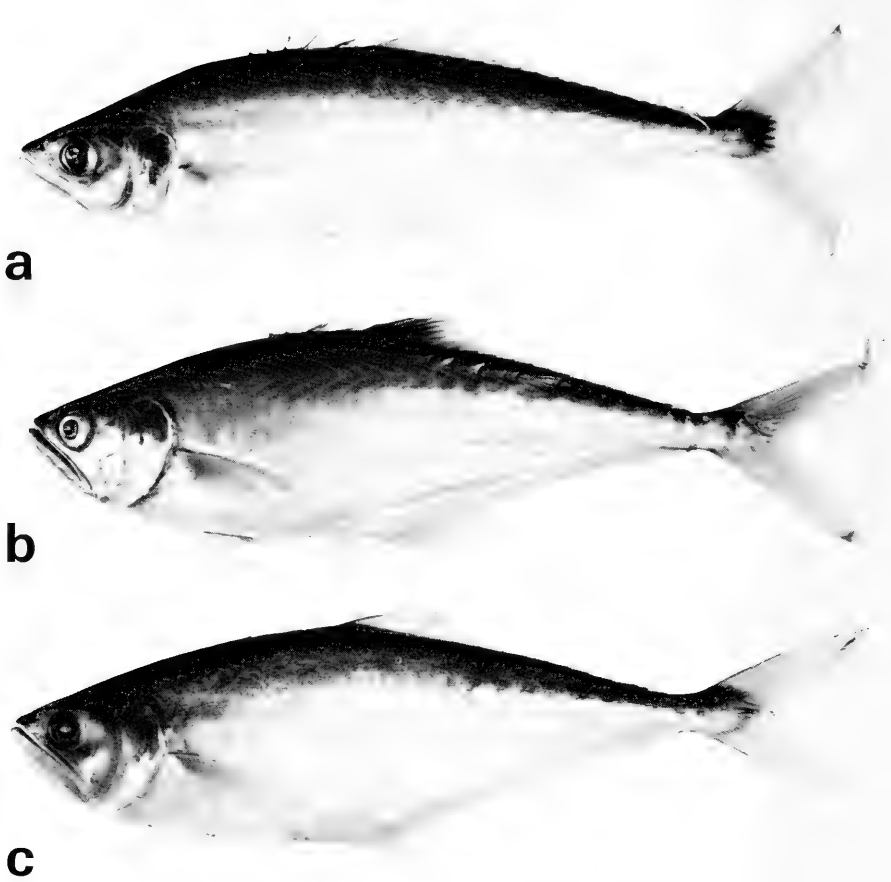

Figure 9. Western Atlantic *Oligoplites*: a, *O. s. saurus*, TABL 101582, 225 mm. FL; b, *O. palometa*, USNM 121804, 245 mm. FL; c, *O. saliens*, TABL 101351, 204 mm. FL.

Oligoplites saliens (Bloch).

(Figures 9c, 11, 14f, 19, 24c; tables 4–5.)

Scomber saliens Bloch, 1793, p. 49, pl. 335 (type locality Antilles).
?*Scomber calcar* Bloch, 1793, p. 55, pl. 336, fig. 2 (type locality Accra, coast of Guinée).
Scomberoides saltator Lacépède, 1802, p. 50 (based on unpublished manuscript of Plumier).

Schultz (1945) did not include *Scomber calcar* in his synonymy of *O. saliens.* Bloch's illustration shows what appears to be a species of *Oligoplites,* with a relatively deep body and 3 first dorsal spines. Since Bloch's description was based on a small specimen, Regan (1903, p. 349) is probably correct in stating that it is "without much doubt, based on a young example of *Scomberoides* [=*Oligoplites*] *saliens,* Bl.". The eastern Atlantic type locality would seem to

FIGURE 10. Eastern Pacific *Oligoplites*: a, *O. refulgens*, SIO 59–245, 170 mm. FL; b, *O. saurus inornatus*, TABL 103480, 200 mm. FL; c, *O. altus* UCLA w58-304, 195 mm. FL; d, *O. altus* ('*mundus*' form), UCLA w58-304, 180 mm. FL.

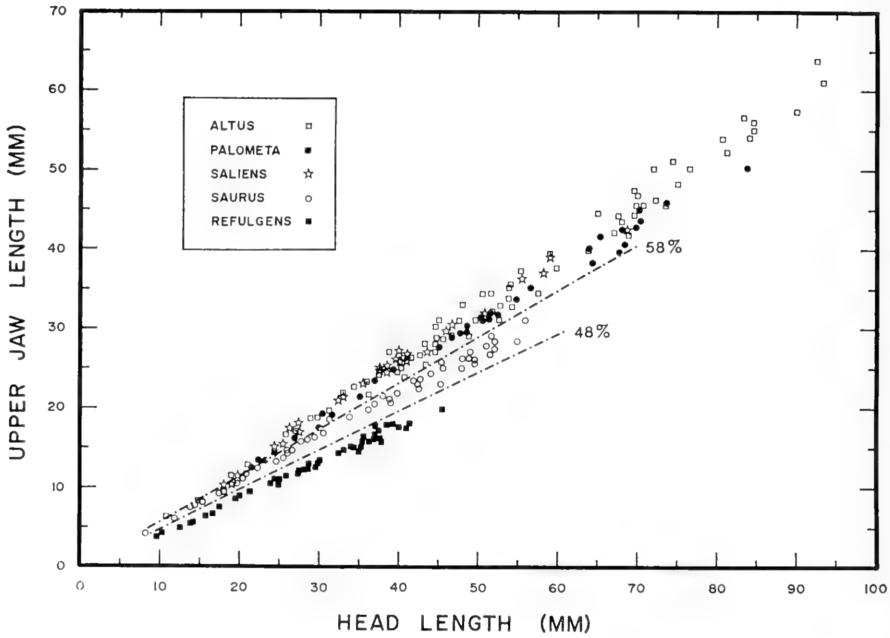

Figure 11. Relationship of upper jaw length to head length in *Oligoplites* species. Dashed lines represent upper jaw length as percent head length.

exclude *S. calcar* representing a species of *Oligoplites*, but the type locality is possibly in error. C. L. Smith has documented a number of such errors (Smith, 1971, pp. 165 and 208) involving other species described by Bloch.

The most diagnostic character of *O. saliens* is the strongly convex ventral profile of its massive lower jaw (see fig. 9c). It is the most specialized species of *Oligoplites* and does not appear to be closely related to any other species. It differs in having a 5 + 4 arrangement of predorsal bones and first dorsal pterygiophores (see table 4), a single row of enlarged premaxillary teeth, and a relatively constant number of outer dentary teeth (see fig. 19) that do not exhibit any recognizable ontogenetic changes. *Oligoplites saliens* can also be distinguished from the other two Atlantic species of *Oligoplites* by its higher number of gillrakers on the lower limb of the first gill arch.

Oligoplites saliens is a large species, attaining at least 390 mm. FL. In the western Atlantic it ranges north at least to Cartasca Lagoon, Honduras, and south to Rio de Janeiro, Brazil.

Material (42 specimens, 88–390 mm. FL, from 25 collections). HONDURAS: Caratasca Lagoon, TABL 101351 (11: 185–219), 101353 (2: 183.5–207), 104795 (5: 195–208). COLOMBIA: UMML 27265 (1: 122). GULF

OF VENEZUELA: TABL 103213 (1: 390), USNM 123073 (1: 88), 123075 (1: 94). TRINIDAD: TABL 104796 (1: 203). GUYANA: TABL 104330 (1: 211), 104378 (1: 235), 107716 (1: 165), 107717 (1: 177). SURINAM: USNM uncataloged *R/V Oregon* station 4175 (1: 169). BRAZIL: Rio Pára, SU 53055 (1: 201), 53062 (1: 249), 53063 (1: 315), 53064 (1: 165); Vitoria, SU 66973 (3[2 cleared and stained]: 95–133), 66975 (1: 146), 66976 (1: 145); Rio de Janeiro, SU 53056 (1: 215), 53057 (1: 270), USNM 76330 (1: 194), 100824 (1: 303), 100825 (1: 295).

Oligoplites saurus (Bloch and Schneider).

(Figures 9a, 10b, 11, 14e, 18, 19, 20c, 21d, 22d; tables 4–5.)

Scomber saurus Bloch and Schneider, 1801, p. 32 (type locality Jamaica).
?*Lichia quiebra* Quoy and Gaimard, 1824, p. 365 (type locality Brazil).
Chorinemus saltans Cuvier *in* Cuvier and Valenciennes, 1831, p. 393 (289) (type locality Martinique).
Chorinemus lanceolatus Girard, 1858, p. 168 (type locality Joseph's Island, Texas).
Chorinemus occidentalis Günther, 1860, p. 475 (type localities Jamaica; San Domingo; Trinidad; Puerto Cabello; Bahia).
Oligoplites inornatus Gill, 1863, p. 166 (type locality west coast of Panama).
Oligoplites rathbuni Miranda-Ribeiro, 1915, p. 8 (type locality Bahia Fish Market, Brazil).

Schultz (1945) apparently overlooked the descriptions of *Chorinemus saltans* and *C. lanceolatus*. The descriptions of both species and their type localities are sufficient to identify them positively as synonyms of *O. saurus*. We have examined the 102 mm. holotype (USNM 710) of *C. lanceolatus*.

Centronotus argenteus Lacépède (1802, p. 316) was questionably included by Schultz in the synonymy of *O. s. saurus*. The name, however, does not appear to be available nomenclaturally, and we regard it as a *nomen nudum*. No description was given and species belonging to two different genera were listed as synonyms.

Oligoplites inornatus was not compared with *O. saurus* in the original description. Despite the fact that these two nominal species were described from different oceans, recent workers have regarded them as only subspecifically distinct at best. The only characters that appear to distinguish them are a slightly higher number of gillrakers and a few more premaxillary teeth anteriorly in Pacific specimens. Certainly the slight differences shown between these two nominal species are not of sufficient magnitude to justify specific separation. However, until large series of specimens from throughout the range of both populations are compared, we believe it is best to maintain them as subspecifically distinct.

The best characters by which to distinguish *O. saurus* are given in the key to *Oligoplites* species. Berry *in* McClane (1965, p. 476) reported that the two detached anal-fin spines of *O. s. inornatus* apparently are connected with toxic glands. In south Florida *O. saurus* is commonly referred to by commercial fishermen as stinging jack. We know of no report of 'stinging' characteristics in any other species of *Oligoplites*.

Although *O. saurus* attains at least 285 mm. FL, it seldom exceeds 250 mm. In the western Atlantic it occurs as far north as the Gulf of Main (Bigelow and Schroeder, 1953, p. 381) and south at least to Recife, Brazil. It is the only species of *Oligoplites* that occurs along the coast of the United States and throughout most of the Caribbean. It has not, however, been reported from the Bahama Islands, perhaps because of the absence of suitable estuarine habitats. In the eastern Pacific *O. saurus inornatus* occurs in the Gulf of California at least to Concepcion Bay, along the outer coast of Baja California to Magdalena Bay, and south to Esmeraldas, Ecuador, and the Galápagos Islands.

MATERIAL. The specimens of *O. saurus* which we have studied are listed under the two subspecies as follows:

Oligoplites saurus saurus (71 specimens, 31–285 mm. FL, from 30 collections). GEORGIA: TABL 102643 (1: 191), 103197 (1: 236), 107781 (2: 92–98, cleared and stained). FLORIDA: UMML 39 (1: 67), 3144 (5: 51–93), 4273 (2: 47–139), 4436 (2: 90–92), 5114 (1: 116), 5628 (1: 60), 5975 (1: 73), 9597 (2: 165–185), 13123 (1: 253), 29468 (4: 211–250), TABL 102682 (1: 188), 104730 (9: 101–128), 105386 (3: 196–285), TABL uncataloged station 67–258 (4: 126–168), station 67–280 (3: 131–152). MISSISSIPPI: TABL 102644 (1: 202). LOUISIANA: TABL 102683 (1: 155). TEXAS: USNM 710 (102, holotype of *Chorinemus lanceolatus*). JAMAICA: TABL 101582 (4: 208–225). MARTINIQUE: TABL 103469 (1: 206), 105791 (3: 130–179). GRENADINE ISLAND: TABL 104420 (2: 84–98). TRINIDAD: TABL 103466 (4: 31–144), 104372 (1: 259), 105364 (4: 230–269). VENEZUELA: Carupano, TABL 103207 (3: 199–280). BRAZIL: Recife, SU 51844 (2: 192–196).

Oligoplites saurus inornatus (27 specimens, 53–257 mm. FL from 12 collections). GULF OF CALIFORNIA: TABL 103481 (6: 112–132), 103483 (7: 53–93), SIO 60–298 (2: 110–125), USNM 101037 (1: 246). BAJA CALIFORNIA: Magdalena Bay, SIO-304 (3: 104–109). MEXICO: Banderas Bay, TABL 103479 (1: 220), 103482 (1: 104). COSTA RICA: SIO H52-93 (2: 253–257). PANAMA: USNM 30959 (248, holotype of *Oligoplites inornatus*), TABL 105800 (1: 127). ECUADOR: Esmeraldas, TABL 103480 (1: 200). GALÁPAGOS ISLANDS: AMNH 8308 (2: 71–75).

Oligoplites altus (Günther).

(Figures 10c, 10d, 11; tables 4–6.)

?*Lichia albacora* GUICHENOT, 1848, p. 231 (type locality Valparaiso, Chile).

Chorinemus altus GÜNTHER, 1868, p. 433, unnumbered fig. (of head) (type locality west coast of Panama).

Oligoplites mundus JORDAN and STARKS *in* Jordan and Evermann, 1898, p. 2844 (type locality San Juan Lagoon, Mexico, mouth of Ahome River).

In the original description *Lichia albacora* was compared only with *Scomber calcar* Bloch, a probable synonym of *Oligoplites saliens*. The description, although poor, applies best to a species of *Oligoplites*. The statement "each jaw has two rows of velvet teeth" is a good description of the teeth in a young individual of *Oligoplites*, but the single type was reported to be 45 inches total length. However the following statements, also given in the description, suggest that the type was small, probably only 4.5 inches TL: "The fishermen of Valparaiso catch it on rare occasions. It seems that it is usually much larger than the one we have observed." *Lichia albacora* may have been based on a young specimen of *O. altus*. This species is known to occur farther south than the other eastern Pacific members of *Oligoplites*, and the first dorsal spine count of three may have been the result of overlooking the small, frequently depressed, first spine. The type of *Lichia albacora* could not be located in the Museum National d'Histoire Naturelle, Paris, where, if extant, it should be deposited.

Schultz (1945) regarded *Oligoplites mundus* as a distinct species, distinguished from *O. altus* on the basis of a slightly longer upper jaw. Both species were otherwise very similar, sharing a number of characters not found in other Pacific species of *Oligoplites*. Schultz had only two examples which he considered conspecific with *O. altus*, the same two specimens on which the account of the species in Meek and Hildebrand (1925, p. 388) is based. We have examined 80 specimens, including the type of *O. mundus* and Schultz's two examples of *O. altus*. However, more specimens are needed before it will be possible to resolve the systematic status of the two forms. Because we are unable to confidently assign a large number of specimens to one or the other form, we tentatively regard them as conspecific.

The species, as here defined, exhibits a more extreme range of variation in several characters than is found in other species of *Oligoplites*. Particularly striking is the range of variation in upper jaw length (see table 6). This variation is not due to sexual dimorphism; nor is it due to population differences, because specimens of approximately the same size, from the same station, exhibit the extremes in variation for several characters. Individuals with long jaws generally have deeper bodies, higher fin lobes, smaller eyes, fewer gillrakers, dorsal spines, and segmented dorsal- and anal-fin rays than do their short jawed counterparts. When any of these characters are plotted against upper jaw length (expressed as percent head length) an obvious negative or positive correlation with jaw length is apparent. It is however, impossible to separate specimens into two groups on the basis of these characters. Both forms are distinguished from their congeners in having the dorsum of the head covered with numerous

TABLE 6. *Comparison of fork length and upper jaw length (as percent head length) in* Oligoplites altus.

Fork Length Class (mm.)	Upper Jaw Length						N
	58–59.9	60–61.9	62–63.9	64–65.9	66–67.9	68–70	
100–150	—	1	3	6	—	—	10
151–199	3	5	6	4	1	3	22
200–249	2	1	3	2	3	2	13
250–299	—	1	5	3	2	3	14
300–349	—	2	—	4	1	2	9
350–380	—	—	1	3	1	1	6

sensory pores, which are connected by a network of tubes visible beneath the skin. They may also be distinguished from those species with which they occur sympatrically by their premaxillary dentition, lower number of gillrakers, and longer upper jaw (see table 5). An explanation for the wide range of variation in upper jaw length and strong correlation with several other characters in *O. altus* is a subject that requires investigation by future workers. One possibility that should be considered is that this variation is due to introgressive hybridization (see Anderson, 1949). In many of its characters the short jawed form of *O. altus* is intermediate between the long jawed form and *O. saurus inornatus.*

Oligoplites altus reaches at least 379 mm. FL and attains the greatest body depth of any *Oligoplites* species. On the basis of our material, *O. altus* occurs in the northern Gulf of California, north at least to Punta Estrella, along the outer coast of Baja California to Magdalena Bay, and south to the Gulf of Guayaquil. It has also been reported by several authors from Peru, apparently on the authority of Tortonese (1939, p. 338), who listed a single specimen from Callao.

MATERIAL (81 specimens, 27–379 mm. FL, from 36 collections). BAJA CALIFORNIA: Magdalena Bay, TABL 105541 (2: 354–372), 105544 (1: 348), SIO 62–718 (2: 259–299), 62–725 (7 of 11: 281–300). GULF OF CALIFORNIA: TABL uncataloged, Almejas Bay (2: 236–317), TABL 105534 (1: 315), 105542 (1: 355), 105543 (2: 332–354), SIO 61–180 (8: 171–199), 61–182 (1: 257), UCLA W50-46 (2: 195–209), W52-132 (1: 168), W58-48 (2: 147–149). MEXICO: San Juan Lagoon, USNM 48876 (231, holotype of *O. mundus*); Tepic, USNM 130860 (2: 122–137.5); Banderas Bay, TABL uncataloged (2: 112–114). EL SALVADOR: USNM 87338 (1: 72), TABL 104616 (1: 231). COSTA RICA: Gulf of Nicoya, TABL uncataloged (2: 292–314), UCLA W54-12 (1: 130), W54-171 (1: 138.5). GULF OF PANAMA: SIO 58–402 (3: 250–310), UCLA W58-303 (2: 189–212), W58-304 (8: 162–202), W58-305 (3: 137–155), USNM 80063 (1: 198), 82043 (1:215), 128698 (3: 27–59), 128699 (1: 83); San Miguel, TABL uncataloged (3: 178–298). COLOMBIA: Buenaventura Market, TABL uncataloged (1: 241). ECUADOR: Esmeraldas, TABL 105528 (1: 207), 105529 (2: 195–201), TABL uncataloged (1: 220); Gulf of Guayaquil, TABL 107260 (2: 379), TABL uncataloged (6: 222–337).

Oligoplites palometa (Cuvier).

(Figures 9b, 11, 19; tables 4–5.)

Chorinemus palometa Cuvier *in* Cuvier and Valenciennes, 1831, p. 392 (288) (type locality Lake Maracaibo, Venezuela).

?*Chorinemus guaribira* Cuvier *in* Cuvier and Valenciennes, 1831, p. 393 (289) (type locality Brazil).

This western Atlantic species is very closely related to the eastern Pacific *O. altus.* Both species are separable from other forms of *Oligoplites* on the basis of their premaxillary dentition, which consists of a band of villiform teeth along entire length of premaxilla, wide anteriorly, becoming narrow posteriorly. Superficially they are very similar, although *O. altus* is generally a more deep-bodied fish. The only character that will separate these two species is the relative development of cephalic pores. Reduction of cephalic pores in *O. palometa* suggest that it is the more specialized of the two species.

Oligoplites palometa is a large species, attaining at least 392 mm. FL. It occurs from Lake Yzabal, Guatemala, south to São Paulo, Brazil.

Material (42 specimens, 84–392 mm. FL, from 22 collections). GUATEMALA: Lake Yzabal, USNM 13480 (1: 139). NICARAGUA: AMNH 19027 (18: 84.5–160), USNM 44205 (3: 329–268), 45373 (1: 348), 45374 (1: 317), 45375 (1: 304). GULF OF VENEZUELA: USNM 121803 (1: 344), 121804 (1: 245), 121805 (2: 241–303), 121806 (1: 133.5). BRAZIL: USNM 100817 (1: 342), 100847 (1: 392), 100851 (1: 297), SU 66978 (1: 141); Rio Para, SU 53059 (1: 248), 53060 (1: 219), 53061 (1: 222); Salvador (Bahia), SU 53054 (1: 335); Recife, SU 53058 (1: 305), 67028 (1: 334); São Paulo, SU 67007 (1: 171), 67014 (1: 228).

Parona Berg, 1895

Paropsis Jenyns, 1842, p. 65 (type-species: *Paropsis signatus* Jenyns, 1842, by monotypy).

Parona Berg, 1895, p. 39 (substitute name for *Paropsis* Jenyns, 1842, preoccupied, and, therefore, taking the same type species: *Paropsis signatus* Jenyns, 1842).

This monotypic genus is restricted to subtropical and temperate waters of the south Atlantic from Brazil to southern Argentina. Almost nothing has been published on the biology of *Parona,* although the genus is reported (Evermann and Kendall, 1906, p. 99) to be very common along the whole coast of Argentina, and caught at Montevideo, Uruguay, during certain times of the year in enormous quantities. The unusual lateral line with 5–9 dorsal branches, the deep, compressed body, and the lack of pelvic fins suggest that their ecology differs from that of most carangids. Norman (1937, p. 59) reported six specimens, 465–600 mm. SL, caught by otter trawl in 51–56 m.; these specimens are the largest examples known to us. Nothing on the osteology of *Parona* has been published previously.

DESCRIPTION. Body strongly compressed. Adipose eyelids poorly developed. Body, except head, covered with oval-shaped scales. Lateral-line scales not developed into scutes. Lateral line with 5–9 dorsal branches; horizontal portion of lateral line straight except for moderate curve over pectoral fin. Anterior rim of shoulder girdle smooth, without fleshy papillae or deep groove near isthmus. Premaxillae not protractile, connected anteriorly to snout at midline by a narrow fleshy bridge. Swimbladder simple, not bifid posteriorly. Posterior dorsal- and anal-fin rays not consisting of semidetached finlets; ultimate and penultimate rays no more closely spaced than adjoining rays; none of dorsal- or anal-fin rays produced into long filaments. Pelvic fins absent. Pectoral fins short, not falcate, 60.0 to 67.0 percent head length in adults. Upper jaw extending posteriorly from slightly behind (young) to well behind (adult) orbital rim, 52.6 to 57.0 percent head length in adults. Depth (origin D_2 to A_2) 37.4 to 44.0 percent fork length in adults.

Predorsal bones 4; dorsal-fin rays VI-VII (rarely VII) + I, 32 to 37; total dorsal-fin rays 39–44. Anal-fin rays II + I, 34 to 38. Pectoral-fin rays I, 19–21. Pelvic fins absent. Vertebrae 10 + 17 = 27, epipleural ribs 10 or 11. Branchiostegal rays 3 + 6 (epihyal + ceratohyal). Upper gillrakers 4 to 8; lower gillrakers 15 to 17; total gillrakers 20 to 24.

Fronto-supraoccipital crest high; temporal crest extending nearly straight forward to front of the frontal; preorbital region short. Epiotics broadly united along midline of cranium internally. Zygapophyses of exoccipital united beneath foramen magnum. Parasphenoid not expanded into a broad, flattened plate posteriorly. Myodome with broad, posterior opening. Basioccipital without a pair of lateral processes on ventral surface. Ascending process of premaxilla short and triangular; maxilla and premaxilla relatively broad, not closely attached to premaxilla. Premaxillary spur very reduced, consisting of only a slight bulge. Large supramaxilla present. Interosseous space between dorsal arm of dentary and upper margin of articular well developed. Well developed teeth on dentary, premaxilla, palatines, and vomer; dentary and premaxillary teeth conical, arranged in a narrow band anteriorly becoming a single row posteriorly; symphyseal premaxillary and dentary teeth of juveniles slender and caniniform. Mesopterygoids partially covered by a patch of free-floating granular teeth. Pharyngeals not noticeably enlarged, covered with sharp, pointed teeth.

FIGURE 12. *Parona signata*, USNM 87730, 335 mm. FL.

Suborbital shelf present; lower and posterior suborbitals not expanded posteriorly to cover a large portion of cheek. Basibranchials 1–3, each with a large, median tooth plate. Lower limb of posttemporal not noticeably short or thickened. Postcoracoid process well developed. Inter-pelvic keel absent; postpelvic process of each side coalesced entire length, not forming an apical fork. Inferior vertebral foramina absent. First anal pterygiophore and haemal spine of first caudal vertebra firmly attached to form a strong strut. Anal pterygiophore not expanded anterolaterally to form roof over first two anal spines; first two anal spines not articulated proximally with each other; second anal spine symmetrical, without deep groove on one side of anterior face. Caudal skeleton with 2 epurals and 2 pairs of uroneurals.

Parona signata (Jenyns).

(Figures 12, 14a, 15a, 16a, 20a, 21a, 22a, 23a, 24d, 25a.)

Paropsis signatus JENYNS, 1842, p. 66, pl. 13 (type locality Bahia Blanca, coast of northern Patagonia).

DESCRIPTION. Since *Parona* is monotypic, refer to generic description.

PIGMENTATION. Most specimens of *Parona signata* have a conspicuous elongate, horizontal, black blotch on sides beneath pectoral fins, which may also extend onto base of ventral third of pectoral fin. In a few specimens this blotch is short and almost completely hidden by the pectoral fin; it is completely absent in 7 small specimens (TABL 102908) from Argentina. A small round spot at the dorsal origin of the pectoral fin is present on all specimens. Also present on all specimens is a dusky blotch on dorsal third of opercle, heavily pigmented areas, slightly larger than pupil, on either side of snout that are separated at dorsum by paler region, and concentration of pigment at tip of lower jaws. Jenyns (1842, p. 67) reported the life colors as "uniform bright silvery, the ridge of back bluish: a patch of black on the gill-cover, and another under the pectoral fin."

Distribution. Southern Brazil to southern Argentina. Apparently restricted to western Atlantic Ocean. Reported from Chile "Blacino del Rio Santa Cruz" (Fowler, 1945, p. 70), but this record needs verification. The same locality is generally listed as being in Argentina.

Material (20 specimens, 75–368 mm. FL, from 11 collections). BRAZIL: TABL 107713 (2: 358–368); Florianopolis, SU 53052 (1: 264), 53053 (1: 360); Port of Rio Grande do Sul, SU 51868 (2: 171–192). URUGUAY: USNM 87730 (2: 312–335), 86715 (1: 148 mm. SL, cleared and stained); Montevideo, USNM 77375 (1: 135), 86689 (1: 298). ARGENTINA: USNM 53441 (1: 289); Buenos Aires, TABL 101156 (1: 270); Mar del Plata, TABL 102908 (7: 75–84, 3 cleared and stained).

Hypacanthus Rafinesque, 1810

Hypacanthus Rafinesque, 1810, p. 43 (type-species: *Centronotus vadigo* Lacépède, 1802 = *Scomber amia* Linnaeus, 1758, by present designation).

Lichia Cuvier, 1817, p. 321 (type-species: *Scomber amia* Linnaeus, 1758, by monotypy).

Porthmeus Valenciennes *in* Cuvier and Valenciennes, 1833, p. 255 (190) (type-species: *Porthmeus argenteus* Valenciennes, 1833, by original designation).

This monotypic genus is restricted to subtropical and temperate waters of the Mediterranean, eastern Atlantic, and southern Indian Ocean. The habitat of *Hypacanthus* is littoral (Poll, 1954, p. 160) ". . . judging by the origins of specimens—collections and total absence of this species from catches of trawls." Along the west African Gold Coast small specimens of *Hypacanthus* are caught in seines, but uncommonly, and they are taken with lines from January to April (Norman and Irvine, 1947, p. 144). Smith (1949, p. 222) states that it "grows to at least 6 feet and is one of the finest game fishes, fighting fiercely to the end; prefers live or moving bait, enters estuaries, and may often be seen in pursuit of mullet on the surface." Superficially *Hypacanthus* most closely resembles *Scomberoides* but differs in having scaled cheeks and a lateral line that is very irregular and sinuous, dropping below midline of body between pelvic fins and origin of anal fin. Nothing on the osteology of *Hypacanthus* has been published previously.

Nomenclature. In his paper on the nomenclature of the European fishes of the subfamily Trachinotinae, Wheeler (1963) clearly demonstrated that *Hypacanthus* is a senior synonym of *Lichia* but chose to regard the older name as a *nomen oblitum* and advocated suppression of the name. We do not believe that this action is justified and continue to recognize *Hypacanthus*. In so doing we have taken special note of the fact that the name *Hypacanthus* has always been correctly applied, while fishes belonging to at least four different carangid genera have been described as new species of *Lichia*.

In the generic diagnosis of *Hypacanthus*, Rafinesque referred to only two species. One of these species, *Centronotus vadigo* Lacépède, is clearly a synonym of *Scomber amia* Linnaeus and is here designated the type-species of *Hypacanthus*. The other reference was to "*Scomber aculeatus* di Linnaeus." As noted by Wheeler (1963, p. 535), the species does not seem to exist in Linnaeus's works and it might be argued that Rafinesque wrote "di Linnaeus" in error for *S. aculeatus* Bloch (1793). Bloch's illustration strongly suggests a species of *Oligoplites* or *Scomberoides*, and several workers have followed Cuvier and Valenciennes (1831, p. 384) in questionably regarding *S. aculeatus* Bloch as a species of *Chorinemus* (=*Scomberoides*). We concur with Wheeler (1963, p. 537) that it is a junior synonym of *Hypacanthus amia* (Linnaeus). Bloch's illustration shows a fish with 7 first dorsal spines (which does not agree with *Oligoplites*), and the species is reported from the Mediterranean where neither *Oligoplites* or *Scomberoides* occurs.

The illustration of *Porthmeus argenteus* Valenciennes (see fig. 13) is unmistakably based on a young individual of *Hypacanthus amia*.

DESCRIPTION. Body moderately to strongly compressed. Adipose eyelids developed. Body, including cheeks, covered with narrow, oval-shaped embedded scales, becoming needlelike on breast. Lateral-line scales not developed into scutes. Lateral line without side branches, very irregular and sinuous, dropping below midline of body between pelvic fins and origin of anal fin. Anterior rim of shoulder girdle smooth, without fleshy papillae or deep groove near isthmus. Premaxillae protractile, separated anteriorly from snout at midline by a complete groove. Swimbladder moderately bifid (in adults), bifurcated portion of swimbladder extending posteriorly to beneath caudal vertebra 6 or 7. Posterior dorsal- and anal-fin rays not consisting of semidetached finlets; ultimate and penultimate rays no more closely spaced than adjoining rays; none of dorsal- or anal-fin rays produced into long filments. Pelvic fins relatively short, not depressible into shallow abdominal groove. Pectoral fins short, not falcate, 51.2 to 63.4 percent head length. Maxilla extends posteriorly to slightly behind orbital rim, 50.5 to 54.2 percent head length. Body depth (origin D_2 to A_2) 31.0 to 39.4 percent fork length.

Predorsal bones 3; dorsal fin rays VII + I, 19–21; total dorsal rays 27–29. Anal-fin rays II-I, 17–20. Pectoral-fin rays I, 18–20. Pelvic-fin rays I, 5. Vertebrae 10 + 14 = 24; epipleural ribs 10 or 11. Branchiostegal rays 2½ + 5½ (epihyal + ceratohyal). Upper gillrakers 1 or 2; lower gillrakers 8 or 9; total gillrakers 9 to 11.

Fronto-supraoccipital crest low; temporal crest poorly developed, not extending forward to posterior rim of orbit and not reaching edge of cranium; preorbital region short. Epiotics not united along midline of cranium internally. Zygapophyses of exoccipital united beneath foramen magnum. Parasphenoid not expanded into a broad, flattened plate posteriorly. Myodome with broad, posterior opening. Basioccipital without a pair of lateral processes on ventral surface. Ascending process of premaxilla short and triangular; maxilla moderately slender, not closely applied to premaxilla. Premaxillary spur absent. Small supramaxilla present. Interosseous space between dorsal arm of dentary and upper margin of articular moderate. Well developed teeth on dentary, premaxilla, palatines, and vomer; dentary and premaxillary teeth slender and pointed, arranged in a broad band anteriorly becoming narrower posteriorly; juveniles without symphyseal premaxillary and dentary canines. Mesopterygoids edentate. Pharyngeals not noticeably enlarged, covered with sharp, pointed teeth.

Suborbital shelf present; lower and posterior suborbitals not expanded posteriorly so as to cover a large portion of cheek. First basibranchial without tooth plates, basibranchials 2–3 each with a pair of small widely separated tooth plates. Lower limb of posttemporal not noticeably short or thickened. Postcoracoid process moderate. Interpelvic keel well developed; postpelvic process on each side not coalesced entire length, forming an apical fork. Inferior vertebral foramina present. First anal pterygiophore and haemal spine of first caudal vertebra firmly attached to form a strong strut. Anal pterygiophore not expanded anterolaterally to form roof over first two anal spines; first two anal spines not articulated proximally with each other; second anal spine slightly asymmetrical, with shallow depression on one side of anterior face. Caudal skeleton with 3 epurals and two pairs of uroneurals.

Hypacanthus amia (Linnaeus).

(Figures 13, 14b, 21b, 22b, 24a.)

Scomber amia LINNAEUS, 1758, p. 299 (based solely on references to Artedi, 1738).
Scomber aculeatus BLOCH, 1793, p. 51, pl. 336, fig. 1 (type locality: no specific locality given; reported from coast of Mediterranean and several localities in Caribbean).
Centronotus vadigo LACÉPÈDE, 1802, p. 318 (type locality Mediterranean).
Porthmeus argenteus VALENCIENNES *in* Cuvier and Valenciennes, 1833, p. 256 (191), pl. 264 (type locality Cape of Good Hope).

NOMENCLATURE. Wheeler (1963, pp. 536–7) gives a detailed discussion of the specific synonymy of *Hypacanthus*. Some additional comments are given in the preceding generic account.

DESCRIPTION. Since *Hypacanthus* is monotypic, refer to generic description.

PIGMENTATION. The young, to at least 120 mm. FL, have prominent vertical bands (fig. 13). Judging from a color illustration of a 2½ inch specimen (Smith, 1949, pl. 25, fig. 539), the bands are brownish-black and the background coloration is yellow-orange. Adults are brown dorsally, silvery white below the lateral line, and have pale brown fins.

DISTRIBUTION. Mediterranean, eastern Atlantic, and Indian Ocean north

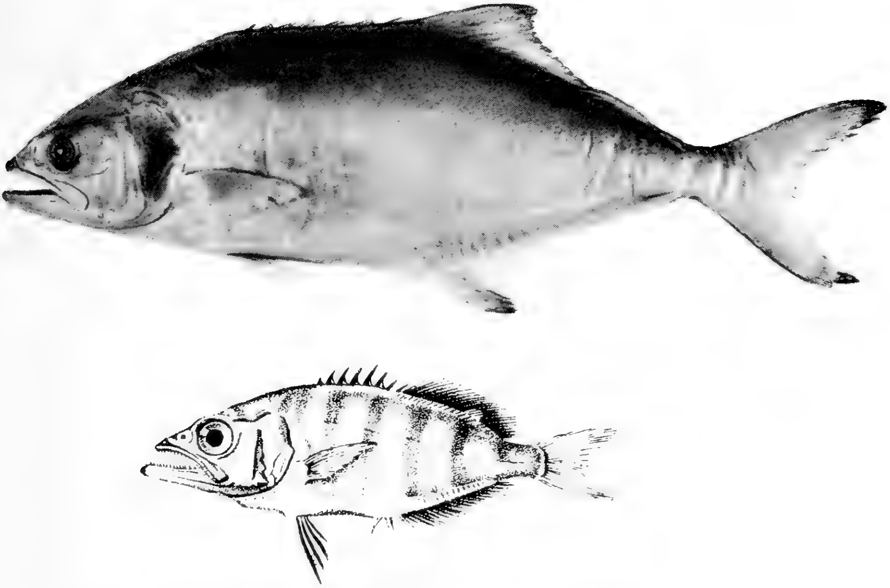

Figure 13. *Hypacanthus amia*: above, TABL 104703, young adult, 200 mm. FL; below, drawing of holotype of *Porthmeus argenteus* = juvenile *H. amia* (after Cuvier and Valenciennes, 1833, pl. 264).

to Delago Bay, Mozambique. The littoral habitat, general occurrence in subtropical and temperate waters and absence of *Hypacanthus* from most of the Indian Ocean indicates that the Indian Ocean distribution of *Hypacanthus* is the result of migration around the Cape of Good Hope.

Material (24 specimens, 62–202 mm. FL, from 5 collections). MEDITERRANEAN: Lebanon, St. George Bay, TABL 104703 (5: 62–200, 1 cleared and stained), 104714 (15 of 30: 79–110, 2 cleared and stained). LIBERIA: Mesurado River, USNM 193783 (1: 202), 193813 (1: 82). SOUTH AFRICA: Durban Harbor, TABL 107250 (2: 190).

Relationships and Zoogeography

Genera *Scomberoides* and *Oligoplites*.

The strong external resemblance and large number of characters shared by *Scomberoides* and *Oligoplites* clearly reflect their intimate relationship, and they are usually placed together in their own subfamily—the Scomberoidinae (=Chorineminae). Some of the more notable shared characters are the following: scales lanceolate or needlelike (fig. 3); the posterior segmented dorsal- and anal-fin rays consisting of semi-detached finlets; two distinct types of dentary

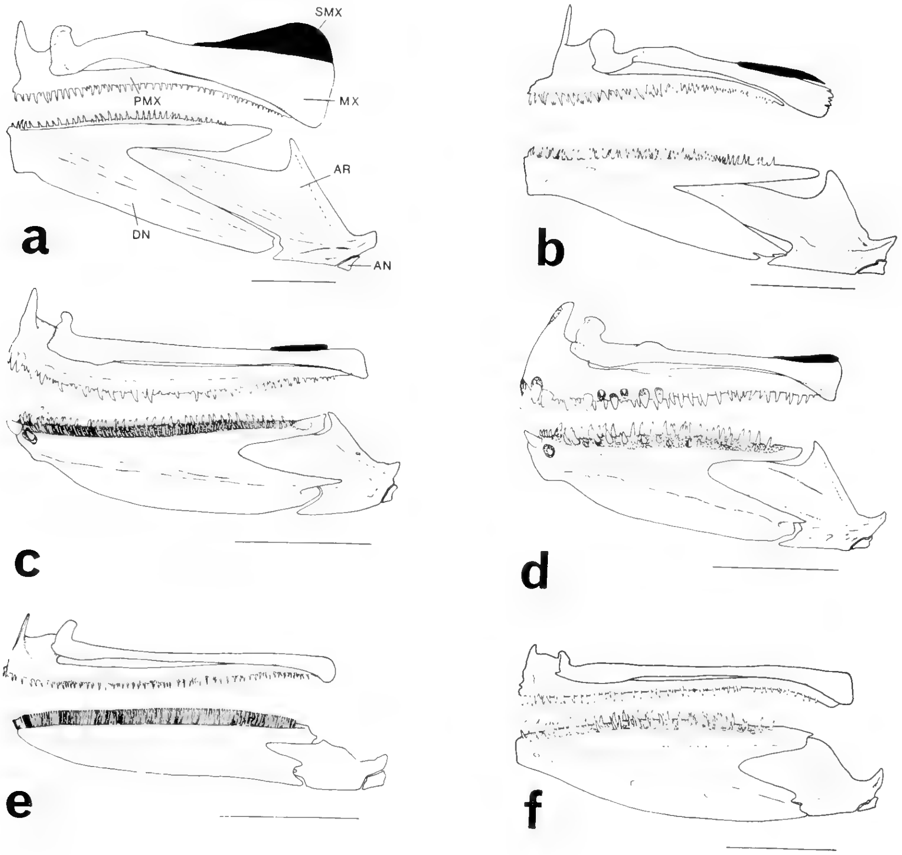

FIGURE 14. Jaw bones: a, *Parona signata*, USNM 86715, 148 mm. SL; b, *Hypacanthus amia*, TABL 104714, 100 mm. SL, c, *Scomberoides commersonianus*, GVF 2195, 86 mm. SL; d, *S. tol*, TABL uncataloged S-V 69–128, 107 mm. SL; e, *Oligoplites s. saurus*, TABL 107781, 91.5 mm. SL; f, *O. saliens*, SU 66973, 122 mm. SL. DN, dentary; AR, articular; AN, angular; PMX, premaxilla; MX, maxilla; SMX, supramaxilla. Scale 5.0 mm.

teeth during different stages of their ontogeny (see discussion below); slender, nearly straight maxillae that are closely applied to the premaxillae; a broad premaxillary frenum; interosseous space between dorsal arm of dentary and upper margin of articular minute or absent (fig. 14); the first anal pterygiophore expanded anterolaterally, forming a roof over anal spines (fig. 15b); the first two anal spines articulated proximally with each other, and the second anal spine asymmetrical with a deep groove on one side of anterior face, so that when anal spines are depressed the first spine folds into the groove in scissor-like fashion; caudal skeleton with 2 epurals (fig. 16b); swimbladder strongly

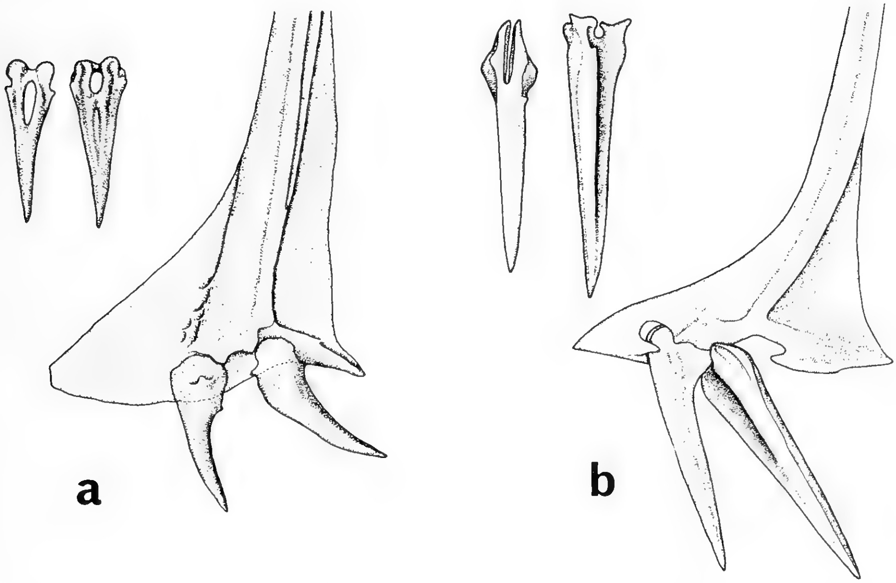

FIGURE 15. First anal pterygiophore: a, *Parona signata*, TABL 102908, 80 mm. SL; b, *Scomberoides tala*, TABL S-V 69–156, 109 mm. SL.

bifid, even in smallest specimens (fig. 17). All of these conditions probably represent specializations.

Each dentary has two rows of teeth in *Scomberoides* and *Oligoplites*. In most species (exceptions are *S. tol* and *O. saliens*) the outer dentary teeth of juveniles and young adults have spatulate tips, and are closely spaced and strongly hooked outward (fig. 18). This arrangement produces a trough between the inner and outer rows of teeth into which the premaxillary teeth fit when the mouth is closed. In adults these outer 'juvenile teeth' are shed and replaced with more robust, wider spaced teeth that are not strongly hooked and have pointed tips (figs. 18–19). The inner dentary teeth, consisting of a single type, apparently are permanent. We know of no other carangid genus in which there are two distinct types of dentary teeth associated with ontogeny. Since this unusual adaptive feature is shared by both *Scomberoides* and *Oligoplites*, we believe the character was possessed by the progenitor of both genera and its loss in *S. tol* and *O. saliens* must be interpreted as a subsequent specialization. Major (1973) has correlated this change in dentition in *Scomberoides lysan*, *Oligoplites refulgens*, and *O. saurus inornatus* with a shift in feeding habits. Juveniles and young feed primarily on larval crustaceans, and on scales and epidermis of schooling fishes. He suggested that the outer spatulate dentary teeth are inserted under the scales, which are then ripped off. With growth and loss of 'juvenile'

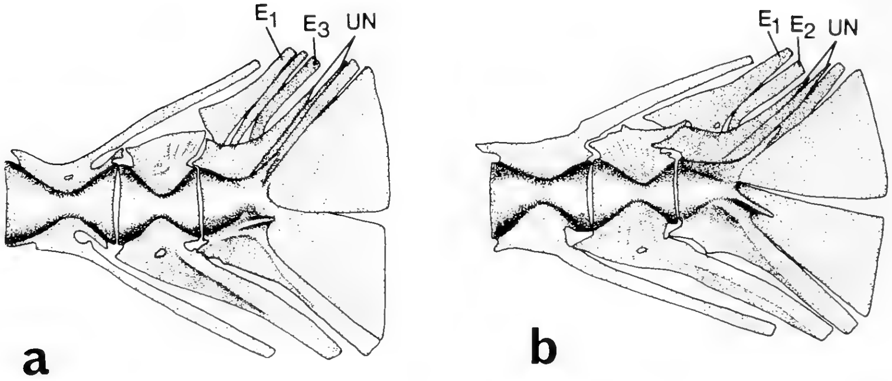

FIGURE 16. Caudal skeleton: a, *Parona signata*, USNM 86715, 148 mm. SL; b, *Scomberoides commersonianus*, GVF 2195, 86 mm. SL. E, epural; UN, uroneural.

teeth there is a gradual shift in diet until these species become fully piscivorous, ingesting whole fish. In juveniles of all species of *Scomberoides* except *S. lysan* the symphyseal dentary and premaxillary teeth are robust and caninelike (figs. 14c–d). Such teeth are greatly reduced or absent in the adults; they are never present in *Oligoplites*.

Carr and Adams (1972) found that ectoparasites, primarily caligoid co-

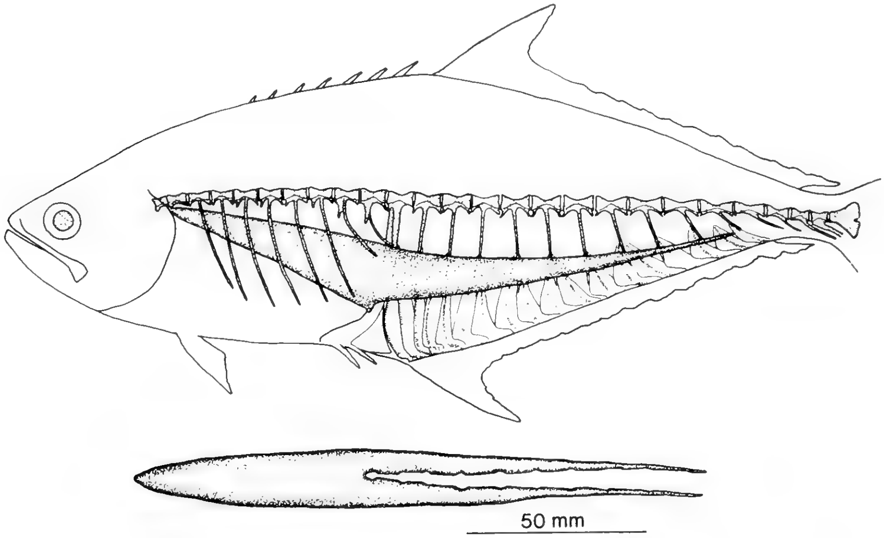

FIGURE 17. Lateral and ventral view of swimbladder of *Scomberoides tala*, TABL 107712, 264 mm. FL.

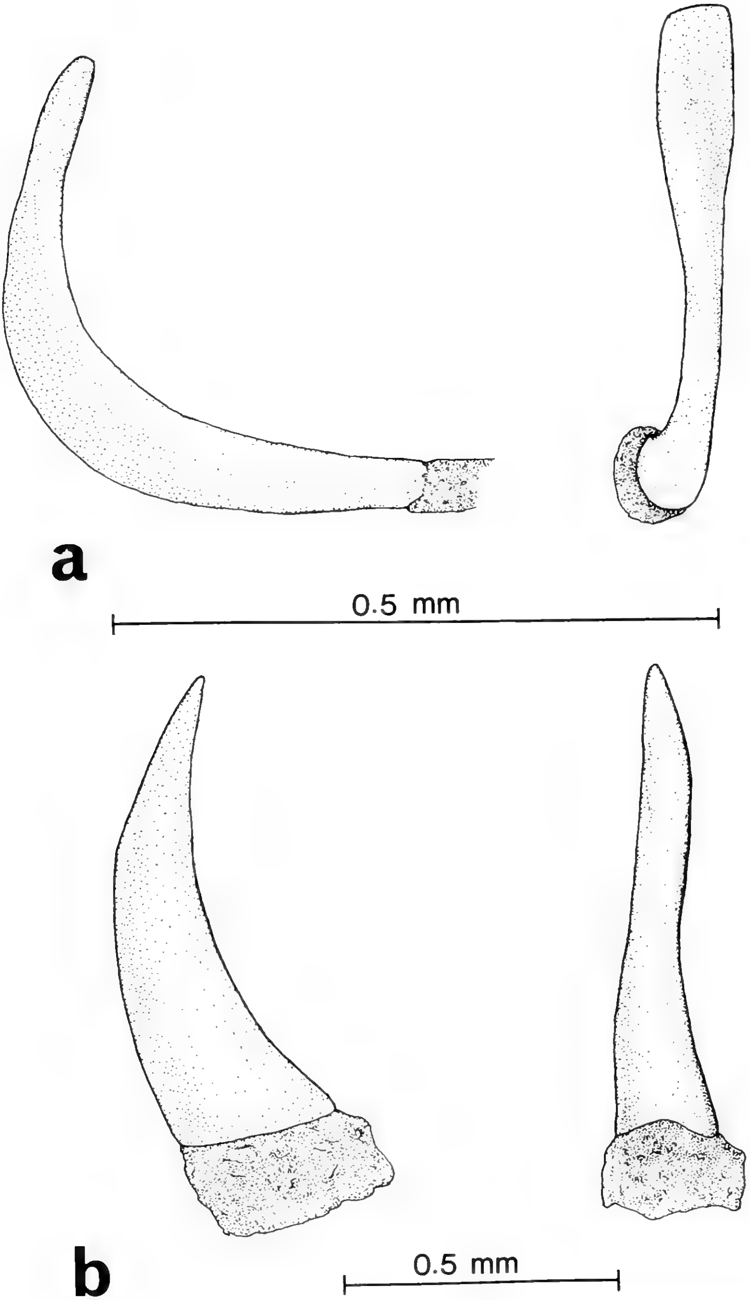

FIGURE 18. Lateral and frontal view of outer row, dentary tooth of *Oligoplites s. saurus*: a, juvenile 90 mm. FL; b, adult 185 mm. FL.

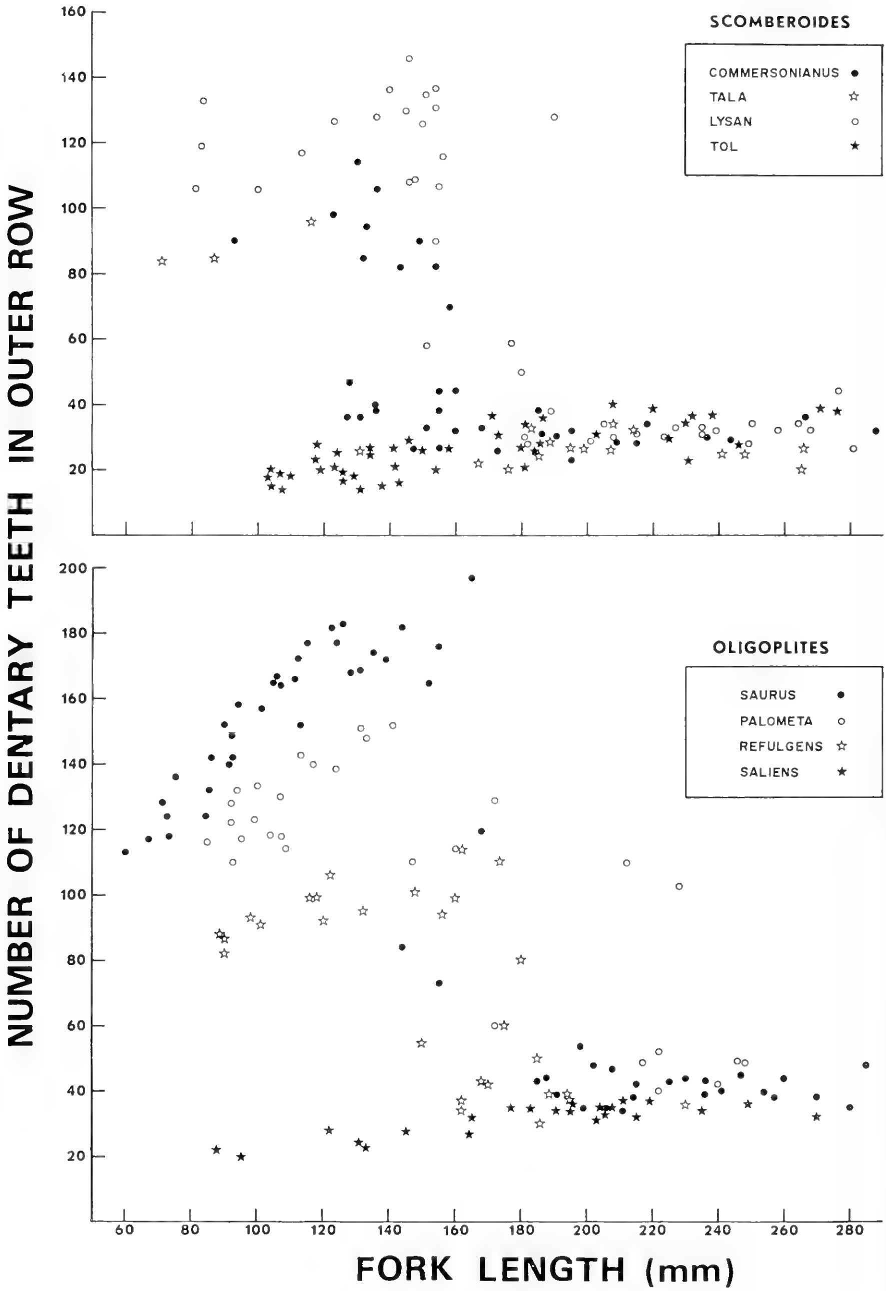

FIGURE 19. Scatter diagram of outer row teeth on dentary (one side) plotted against fork length for species of *Scomberoides* and *Oligoplites* (*O. altus* and eastern Pacific specimens of *O. saurus* were not plotted).

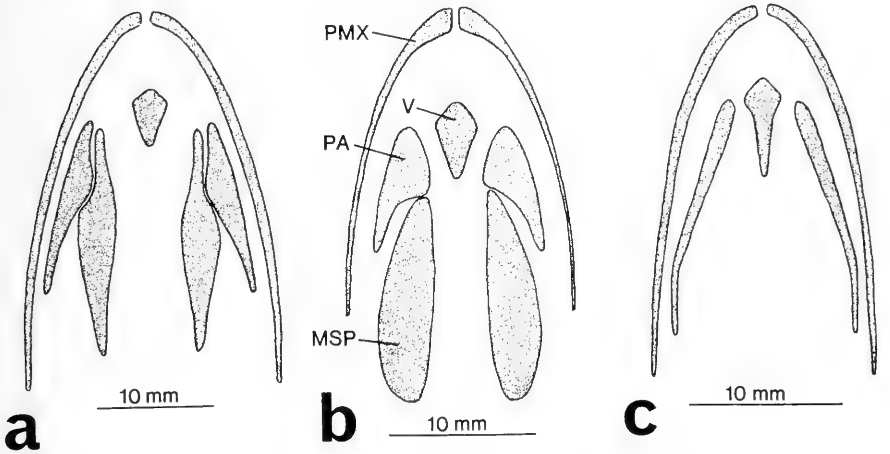

Figure 20. Upper dentition: a, *Parona signata*, TABL 101156, 271 mm. FL; b, *Scomberoides tol*, TABL 107707, 284 mm. FL; c, *Oligoplites s. saurus*, TABL 105364, 230 mm. FL. PMX, premaxilla; V, vomer; PA, palatine; MSP, mesopterygoid.

pepods, accounted for approximately 50 percent of the stomach contents of juveniles of *Oligoplites s. saurus* 26 to 40 mm. SL. In contrast, ectoparasites constituted only 2 to 4 percent of the stomach contents in fish less than 26 mm. or greater than 60 mm. SL. Although no feeding observations were made, they postulated that this carangid passes through a stage in its development in which intentional removal of ectoparasites from other fishes is an important activity. Most of the fish skin, flesh, and scales found in the stomachs of juveniles was presumed to have come from cleaning activities. Major (1973) believed that scales and/or epidermal tissue was the primary food source sought by juveniles of *Scomberoides lysan* in Hawaii. His analysis of the stomach contents of *Oligoplites* juveniles is inconclusive, since the smallest specimen examined was 48 mm. SL. If the conclusions regarding the primary food source sought by juveniles of *Oligoplites* and *Scomberoides* are valid, they may provide valuable insight into the evolution of cleaning symbiosis in fishes. Ectoparasite removal seems to be a more specialized type of feeding than is aggressive scale ingestion, although one that might easily have evolved from the latter activity.

The following characters of *Oligoplites* are interpreted as specializations of the condition found in *Scomberoides* and suggest that the amphi-American endemic distribution of *Oligoplites* is a relatively recent evolutionary development (this does not necessarily imply that the genus evolved elsewhere): 1) reduced number of dorsal spines with a concomitant increase in number of predorsal bones (see discussion under Characters and Methods Section); 2) loss of mesopterygoid teeth (fig. 20c); 3) loss of supramaxilla; 4) loss of suborbital

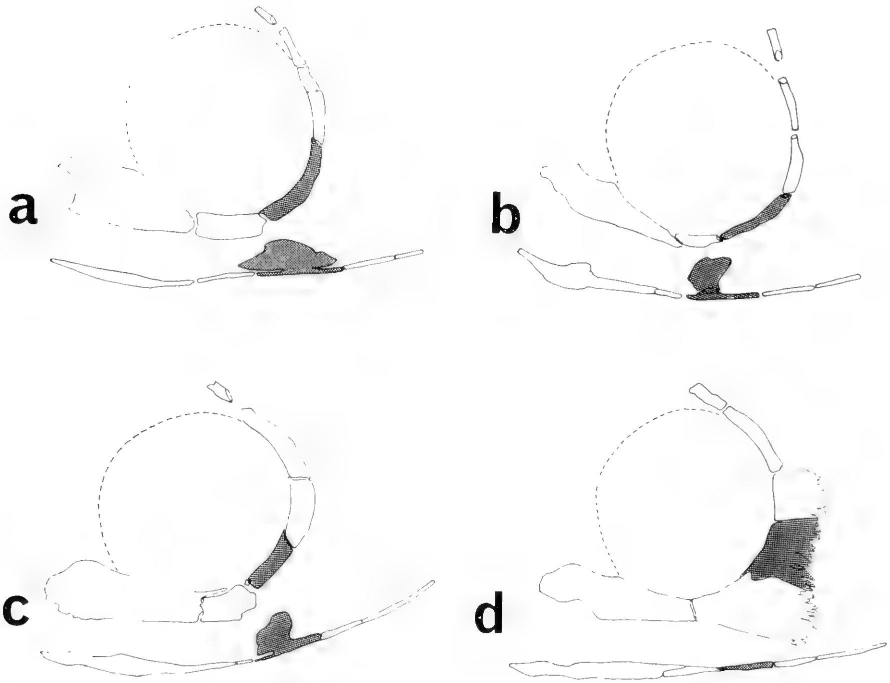

FIGURE 21. Lateral and dorsal view of suborbital bones: a, *Parona signata* TABL 102908, 83 mm. SL; b, *Hypacanthus amia*, TABL 104714, 100 mm. SL; c, *Scomberoides tol*, TABL S-V 69–128, 122 mm. SL; d, *Oligoplites s. saurus*, TABL 107781, 91.5 mm. SL. Third suborbital bone shaded.

shelf (Smith and Bailey, 1962) and expansion of suborbitals 2–4 posteriorly across cheek (fig. 21d), a character best developed in large specimens; 5) reduction in number of branchiostegal rays (fig. 22d); and 6) presence of needlelike scales in all species. Steps in the evolution from broadly lanceolate to needlelike scales can be seen in figure 3.

We believe that *Oligoplites* evolved from a *Scomberoides*-like ancestor that reached the New World via the Pacific. Although the East Pacific Barrier restricts the distributions of many groups of tropical shorefishes (Briggs, 1961), it is not such a formidable obstacle to carangids as evidenced by the relatively

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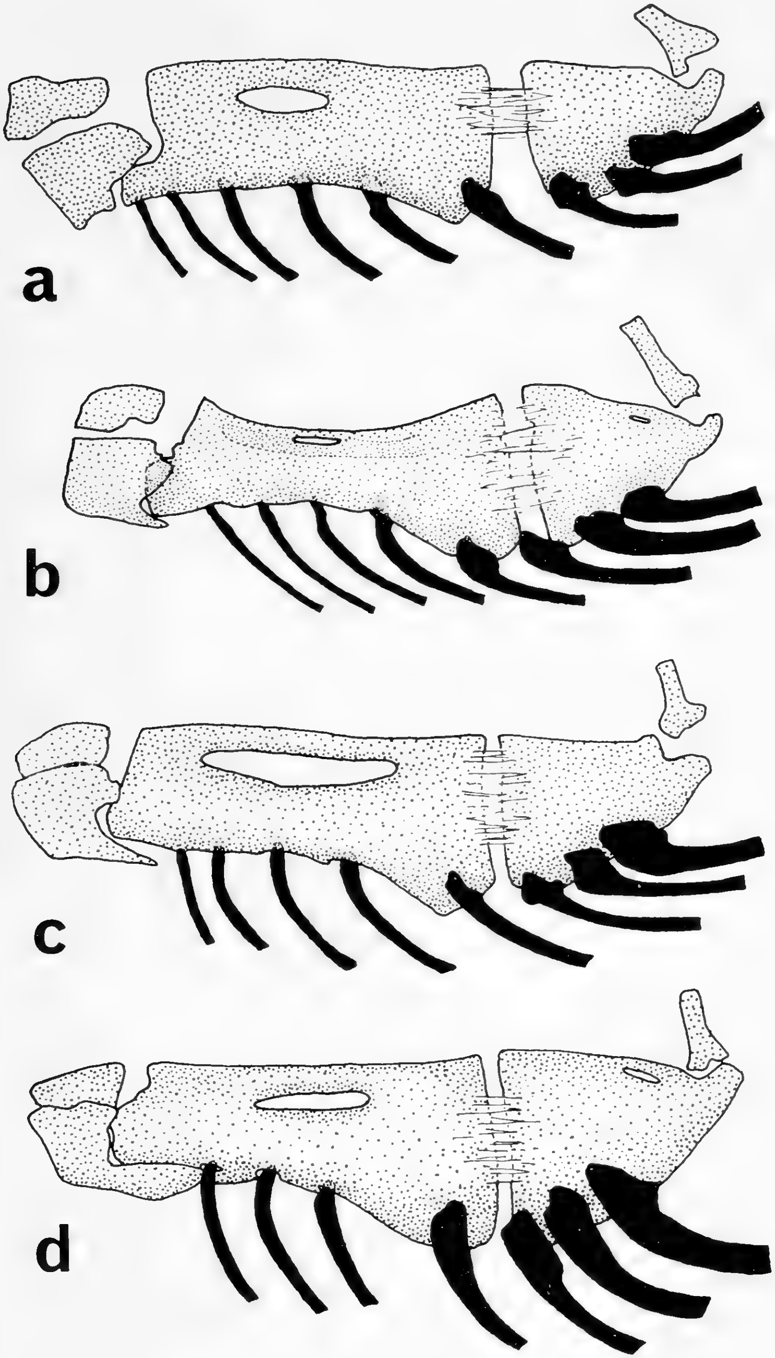
FIGURE 22. Left hyoid arch; branchiostegal rays shown in black: a, *Parona signata*, USNM 86715, 148 mm. SL; b, *Hypacanthus amia*, TABL 104714, 100 mm. SL; c, *Scomberoides tol*, TABL S-V 69–128, 122 mm. SL; d, *Oligoplites s. saurus*, TABL 107781, 91.5 mm. SL.


a
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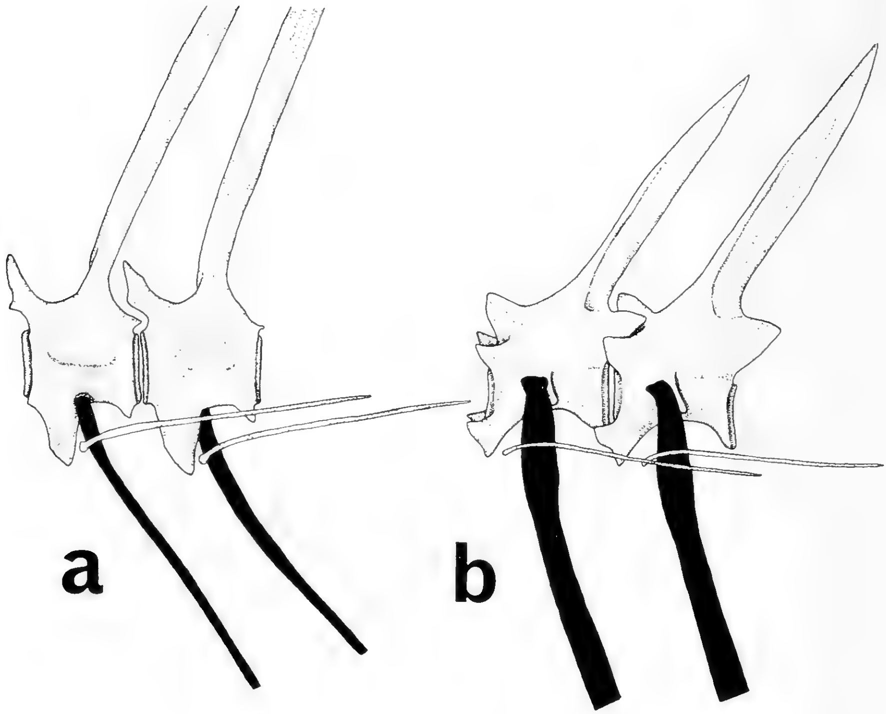

FIGURE 23. Fifth and sixth precaudal vertebrae (pleural ribs are shown in black): a, *Parona signata*, TABL 102908, 80 mm. SL; b, *Scomberoides commersonianus*, GVF 2195, 86 mm. SL.

large number of circumtropical genera and species. One widely distributed Indo-West Pacific carangid, *Caranx* (*Gnathanodon*) *speciosus* (Forskål), that has become established in the eastern Pacific appears to be a recent migrant across this several thousand mile stretch of open ocean. The wide distribution of *Scomberoides lysan* in the central Pacific demonstrates that this group of carangids also has the ability to cross large stretches of oceanic water. Given this potential, it is not difficult to envision successful bridging of the East Pacific Barrier by a *Scomberoides*-like carangid. As previously noted, the nature of the characters that differentiate *Oligoplites* from *Scomberoides* indicates a relatively recent evolutionary separation. This suggests that by the time the progenitor of *Oligoplites* reached the new world it possessed most of the characters present in *Scomberoides*.

Although inconclusive, the known fossil carangid record supports the above hypothesis. Middle Eocene deposits from Monte Bolca near Verona, Italy contain a fairly rich carangid fauna (Blot, 1969) but no *Oligoplites*-like fossil has

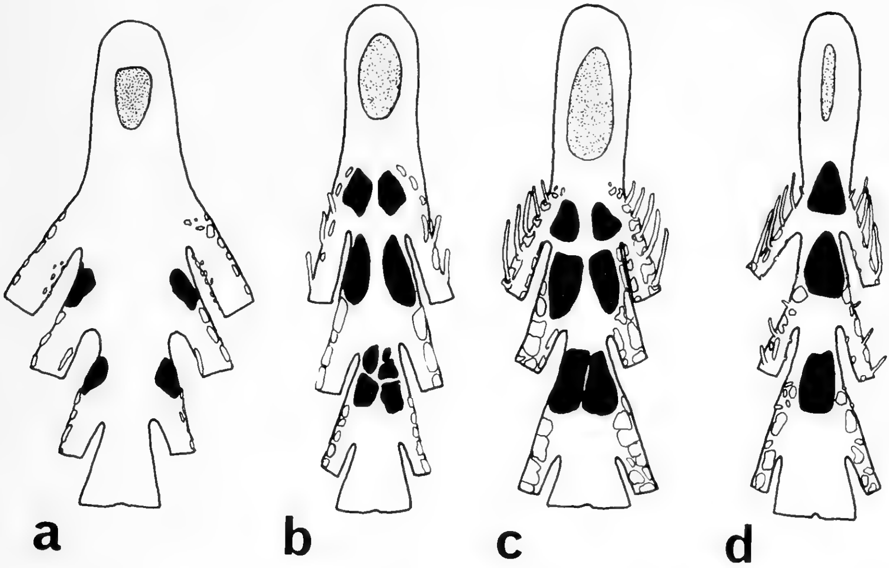

Figure 24. Basibranchial tooth plates (shown in black) and basihyal teeth (stippled): a, *Hypacanthus amia*, TABL 104714, 100 mm. SL; b, *Scomberoides tala*, TABL S-V 69–156, 109 mm. SL; c, *Oligoplites saliens*, SU 66973, 122 mm. SL; d, *Parona signata*, TABL 102908, 80 mm. SL.

been found. The only record of a fossil *Oligoplites* outside the new world appears to have been based on a misidentification (see discussion of *Scomberoides spinosus*).

Genus *Parona*.

Parona parallels *Scomberoides* (and *Oligoplites*) in several of its specialized characters, has others not found elsewhere in the Carangidae, and shares with *Hypacanthus* and *Trachinotus* a number of generalized (primitive) characters that have become specialized in the Scomberoidinae. Characters that suggest affinity with *Scomberoides* are the broadly united epiotics, high number of caudal vertebrae, fusion of the basibranchial tooth plates and presence of a premaxillary frenum. In having the epiotics broadly united internally, *Parona* possesses a character utilized by Starks (1911) and Suzuki (1962) in defining the subfamily Scomberoidinae. The shape of the precaudal vertebrae and the position of attachment of the pleural ribs is very different from the condition in *Scomberoides* (fig. 23). This is probably due to differences in body shape however, because *Parona* and *Trachinotus ovatus* (Linnaeus), which have considerably deeper bodies than do the species of *Scomberoides*, have precaudal vertebrae that are nearly identical.

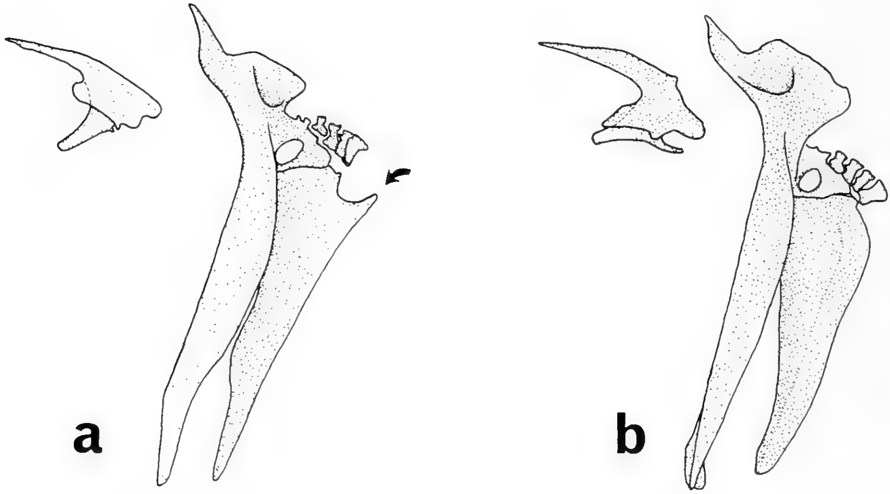

FIGURE 25. Posttemporal, clavicle, hypercoracoid, hypocoracoid, and radials (arrow points to postcoracoid process): a, *Parona signata*, TABL 102908, 80 mm. SL; b, *Scomberoides commersonianus*, GVF 2195, 86 mm. SL.

Nelson (1969, p. 500) noted that there are three pairs of basibranchial tooth plates in *Chorinemus*, and the median plates of *Parona* (fig. 24d) must have arisen through fusion of such paired elements (his "*Chorinemus occidentalis*" = *Oligoplites s. saurus*). He also stated (p. 502) that "jaw protrusion and pharyngeal-bone mobility seem to be improvements, and shearing and grinding jaw dentitions are specializations, inversely correlated with basibranchial dentition. The large paired plates (and their median derivatives, e.g., in *Parona*) that in some cases occur over the basibranchials of teleosts could represent a reversal in the general trend toward loss of basibranchial dentition. Functionally, this reversal would mean that the basibranchial area in some cases is secondarily involved in seizing and holding large prey." Since the species of *Parona, Scomberoides*, and *Oligoplites* have the best developed basibranchial dentition in the family, comprise the only carangid genera that have a premaxillary frenum (which restricts upper jaw protrusability), and feed on large prey as adults, we believe that the well developed basibranchial plates of these genera represent a secondary specialization associated with mode of feeding.

The mutual occurrence in these genera of several derived character states that are not found in any other carangids is here interpreted as evidence that *Parona* and *Scomberoides* evolved from a common ancestor. Although some of the shared specializations, especially those associated with trophic ecology, might be due to parallelism, this does not seem likely in the case of united epiotics.

Parona differs from all other carangids in having typically 9 branchiostegal rays and in lacking pelvic fins (a small pelvic girdle is retained). The pelvic fins are very reduced, however, in *Trachinotus stilbe* (Jordan and McGregor), and in fossil trachinotid genus *Paratrachinotus* (Blot, 1969, p. 285). The lateral line of *Parona* is unusual in having 5–9 dorsal branches. The mesopterygoid teeth are firmly ankylosed to the mesopterygoid in *Scomberoides*. In *Parona* the 'mesopterygoid' teeth are free-floating and thus may not be homologous. The first anal pterygiophore and articulation of the first two anal spines is very generalized compared to the complex arrangement in *Scomberoides*. Other generalized characters of *Parona* are the relatively broad, curved maxillae; well developed interosseous space between dorsal arm of dentary and upper margin of articular; large supramaxillae; caudal skeleton with 3 epurals; and broad, oval-shaped scales. The shoulder girdle of *Parona* differs from that of all other carangids, except those of the subfamily Naucratinae, in having a well developed postcoracoid process (fig. 25a).

The large number of differences between *Parona* and *Scomberoides* suggest that they have had a long history of evolutionary separation. The restriction of *Parona* to subtropical and temperate waters of the South Atlantic Ocean probably reflects an extended period of isolation in that region.

Genus *Hypacanthus*.

Hypacanthus differs from the previous genera in having inferior vertebral foramina; post-pelvic processes forming an apical fork; the lateral line very irregular and sinuous, dropping below the midline of body between the pelvics and origin of anal fin; poorly developed basibranchial dentition; young with strong vertical bars (young of the other genera lack such bars); and completely scaled cheeks. The most notable thing about *Hypacanthus* is the lack of any obvious specialized characters (except perhaps the lateral line). The eastern Atlantic-Mediterranean distribution of *Hypacanthus* and its general occurrence in subtropical and temperate waters supports the hypothesis that it evolved in the Mediterranean region.

The exact phyletic position of *Hypacanthus* is obscure owing to the lack of specialized characters which might be useful in determining relationships. The greatly reduced basibranchial dentition of *Hypacanthus* (fig. 24a), suggests, however, that it did not share a common ancestor with *Parona-Scomberoides*.

Trachinotus, a circumtropical genus consisting of about 19 species (F. H. Berry, personal communication) that is at least superficially similar to *Hypacanthus*, differs from *Hypacanthus* and the other genera most notably in having dentary and premaxillary teeth that are poorly developed or absent; upper pharyngeals that are noticeably enlarged and covered with blunt, molariform teeth; the parasphenoid expanded into a broad, flattened plate posteriorly; and the basioccipital with a pair of lateral processes on its ventral surface. The complete absence of basibranchial dentition in *Trachinotus* represents the end product of a trend toward specialization in the opposite direction from that of *Parona-Scomberoides*. All of the above characters are probably correlated and constitute a single character complex associated with trophic ecology. Although the species of *Trachinotus* comprise a well defined group, there are no characters that are useful in establishing from what group of carangids they evolved.

SUBFAMILIAL RECOGNITION.

In comparing the Carangidae to the Scombridae, Starks (1911) made the following observations which illustrate some of the problems encountered in subfamilial partitioning of the Carangidae: "The family Carangidae is a much more compact group than the Scombridae. The gaps between the genera are much smaller, and though the osteological characters, like the form of the body, differ much in the extremes of variation, there are no sudden or complete changes." Although he recognized four subfamilies (Scomberoidinae, Trachinotinae, Naucratinae, and Caranginae), Starks (1911, p. 30) acknowledged the largely artificial nature of these subfamilies by stating: "though *Selene* is not nearly so closely related to *Trachyurops* [= *Selar*]—for instance—as some forms are to each other that are here arranged in different subfamilies, there is no place to draw a dividing line." *Parona* and *Scomberoides* are probably no more divergent phylogenetically than are some genera presently placed together in the subfamily Caranginae. Within the present classification of the family, *Parona* might be recognized as a monotypic tribe in the subfamily Scomberoidinae. *Hypacanthus* would require its own subfamily, since its relationship to other carangid genera is obscure. Until the relationships of the other genera are better understood, we prefer not to recognize any carangid subfamilies.

The following characters shared, in combination, by *Oligoplites*, *Scomberoides*, *Parona*, *Trachinotus*, and *Hypacanthus* distinguish them as a group from all other carangids: lateral line without scutes; body moderately to strongly compressed; second dorsal-fin base approximately equal in length to anal-fin base; and haemal spine of first caudal vertebra and first anal pterygiophore firmly attached to form a strong strut. These characters may, however, have little or no phylogenetic significance. Other characters possessed by these five genera are summarized in table 7.

PHYLOGENETIC POSITION OF *Campogramma* REGAN, 1903

(Figure 26)

Wheeler (1963) illustrated this poorly known eastern Atlantic-Mediterranean carangid and discussed its nomenclatural history. We agree with Wheeler (1963, p. 538) that the description of *Centronotus glaycos* Lacépède, 1803 is sufficiently diagnostic to determine its specific identity, thereby establishing it as a senior synonym of the widely used but nomenclaturally invalid name *Campogramma*

TABLE 7. *Summary of selected characters used to define genera.*

Character	*Trachinotus*[1]	*Hypacanthus*	*Parona*	*Scomberoides*	*Oligoplites*
epiotics united internally	no	no	yes	yes	yes
fronto-supraoccipital crest	high	low	high	low	low
suborbital shelf	present	present	present	present	absent
suborbitals 2–4 expanded posteriorly	no	no	no	no	yes
interosseous space between dentary and articular	well developed	moderate	well developed	minute	minute or absent
supramaxilla	absent	small	large	small	absent
premaxillary frenum	absent	absent	present (narrow)	present (wide)	present (wide)
dentary teeth	villiform band (often absent in adults)	wide band	narrow band (single row posteriorly)	2 rows	2 rows
'mesopterygoid' teeth	absent	absent	present (free-floating)	present (ankylosed to bone)	absent
branchiostegal rays	7–8	8	9	8	7
basibranchial tooth plates	absent	poorly developed	well developed (large median plate)	well developed (paired plates)	well developed (paired plates)
caudal vertebrae	14	14	17	16	16
inferior vertebral foramina	absent	present	absent	absent	absent
epural bones	3	3	3	2	2
predorsal bones	4 or 5 (rarely 5)	3	4	3 or 4 (rarely 4)	4 to 6 (rarely 4)
dorsal-fin rays	VI–VII+ I, 16–29	VII+ I, 19–21	VI–VII+ I, 32–38	VI–VII+ I, 19–21	IV–VI (rarely VI)+ I, 18–21
posterior dorsal- and anal-fin rays	normal	normal	normal	semidetached finlets	semidetached finlets
pelvic fins	present	present	absent	present	present
postpelvic processes	united distally	forming apical fork	united distally	united distally	united distally
postcoracoid process	moderate	moderate	well developed	absent	absent
first anal pterygiophore expanded antero-laterally, forming roof over anal spines	no	no	no (fig. 15a)	yes (fig. 15b)	yes like *Scomberoides*
body scales	oval-shaped	oval-shaped, becoming strongly lanceolate on breast	oval-shaped	broadly lanceolate to needlelike (fig. 3)	needlelike
cheek scales	present or absent	present	absent	absent	absent
lateral line	normal	irregular and sinuous dropping below midline of body between pelvics and anal fin	5–9 dorsal branches	normal	normal
swimbladder	simple (young) to moderately bifid (adults)	simple (young) to moderately bifid (adults)	simple (all sizes)	strongly bifid (all sizes)	strongly bifid (all sizes)

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[1] Several unique characters of *Trachinotus* not included here are discussed in the text under Relationships and Zoogeography.

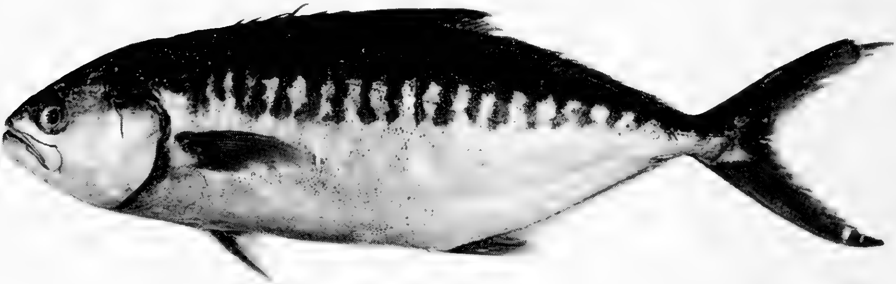

FIGURE 26. *Campogramma glaycos*, BMNH 1892.4.20.3, 377 mm. SL. Mediterranean. Snout appears unnaturally short due to bent condition of specimen.

vadigo (Risso, 1810). We do not agree with Wheeler who treated *C. glaycos* as a *nomen oblitum* because past workers either overlooked the name or considered it unavailable because of homonymy with *Lichia glauca* of authors. In fact, *C. glaycos* can not be considered a homonym of the differently spelled *L. glauca*. *Campogramma liro* proposed by Dollfus (1955, p. 58) as a replacement name for *C. vadigo* Risso is unnecessary. A junior synonym of *Campogramma glaycos* (Lacépède) overlooked by Wheeler is *Oligoplites africana* Delsman (1941). Bauchot and Blanc (1963, p. 53) proposed *Solagmedens* with *Oligoplites africana* as the type species. They apparently were unaware of the description of *Campogramma*.

Recent authors have assigned the monotypic *Campogramma* to the subfamily Trachinotinae, but without presenting substantiating data. Characters used to define the Trachinotinae that are associated with trophic ecology, such as enlarged pharyngeals and expansion of the parasphenoid posteriorly into a broad flattened plate, are absent in *Campogramma*. Three external characters of *Campogramma* that are shared, in combination, exclusively with naucratinine (= Seriolinae) genera are: lateral line without scutes; body terete, only slightly compressed; anal-fin base shorter than second dorsal-fin base.

The osteology of *Campogramma* suggests that it evolved from a form close to *Seriola*. The haemal spine of the first caudal vertebra is weakly articulated with the first anal pterygiophore, not enlarged and indistinguishable from the haemal spines of other caudal vertebrae. In lateral view the anterior margin of the first anal pterygiophore is distinctly concave, with a free distal tip, as in most species of *Seriola* (Mather, 1971, p. 186, fig. 3b). The last three pairs of parapophyses are connected dorsally by a bony bridge which encircles the haemal canal, and the last two are united distally to form a single haemal spine. As noted by Starks (1911, p. 29), in the other carangid subfamilies the posterior parapophyses are distinct, and not united as a single haemal spine, though a bony bridge connects their bases. Other characters shared with *Seriola* are:

zygapophyses of exoccipital joined beneath foramen magnum; myodome with a large posterior opening; large supramaxilla; premaxillary spur present; branchiostegal rays 3 + 4 (epihyal + ceratohyal); vertebrae 10 + 14 = 24; caudal skeleton with 3 epurals; cluster of free-floating, irregularly shaped patches of minute granular teeth overlying mesopterygoids; and swimbladder not bifid.

Campogramma is distinguished from all other genera of Naucratinae in having a single row of caniniform teeth in both jaws, naked cheeks, partially naked breast, and slightly falcate pectoral fins.

MATERIAL EXAMINED. BMNH 1893.2.24.3, 112 mm. SL, cleared and stained; BMNH 1892.4.20.3, 377 mm. SL, x-rayed.

SUMMARY

The carangid fish genera *Scomberoides*, *Oligoplites*, *Parona*, and *Hypacanthus* are revised. These four genera, along with *Trachinotus*, are distinguishable as a group from all other genera of Carangidae. *Campogramma*, formerly placed in the subfamily Trachinotinae, is considered to be more closely related to *Seriola*.

Scomberoides consists of four recent species, *S. commersonianus* Lacépède, *S. tala* (Cuvier), *S. lysan* (Forskål), and *S. tol* (Cuvier). *Scomberoides spinosus* (Smirnov), described from Lower Miocene deposits, is believed to be closely related to *S. tol*. *Scomberoides lysan*, consistently treated as a senior synonym of *S. commersonianus*, is instead a senior synonym of the widely used *S. tolooparah* (Rüppell). The species of *Scomberoides* range from the Indian Ocean and Red Sea into the central Pacific; only one species, *S. lysan*, occurs east of the Solomon Islands and frequents entirely oceanic habitats.

Oligoplites consists of five species, *O. saurus* (Bloch and Schneider), *O. saliens* (Bloch), *O. palometa* (Cuvier), *O. refulgens* Gilbert and Starks, and *O. altus* (Günther). *Oligoplites mundus* Jordan and Starks is placed in the synonymy of *O. altus*. The genus is restricted to the eastern Pacific and western Atlantic oceans; only *O. saurus* occurs in both oceans.

Parona, a monotypic genus restricted to the western South Atlantic Ocean, is believed to be most closely related to *Scomberoides* and *Oligoplites*. *Parona signata* (Jenyns) is unique among carangids in that it lacks pelvic fins.

Hypacanthus, also monotypic, has a littoral distribution in the Mediterranean Sea, along the Atlantic coast of Africa, and the southern Indian Ocean. *Hypacanthus amia* (Linnaeus) is the least specialized of the carangids studied.

Osteological descriptions are given for *Scomberoides*, *Oligoplites*, *Parona*, and *Hypacanthus*. Of the genera treated, *Scomberoides* and *Oligoplites* are the most closely related, with *Oligoplites* the most specialized. Within the framework of the present classification of the family Carangidae the two monotypic genera would require their own subfamilies. The phyletic relationship of all of these genera is such that we do not recognize any subfamilies.

APPENDIX

LIST OF NOMINAL SPECIES OF *Scomberoides* AND *Oligoplites*, INCLUDING SOME NAMES ORIGINALLY ASSIGNED TO ONE OF THESE GENERA (OR THEIR SYNONYMS) THAT WERE MISAPPLIED OR ARE UNIDENTIFIABLE.

The following list gives in order: (1) the scientific name in alphabetical order by species as it originally appeared (capitalized specific names in lower case, however); (2) the author or authors (Cuvier and Valenciennes, 1831 is abbreviated to C. & V., 1831, and Jordan and Evermann, 1898 is abbreviated to J. & E. 1898); (3) date of publication; (4) page reference (see literature cited section for complete reference); the genus and species to which we currently assign the species, if such is possible. Included are several nominal species described in *Scomberoides* or *Chorinemus* that are unidentifiable. The basis for our assignment of nominal species of *Scomberoides* is discussed in the text under their senior synonyms. Unless stated otherwise in the text, synonymy of *Oligoplites* species follows that of Schultz (1945).

Species, author, publication date, and page reference	Present allocation
Oligoplites africana Delsman, 1941, p. 52	*Campogramma glaycos*
Lichia albacora Guichenot, 1848, p. 231	*?Oligoplites altus*
Chorinemus altus Günther, 1868, p. 433	*Oligoplites altus*
Scomber calcar Bloch, 1793, p. 46	*?Oligoplites saliens*
Scomberoides commersonnianus Lacépède, 1802, p. 50	*Scomberoides commersonianus*
Chorinemus delicatulus Richardson, 1846, p. 269	*Scomberoides commersonianus*
Chorinemus exoletus Ehrenberg *in* C. & V., 1831, p. 379 (278)	*Scomberoides commersonianus*
Chorinemus farkharrii Cuvier *in* C. & V., 1831, p. 388 (285)	unidentifiable (?Scombridae)
Scomberoides formosanus Wakiya, 1924, p. 236	*Scomberoides tol*
Scomberoides formosanus Oshima [non Wakiya], 1925, p. 349	*Scomberoides lysan*
Scomber forsteri Bloch & Schneider, 1801, p. 26	*Scomberoides lysan*
Chorinemus guaribira Cuvier *in* C. & V., 1831, p. 393 (289)	*Oligoplites palometa*
Chorinemus hainanensis Chu and Cheng, 1958, p. 317	*Scomberoides tala*
Oligoplites inornatus Gill, 1863, p. 166	*Oligoplites saurus inornatus*

Chorinemus lanceolatus Girard, 1858, p. 168	*Oligoplites s. saurus*
Chorinemus leucopthalmus Richardson, 1846, p. 269	*Scomberoides commersonianus*
Scomber lysan Forskål, 1775, p. 54	*Scomberoides lysan*
Scomber maculatus Forster, 1844, p. 195	*Scomberoides lysan*
Chorinemus maculosus Saville-Kent, 1893, p. 369	*nomen nudum* (*Scomberoides* species)
Scomber madagascariensis Shaw, 1803, p. 590	*Scomberoides commersonianus*
Chorinemus mauritianus Cuvier *in* C. & V., 1831, p. 382 (281)	*Scomberoides lysan*
Chorinemus moadetta Ehrenberg *in* C. & V., 1831, p. 382 (280)	*Scomberoides lysan*
Thynnus moluccensis Gronovius *in* Gray, 1854, p. 121	*Scomberoides lysan*
Oligoplites mundus Jordan & Starks *in* J. & E., 1898, p. 2844	*Oligoplites altus*
Scomberoides noelii Lacépède, 1802, p. 50	unidentifiable (?Scombridae)
Chorinemus occidentalis Günther, 1860, p. 475	*Oligoplites s. saurus*
Chorinemus orientalis Temminck & Schlegel, 1844, p. 106	*Scomberoides lysan*
Scomberoides oshimae Whitley, 1951, p. 65	*Scomberoides lysan*
Chorinemus palometa Cuvier *in* C. & V., 1831, p. 392 (288)	*Oligoplites palometa*
Eleria philippina Jordan & Seale, 1905, p. 744	*Scomberoides tala*
Lichia quiebra Quoy & Gaimard, 1824, p. 365	*Oligoplites* (*?s. saurus*)
Oligoplites rathbuni Miranda-Riberio, 1915, p. 8	*Oligoplites s. saurus*
Oligoplites refulgens Gilbert & Starks, 1904, p. 73	*Oligoplites refulgens*
Scomber saliens Bloch, 1793, p. 41	*Oligoplites saliens*
Chorinemus saltans Cuvier *in* C. & V., 1831, p. 393 (289)	*Oligoplites s. saurus*
Scomberoides saltator Lacépède, 1802, p. 50	*Oligoplites saliens*
Chorinemus sancti petri Cuvier *in* C. & V., 1831, p. 379 (279)	*Scomberoides lysan*
Scomber saurus Bloch & Schneider, 1801, p. 32	*Oligoplites s. saurus*

Palaeoscomber spinosus Smirnov, 1936, p. 49–59	*Scomberoides spinosus*
Chorinemus tala Cuvier *in* C. & V., 1831, p. 377 (277)	*Scomberoides tala*
Chorinemus tol Cuvier *in* C. & V., 1831, p. 385 (283)	*Scomberoides tol*
Chorinemus toloo Cuvier *in* C. & V., 1831, p. 377 (277)	*Scomberoides* (?*tala*)
Lichia toloparah Rüppell, 1828, p. 91	*Scomberoides lysan*

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CTENACIS AND *GOLLUM*, TWO NEW GENERA OF SHARKS (SELACHII; CARCHARHINIDAE)

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Abstract: Two new genera are described for two species of carcharhinid sharks formerly placed in *Triakis* Müller and Henle. *Ctenacis*, new genus, is proposed for *Triakis fehlmanni* Springer, 1968. *Gollum*, new genus, is proposed for *Triakis attenuata* Garrick, 1954. Both genera are closest to *Proscyllium* Hilgendorf and *Eridacnis* H. M. Smith within the Carcharhinidae. *Ctenacis* is most similar to *Eridacnis* and somewhat less so to *Proscyllium*. *Gollum* is more distant from *Proscyllium*, *Ctenacis*, and *Eridacnis* than the latter three genera are from each other.

Garrick (1954) described a peculiar new shark, *Triakis attenuata*, that in many features differs strikingly from typical species of that genus. Subsequent workers on *Triakis*, as Smith (1957), Kato (1968), and Springer (1968), accepted Garrick's generic placement of '*attenuata*.' In addition, Springer (1968) described another new species of *Triakis*, *T. fehlmanni*, that also differed greatly from the type-species, *T. scyllium*, and its closest relatives. Springer regarded the generic position of '*fehlmanni*' as provisional pending a revision of *Triakis*.

Compagno (1970) proposed a preliminary reorganization of *Triakis*. He removed *T. leucoperiptera* from *Triakis* and assigned it to the genus *Hemitriakis*. *Proscyllium* was resurrected for *T. habereri* and *T. venusta* and *Calliscyllium* were synonymized with it. *Eridacnis* and *Neotriakis* were previously synonymized with *Triakis* by Kato (1968), but Compagno revived *Eridacnis* for *E. radcliffei*, *Neotriakis sinuans*, and *Triakis barbouri*. *Neotriakis* was synonymized with *Eridacnis*. Following several previous workers, Compagno transferred *Triakis henlei* to *Mustelus*.

Triakis, as restricted by Compagno (1970), contained a group of closely similar species, *T. scyllium*, *T. semifasciata*, *T. maculata*, and *T. acutipinna*, that seem to grade into *Mustelus* through intermediate forms as *M. nigropunctatus*, *M. megalopterus*, *M. henlei*, and *M. dorsalis*. *Triakis attenuata* was considered to be probably distinct from *Triakis* proper but inadequate data on the species at the time precluded more definite generic assignment. *Triakis fehlmanni* was treated as a doubtful appendage to *Eridacnis* that might merit generic or subgeneric distinction.

Reconsideration of available data on *T. fehlmanni* indicates that this species should be separated from *Eridacnis* and *Triakis* in a new genus. Examination of two specimens of *T. attenuata* confirmed my earlier opinion that '*attenuata*' was generically distinct from *Triakis* and required a new genus also.

The terminology used here for external morphology, vertebral counts, and dentition is from Compagno (1970). Clasper terminology follows Leigh-Sharpe (1921) and Compagno and Springer (1971). Terms for vertebral calcification patterns are from Ridewood (1921). Cranial terms are modified from Gegenbaur (1872), Allis (1923), and Holmgren (1941).

Ctenacis Compagno, new genus

TYPE SPECIES. *Triakis fehlmanni* Springer, 1968.

DEFINITION. Head very broad, depressed, its length 23 percent of total length in adult. Head length greater than distance between pectoral and pelvic bases. Snout outline subparabolic in dorsoventral view, not bell-shaped. Snout short, length 6.5 percent of total length. Eyes high on sides of head, above level of nostrils by a space about equal to eye height. Subocular ridge very strong, not indented on its dorsal surface. Eyes not visible in ventral view of head. Eyes elongate-elliptical, about 2.5 times as long as high. Nictitating lower eyelid rudimentary, with its edge horizontal. Subocular pouch very shallow, with its interior surface covered with denticles.

Spiracles present, their length about 5 times in eye length. Shortest gill opening over ¾ as long as longest. Gill rakers present on gill arches.

Internarial space about 1.2 times nostril width. Anterior nasal flaps are broad, low, triangular lobes with fringed posterior edges, not elongated, barbel-like, or tubular. Posterior edges of anterior nasal flaps close to mouth but separated from level of upper symphysis by distance equal to ⅓ of nostril width. Posterior nasal flaps large, with fringed edge. No nasoral grooves.

Mouth distinctly angular in shape, with edges of lower jaw nearly straight. Large papillae present in buccal cavity. Labial furrows extremely short, essentially confined to the mouth corners.

Dignathic heterodonty weak, upper teeth with higher and narrower crowns than lowers at symphysis, lower teeth more comblike than uppers at ends of dental bands. No disjunct monognathic heterodonty. In both jaws teeth decrease in size and height relative to root width towards rictuses. In the lower jaw premedial cusplets increase in size and number and the primary cusp shifts postlaterally on the crown base towards the rictus, producing comblike posterior teeth.

Tooth rows 86/88, series functional 4–5/5–7. Teeth not bladelike, without serrations or sharp edge. Premedial cusplets present on all teeth except a few in the region of the symphysis. Postlateral cusplets present on all teeth. Primary cusp present on all teeth, narrow, erect or slightly oblique. Crown foot with a strong basal ledge overlapping a deep basal groove. Transverse ridges present on all teeth, extending on to the cusps of uppers, confined to the bases in lowers. Roots of teeth broad, flat, low, platelike. No transverse groove and notch on attachment surface of roots. Teeth not extending onto sides and ventral surfaces of lower jaw.

No interdorsal ridge, lateral dermal keels on the caudal peduncle, or precaudal pits. Length of head and trunk (from snout tip to vent) about 46 percent of total length.

Denticles below first dorsal fin with crowns about as wide as long or slightly longer than wide in adult. Denticle crowns with a strong medial cusp and a pair of strong medial ridges; a pair of weaker lateral ridges are also present and a pair of very weak lateral cusps may be present or not.

Pectoral fin skeleton projecting about ⅓ of pectoral anterior margin length into fin. Longest distal radials of pectoral much shorter than longest proximal ones. Distal pectoral radials with parallel edges and truncate tips.

Pelvic bases over twice as far from second dorsal base as from first dorsal base. Posterior margins, free rear tips, and posterior margins of pelvic fins not attenuate. Clasper morphology unknown.

Midpoint of first dorsal base about twice as far from pectoral bases as from pelvic bases. Free rear tip of first dorsal posterior to pelvic origins.

Second dorsal fin nearly as large as first, its height almost ⁹⁄₁₀ of height of first, its base length 1.2 times base length of first dorsal. Posterior margin of second dorsal weakly concave.

Anal fin much smaller than second dorsal, its height about half of second dorsal height, its base length about ¾ of second dorsal base length. Anal origin posterior to second dorsal origin by distance about ¼ of second dorsal base length. Anal insertion under second dorsal insertion. Posterior margin of anal straight.

Caudal fin without distinct ventral lobe, postventral caudal margin not notched or otherwise differentiated. Subterminal caudal margin about ⅘ of terminal caudal margin. Caudal short, not tapelike, dorsal caudal margin 23 percent of total length. No lateral undulations in dorsal caudal margin. Terminal sector of caudal about 4 times in dorsal caudal margin. No caudal crest of denticles.

Cranium with paired lateral and unpaired medial rostral cartilages, fused

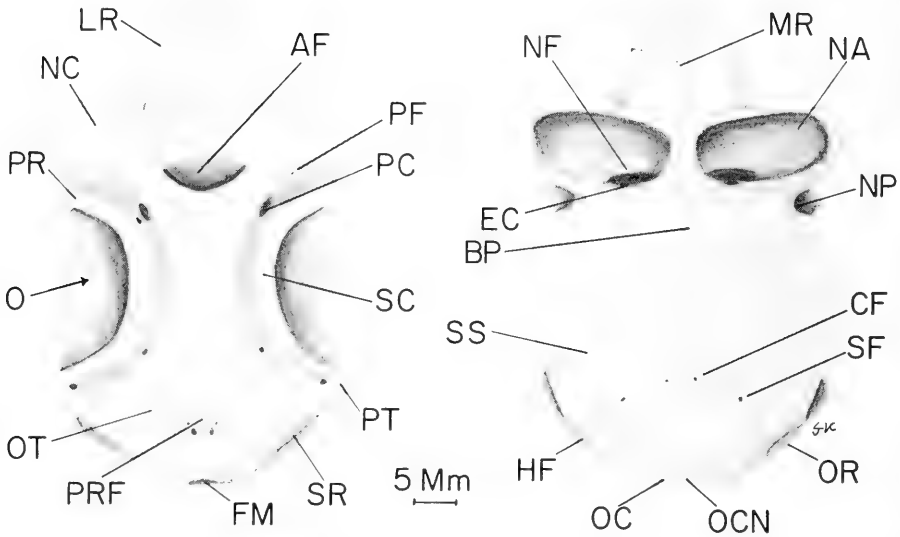

Figure 1. *Ctenacis fehlmanni*, U. S. National Museum 202969, 46 cm. adult female, neurocranium in dorsal (left) and ventral (right) views. Abbreviations: AF, anterior fontanelle; BP, basal plate; CF, internal carotid foramen; EC, ectethmoid chamber; FM, foramen magnum; HF, hyomandibular facet; LR, lateral rostral cartilage; MR, medial rostral cartilage; NA, nasal aperture; NC, nasal capsule; NF, nasal fontanelle; NP, notch for orbital process of palatoquadrate; O, orbit; OC, occipital condyle; OCN, occipital centrum; OR, opisthotic ridge; OT, otic capsule; PC, preorbital canal; PF, profundus foramen; PR, preorbital process; PRF, parietal fossa; PT, postorbital process; SC, supraorbital crest; SF, stapedial foramen; SR, sphenopterotic ridge; SS, suborbital shelf.

at their tips to form a tripod (fig. 1). Rostral node (conjoined tips of rostral cartilages) not yokelike, not penetrated by a rostral fenestra. Rostrum fairly short, length of medial rostral cartilage from its base on the internasal septum to the anterior tip of the rostral node about three times in nasobasal length (distance from base of medial rostral cartilage to the posterior edge of the occipital centrum; here used as an independent variable for cranial proportions). Distance between bases of lateral rostral cartilages about equal to length of medial rostral cartilage. Lateral rostral cartilages with their bases far anterior to the anterior fontanelle and not connected to the dorsal edge of the fontanelle by a ridge.

Nasal capsules oval-shaped, their long axis transverse to the longitudinal axis of the cranium. Transverse width of capsule from internasal septum to lateral edge of capsule about twice its length across its anterior and posterior walls. Greatest transverse width across nasal capsules about 1.3 in nasobasal length. Nasal aperture and nasal fontanelle apparently broadly continuous with each other, the fontanelle not separated from the nasal aperture by a

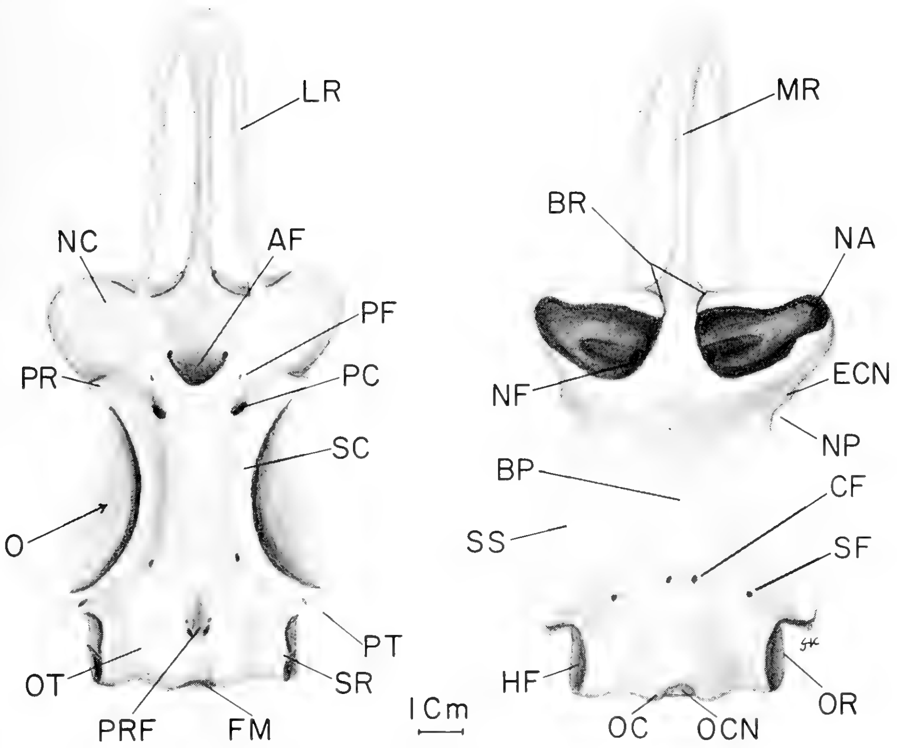

Figure 2. *Gollum attenuatus*, DM-3636, 955 mm. adult male, neurocranium in dorsal (left) and ventral (right) views. Abbreviations as in figure 1, except: BR, basirostral fenestra; ECN, lateral ectethmoid condyle.

bridge of cartilage. Greatest width of nasal aperture about six times distance between nasal apertures across internasal septum. Ectethmoid chamber opening inside nasal capsule on its posteroventral wall, with its aperture just above posterior edge of nasal fontanelle and not separated from the fontanelle by a horizontal ledge beneath it. No ectethmoid condyles or subethmoid fossa. No ectethmoid foramen communicating between the ventral surface of the nasal capsule and the ectethmoid chamber.

Anterior fontanelle subcircular in shape, its greatest width about 4.6 in nasobasal length. Cranial roof convex between orbits.

No deep notch separating anterior end of suborbital shelf from nasal capsule. Basal plate expanded just posterior to nasal capsules into a broad suborbital ledge, the least width across which is about 1.7 in nasobasal length. Arterial foramina on ventral surface of basal plate include a pair of small internal carotid foramina about half as far from each other as from each of the stapedial foramina distal to them. The paired stapedial foramina, for the

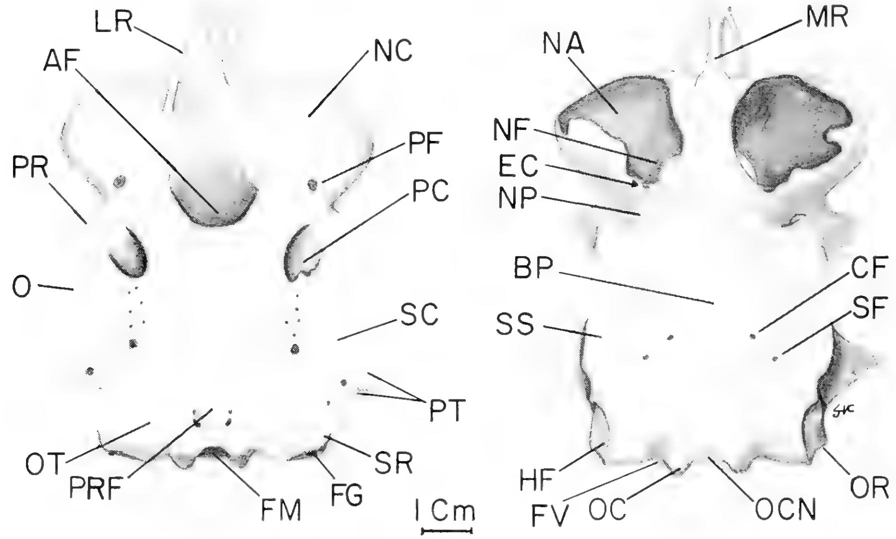

FIGURE 3. *Triakis semifasciata*, LJVC (writer's personal collection) 0067, 937 mm. immature female, neurocranium in dorsal (left) and ventral (right) views. Abbreviations as in figure 1, except: FG, foramen for glossopharyngeal (IX) nerve; FV, foramen for vagus (X) nerve.

stapedial or orbital arteries, are tiny pinhole apertures. Basal plate nearly flat, without keels.

Supraorbital crest present, connecting low preorbital and postorbital processes. Edge of supraorbital crest arcuate in dorsal view. Dorsal edge of crest not extending above level of cranial roof between the orbits. Width across narrowest part of supraorbital crest about 2.6 in nasobasal length. Postorbital processes not extending from supraorbital crest and sphenopterotic ridge, with tips not bifurcated. Suborbital shelf very wide, greatest width across it 1.3 in nasobasal length.

Otic capsules short, not greatly enlarged or inflated. Length of otic capsule about 4 in nasobasal length. Sphenopterotic ridge extending slightly lateral to side of otic capsule.

Occipital condyles very small, without dorsolateral and ventrolateral plates that partially sheath base of vagus nerve.

Total vertebral count 136 (1). Monospondylous precaudal (MP) centra 28.6, diplospondylous precaudal (DP) centra 35.2, and diplospondylous caudal (DC) centra 36 percent of total vertebral count. Ratio of DP/MP centra counts 1.23, DC/MP centra 1.26. "A" ratio (length of penultimate MP centrum/first DP centrum) 138, "B" ratio (length/width of penultimate MP centrum) 114. No 'stutter zone' of alternating long and short centra in DP region. Last few MP centra not greatly enlarged.

Vertebral centra without wedgelike intermedialia. Diagonal calcified lamellae present in form of knoblike projections from calcified double cone. Notochordal canal rather large, not blocked at apices of double cone.

Spiral intestinal valve present, with about 10 turns.

Mode of development not known, though possibly oviparous (see Springer, 1968, for discussion).

A color pattern of dark saddles, blotches, bars, and spots on a light background present.

Size small, the one specimen of *C. fehlmanni* known at present being an adult female 46 cm. long.

Comparison with other genera. *Ctenacis* is a member of Compagno's (1970) group of 'scyliorhiniform triakoids,' which are morphologically intermediate between scyliorhinids and genera such as *Triakis*, *Mustelus*, and *Hemitriakis*. *Ctenacis* is most similar to *Eridacnis*, somewhat less so to *Proscyllium*, and yet more distant from *Gollum*, the other new genus described here. All four genera show sufficient similarity in external morphology, dentition, cranial anatomy, and vertebral calcification pattern to form an apparently related group.

For brevity comparisons of both *Ctenacis* and *Gollum* with other carcharhinid genera is here limited to the other 'scyliorhiniform' genera and to *Triakis-Mustelus*, the generic complex to which '*fehlmanni*' and '*attenuata*' were originally assigned. Both genera are not particularly close to carcharhinid from these genera by many characters given in the generic definitions. genera other than *Proscyllium* and *Eridacnis* and can be readily distinguished

Eridacnis differs from *Ctenacis* in having a narrower head; anterior and posterior nasal flaps not fringed; tooth rows less numerous, 55–78/63–77; head and trunk slightly shorter, 38–43 percent of total length, and rather slim; pelvic posterior margins, free rear tips, and inner margins elongate, somewhat attenuate; caudal very long, tapelike, length 25–30 percent of total length; cranium narrower, width across nasal capsules 1.4–1.6 in nasobasal length; nasal capsules nearly spherical; no diagonal calcified lamellae in vertebral centra; no striped and spotted color pattern on body; and size smaller, less than 370 mm. total length.

Proscyllium differs from *Ctenacis* in having a narrower and shorter head, with length only 16–18 percent of total length; fifth gill opening less than half length of third; anterior nasal flaps very large, reaching nearly to upper symphysis; internarial space very narrow, nostril width 1.7–2.2 times internarial; anterior and posterior nasal flaps not fringed; tooth rows less numerous, 46–62/49–59; head and trunk very short, only 39–41 percent of total length, very slender; first dorsal origin well posterior to free rear tip of pectoral; anal origin slightly anterior to second dorsal origin; cranium narrower, width across nasal capsules 1.5 in nasobasal length; nasal capsules nearly spherical; total vertebral counts 146–168 (6); and DP/MP ratio 1.6–1.8.

Ctenacis is compared with *Gollum* in the account of the latter genus below.

Triakis and *Mustelus* differ from *Ctenacis* in having external, transitional, or internal nictitating lower eyelids; no gill rakers or buccal papillae; anterior nasal flaps elongated and lobate; posterior nasal flaps absent or rudimentary; labial furrows long and extending well onto upper and lower jaws; lower teeth towards ends of dental band not comblike, with cusplets reduced or absent; roots of teeth usually subdivided on their attachment surface by a transverse groove and notch; interdorsal ridge present; longest distal radials of pectoral fin skeleton about as long as longest proximal radials or slightly longer; midpoint of first dorsal fin base about equidistant between pectoral and pelvic bases or definitely closer to pectoral bases; anal insertion slightly posterior to second dorsal insertion; anal posterior margin concave to deeply notched in adults; cranium with a deep notch separating the anterior end of the suborbital shelf from the nasal capsule (fig. 3); postorbital process exserted from the supraorbital crest and bifurcated distally; and vertebral centra with wedge-shaped intermedialia.

In addition *Triakis* (including only *T. scyllium*, *T. semifasciata*, *T. maculata*, *T. acutipinna*, and probably *'Mustelus' megalopterus* and *'M.' nigropunctatus*) differs from *Ctenacis* in having an arcuate mouth (fig. 4C); fewer tooth rows, 44–65/34–56; and a well developed ventral caudal lobe in adults. *Mustelus* (including *'Triakis' henlei*) also differs from *Ctenacis* in having a longer snout, with a narrowly parabolic to almost angular shape in dorsoventral view and narrowly wedgelike shape in lateral view; teeth extending onto sides and ventral surface of lower jaw; teeth forming a regular pavement, with primary cusp typically reduced or absent in most species; a tooth peg present on the inner face of the crown; and ectethmoid condyles present on the nasal capsules.

Derivation of name. *Ctenacis*, from Greek *ktenos*, comb, and *akis*, point (feminine), in allusion to the comblike posterior teeth of this genus.

Species. Only one, *Ctenacis fehlmanni* (Springer, 1968).

Study material. The holotype and only known specimen of *Ctenacis fehlmanni*, U. S. National Museum 202969.

Gollum Compagno, new genus

Type species. *Triakis attenuata* Garrick, 1954.

Definition. Head very broad, depressed, its length about ⅕ (21.3–21.6 percent) of total length in adults. Head length considerably shorter than distance

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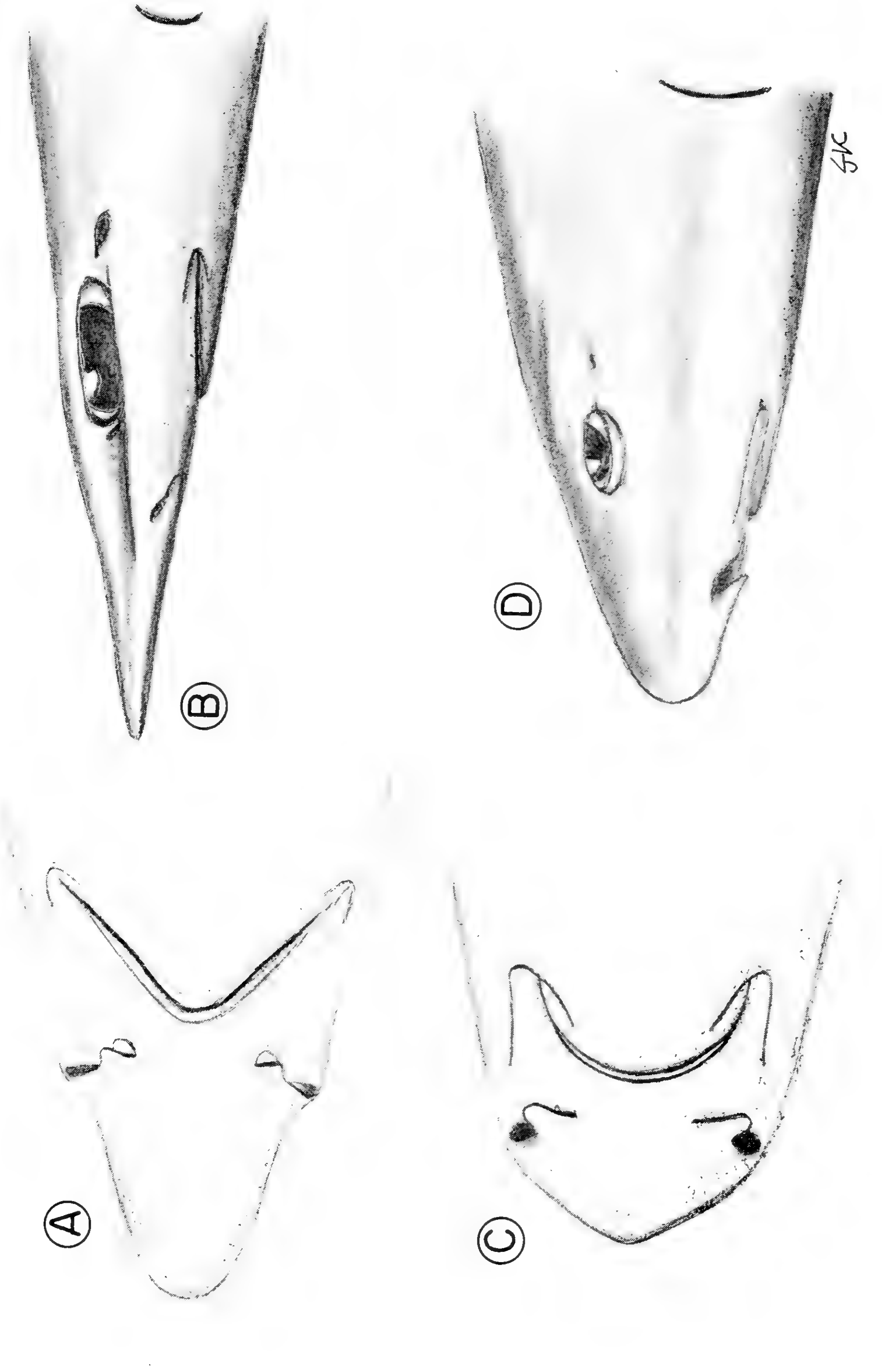
Figure 4. A–B, *Gollum attenuatus*, DM-4841, 1015 mm. adult female. Prebranchial head in ventral (A) and lateral (B) views. C–D, *Triakis scyllium*, University of Michigan Museum of Zoology 179067, 700 mm. immature male. Prebranchial head in ventral (C) and lateral (D) views.


B
D
A
C

between pectoral and pelvic bases. Snout with peculiar bell-shaped outline in dorsoventral view (fig. 4A). Snout very long, preoral length 8.4–8.6 percent of total length in adults. Eyes high on sides of head, above level of nostrils by a space equal to about half eye height or slightly less. Subocular ridge very strong, with a distinct depression on its dorsal surface (fig. 4B). Eyes not visible in ventral view. Eyes elongate-elliptical, with their apertures about 2¼ to 2½ times as long as high. Nictitating lower eyelid rudimentary, with its edge horizontal. Subocular pouch very shallow and covered with denticles.

Spiracles present, their length about 3.8 to 8 times in eye length. Shortest gill opening ¾ to ⅘ as long as longest one. No gill rakers.

Internarial space about 1.8 to 1.9 times nostril width. Anterior nasal flaps short and subtriangular, not tubular or barbel-like, with edges entire and not fringed. Posterior edges of anterior nasal flaps close to mouth but separated from the upper symphysis by distance equal to ½ to ¾ of nostril width. Posterior nasal flaps large, with fringed edges. Nasoral grooves absent.

Mouth distinctly angular in shape, with edges of lower jaw straight. No large papillae in buccal cavity. Labial furrows very short, essentially confined to mouth corners.

Dignathic heterodonty weak, virtually absent at symphysis but increasing towards ends of dental bands, where lower teeth are more comblike than uppers. No disjunct monognathic heterodonty. In both jaws teeth decrease in size and height relative to root width toward rictuses. In the lower jaw premedial cusplets increase in number and size relative to the primary cusp and the cusp shifts postlaterally on the crown in a direction towards the rictus, producing comblike posterior teeth. Gynandric heterodonty absent.

Tooth rows 96–99/108–114 (3), series functional 3–6/3–7. Crown not sharp, serrated, or bladelike. Premedial and postlateral cusplets present on all teeth. Primary cusp present on all teeth, narrow and erect. Crown foot with a deep basal ledge overlapping a deep basal groove. Transverse ridges present on teeth, numerous and small, extending onto primary cusp and cusplets. Roots of teeth moderately high and deep, not subdivided on their attachment surface by a transverse groove and notch. Teeth not extending onto sides and ventral surface of lower jaw.

Interdorsal ridge present. No lateral dermal keels or precaudal pits present on the caudal peduncle. Length of head and trunk about equal to tail length.

Denticles from sides of body below first dorsal fin with crowns much longer than wide in adults. Denticle crowns with a strong medial cusp, a strong medial ridge or a pair of medial ridges, a pair of short but strong lateral cusps, and a pair of lateral ridges.

Pectoral fin skeleton projecting slightly less than ⅓ of pectoral anterior margin length into fin. Longest distal radials of pectoral skeleton somewhat shorter than longest proximal ones. Distal radials with parallel edges and truncate tips.

Pelvic fin bases slightly closer to second dorsal base than to first dorsal base. Pelvic posterior margins, free rear tips, and inner margins not attenuate.

Dorsal edges of clasper groove not fused together between apopyle and hypopyle. A soft-edged, fleshy rhipidion present, with its dorsal surface exposed for most of its length and not concealed by the cover rhipidion. Cover rhipidion present, a small, short, square, fleshy flap. Exorhipidion present, a low, fleshy flap lateral to pseudopera. Exorhipidion without clasper hooks. A large pseudosiphon and pseudopera present.

Midpoint of first dorsal base about 1.3 times as far from pelvic bases as from pectoral bases. Free rear tip of first dorsal well anterior to pelvic origins.

Second dorsal fin about as large as first, its height equal or slightly larger than height of first dorsal, its base length equal or slightly less than base length of first dorsal. Posterior margin of second dorsal moderately concave.

Anal fin much smaller than second dorsal, its height 44–46 percent of first dorsal height, base length about ½ to ⅗ of second dorsal base. Anal origin posterior to second dorsal origin by distance equal to 11 to 27 percent of second dorsal base length. Anal insertion anterior to second dorsal insertion by distance about 25 to 36 percent of second dorsal base length. Anal posterior margin nearly straight, not deeply concave or notched.

Caudal fin with ventral lobe poorly developed in adults. Postventral caudal margin not notched. Subterminal caudal margin about ⅔ to 7/10 of terminal margin. Caudal short, not tapelike, in adults about ⅕ (19.4–21.2 percent) of total length. No lateral undulations in dorsal caudal margin. Terminal sector of caudal between 3 and 4 times in dorsal caudal margin. A weak supracaudal crest of enlarged, circular or oval-crowned denticles present along the anterior half of the dorsal caudal margin.

Cranium with lateral and medial rostral cartilages fused at their tips to form a tripod (fig. 2). Rostral node not yokelike, not penetrated by a rostral fenestra. Rostrum very long, length of medial rostral cartilage only 1.3 in nasobasal length. Distance between bases of lateral rostral cartilages about 2.7 times in length of medial rostral. Lateral rostrals with their bases far anterior to anterior fontanelle but with their dorsal edges connected to fontanelle by a low ridge.

Nasal capsule oval in shape, transversely elongated. Transverse width of capsule about 1.4 times its length. Greatest width across nasal capsules 1.4 in nasobasal length. Nasal aperture and nasal fontanelle broadly continuous with each other, the fontanelle not separated from the nasal aperture by a bridge of cartilage. Greatest width of nasal aperture about 5 times distance between nasal apertures. Ectethmoid chamber opening inside nasal capsule on its posteroventral wall, with its aperture just above posterior edge of nasal fontanelle and not separated from the latter by a horizontal ledge beneath it. No true ectethmoid condyles, though a pair of low condyles are present on the posteroventral surfaces of the nasal capsules (but well lateral to the position of the ectethmoid condyles of carcharhinoid genera that have them). Subethmoid fossa absent. No separate ectethmoid foramen on the ventral surface of the nasal capsule.

Anterior fontanelle rhomboidal in shape, its greatest width only 7 times in nasobasal length. Cranial roof flattened between orbits.

No deep notch separating suborbital shelf from nasal capsule. Basal plate expanded just posterior to nasal capsules into a broad suborbital ledge, the least width across which is about 2.0 in nasobasal length. Arterial foramina on ventral surface of basal plate include a pair of small internal carotid foramina about half as far from each other as from each of the tiny stapedial foramina distal to them. Basal plate slightly arched, without keels.

Supraorbital crest present, with an arcuate lateral edge. Dorsal edge of crest extending well above level of cranial roof between orbits. Width across narrowest part of crest about 3.6 in nasobasal length. Postorbital processes narrow, exserted beyond supraorbital crest and sphenopterotic ridge, with tips not bifurcated. Suborbital shelf very wide, greatest width across shelves 1.4 in nasobasal length.

Otic capsules short, not greatly enlarged and inflated. Length of otic capsule about 4 in nasobasal length. Sphenopterotic ridge extending medial to sides of otic capsule.

Occipital condyles very small, without dorsal and ventral covering plates for base of vagus nerve.

Total vertebral counts 166 (2). MP centra 30.7, DP centra 35.6, and DC centra 33.7 percent of total counts. DP/MP ratio 1.16, DC/MP ratio 1.10. "A" ratio 129 to 141, "B" ratio 87 to 99. No stutter zone. Last few MP centra not greatly enlarged.

Vertebral centra without wedgelike intermedialia or diagonal calcified lamellae. Notochordal canal rather large through apices of calcified double cones.

Valvular intestine with a spiral valve having about 11 turns.

Development ovoviviparous (Kato, 1968; J. A. F. Garrick, personal communication).

Ground color brownish gray dorsally, lighter below. No color pattern.

Size small-medium, males mature at 932 to 955 mm. total length, females at 1015 mm.

Comparison with other genera. *Gollum* belongs to Compagno's (1970) group of 'scyliorhiniform triakoids,' in which it is a singular and isolated member. *Ctenacis*, *Proscyllium*, and *Eridacnis* all differ from *Gollum* in having shorter snouts, only 4.3 to 6.7 percent of total length and not bell-shaped in dorsoventral view; no concavity or depression on the dorsal surface of the subocular ridge; gill rakers present; internarial space only 0.5 to 1.2 times nostril width; large papillae present in buccal cavity; fewer tooth rows, 46–86/49–88; interdorsal ridge absent; pelvic bases much closer to first dorsal base than second dorsal base; midpoint of first dorsal base much closer to pelvic bases than pectoral bases; first dorsal free rear tip over or posterior to pelvic origins; no supracaudal crest of denticles; rostral cartilages much shorter, medial rostral length 3 to 4 in nasobasal length; no lateral condyle on posteroventral wall of nasal capsule; postorbital process not exserted from supraorbital crest; sphenopterotic ridge not medial to sides of otic capsule; and size smaller, not exceeding 700 mm. total length when adult.

In addition *Ctenacis* differs from *Gollum* in having the head longer than the distance between pectoral and pelvic bases; second dorsal insertion over the anal insertion; distance across narrowest part of supraorbital crest greater, 2.6 in nasobasal length; total vertebral count 136; vertebral centra with knoblike diagonal calcified lamellae; and a color pattern of dark blotches and spots. *Eridacnis* also differs from *Gollum* in having the head about equal to the distance between pectoral and pelvic bases or longer than it; posterior nasal flaps not fringed; gynandric heterodonty more or less developed, in males spikelike teeth present in one or both jaws at the symphysis; head and trunk considerably shorter than the tail; pelvic inner margins, free rear tips, and posterior margins elongate-attenuate; anal origin under second dorsal origin or slightly anterior to it; caudal very long, tapelike, with dorsal caudal margin 24 to 30 percent of total length; and total vertebral counts only 113 to 144. *Proscyllium* also differs from *Gollum* in having the shortest gill opening less than half as long as the longest; anterior nasal flaps very large, broadly triangular, and nearly reaching the upper symphysis; edges of posterior nasal flaps not fringed; head and trunk only 39 to 41 percent of total length; dorsal edges of clasper groove fused together between hypopyle and apopyle; exorhipidion very strong, with clawlike clasper hooks on its distal edge; first dorsal origin well posterior to pectoral free rear tip; anal origin slightly anterior to second dorsal origin; DP/MP ratio 1.6 to 1.8; knoblike diagonal calcified lamellae present in vertebral centra; development oviparous; and a color pattern of dark spots and bars present.

Triakis and *Mustelus* differ from *Gollum* in lacking a bell-shaped snout profile in dorsoventral view (fig. 4C); no concavity or depression in dorsal surface of subocular ridge (fig. 4D); nictitating lower eyelid external or transitional in young but usually transitional or internal in adults; anterior nasal flaps somewhat elongated; posterior nasal flaps rudimentary or absent; tooth roots low, with transverse groove and notch usually present; crowns of teeth towards ends of tooth band not comblike, with cusps and cusplets reduced or absent; longest distal radials of pectoral fin equal in length or somewhat longer than longest proximal radials; claspers without exorhipidion; anal fin insertion slightly posterior to second dorsal insertion; anal posterior margin moderately concave to deeply notched; no supracaudal crest of denticles; rostrum shorter, length of medial rostral cartilage 1.9 to 4.4 in nasobasal length; bases of lateral rostral cartilages not connected to edge of anterior fontanelle by a ridge; least distance across supraorbital crest 1.5 to 2.3 in nasobasal length; suborbital shelf separated from nasal capsule by a deep notch; no suborbital ledge between nasal capsule and suborbital shelf; postorbital processes bifurcated distally; sphenopterotic ridge above side of otic capsule or slightly distal to it, not medially situated; and vertebral centra wtih intermedialia and diagonal calcified lamellae.

In addition *Triakis* differs from *Gollum* in having a thick short snout (fig. 4D), bluntly rounded or obtusely triangular in dorsoventral view (fig. 4C) and bluntly rounded in lateral view; an arcuate mouth; very long labial furrows extending along margins of upper and lower jaws; fewer tooth rows, 44–65/34–56; and a well developed ventral caudal lobe in adults. *Mustelus* also differs from *Gollum* in having a snout less acutely wedge-shaped in lateral view; labial furrows usually longer, extending well onto the upper and lower jaws; teeth forming a regular pavement, with primary cusps and cusplets reduced or absent in most forms; and a true ectethmoid condyle present on the nasal capsule.

DERIVATION OF NAME. *Gollum* (treated as a masculine noun), named for the antihero of J. R. R. Tolkien's *Lord of the Rings* trilogy, to whom this shark bears some resemblance in form and habits.

SPECIES. Only one known, *Gollum attenuatus* (Garrick, 1954).

STUDY MATERIAL. Dominion Museum (DM) 3636, 955 mm. adult male, from about 25 miles off Cape Brett, North Island, New Zealand; DM-4841, 1015 mm. adult male, off Karamea Bight, South Island, New Zealand.

ACKNOWLEDGMENTS

Stewart Springer (National Marine Fisheries Service Systematics Laboratory, U. S. National Museum) discussed the generic classification of *Ctenacis fehlmanni* with me on several occasions both in person and in correspondence. In addition, he allowed me to examine the holotype of this species and dissect a 'door' in its head to expose the neurocranium. J. A. F. Garrick (Victoria University, Wellington, New Zealand) advised me on the classification of *Gollum attenuatus* and of additional specimens of this species collected since his original description. J. M. Moreland (Dominion Museum, Wellington, New Zealand) sent me two specimens of *G. attenuatus*.

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CHEMICAL EXTRACTION TECHNIQUES TO FREE FOSSIL SILICOFLAGELLATES FROM MARINE SEDIMENTARY ROCKS

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Abstract. Techniques of extracting fossil silicoflagellates and other siliceous microfossils from marine sedimentary rocks are described. The extraction is achieved by dissolving and chemically disaggregating all the rock (or the cementing agents of the rocks) except the siliceous fraction, and by removing the nonfossiliferous fraction so that the fossils will not be hidden.

INTRODUCTION

This paper, while written primarily for micropaleontologists who work with silicoflagellates,[1] can also be used by those who study other siliceous microfossils such as diatoms, radiolarians, ebriata, sponge spicules, and rocellids.

It is our intent that this paper be a useful working tool for micropaleontologists who are not either chemists or geochemists. It is not intended to be a monographic study, recording, comparing, and evaluating other techniques. Hence

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[1] Silicoflagellates are defined here as marine, planktonic Mastigophora (Protozoa) with a pseudopodium, a flagellum, and a skeleton of hollow siliceous rods. These organisms also contain color pigment organelles and therefore are treated by some workers as plants (Algae) and by others as an animal-plant group (Protista).

no long list of prior papers dealing with this subject is cited. Papers omitted from our much abridged list have not been judged less worthy by us. Their omission results simply from our wish to present a short list. The reader who wishes to compare other techniques is referred to the following papers and their bibliographies: Mann (1922), Hustedt (1958), Hanna (1937), Burma (1965), Gray (1965), and Schopf (1965). The first four workers have techniques that are similar to each other, and similar to our techniques. However, there are sufficient differences between our methodology and the earlier procedures to justify making our data available to those who work with siliceous microfossils. Gray and Schopf deal with pollen, but their papers include some techniques and procedures that are transferable to the study of siliceous microfossils.

Rocks that contain fossil silicoflagellates vary from friable (*e.g.* pure diatomite) to well indurated (*e.g.* limestone). The techniques presented here can be used for all marine sedimentary rocks except those which have essentially the same chemical composition as silicoflagellates. Examples of rocks for which these techniques will not work are chert and jasper. Siliceous microfossils in these kinds of rocks must be studied by thin sections and polished surfaces. The reader is referred to any standard petrographic text for these techniques. They are not included here because it has been our experience that the study of silicoflagellates and diatoms by thin sections and polished surfaces is at best not satisfactory and, in most cases, not worth the effort.

Objectives

The purpose of this paper is to describe our techniques of extracting fossil silicoflagellates and other siliceous microfossils from marine sedimentary rocks. If the procedures given here are followed, all individual specimens of these microorganisms will be relatively clean (i.e., no large particle of debris will be cemented to the specimens).

These results are achieved by: (1) dissolving and chemically disaggregating all the rock (or all the cementing agent of the rock) except the siliceous fraction of the rock and the siliceous microfossils in the rock; and (2) decanting away the nonfossiliferous part of the rock so that silicoflagellates will not be hidden by these materials. In general only acids and other chemicals that do not attack siliceous microfossils are used, the one exception being the use of sodium hydroxide (NaOH), which can dissolve silicoflagellates. However we use it as a dilute solution (0.25–1.0 N) and only for a relatively short time. No appreciable damage to silicoflagellates or diatoms by such use of sodium hydroxide has been observed.

Deep-sea core samples and outcrop samples. There is such a wide variation in the lithology, mineralogy, and chemistry of marine sedimentary rocks containing fossil silicoflagellates that no one simple chemical extraction (or simple generalized method) will be applicable to all marine sedimentary rocks. However, one generalization is possible: most deep-sea core samples are more easily prepared chemically, as compared with most older Cenozoic samples taken from outcrops of well indurated rock. Therefore many steps of the procedure presented here may not be necessary for deep-sea core samples. In contrast, a large number of important New Zealand Early Tertiary samples taken from outcrops consisting of well indurated rock and cemented by complex compounds, have taken as long as two weeks of continuous work per sample to prepare.

Number of samples to be processed at one time. If the worker has adequate experience and adequate equipment, and no problems develop, then six samples can be processed as a batch—at one time. However, at the sulfuric acid fuming[2] step only one sample at a time can be worked. Frequently we find that three or four samples are all that the most experienced worker can handle at one time. Again, this excludes the sulfuric acid fuming step, when but one sample should be handled. Furthermore it is not uncommon that one sample could be such a continous source of trouble that it should be processed alone. Beginners, for reasons of safety and efficiency, should work with only one sample at a time.

Directions and Comments

Read each set of directions completely before you start to do each step.

Rubber gloves, plastic apron, face mask, and goggles should be used at all times while handling acids or sodium hydroxide solutions or hydrogen peroxide solutions. Use a fume hood when working with beakers containing acids.

1. Place the rock sample which is to be prepared on a layer of newspapers. With a clean ice pick break a piece from each large fragment of the rock sample so that the material to be treated will be representative of the whole sample. The remaining untreated portion of the rock sample should be preserved for future study. Reduce all the pieces to about one-fourth inch in size with the ice pick. The maximum amount of the sample to be treated should be about 100 grams.

   After each sampling has been made, carefully roll up and discard the newspapers, and clean the ice pick. This procedure will prevent contamination of one sample by another.

2. Label a clean 1000-ml. Pyrex beaker with sample number. Place about 100 grams of the one-fourth inch pieces into the beaker. If the samples are accurately weighed, the abundance of silicoflagellates in the fossil plankton can be quantitatively determined. (Tappan *et al.*, 1971)

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[2] In this paper we use the term "sulfuric acid fuming" in the sense of concentrated H_2SO_4 which is boiling and decomposing to H_2O and SO_3 white fumes. We do not mean "fuming sulfuric acid" which is $H_2S_2O_7$ (H_2SO_4 with SO_3 in solution).

Cover the sample in the 1000-ml. beaker with about 300 ml. of distilled water. Large beakers are needed because some chemical reactions can be quite vigorous.

If a worker is familiar enough with the microorganisms in his source of tap water to recognize them as contaminants, if the mineral content of the tap water is relatively low, and if the expense of distilled water is a factor to be considered, then good tap water filtered at the tap could be used in many of the steps described in this paper.

3. Place a heavy watch glass over the beaker and add concentrated, chemically pure hydrochloric acid (HCl) through the lips in increments of 10 ml. if effervescence is evident. If there is no effervescence, slowly add all 100 ml. at one time. However, care must be taken because if the sample has a high calcium carbonate ($CaCO_3$) content and if a large amount of hydrochloric acid is added at once, excessive effervescence might result in a spill-over.

Calcium carbonate will neutralize the acid, hence more HCl may be needed to insure an excess of acid after all the $CaCO_3$ has reacted.

If chemically pure acids are not available to the worker and if expense is a factor in the operation, then technical quality acids could be used. However, because the chemically pure acids have smaller amounts of impurities their use is recommended.

The purpose of the HCl treatment is to dissolve oxides and salts (other than silicates) of metals whose chlorides are soluble. These soluble chlorides can then be decanted away. This treatment will work for most metals except silver and lead in the marine sedimentary rock sample.

4. Place the beaker on a hot plate and keep the solution at a gentle boil until all reactions have ended. Suggested hot plate dimensions are: top, three-eighths inch thick, good quality stainless steel, 20 × 20 inches; 10-inch-high stainless steel legs; and 1½-inch-high removable stainless steel railing to prevent beakers from falling off the edge. Heat should be supplied by two or three Meker burners. Rubber tubing should not be used because of the high heat. Tygon or other heat resistant tubing should be used, or, better yet, a direct connection with steel piping with valve control.

Add distilled water to the beaker until half-filled, set aside until no microfossils are suspended in the solution. This should be determined by examination of a drop of the solution under the microscope at 100 ×.

Decant carefully so as not to lose any of the microfossils. Fill the beaker half full with distilled water. Cover with a watch glass and again bring the solution to a gentle boil. More soluble chlorides will now be taken into solution as will be indicated by the color of the water. Boil gently for at least an hour, cool, and examine a drop of the solution under a micro-

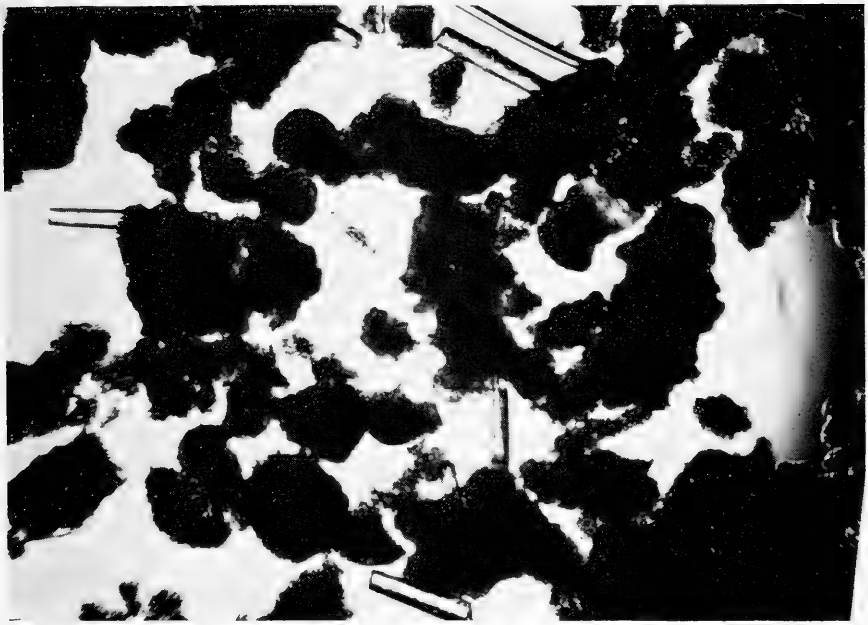

Figure 1. Sample broken down with HCl and water, retained after washing on 400-mesh screen.

scope at 100 ×. If there are no microfossils in the solution, decant. If microfossils are still in suspension, wait until they settle, then decant.

5. Add distilled water to the beaker until half-filled. Remove the fine sediment by vigorously swirling the solution in the beaker so that the fine fraction (i.e. the decomposed and disaggregated material of the rock sample) goes into suspension. Then immediately pour off the solution with its suspended matter into another clean 2000-ml. Pyrex beaker marked with the sample number and an 'A', leaving the coarser material in the original beaker.

   Repeat step 5 several times until the solution in the original beaker is neutral to litmus paper.

6. To the original beaker containing the hydrochloric acid-treated sample that is not yet decomposed and not yet disaggregated, add a solution of sodium carbonate Na_2CO_3 (50 grams per liter of distilled water) until the sample is covered with the solution.

   Heat slowly on the hot plate and gradually add a 30 percent solution of chemically pure hydrogen peroxide (H_2O_2). This must be done carefully, a few drops at a time, because the reaction could be quite vigorous and some of the sample could be lost. Continue this careful addition of

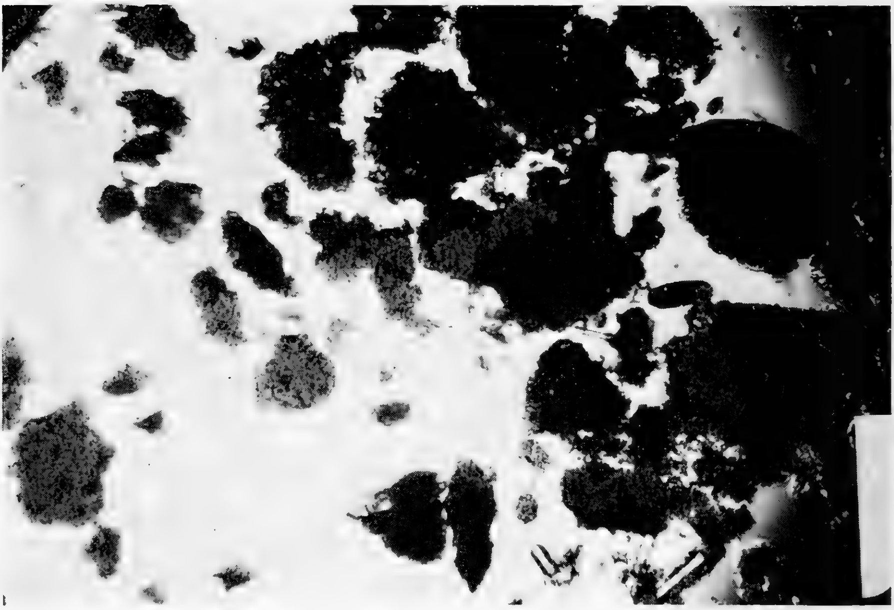

Figure 2. Sample fumed with H_2SO_4, washed and retained on 400-mesh screen.

hydrogen peroxide until 10 ml. have been added. Boil very slowly for 30 minutes. Then remove the beaker from the hot plate to cool and allow the sediment to settle.

The boiling with hydrogen peroxide helps to disaggregate the particles in the sample and also to oxidize the organic matter. The organic matter in the sample probably is the residue of plankton, seaweed, etc., partially decomposed and combined with other materials desiccated and oxidized while at outcrop. If the sample has not been exposed to the atmosphere (e.g. a deep-sea core sample), it will not be oxidized and desiccated; the organic matter will usually go into solution easily and chemical extraction of microfossils is simple. This is why we stated earlier that most deep-sea cores are relatively easy to prepare.

7. If there are no microfossils in suspension, decant and discard the solution which is in beaker 'A'. Test for acidity with litmus paper. If acidic, wash several times and decant until the solution is neutral. Examine a drop of the solution with the microscope at 100 × before each decantation to be sure that no microfossils will be lost.

8. Decant the sodium carbonate - hydrogen peroxide treated fine sediment of step 6 into beaker 'A'. Wash several times by swirling the original beaker until the fine disaggregated and decomposed fraction of the sample is in suspension. Continue washing and decanting until beaker 'A' is nearly filled.

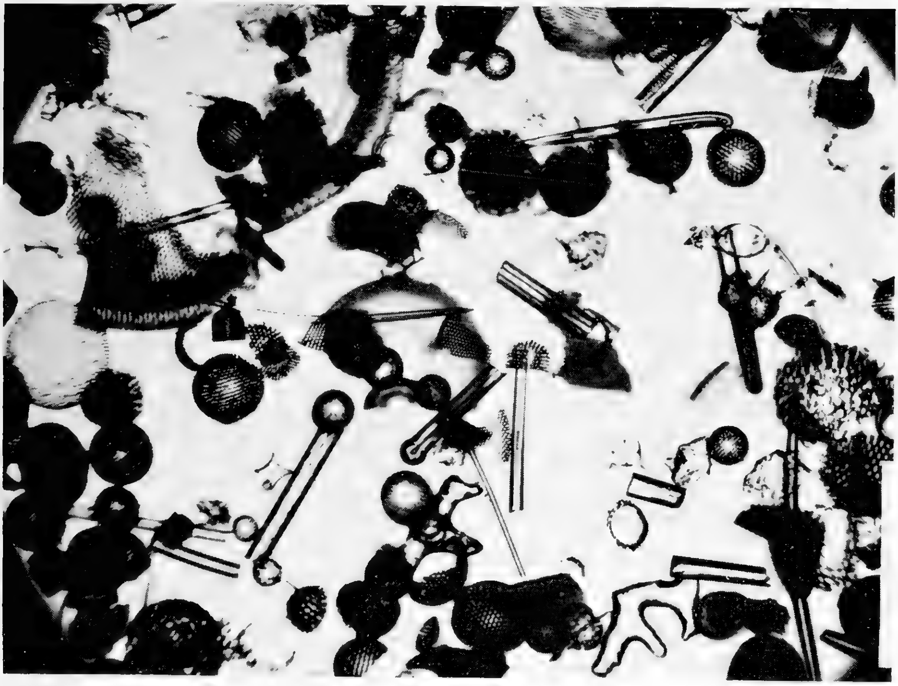

Figure 3. Fumed sample treated with NaOH and H_2O_2, washed and retained on 400-mesh screen.

Then set beaker 'A' aside for the suspension to settle. Decant when the solution above the precipitate in beaker 'A' is clear.

Place the original beaker which contains the undisaggregated material back on the hot plate and add about 400 ml. of distilled water. Bring to boil and keep at a low boil for about three-quarters of an hour.

9. In most cases the sodium carbonate and hydrogen peroxide boiling at this stage should have decomposed or disaggregated most of the remaining cementing agents which have held the rock sample together. The boiling water in step 8 should have completely disaggregated the sample.

However, there are samples that will not react, or will barely react, to this treatment. In such a case, after decanting the sodium carbonate solution into beaker 'A' cover the remaining undecomposed and undisaggregated sample in the original beaker with a solution of sodium hydroxide (20 grams NaOH to 1000 ml. of distilled water) and carefully add 1 ml. of 30 percent chemically pure hydrogen peroxide (H_2O_2). Bring the solution to a boil and continue the boiling for five minutes. Remove from the hot plate, cool and decant the solution and fine sediment into beaker 'A'. Add 400 ml.

of distilled water to the remaining residue in the original beaker and boil for 30 minutes at which time the sample should be completely disaggregated. Remove from the hot plate, cool, swirl the solution, and decant the suspended matter and solution into beaker 'A'. If at this stage undecomposed material still exists in the original beaker, dry it overnight in an oven at 100° C. Label it 'Partially Treated' and store it in a container that also clearly records its locality data.

10. All the fine material that has been separated from the larger pieces of the marine sedimentary rock sample is now in beaker 'A'. Fill this beaker with distilled water and allow the solution to settle. Examine a drop of the solution under the microscope at 100 ×. If there are no microfossils in suspension, decant and discard the solution.

If in the acid treatment all of the metal ions have not been removed, they will now exist as reprecipitated carbonates or hydrates. To remove them, add 100 ml. of concentrated chemically pure hydrochloric acid (HCl) and 400 ml. of distilled water, cover with a watch glass and boil for one hour or more. Remove beaker 'A' from the hot plate, allow it to cool and allow the sediment to settle. Examine the suspended matter in the solution. If the microfossils have settled, decant and discard the solution. Continue to wash the sediment by repeated decantations until the solution is neutral, making sure that no microfossils are poured away.

11. The purpose of this step is to reduce the bulk of the sample. Use a clean 2-inch-deep, 12-inch-diameter, 400-mesh all stainless steel screen, and a clean 10-liter bucket to retain the screened material. Before screening the material, wet the screen on both sides with water; if this is not done water will not pass through this fine mesh.

Add water to beaker 'A' until about half full, swirl the solution in the beaker until the fine sediments are in suspension. Allow the heavier particles to settle: a minute should be sufficient time. Then pour onto the screen a little of the suspended material while agitating the screen by gently striking it on the side with the palm of the hand. To aid the screening, use a plastic wash bottle so held that water will flow onto the screen. The plastic wash bottle should have plastic tubing in order to protect the expensive screen against accidental contact with the tubing. Continue agitating and washing the material on the screen until the water passing through carries no more sediment. Do not use your fingers or any tool to force material through the screen as this will damage both screen and sample. Tilt the screen slightly and wash the retained material to the edge of the screen. With the wash bottle, carefully wash the retained material on the screen into the beaker to be used for the sulfuric acid fuming step. The beaker size should be either 400 or 250-ml. depending upon the amount of residue remaining on the 400-mesh screen.[3] Continue this screening process until all the sample that is being treated has been washed on the 400-mesh screen and transferred to either the 250 or 400-ml. beaker.

12. Because the screen openings of the 400-mesh screen are 38 microns in size, some small silicoflagellates and other small microfossils will pass through these screen openings. These microscopic fossils should be retained for study. However, it has been our experience that the –400 mesh fraction frequently does not contain many silicoflagellates. If there are no microfossils in suspension, decant the solution from the 10-liter bucket, dry its sediment overnight in an oven at 100° C., label, and store for examination and study.

The +400 fraction which does not go through the screen will have undecomposed fragments of the sample containing fossils that are smaller than 38 microns. However, after completing all the steps these remaining specimens, smaller than 38 microns in size, will be freed and available for study.

Clean the screen after use with a surfactant solution. If possible use an ultrasonic cleaning device.

13. In this dangerous step the sample is boiled in sulfuric acid in order to dissolve organic cementing agents.

After the microfossils have settled to the bottom of the 250 or 400-ml. beaker, decant the water. If the layer of the sediment is more than ¼-inch thick, use a 400-ml. beaker.

Extreme caution should be used while the sample is subjected to the sulfuric acid treatment and a face mask and eye goggles should be worn. Place a heavy watch glass over the Pyrex beaker and with the aid of a pipette to which a rubber bulb is attached, slowly add small increments of chemically pure concentrated sulfuric acid through the lip of the beaker. These small amounts of acid should be run down the side of the beaker rather than added directly to the contents of the beaker. Agitate the beaker occasionally as the acid is being added in order to avoid any vigorous action. Continue the addition of sulfuric acid slowly until at least 150 ml. has been added, and the sample is covered with at least one inch of sulfuric acid. Rotate the beaker in an arc with the aid of beaker forceps to mix the acid with the contents of the beaker.

Place the beaker on a ring stand over a Nichrome wire gauze and adjust the Meker burner so that it is about two inches below the wire gauze. This system is necessary because the previously used hot plate will not produce temperatures sufficiently high for this step.

The beaker lip should be kept pointed away from the worker.

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[3] The material that is retained on the 400-mesh screen is called the +400 fraction, and is read as 'plus' 400. Similarly, that which passes through the 400-mesh is called the –400 fraction, and is read as 'minus' 400.

If the contents start to bump, hold the beaker with the beaker forceps and swirl the solution with its sediment. This should minimize the bumping. If the solution becomes viscous, remove from heat and slowly and carefully add more sulfuric acid. Then continue heating. If the solution should start to foam excessively, slide the watch glass partially off the top of the beaker so that the solution is exposed to the air and remove from heat. As soon as the foaming has subsided, heat again. This tendency to foam generally lasts only a short time. **Never** add water to prevent foaming, because a violent reaction would take place. After white fumes appear, continue heating for about ten minutes. Then put the solution aside for about two hours until the beaker has cooled to room temperature.

14. With the aid of a pipette to which a rubber bulb is attached, slowly and carefully add 10 ml. of concentrated chemically pure nitric acid (HNO_3) to the fumed sample through the lip of the beaker which is covered with a watch glass, and again bring the solution to fumes over the Meker burner. The combination of the two acids will oxidize the sample and change the color of the sediment to white. Set this solution aside to cool to room temperature. Through the lip of the beaker which is covered with a watch glass carefully add small amounts of distilled water down the side of the beaker, a few drops at a time. Swirl the solution with beaker forceps after each addition of water until there is no reaction.

15. Fill the beaker three-fourths full with water and allow to settle until the solution above the sediment is clear. At this point do not examine the solution under a microscope because of the high acidity.

Decant carefully and discard the solution making sure that none of the sediment is lost. Fill the beaker three-fourths full with distilled water. Swirl the solution in the beaker as water is added to insure that the sample is being washed. Allow the sediment to settle and examine it under a microscope, as in earlier washings, for the presence of microfossils. Continue the washings, examinations, and decantations until the solution gives a neutral reaction to litmus paper.

16. Add 100 ml. of approximately 1.0 N solution of sodium hydroxide[4] (40 grams of sodium hydroxide per liter of distilled water) and two ml. of a 30 percent solution of hydrogen peroxide to the solution. Place the beaker on a ring stand over gauze and adjust the flame of the Meker burner to give a low heat.

Continue to use extreme care. Gently rotate the beaker holding it with beaker forceps in such a way that the heat of the flame contacts the outer

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[4] NaOH will dissolve siliceous microfossils. Therefore a test was made in order to determine within what limits sodium hydroxide can be used. A solution containing 20 grams of sodium hydroxide per liter of water was placed in a beaker containing a sample of fossil silicoflagellates and diatoms and heated to dryness. Water was then added and the microfossils examined. There was no apparent damage to the fossils.

edges of the beaker. Care should be taken to prevent the flame from coming in contact with the interface between the solution and air, for even a Pyrex beaker might then crack. As soon as the solution becomes warm the H_2O_2 will start decomposing and bubbles of oxygen will become attached to particles of sediment in the beaker, eliminating to a great extent the hazard of bumping. Without the addition of hydrogen peroxide, bumping could be severe enough to cause loss of most of the contents of the beaker. Allow the solution to boil for two minutes. Remove from heat and allow the sediment to settle so that the solution above the sediment does not contain any microfossils in suspension.

The purpose of this sodium hydroxide treatment is to decompose the siliceous fraction of the sample that is cementing the sediment together and to decompose those siliceous particles that are adhering to the microfossils.

17. Decant the solution and add 20 ml. of HCl. Cover the beaker with a watch glass and bring the acidified solution to a boil on the hot plate and continue at a gentle boil for about 30 minutes. Remove from the hot plate and cool. Decant after the sediment and microfossils have settled. This last decantation may be used to determine qualitatively what metallic ions are left in the sample.

Add distilled water to the beaker, allow microfossils to settle, then decant, using the prior described precautions of not decanting any of the sample. Test for acidity. If acidic, wash again by decantation until the solution is neutral to litmus paper. The sample should now be completely clean.

18. Nest three stainless steel screens 150, 250, and 400-mesh. This will yield four fractions: +150, –150 +250, –250 +400, and –400-mesh. Such a division of the treated sample makes it possible to study specimens more effectively as well as to make better slides, because smaller specimens will not be obscured by larger ones. Pour the sample onto the top of the 150-mesh screen of the nested screens, which in turn are placed on top of a 2000-ml. Pyrex beaker. The lip of the beaker will serve as an air vent. Wash each screen well with a wash bottle until little or no sediment passes through the screen. When no more sediment will pass through the 150-mesh screen, tilt it and carefully wash the sample with the wash bottle into a beaker marked with the sample locality description and '+150-mesh'.

As the screening proceeds, check to see that the volume of water is not increased in the 400 and 250-mesh screens to a point of overfill. If this occurs, place the top two screens onto another clean, labeled 2000-ml. beaker and agitate the 400-mesh screen by striking it gently with the palm of the hand until it no longer contains water. Then place the 250-mesh screen on top of the 400-mesh screen and continue the process until the sample has been thoroughly washed and all the sediment transferred to properly marked beakers with distilled water.

Prepare the bottles in which the four samples will be kept by washing the bottles with distilled water, and attaching labels giving the locality data and the appropriate mesh number data (e.g. +150, –150 +250, –250 +400, and –400-mesh).

Allow the fraction of the sample which has passed through the 400-mesh screen to settle for at least two hours. Examine for microfossils in suspension. If fossils are in a drop of the solution, wait until they have settled. Then decant and carefully transfer this fraction to its bottle. Preserve each sample with the addition of four drops of 37 percent solution of formaldehyde in bottles of approximately 30 cc. capacity. Fill bottles about three-fourths full with distilled water. Use leak-proof caps.

ACKNOWLEDGMENTS

We wish to thank Dr. Peter F. Linde, Professor of Chemistry, California State University, San Francisco, and Dr. Milka Zhivadinovich, Professor of Chemistry, California State University, Hayward for their critical reviews of our manuscript.

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TWO NEW SPECIES OF THE SCORPIONFISH GENUS *RHINOPIAS*, WITH COMMENTS ON RELATED GENERA AND SPECIES

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Abstract. A new scorpionfish, *Rhinopias argoliba*, is described from Japan. A new species name, *Rhinopias aphanes*, is given for a specimen identified as *R. frondosa* (Günther) by Whitley (1964), and this single known specimen from New Caledonia is described and figured. Additional specimens of *Rhinopias xenops* (Gilbert) and *Rhinopias frondosa* are described. *Rhinopias godfreyi* Whitley is referred to the genus *Pteroidichthys*. The genus *Pteroidichthys* Bleeker is thought to be closely related to *Rhinopias* Gill. The monotypic genus *Pogonoscorpius* Regan, known only from the holotype of *P. sechellensis* Regan, possibly is a synonym of the genus *Rhinopias*. Remarks are given on the monotypic genera *Hipposcorpaena* and *Pteropelor*, both described by Fowler (1938) from juvenile specimens. Comments on shedding of 'skin' in these and other scorpaenid fishes are given.

Introduction

Specimens of the genus *Rhinopias* are very rare and are among the most striking of fishes in coloration and form. Species are known from the Indian

Ocean and the central and western Pacific Ocean. The two new species described here bring to four the number of species in the genus. The few specimens known previously have received considerable attention (Palmer, 1963; Smith, 1966; and others). We include with the descriptions of the new species information on the other two species, including new records, and offer comments on related genera and species.

The Japanese specimen on which one new species description is based already has had an interesting history. It was collected by Mr. Hajime Masuda and maintained alive in the Enoshima Aquarium, Fujisawa, Japan. This specimen was depicted in color on the cover of *Fish Magazine* (1971) and it was the subject of articles on shedding of skin by one of us (Hirosaki, 1971a–c). The second new species is based on a specimen which was first displayed in the Nouméa Aquarium in New Caledonia and was figured by Whitley (1964) as *Rhinopias frondosa* (Günther).

Shedding of 'skin' in scorpaenid fishes has received some attention, most recently by Hirosaki (1971a–c) and Wickler and Nowak (1969). Information is provided on additional genera of scorpaenid fishes observed to shed.

Acknowledgments

We wish to express our sincere thanks to Mr. Hajime Masuda, Izu Ocean Park, Itō City, Japan, for his generosity and thoughtfulness. He provided the first and only known specimen of *Rhinopias argoliba*, allowing it first to be displayed alive in the Enoshima Aquarium, and second to be studied by us. We gratefully acknowledge the valuable services rendered by Dr. Chūichi Araga, Seto Marine Biological Laboratory (SMBL), Kyoto University, and Dr. Osamu Okamura, Kōchi University (KU); they provided information and sent on loan Japanese specimens and color slides. Similarly, we are grateful to Mr. Paul J. Struhsaker, National Marine Fisheries Service, Honolulu, Hawaii, for providing an unreported specimen of *Rhinopias xenops* from Hawaii and two specimens of *R. frondosa* from the Caroline Islands. We are grateful to Dr. R. Catala, Nouméa Aquarium, New Caledonia, for providing a color slide, photographs, and additional information on the holotype of *R. aphanes*.

Funds from a United States National Science Foundation grant (NSF 15811) permitted the first author to visit museums. The following persons assisted the present study during visits: John R. Paxton, the Australian Museum, Sydney (AMS); M. L. Bauchot and Jean Claude Hureau, Museum National d'Histoire Naturelle, Paris (MNHN); Alwyne C. Wheeler, British Museum of Natural History, London (BMNH); Jørgen Nielson, Zoologisk Museum, Copenhagen (ZMC); M. Boeseman, Rijksmuseum Van Natuurlijke, Leiden (RMNH); Adolf Kotthaus, Biologische Anstalt Helgoland, Hamburg (BAH); and the staff of the U. S. National Museum of Natural History, Washington, D. C. (USNM).

M. L. Bauchot, Jørgen Nielson, and John R. Paxton loaned specimens. Alwyne Wheeler provided additional information for some specimens. Richard Krejsa, California State Polytechnic College, analyzed shed 'skin' from scorpionfishes for us. Pearl Sonoda, Tomio Iwamoto, Maury Giles, Kathy Smith, Kathryn Boyer, and other staff members of the California Academy of Sciences (CAS) aided the study.

We wish to thank Lillian J. Dempster, CAS, for her help with literature, for her comments on the manuscript, and for assisting in the selection of new species names. K. V. Rama Rao provided comments on the manuscript.

METHODS

Methods of measuring and counting follow Eschmeyer (1969); exceptions to measurements commonly used to describe teleosts include the following: pectoral-fin length is measured from the base of the first ray to the end of the longest ray with the fin pointing back; measurements originating from the anterior end of the fish are taken from the most anterior point of the left premaxillary, and measurements are made on the left side of specimens. The last soft ray of the dorsal fin and anal fin is a double ray and the expression XII + 9½ is used to signify 12 spines and 9 soft rays (last double). Terminology of head spines follows Matsubara (1943) and Eschmeyer (1969). Abbreviations for depositories of specimens are given in the Acknowledgments section except for the following: EA—Enoshima Aquarium, Fujisawa.

Genus **Rhinopias** Gill

Rhinopias Gill, 1905, p. 225 (type-species *Scorpaena frondosa* Günther, 1891, by original designation; monotypic).

Peloropsis Gilbert, 1905, p. 630 (type-species *Peloropsis xenops* Gilbert, 1905, by original designation; monotypic).

Remarks. The genus *Rhinopias* has about six months priority over the genus *Peloropsis*. The monotypic genus *Pogonoscorpius* Regan (1908), with the type-species *P. sechellensis*, may also be a synonym of *Rhinopias*. *Pogonoscorpius sechellensis* is still known only from the holotype (see our treatment of *Pogonoscorpius*). *Rhinopias godfreyi* Whitley (1954) is referred to the genus *Pteroidichthys* Bleeker.

Diagnosis. Dorsal fin XII + 9½; anal fin III + 5½; pectoral rays 15–18, some rays branched in larger specimens; scales on body small and cycloid, over 60 vertical scale rows; head unscaled; vomerine teeth present; palatine teeth absent; vertebrae 24; body compressed; second suborbital bone becoming wider posteriorly, attached to preopercle; third suborbital bone absent; no slit behind fourth gill arch.

Spination. Head spination is similar for all species. Most spines poorly developed. Nasal spines small, usually absent in one species. Preocular, supraocular, and postocular spines present; sometimes preocular and supraocular spines reduced; supraocular spine obscured by tentacle; postocular spine as broad shelf above rear of orbit. Parietal and nuchal spines well developed, joined. Sphenotic spine (as group of small spines) absent in some species. Pterotic spine well developed. Upper posttemporal spine small; lower posttemporal spine well developed. Supracleithral and cleithral spines rounded. Opercular spines blunt at tips. Tympanic, coronal, and interorbital spines absent. Supplemental preopercular spine present or absent. First three preopercular spines moderate, fourth small, fifth absent or barely perceptible. Suborbital ridge with four low spines or lumps, first on lateral face of preorbital bone, followed by one under front of eye, and two just before preopercular bone; sometimes these spines may be absent or poorly developed. Preorbital bone with 2 poorly defined spines over maxillary (second and third preorbital lobes of Matsubara, 1943).

KEY TO THE SPECIES OF THE GENUS *Rhinopias*

1. Pectoral rays 18 [17 and 19 should be expected]; no black spot or ocellus on soft dorsal fin 2

1. Pectoral rays 16 or 15 [17 should be expected]; black spot or ocellus present on soft dorsal fin 3

2. Skin flaps absent on lower jaw; few skin flaps on body; third dorsal spine about 3 times in head length and about two-thirds of snout .... *Rhinopias argoliba* (figs. 1–2A)

2. Skin flaps present on lower jaw; head, body, and fins with numerous skin flaps; third dorsal spine about two times in length of head or less than 2 times if third spine is especially elongate, third spine longer than snout .... *Rhinopias xenops* (figs. 2B, 3–4)

3. Body, head, and fins with round and oblong pale (dark rimmed) spots or blotches; sometimes almost entirely pallid in preservative .... *Rhinopias frondosa* (figs. 5–7)

3. Body, head, and fins with dark reticulations on a paler background .... *Rhinopias aphanes* (fig. 8)

SPECIES ACCOUNTS

Rhinopias argoliba Eschmeyer, Hirosaki, and Abe, new species.

(Figures 1–2A.)

No scientific name used, HIROSAKI, 1971a, pp. 4–5, 2 figs. (shedding); 1971b, pp. 26–27, front cover, 5 figs. (shedding; cover in color showing live coloration); 1971c, p. 170, fig. (shedding).

Inimicus didactylum (not of Pallus), AXELROD and BURGESS, 1972, figs. 466, 470 (misidentification; poor color reproduction of specimen when alive in the Enoshima Aquarium).

HOLOTYPE. Enoshima Aquarium no. 1 (129 mm. S.L., 167 mm. T.L.), Japan, Sagami Bay, caught off Izu Ocean Park, Itō City, at a depth of 50 meters, 15 January 1971 [transferred alive to Enoshima Aquarium on 30 January 1971, where it died on 23 May 1971].

DESCRIPTION. (Based on the holotype and only known specimen.) A large-headed, compressed scorpionfish. Dorsal fin with 12 spines and 9½ soft rays;

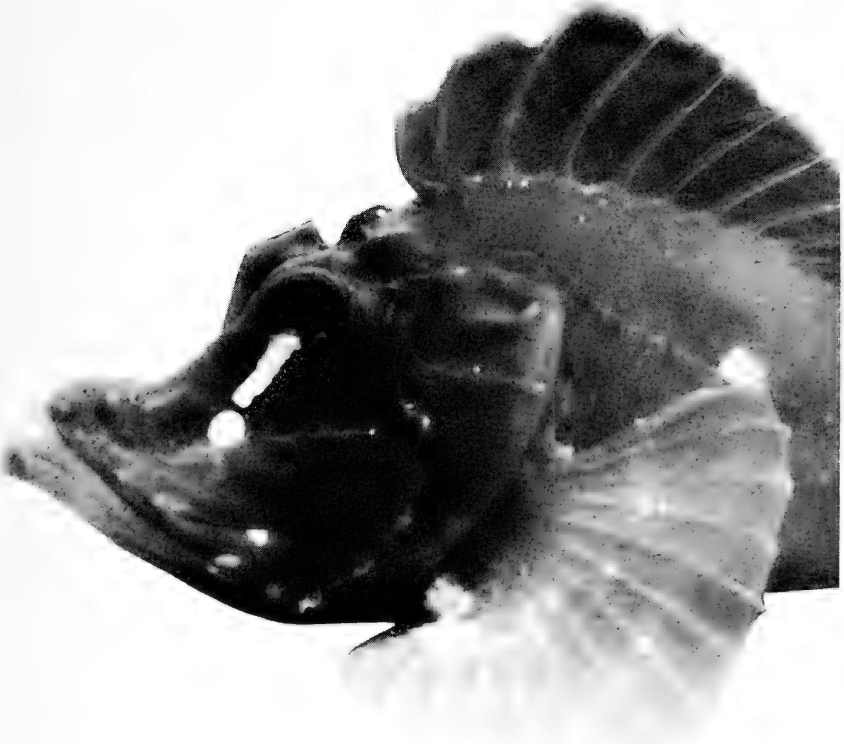

Figure 1. *Rhinopias argoliba*, holotype, EA no. 1, 129 mm. S.L., Japan; note white coloration below eye and above pectoral fin (from the specimen when alive).

third dorsal spine not elongate, fourth spine the longest, eleventh dorsal spine about ¾ the length of the twelfth spine. Anal fin with 3 spines and 5½ soft rays; first spine slightly more than one-half length of second, third spine longest. Pectoral rays 18, only one or two branched rays in each fin (branching of pectoral rays variable with size in other species). Gill rakers (including rudiments) total 23, 7 on upper arch, 16 on lower arch including one at angle, all rakers as short spiny knobs. Scales on body small and cycloid; about 80 vertical scale rows (count made a few scale rows above lateral line from above first lateral-line scale to end of hypural plate). Head without scales.

Spination similar to that of other species of *Rhinopias* (see account under genus). Nasal spines small. Supplemental preopercular spine present, small, lying above first preopercular spine. Sphenotic spines absent in available specimen. Suborbital ridge with 4 spines; first a sharp one on preorbital bone, followed by one under the eye and two lumps before the preopercular bone.

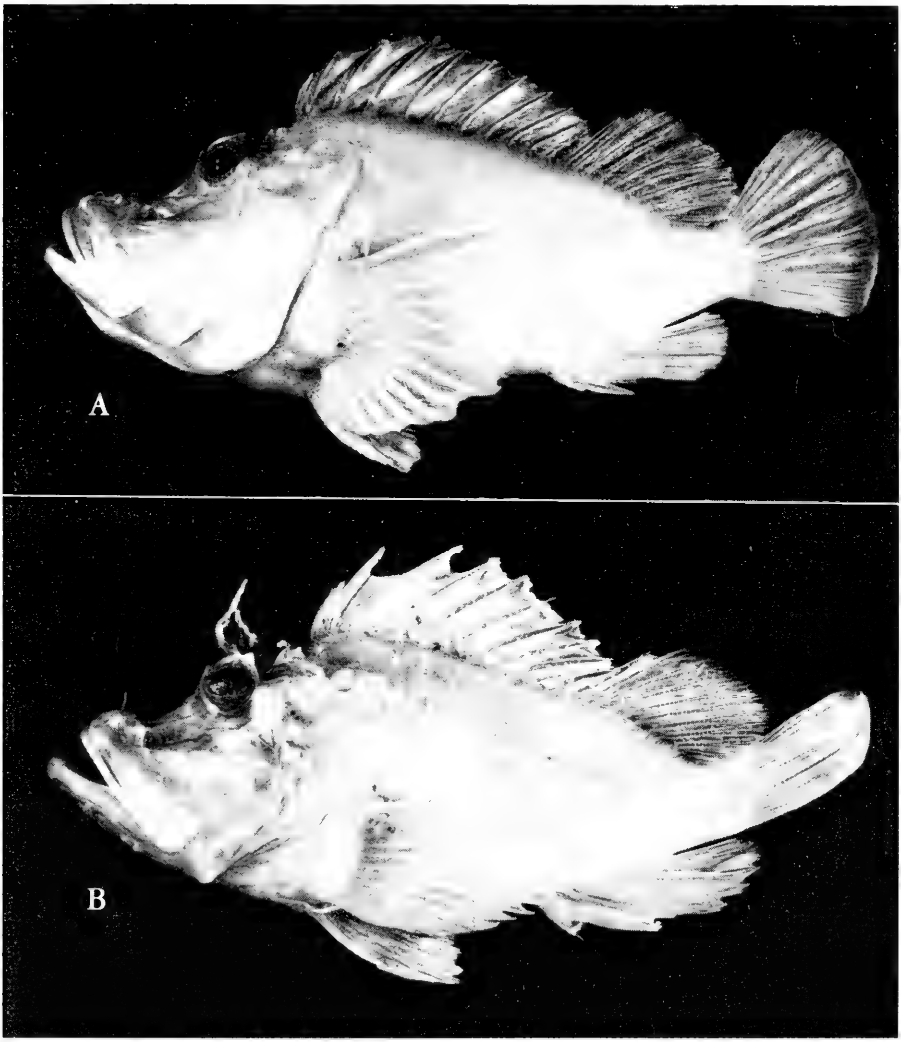

FIGURE 2. A. *Rhinopias argoliba*, holotype, EA no. 1, 129 mm. S.L., Japan. B. *Rhinopias xenops*, USNM 209415, 107 mm. S.L., Hawaii.

Measurements for the holotype in table 1.

Tentacles on body few. No supraocular tentacle in available specimen; no skin flaps on lower jaw as in other species; small skin flaps on nostrils, on eye, on lower margin of preopercle, on some lateral-line scales, and a few very tiny ones on the pectoral fin. (The development of tentacles and skin flaps is somewhat variable in scorpaenid fishes. See the 'Comparisons and Remarks' section below.)

Coloration in preservative almost entirely pallid (fig. 2); no reticulations present, no dark spot on soft dorsal fin. White stripe before eye slightly visible; some faint dark areas below eye (melanophores contracted). Color in life bright red, including all of body, head, and fins, with the exception of the white stripe before the eye, white patches near base of lower pectoral rays, a few scattered white spots on body and snout, one conspicuous spot about size of pupil just above lateral line over pectoral fin, and another spot on dorsal part of caudal peduncle. About 15–20 small (0.2–0.5 mm. in diameter) dark blue specks on head, most concentrated below eyes just above suborbital ridge. Spinous dorsal fin tipped with white. The white stripe (fig. 1) before the eye expanded into a circular spot at distal end (resembling an exclamation point [!]), 'spot' separated from stripe on left side, partially joined to stripe on right side (see Hirosaki, 1971c, fig. on p. 170, or Axelrod and Burgess, 1972, figs. 466, 470).

Comparisons and Remarks. This species is easily distinguished from *R. frondosa* and *R. aphanes* by having a higher pectoral fin ray count (18 versus 16 or 15). The development of tentacles and skin flaps on the head and body is variable but presence on the lower jaw is a stable feature in species of other genera. Of the four species of *Rhinopias* only *R. argoliba* lacks tentacles on the lower jaw. *Rhinopias argoliba* appears to be closely related to *R. xenops* with which it shares a pectoral fin ray count of 18. The holotype of *R. xenops* has the third dorsal spine notably elongate, but the additional specimens from Hawaii and two Japanese specimens do not, although the third spine is slightly elongate in two. In some scorpionfishes which have one or more dorsal spines elongate, this elongation is variable and does not occur until the fish reaches the subadult stage or even the adult stage; we do not know if this difference will be useful for distinguishing large specimens. The dorsal spines are proportionally shorter in the specimens of *R. argoliba* than in *R. xenops*. The second anal spine is shorter than the third in *R. argoliba*, but about equal in length to the third in *R. xenops*. Most fin spines are proportionately shorter in *R. argoliba* than in *R. xenops*. The pectoral fin in *R. argoliba* is shorter than in *R. xenops*. The holotype of *R. argoliba* is as large or larger than the known specimens of *R. xenops* but has fewer branched pectoral rays (2 or 3 versus 5 to 7). Branching of pectoral rays in scorpaenids begins in juveniles and increases with increase in size to a maximum number of branched rays. The dentition on the premaxillaries is stronger in *R. xenops* than in *R. argoliba*. Differences in coloration of *R. argoliba* and *R. xenops* may be useful in distinguishing these species. The entire specimen of *R. argoliba* was bright red in life, including the head, body, and fins, with the exception of milky white spots on the body and the white stripe before the eye as given in the description above. The coloration in *R. xenops* is quite different (see account of *R. xenops*).

We do not know what affect, if any, the 114-day stay in the Enoshima Aquarium had on the growth of the holotype of *R. argoliba* as might be reflected in unnatural lengths of some body parts. The only damage to the specimen seems to be that a callus formed at the symphysis of the lower jaw, caused by friction against glass.

Distribution. Known only from the holotype collected from Japan, off Itō, Sagami Bay, at a depth of 50 meters.

Name. The scientific name '*argoliba*' (treated as an adjective) is from Greek, *argos* (white) plus *libos* (tear or drop), alluding to the milky-white teardrop below the eye. The Japanese common name Namida-kasago is proposed and is based on "namida," or tear, plus "kasago," the Japanese name for *Sebastiscus marmoratus*.

Rhinopias xenops (Gilbert).

(Figures 2B, 3–4.)

Peloropsis xenops Gilbert, 1905, pp. 630–631, text fig. 245 (original description; type locality Hawaii, Auau Channel, between Maui and Lanai Islands, depth 32 to 43 fathoms, *Albatross* station 3872, 12 April 1902; holotype USNM 51604); Jordan and Seale, 1906, p. 379 (listed; Hawaii); Jordan and Evermann, 1926, p. 10 (listed; Hawaii); Fowler, 1928, p. 287 (compiled description); 1938, p. 290 (listed; Hawaii); Tinker, 1944, pp. 262–264, fig. (compiled; figure from Gilbert, 1905); Gosline and Brock, 1960, pp. 284, 286, 341 (in key; compiled); Palmer, 1963, pp. 701–704, pl. XX (in part; wrongly included Japanese specimens [Kamohara, 1942, *et seq.*]; compared with *R. frondosa*); Gosline, 1965, p. 825 (depth distribution; compiled).

Rhinopias xenops, Whitley, 1954, p. 61 (placed in genus *Rhinopias*; distinguished from other species); Smith, 1966, pp. 74, 77–79 (in key, distinguished from *R. frondosa*).

Peloropsis frondosus, Kamohara, 1959, pp. 5–6 (in part; *R. xenops* in synonymy; thought *R. xenops* may be variant of *R. frondosus* rather than a distinct species).

Material. USNM no. 51604 (1, 110 mm. S.L., holotype), Hawaii, Auau Channel, between Maui and Lanai Islands, depth 32 to 43 fathoms, *Albatross* station 3872, 12 April 1902. USNM no. 209415 (1, 107 mm. S.L.), Hawaii, Haleiwa, 21°39.6′ to 21°42′N., 158°07.3′ to 158°05′W., 41-ft. shrimp trawl, in 95–110 meters, *Townsend Cromwell* cruise 36, station 19, 3 May 1968. SMBL no. 7201 (1, 114 mm. S.L.), Japan, off Shirahama Town, Nishimuro County, Wakayama Prefecture, rocky bottom, 31 October 1971. SMBL no. 7202 (1, 129 mm. S.L.), Japan, off Nambu Town, Hidaka County, Wakayama Prefecture, bottom gill net on rocky substrate, 31 January 1969.

Distinguishing features. Preserved specimens mostly pallid; pectoral fin rays 18; no ocellus or dark spot on soft dorsal fin; vertical scale rows about 70; skin flaps present on lower jaw.

Remarks. The specimens reported here agree with the holotype in most features. The third dorsal spine is elongate in the holotype (fig. 3) but it is not especially elongate in the other specimens (figs. 2B, 4). The specimens agree in counts. All have 18 pectoral rays, rays 2–7 branched in the holotype (also

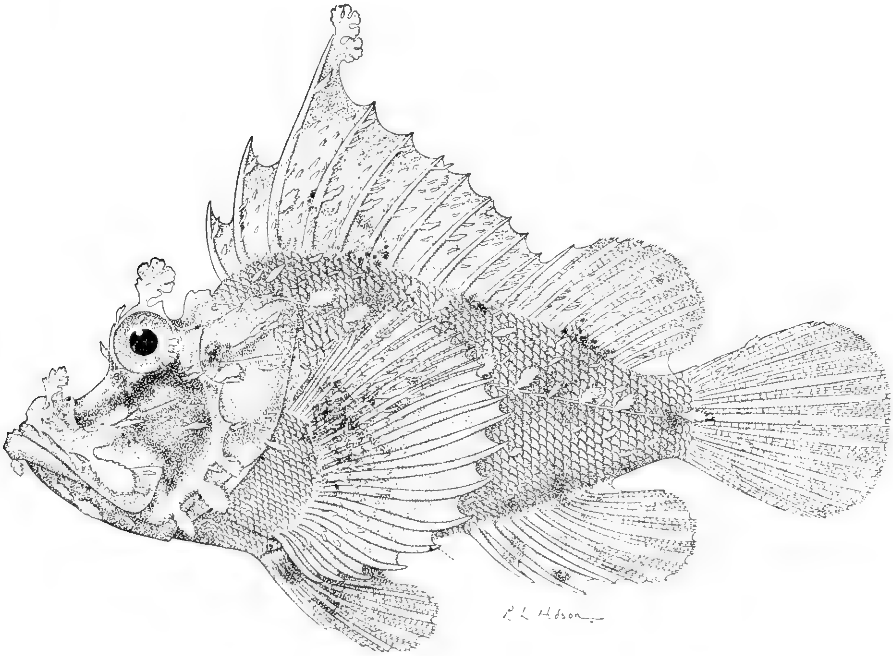

Figure 3. *Rhinopias xenops*, holotype, USNM no. 51604, 110 mm. S.L., Hawaii.

the 9th on left side in the holotype), rays 1–7 or 2 through 6 or 7 branched in the other specimens. Gill rakers (including rudiments) total 21 to 23, 6(7) on upper arch, 15–17 on lower arch. Vertical scale rows number about 70–75, and lateral line scales 22 or 23. Head spination as for the genus. Nasal spines small. Supplemental preopercular spine present, small. Sphenotic spines absent or small.

An extensive color description was given by Gilbert (1905, p. 631) as follows:

> "Head, body, and fins bright vermilion, upper parts of head and body darkened with olive tint, and with small scattered purplish spots, which are also found on upper half of pectoral fin; head, lower parts of body, and fins mottled with yellowish-white; flaps and tentacles narrowly edged with bright lemon-yellow; a large blackish blotch below eye, one on opercle and one at base of pectoral; a conspicuous broad, yellowish white bar on each side of compressed part of rostrum; three groups of brownish spots along base of dorsal fins; conspicuous white spots on back of tail and at base of eighth and ninth dorsal spines; a larger blotch below the latter just above lateral line."

No information on fresh coloration is available for the additional specimen from Hawaii. A Kodachrome slide of a Japanese specimen (SMBL 7202) revealed the following: body and head mostly orange-red; small purplish specks on upper part of head and body; large patch of white on body below dorsal spines

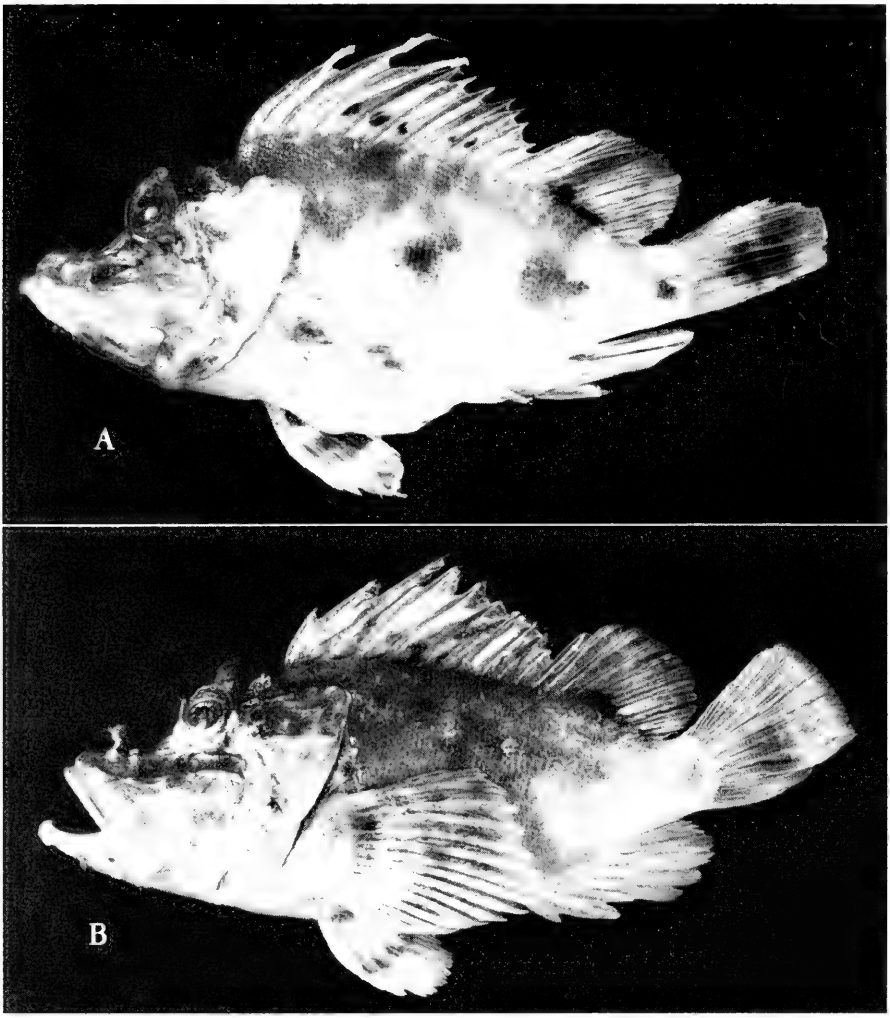

FIGURE 4. *Rhinopias xenops.* A. SMBL no. 7201, 114 mm. S.L., Japan. B. SMBL no. 7202, 129 mm. S.L., Japan.

7–10, with a smaller white spot just above lateral line below this large white patch; other white patches on head, pectoral fin, and scattered on body; small, tapering pale stripe leading forward and down from eye. The coloration of the Japanese specimen is similar to that given by Gilbert for the holotype with a few exceptions. The Japanese specimen had more orange and less red pigment on the head and body and lacked most of the lemon-yellow pigmentation as found by Gilbert. Some differences may result from occurrence at different depths; the Japanese specimen was on display in an aquarium when photographed while Gilbert's description was taken from the holotype recovered from 32–43 fathoms. Dusky patches were similar as evidenced by the preserved condition. The major features of the distribution of white patches were very similar.

Coloration in preservative (figs. 2B, 3–4) for all specimens is basically similar, the most conspicuous feature being the dusky pigment at the base of the soft dorsal fin.

Measurements are given in table 1.

Distribution. *Rhinopias xenops* is now known from Hawaii and Japan. Previous records of this species from Japan were based on specimens of *R. frondosa*. Depths of capture for the Hawaiian specimens were between 32 and 43 fathoms and between 52 and 60 fathoms. Depths of capture for the Japanese specimens are not available, but they were captured offshore. Habitat appears to be rocky or coralline areas.

Name. 'Nise-boro-kasago' is proposed as the Japanese common name, from 'nise' (pseudo) + 'boro' (ragged or tattered) + 'kasago' (*Sebastiscus marmoratus* or similar fish). Boro-kasago is the Japanese name for *Rhinopias frondosa*.

Rhinopias frondosa (Günther).

(Figures 5–7.)

Scorpaena frondosa Günther, 1891, pp. 482–483, pl. XXXIX (original description; type locality Mauritius; holotype BMNH 1891.4.30.3).

Peloropsis xenops (not of Gilbert), Kamohara, 1942, pp. 27–28, fig. 1 (description; differences between his specimens and the holotype of *R. xenops*; two specimens from Shirahama, Wakayama Prefecture, Japan); 1950, p. 219, fig. 165 (compiled; figure from Kamohara, 1942).

Peloropsis frondosa, Deraniyagala, 1952, p. 109, pl. 32 (specimen from Ceylon; figure poor; lengths and body proportions incorrect [see Smith, 1966, p. 77]).

Peloropsis frondosus, Munro, 1955, p. 250, pl. 48, fig. 726 (compiled; figure copied from Deraniyagala, 1952); Kamohara, 1959, pp. 5–6, fig. 2 (description; one specimen from Susaki Fish Market; figure from Kamohara, 1942); 1964, pp. 73–74, fig. 47 (listed; Kochi Prefecture, Japan; figure from Kamohara, 1942); Fourmanoir and Nhu-nhung, 1965, p. 93, fig. 59 (two specimens from Viet Nam; line drawing); Fourmanoir and Guézé, 1966, pp. 56–57, fig. III d (Reunion Island, 90 m.)

Rhinopias frondosa, Smith, 1957, p. 62, pl. 4, fig. C (compiled; copied from Günther); Palmer, 1963, pp. 701–704, pl. XX (summary of earlier records of *Rhinopias*; treated *R. xenops* and *R. frondosa* as separate species; radiographs of *R. xenops* and *R. frondosa*); Kotthaus, 1966, p. 122 (figure of a specimen from the northern Indian Ocean); Smith, 1966, pp. 74–79, fig. B on pl. 14 (synonymy; description; new record for South African waters; summary of earlier knowledge on *R. xenops* and *R. frondosa* and differences between them; retouched photo of a 45 mm. S.L. specimen).

Material. BMNH no. 1891.4.30.3 (1, 146 mm. S.L., holotype), Mauritius, collected by Robillard. MNHN 1967–550 (1, 79.5 mm. S.L.), Reunion Island. BAH uncat. (1, 145 mm. S.L.), off Somalia, 6°06′ to 6°03′N., 49°05′ to 49°03′E.,

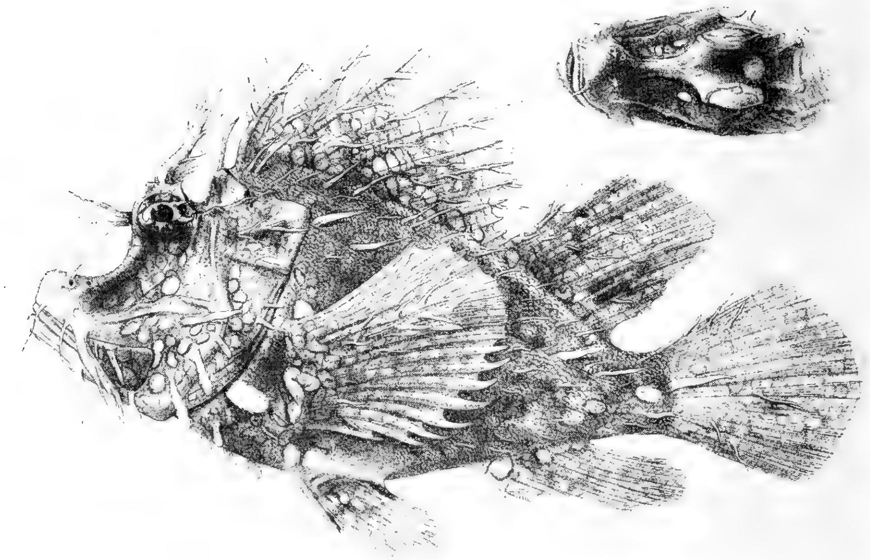

FIGURE 5. *Rhinopias frondosa*, holotype, BMNH no. 1891.4.30.3, 146 mm. S.L., Mauritius (from Günther, 1891, pl. 39).

in 55–65 meters, *Meteor* station 123. KU no. 8465 (1, 152 mm. S.L.), Japan, Kochi Prefecture, Susaki Fish Market, 12 March 1959. SMBL no. 7203 (1, 127 mm. S.L.), Japan, Nambu Town, Hidaka County, Wakayama Prefecture, gill-net on rocky bottom, 17 January 1959. SMBL no. 7204 (1, 146 mm. S.L.), Japan, off Iwashiro, Hidaka County, Wakayama Prefecture, lobster gill-net on rocky bottom, 18 April 1959. USNM no. 209416 (1, 103 mm. S.L.) and CAS no. 15320 (1, 115 mm. S. L.), Caroline Islands, Condor Reef, in 30 fathoms, 12.5-m. shrimp trawl, *Townsend Cromwell* Cruise 57, 24 May 1972.

DISTINGUISHING FEATURES. Pectoral rays 16 (rarely 15, but 17 rays would not be unusual); dark spot on membrane of soft dorsal fin between rays 7–9, sometimes more restricted; body and fins of preserved specimens covered with large brown circles or with pale spots or oblong blotches on light brown background, vertical scale rows about 70–75; skin flaps present on lower jaw.

REMARKS. The known specimens up until now of this species have been reviewed in two articles (Palmer, 1963; Smith, 1966). Both authors reached the conclusion that *R. frondosa* is distinct from *R. xenops*. The color patterns of all the known preserved specimens of *R. frondosa* are similar except for one from Nouméa reported on by Whitley (1964, p. 9, pl. II). The Nouméa specimen is felt by us to represent a separate species and is treated as a new species, *R. aphanes*, in a separate section of this paper.

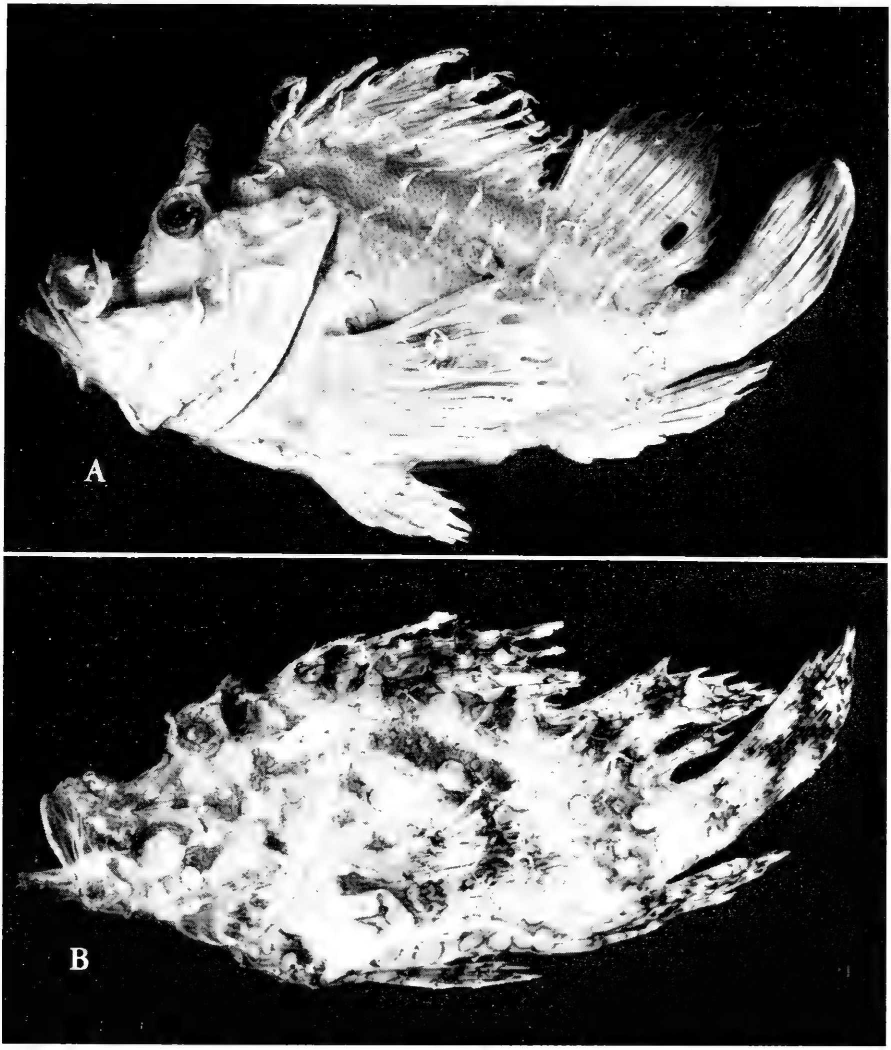

Figure 6. *Rhinopias frondosa.* A. KU no. 8465, 152 mm. S.L., Japan. B. MNHN no. 1967–550, 79.5 mm. S.L., Reunion Island.

Measurements and counts are presented in table 1. The holotype, specimens from Japan, Reunion Island, and the Caroline Islands are figured (figs. 5–7).

Color slides provided by Dr. Araga of 2 Japanese aquarium specimens (both about 230 mm. T.L.) revealed the following: specimen 1 with body, head, and fins reddish pink (approaching maroon); all of specimen covered with mostly

TABLE 1. *Counts and measurements for specimens of the genus* Rhinopias. *(Measurements are in mm.; percent standard length in parentheses; see Materials Examined for catalog numbers and locality information; holotype marked with an asterisk.)*

	R. argoliba	*R. xenops*				*R. aphanes*	*R. frondosa*
Standard length	129*	107	110*	114	129	178*	79.5
Dorsal rays	XII+9½	XII+9½	XII+9½	XII+9½	XII+9½	XII+9½	XII+9½
Anal rays	III+5½	III+5½	III+5½	III+5½	III+5½	III+5½	III+5½
Pectoral rays	18+18	18+18	18+18	18+18	18+18	16+16	16+16
Gill rakers	7+16	6+15	6+16	6+17	6–7+16	6+14	?6+14
Vertebrae	24	24	24	24	24	24	24
Vertical scale rows (approximate)	80	70	68	76	73	70	—
Head length	59.5(46)	51.7(48)	51.2(46)	53.9(47)	60.1(47)	85.5(48)	36.8(46)
Body depth	55.2(43)	45.7(43)	48.7(44)	47.4(42)	53.3(41)	82.1(46)	35.0(44)
Orbit diameter	10.3(08)	9.5(09)	10.0(09)	10.0(09)	11.1(09)	13.5(07)	7.0(09)
Snout length	26.5(21)	21.1(20)	20.6(19)	22.2(19)	25.6(20)	40.0(22)	14.8(19)
Interorbital width	5.8(04)	4.4(04)	5.3(05)	4.5(04)	6.0(05)	10.5(06)	4.2(05)
Jaw length	29.5(23)	26.4(25)	26.4(24)	28.4(25)	31.2(24)	42.0(24)	16.9(21)
Predorsal-fin length	47.7(37)	40.7(38)	42.2(38)	45.6(40)	48.8(38)	74.1(42)	29.3(37)
Caudal fin length	32.6(25)	—	—	33.6(29)	38.6(30)	52.6(30)	30.5(38)
Pectoral fin length	37.5(29)	33.3(31)	39.9(36)	42.2(37)	45.6(35)	67.7(38)	30.3(38)
Pelvic fin length	29.2(23)	29.3(27)	33.6(30)	31.3(27)	33.2(26)	49.3(28)	23.9(30)
Length 1st anal spine	9.6(07)	11.6(11)	13.2(12)	10.6(09)	13.2(10)	16.1(09)	8.7(11)
Length 2nd anal spine	17.2(13)	22.0(21)	22.6(21)	23.0(20)	21.4(17)	23.5(13)	14.1(18)
Length 3rd anal spine	20.0(16)	21.4(20)	22.7(21)	21.7(19)	21.5(17)	25.1(14)	15.1(19)
Length 3rd dorsal spine	20.3(16)	25.2(24)	40.0(36)	34.7(30)	35.3(27)	41.7(23)	22.6(28)
Length 4th dorsal spine	21.2(16)	25.8(24)	31.2(27)	32.8(29)	30.9(24)	—	24.9(31)
Length 11th dorsal spine	11.7(09)	—	—	12.1(11)	11.7(09)	8.5(05)	6.3(08)
Length 12th dorsal spine	12.2(10)	—	—	16.3(14)	16.8(13)	21.9(12)	13.6(17)

circular white spots or blotches, but with central area of blotches or spots usually colored same as body; pigment around edges of these pale areas slightly darker than surrounding areas; some small pale blotches between larger circular areas. Specimen 2 with more pink on fins and tentacles, and with head and body more brownish red. Transparent, oblong areas between upper pectoral rays at about midheight of fin visible in specimen two. Kamohara (1959) reported that the body (our KU 8465, 152 mm. S.L.) was uniform reddish; head bluish, lower parts of body and fins mottled with white, and black blotch on membrane between seventh and eighth dorsal rays. Smith (1966, p. 77, pl. 14B) reported the coloration of his 45 mm. S.L. specimen as follows:

> "Colour in life. . .milky yellow, with orange tinge over the opercle. The body is covered with thin brown lines forming irregular loops of varying size and shape. The iridal flaps are almost black, giving a radial effect. There are a few prominent dark

Table 1 (*Continued*)

	R. frondosa (continued)						
Standard length	103	115	127	145	146*	146	152
Dorsal rays	XII+9½	XII+9½	XII+9½	XII+9½	XII+9½	XII+9½	XII+9½
Anal rays	III+5½	III+5½	III+5½	III+5½	III+5½	III+5½	III+5½
Pectoral rays	16+16	16+16	16+16	16+16	16+16	16+16	16+16
Gill rakers	6+15	6+15	7+15	—	6+15	6–7+15	6+14
Vertebrae	24	24	24	—	24	24	24
Vertical scale rows (approximate)	70–75	72	—	—	—	75	75
Head length	46.3(45)	57.1(50)	59.0(46)	65.3(45)	66.6(46)	68.0(46)	67.3(44)
Body depth	46.8(45)	59.6(52)	61.6(48)	66.3(46)	66.8(46)	69.8(48)	70.7(46)
Orbit diameter	8.2(08)	11.2(10)	10.3(08)	11.4(08)	12.4(08)	13.0(09)	12.0(08)
Snout length	20.5(20)	23.8(21)	26.6(21)	30.2(21)	29.9(20)	28.9(20)	29.1(19)
Interorbital width	6.3(06)	7.7(07)	8.3(06)	8.0(06)	8.6(06)	9.7(07)	8.3(06)
Jaw length	20.5(20)	26.0(23)	25.8(20)	30.1(21)	30.8(21)	30.7(21)	32.1(21)
Predorsal-fin length	37.6(36)	46.2(40)	47.8(38)	50.6(35)	58.0(40)	56.5(39)	56.4(37)
Caudal fin length	35.7(35)	43.7(38)	41.9(33)	48.0(33)	49.0(34)	47.4(32)	48.5(32)
Pectoral fin length	37.3(36)	48.4(42)	47.4(38)	49.5(34)	49.5(34)	53.9(37)	55.1(36)
Pelvic fin length	26.2(25)	32.3(28)	33.4(26)	39.2(27)	42.1(29)	40.3(28)	37.8(25)
Length 1st anal spine	8.4(08)	9.3(08)	8.8(07)	—	10.5(07)	11.2(08)	10.0(07)
Length 2nd anal spine	13.0(13)	15.5(14)	15.7(12)	—	19.0(13)	17.8(12)	17.9(12)
Length 3rd anal spine	16.3(16)	18.5(16)	17.1(13)	—	21.7(15)	20.9(14)	21.7(14)
Length 3rd dorsal spine	27.4(27)	39.7(34)	38.0(30)	—	45.7(32)	41.6(28)[1]	37.8(25)
Length 4th dorsal spine	27.5(27)	38.6(34)	33.0(26)	—	53.0(36)	47.7(33)	36.2(24)
Length 11th dorsal spine	5.3(05)	5.8(05)	6.2(05)	—	9.0(06)	9.7(07)	7.8(05)
Length 12th dorsal spine	13.6(13)	18.2(16)	17.1(14)	—	19.0(13)	24.4(17)	20.4(14)

[1] Broken at tip.

> marks on the fins, one rectangular, low, between the 5–6th dorsal spines, one, smaller, behind the base of the ninth dorsal spine, one across the upper part of the second dorsal ray, a small one on the upper and another at the lower part of the caudal. The largest is low down between the seventh and eighth dorsal rays, and the smallest (but distinct) between the apices of the first and second (upper) rays of the pectoral fin."

Deraniyagala (1952, pl. 32) illustrates a 126-mm. T.L. specimen as mostly orange-red. The general body coloration appears to change from mostly yellow in small specimens to mostly red or crimson in large specimens. Our specimen from Reunion Island (fig. 6B) has the dark pigment most concentrated in the areas mentioned by Smith as prominent dark marks. The retention in preservative of the dark, mostly circular lines (outlining the pale areas) is variable (figs. 5–7) and seems to depend on the amount of black or brown pigment

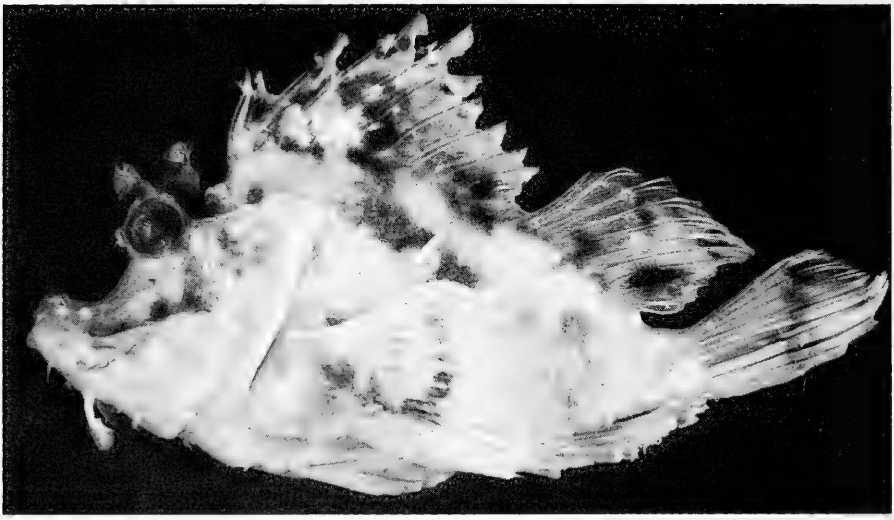

Figure 7. *Rhinopias frondosa,* CAS 15320, 115 mm. S.L., Caroline Islands.

present initially and perhaps on the method of preservation. Kotthaus (1966, pl. 22) provides an excellent figure of a 145-mm. S.L. specimen.

Spination as for the genus. Nasal spines usually absent. Supplemental preopercular spine absent or poorly developed. Sphenotic spines present.

The reader is referred to the papers cited above for a detailed description of *R. frondosa.*

Distribution. *Rhinopias frondosa* is known from Mauritius, Reunion Island, Natal, Somalia, the Arabian Sea, Ceylon, Vietnam, Japan, and the Caroline Islands. Few depths of capture are available: dredged in 13 meters in Ceylon (Deraniyagala, 1952); in 55–65 meters off Somalia, in 90 meters at Reunion, and in 55 meters at the Caroline Islands. Habitat is rocky or coralline areas.

Name. The Japanese name 'Boro-kasago' has been used for this species; from 'boro' (ragged or tattered) + 'kasago' (*Sebastiscus marmoratus* or similar species).

Rhinopias aphanes Eschmeyer, new species.

(Figure 8.)

Rhinopias frondosa (not of Günther), Whitley, 1964, p. 9, pl. II (3-sentence account reporting a specimen from New Caledonia [this specimen now holotype of *R. aphanes*]).

Holotype. AMS IB7079 (178 mm. S.L., 235 mm. T.L.), New Caledonia, outside barrier reef facing Nouméa, at a depth of 30 meters, collected by Yves Merlet and Madame R. Catala-Stucki [transferred alive to the Nouméa Aquarium where it lived for less than a week].

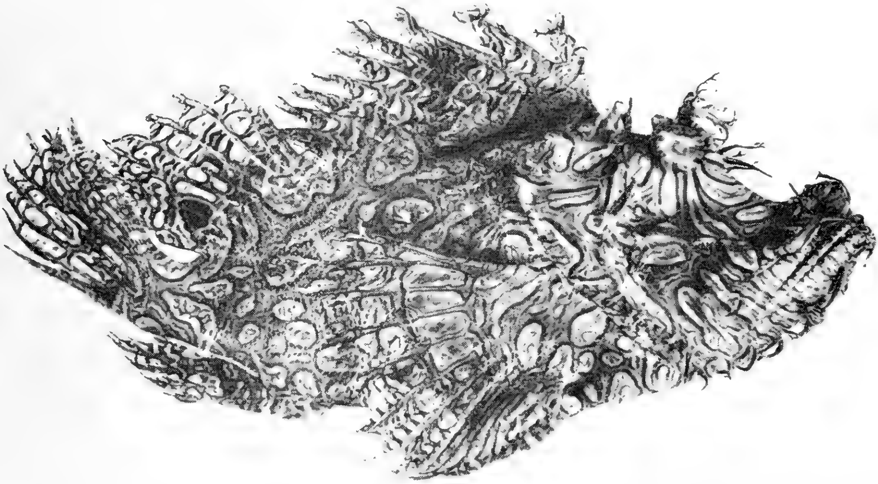

FIGURE 8. *Rhinopias aphanes*, holotype, AMS no. IB7079, 178 mm. S.L., New Caledonia.

DESCRIPTION. (Based on the holotype and only known specimen.) A large-headed, strongly compressed scorpionfish. Dorsal fin with 12 spines and 9½ soft rays; no dorsal spine notably longer than the others, third and fourth spines the longest, eleventh dorsal spine about ⅓ the length of the twelfth spine. Anal fin with 3 spines and 5½ soft rays; third spine slightly longer than second, third extends past second when fin is depressed. Pectoral rays 16, rays 1 or 2 through 6 branched. Gill rakers, including rudiments, total 20, 6 on upper arch, and 14 below, including one at angle; all rakers as short spiny knobs. Scales on body small and cycloid; about 70 vertical scale rows (counting a few scale rows above lateral line from above first lateral line scale to end of hypural plate). Head without scales.

Spination similar to that in other species of *Rhinopias*; see account under the genus. Preorbital bone with two slight lumps over maxillary, obscured by tentacles. Suborbital ridge with 4 spines, first as tiny lump on lateral face of preorbital bone, followed by one below anterior part of orbit and two posterior ones (poorly defined) just before preopercle bone. Nasal spines small. Preocular spine well defined; supraocular spine obscured by tentacle; postocular spine very large and broad. Sphenotic spine as a lump. Supplemental preopercular spine small, obscured by tentacle. First and second preopercular spines longest; third and fourth smaller, fifth almost imperceptible.

Measurements for the holotype in table 1.

Tentacles and skin appendages numerous; most slender; black or striped with black; most branched.

Preserved coloration as in figure 8. Transparent ovoid and round areas present between the pectoral rays, most prominent as a row near mid-height of pectoral fin. A slide and color photographs taken by Madame Catala-Stucki when the specimen was alive show that the holotype was a beautiful yellow and black. The pallid areas in figure 8 were lemon yellow, with a few traces of white (particularly in one patch on the suborbital stay), and the dark areas in figure 8 were black to dark brown. The skin flaps and tentacles were black bordered by yellow. The transparent areas of the pectoral fin were apparent.

COMPARISONS AND REMARKS. Although this specimen was originally identified as *R. frondosa* (Whitley, 1964; Smith, 1966), its color pattern seems distinctive and it is thought to represent a separate species. All of the reported specimens of *R. frondosa* seem to have a fairly consistent color pattern as shown in our figures 5–7, and the figures reported in the synonymy. The holotype of *R. aphanes* is a little larger in size than the holotype and largest known specimen of *R. frondosa*, but it seems unlikely that the color pattern would change this much with growth; there is no indication that the roundish pale areas of *R. frondosa* would become elongate as in *R. aphanes* (see especially the head). The differences in coloration are apparent by comparing figures 5–7 with figure 8. Other differences between *R. frondosa* and *R. aphanes* are as follows: *Rhinopias aphanes* appears to have a smaller orbit, longer snout, a longer jaw, a longer predorsal-fin length, a shorter caudal fin, and some shorter fin spines (table 1); some of these differences may not remain when additional material is found.

Rhinopias aphanes is easily separated from *R. xenops* and *R. argoliba* on the basis of pectoral rays (16 instead of 18) and coloration.

DISTRIBUTION. This species is known only from the holotype collected near Nouméa, New Caledonia.

NAME. The species name is from the Greek word *aphanes* (aph′-å-nēs), a noun, meaning that which is unapparent or inconspicuous, alluding to the camouflage provided by its remarkable coloration and skin flaps.

The common name 'Merlet's scorpionfish' is suggested. Doctor Yves Merlet, an avid diver and underwater naturalist, captured the holotype. Over a 12-year period he made available numerous valuable specimens for display in the Nouméa Aquarium and for study by systematists. He died in a diving accident in 1969.

RELATED GENERA AND SPECIES

Other genera and species which appear to be related to, or members of, *Rhinopias* are discussed below. The subfamily name Pteroidichthyinae Fowler is available. Fowler (1938, p. 51, in key) provided the following meager description for the subfamily: "Pterodichthyinae, new subfamily. Dorsal spines 11, anal spines 2 . . . . . *Pteropelor*." The subfamily name is based on the genus *Pteroidichthys* Bleeker. Fowler's incorrect spelling of the subfamily (no i before the d) was emended by Whitley (1954). In the subfamily description in the key Fowler listed the dorsal spines as 11 and anal spines as 2, but in his description of *Pteropelor*, the only genus he specifically included in the subfamily, he listed dorsal spines as 12 and anal spines as 3. Problems surrounding the dorsal and anal spine counts are discussed below. Whitley (1954, p. 60) is evidently the only subsequent worker to use the subfamily name, and Whitley recognized *Pteropelor* as a synonym of *Rhinopias* and referred *Rhinopias* to the subfamily Pteroidichthyinae. It seems likely that the nominal genera *Rhinopias*, *Pteropelor*, and *Pteroidichthys*, as well as the genera *Pogonoscorpius* Regan and *Hipposcorpaena* Fowler, are closely related. They appear to be derivatives of the subfamily Scorpaeninae, differing mainly in having a more compressed body; but whether they should be retained as a separate subfamily must await a more detailed study.

The monotypic genus *Pogonoscorpius* Regan is here referred to the subfamily Pteroidichthyinae; in fact it may be a synonym of the genus *Rhinopias*. The monotypic genus *Hipposcorpaena* Fowler, based on a juvenile, also seems closely related to *Rhinopias*. The nominal genera *Pteroidichthys* and *Pteropelor* are each known from a single species based on 1 or 2 specimens. *Rhinopias godfreyi* Whitley, also known from a single specimen, seems referable to *Pteroidichthys*. The status of each of these nominal genera and species is discussed below, and some corrections for information given in the original descriptions are made based on examination of the type specimens by the first author.

1. Pogonoscorpius.

Pogonoscorpius Regan, 1908, p. 236 (type-species *Pogonoscorpius sechellensis* by original designation; monotypic).

Pogonoscorpius sechellensis Regan, 1908, p. 236, fig. 3 on pl. 28 (original description; type locality Seychelles; holotype BMNH 1908.3.23.172).

Pogonoscorpius seychellensis, Smith, 1957, pp. 51 and 59, fig. D on pl. 4 (compiled; figure from Regan, 1908; misspelled species).

The genus *Pogonoscorpius* and the species *P. sechellensis* are known only from the holotype of the species. It is clear that Regan intended the species name to be spelled *sechellensis* rather than *seychellensis*, since the same spelling was used both for the description and figure, and Regan also used this same spelling for *Champson sechellensis*, *Synchiropus sechellensis*, and *Scaeops sechellensis*, three other new species described by him in the same work. Smith's spelling (*seychellensis*) is an unjustified emendation.

The holotype agrees with species of the genus *Rhinopias* in meristic features, dentition, spination, and body shape. It differs from them in coloration, distribution of skin flaps (particularly the presence of a median chin barbel), and a less elevated orbit. The drawing accompanying the original description (Regan, 1908, fig. 3 on pl. 28) is poor. We have reproduced a photograph of the holotype

FIGURE 9. *Pogonoscorpius sechellensis*, holotype, BMNH no. 1908.3.23.172, 51.4 mm. S.L., Seychelles.

(fig. 9) which better illustrates the body shape. Additional study when specimens become available may show that this species is best placed in the genus *Rhinopias*.

The following counts for the holotype were recorded: dorsal rays XII + 9½; anal rays III + 5½; pectoral rays 18+18, all rays appear to be unbranched; vertical scale rows estimated at about 60 as given by Regan, many missing; gill rakers difficult to count, 7 on upper arch, 9 (including one at angle) plus additional rudiments on the lower arch. Spination about as in species of the genus *Rhinopias*; supplemental preopercular spine present only on left side, most spines small or low. Some measurements (in mm., percent standard length in parentheses) were recorded as follows: standard length 51.4; total length about 66; head length 23.7 (46); body depth 19.8 (38); orbit diameter 4.5 (09); snout length 10.1 (20); interorbital width 2.2 (04); jaw length 12.1 (24); predorsal-fin length 20.3 (40); caudal fin length 14.4 (28); pectoral fin length 15.9 (31); pelvic fin length 12.3 (24).

Coloration as given by Regan, "yellowish; fins tinged with reddish."

This species appears to be a valid one and is known only from the holotype collected in the Seychelles in 37 fathoms.

2. **Hipposcorpaena.**

Hipposcorpaena FOWLER, 1938, pp. 71–72 (type-species *Hipposcorpaena filamentosa*, by original designation; monotypic).

Hipposcorpaena filamentosa FOWLER, 1938, pp. 72–73, fig. 31 (original description; type locality Philippine Islands, Gulf of Davao, 7°04′48″N., 125°39′38″E., in 28 fathoms, *Albatross* station D.5253, 18 May 1908; holotype USNM 98819).

The genus *Hipposcorpaena* was based on a single specimen of about 29 mm S.L., USNM 98819. One additional Philippine specimen is available (USNM 168183, *Albatross* station 5174) and is of about the same size as the holotype.

The holotype is now in poor condition. Fowler (1938, p. 73) gives a dorsal fin count of XI + 10, but this should have been XII + 9½; he lists anal rays as 9, but they total 8½ and seem to be III + 5½. Pectoral rays appear to number 14 as given by Fowler. The rays near the lower end of the pectoral fin are the longest, and the fifth from the bottom extends past the posterior base of the anal fin (not as in Fowler's figure 31); the lower principal caudal rays are also the longest. The vertical scale rows were given by Fowler as 30; although many scales are missing, the scale rows probably number about 35–40. *Hipposcorpaena filamentosa* appears to be a valid species known only from the Philippines.

3. Pteroidichthys.

Pteroidichthys BLEEKER, 1856, pp. 33–34 (type-species *Pteroidichthys amboinensis* Bleeker by original designation; monotypic); 1876, p. 5 (generic diagnosis).

Pteroidichthys amboinensis BLEEKER, 1856, pp. 34–35 (original description; type locality Amboina and Manado, Celebes; two syntypes, RMNH 5873); GÜNTHER, 1860, p. 127 (compiled); BLEEKER, 1876, pp. 5, 9–10, 12–13, 57–58, fig. 5 on pl. 1 (description compiled from Bleeker, 1856; figure good); 1879, fig. 1 on pl. 414 (figure from Bleeker, 1876); HERRE, 1952, p. 436 (compiled from Bleeker); DE BEAUFORT *in* Weber and de Beaufort, 1962, p. 54 (re-examined types; figure redrawn from Bleeker, 1876).

The two syntypes, RMNH 5873, were briefly examined. They are in fairly poor condition and now measure about 67 and 80 mm. in total length and 51 and 57 mm. in standard length. The counts as given by Bleeker and by de Beaufort are dorsal rays XI + 11 and anal rays II + 7. The twelfth element in the dorsal fin does not appear to be segmented, although this is difficult to determine and the ray is long and flexible; counting by the methods used in this paper the dorsal rays number XII + 9½, with the twelfth element very long and at the leading edge of the soft dorsal fin; anal rays II + 6½. For further information see 'Remarks' below.

4. Pteropelor.

Pteropelor FOWLER, 1938, p. 77 (type-species *Pteropelor noronhai* Fowler by original designation; monotypic).

Pteropelor noronhai FOWLER, 1938, pp. 78–79, fig. 34 (original description; type locality vicinity of Hong Kong, China Sea, 21°33′N., 116°13′E., in 100 fathoms, *Albatross* station D.5310, 4 November 1908; holotype USNM 98892, paratype USNM 99009).

The genus and species were based on two juvenile specimens of 32.7 (USNM 98892) and 35.5 (USNM 99009) mm. in standard length. Fowler (1938, in key, p. 51) states that the dorsal spines number 11 and the anal spines 2, but in the description (pp. 78–79) he reports 12 dorsal spines and 3 anal spines. As with *Pteroidichthys amboinensis* and *Rhinopias godfreyi*, there is difficulty in determining if the twelfth dorsal fin element and the third anal fin element are spines or segmented rays. In *Pteropelor noronhai* these fin rays appear to be unsegmented. The dorsal spine count would be XII + 9½. The paratype has a total of 8½ anal rays (? III + 5½) and the holotype a total of 9½ (? III + 6½). Fowler states that there are only 5 or 6 lateral line scales anteriorly, but examination of the types shows that the lateral line is probably complete, but many scales have been rubbed off; at least nine tubed scales are present in one specimen. Fowler gives the vertical scale rows as 25 + 2; we estimate that they number considerably more than this, but most scales have been rubbed off. Further information is provided in the 'Remarks' below.

5. **Rhinopias godfreyi.**

Rhinopias godfreyi WHITLEY, 1954, pp. 60–61, pl. 3, fig. 2 (original description; type locality Exmouth Gulf, northwestern Australia; holotype AMS IB2977).

This species is known only from the holotype, a specimen 46.1 mm. in standard length. The counts for the specimen are pectoral rays 15, anal rays II + 6½, and the dorsal count is either XI + 10½ or XII + 9½; the twelfth dorsal fin element appears to be unsegmented; the third anal fin element is segmented distally. The vertical scale rows number about 40; the lateral line seems to have been complete, although some scales are rubbed off. (Whitley incorrectly lists the pectoral rays as 14 and anal rays as III + 6; he gave the dorsal ray count as XI + 10.)

REMARKS. *Pogonoscorpius* and *Hipposcorpaena* are retained for now as separate monotypic genera which appear to be closely related to the genus *Rhinopias*. On the other hand, *Pteroidichthys amboinensis*, *Pteropelor noronhai*, and *Rhinopias godfreyi* are very closely related species, and *Pteropelor* is considered a synonym of *Pteroidichthys*. (Whitley (1954) went even further and considered *Pteroidichthys* a synonym of *Rhinopias*.) It is possible that more thorough study of the available specimens and additional specimens as they are captured will show that *Pteroidichthys amboinensis* Bleeker 1856, *Pteropelor noronhai* Fowler 1938, and *Rhinopias godfreyi* Whitley 1954 are all based on different sized specimens of the same species, or at least that some of them are synonyms of one another. These specimens are characterized by having dorsal fin rays XII + 9½ (the twelfth element which is at the leading edge of the soft dorsal fin may be segmented in large specimens), anal rays normally II + 6½ (possibly with the third element unsegmented in small specimens); and pectoral rays 14 or 15, rays unbranched (?). They are further characterized by having a very compressed body, very long fins (particularly the anal fin), and long supraocular tentacles which are branched in large specimens. They differ from species of the genera *Rhinopias, Pogonoscorpius*, and *Hipposcorpaena* most notably in the condition of the third anal fin element (two rather than three anal spines) and also in such features as a less deep body, shorter head, and lower pectoral ray count. If these three nominal species are all the same species then the localities from which it has been collected are Hong Kong, Celebes,

Figure 10. *Pteroidichthys amboinensis*, ZMC uncat., 36.4 mm. S.L., Vietnam.

Amboina, and northwestern Australia. It is an offshore species, probably living in coral in depths from perhaps 30 to 100 fathoms.

One additional specimen (fig. 10) was found which is referable to this complex. The specimen measures 36.4 mm. in standard length and is from the collection of the Zoological Museum of Copenhagen with the following data: collected at Nhatrang Bay, Vietnam, 16 November 1959, by J. Knudsen. This specimen has counts of dorsal rays XII + 9½, anal rays II + 6½, and pectoral rays 16 + 15 (all simple). In coloration it is most like the type of *Pteropelor noronhai.*

Shedding of 'Skin'

Sloughing of 'skin' in the scorpaenid *Taenianotus triacanthus* has been discussed recently by Wickler and Nowak (1969), although they missed an earlier account of shedding in *Taenianotus* by Faulkner (1961). The first mention of shedding was by Gilchrist (1920) for *Agriopus* (subfamily Congiopodinae). Hirosaki (1957) discussed shedding in scorpaenids, including the genera *Pterois, Parapterois*, and *Erosa*, and other fishes, and (1971a–c) in *Rhinopias argoliba.* Faulkner (1961) also reported sloughing of skin in *Pterois sphex.* From museum specimens we can report that this shedding also occurs in stonefishes (*Synanceia*, subfamily Synanceiinae), the genus *Inimicus*, and evidently all species of *Pterois* (subfamily Pteroinae). The holotype of *Rhinopias aphanes* also has pieces of 'skin' hanging from it as do some specimens of *R. xenops* and *R. frondosa.*

Previous authors who have commented on the shed layer have described it as skin, and have correctly pointed out that it is not mucous. Samples have been analysed for us by Richard Krejsa, and he informs us that the shed layer is best termed a cuticle, an epidermal product; some cells are lost with the shed layer but the basic matrix is cuticular. Further histological studies are being made by Dr. Krejsa.

Hirosaki (1971a–c) found that in *R. argoliba* shedding occurred in the Enoshima Aquarium 9 times in 114 days at regular intervals (January 30, February 13 and 28, March 12 and 30, April 11 and 24, May 8 and 18). The cuticle from the entire body was shed each time. It appears that shedding was a natural event not caused by any sort of shock. The function of the shedding probably involves the removal of algae, external parasites, and other objects which might accumulate on the skin of these basically sedentary fishes.

The genera *Inimicus*, *Minous*, and *Choridactylus* are peculiar scorpaenids which have one to three lower pectoral rays thickened and free. Each free ray is tipped with a 'friction pad' or 'cap.' The caps are easily dislodged in preserved specimens. These thickened caps, covering the distal one-fourth to one-tenth of each ray, are made of the same cuticular substance, although much thicker, as the shed layer of the scorpaenids listed above; almost certainly these caps are used as an aid for 'walking' on the bottom with the free pectoral rays. (These 'caps' will be discussed more fully in a subsequent paper on the subfamily Minoinae.)

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THE BRACHYURAN CRABS OF EASTER ISLAND[1]

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INTRODUCTION

Easter Island or Rapa Nui is a volcanic island lying in the eastern South Pacific at Latitude 27° 10′ S. and Longitude 109° 26′ W. (Cook Bay or Hanga-Roa). Roughly triangular in shape, it measures approximately 11 miles along its major dimension, from southwest to east, and approximately 8 miles along each of its two shorter legs. Each corner is dominated by a volcanic crater or shield, of which La Pérouse Mountain (Rana Hana Kana), near North Cape, is highest (1767 feet). The principal anchorages are at Cook Bay (Hanga-Roa) on the west side and La Pérouse Bay on the northeast side. Neither of these is protected in all weather and a ship must be prepared to up-anchor on an hour's notice, a circumstance that accounts in part for the infrequency with which the island has been visited by scientific parties. Of these only one is known to have made significant collections of marine animals: the *Albatross* Eastern Pacific Expedition of 1904–1905. According to Alexander Agassiz (1906, p. 56), expedition leader, "Considerable collecting was done at Easter Island . . . . We collected a number of shore fishes, and made a small collection of the littoral fauna. The fishes have a decided Pacific look, and the few species of sea urchins . . . have a wide distribution in the Pacific." The Brachyura of this expedition were reported on by Rathbun (1907), who listed the following six species from Easter Island:

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[1] Allan Hancock Foundation Contribution No. 345.

Xanthidae: *Pseudoliomera remota* (Rathbun)
Trapezia ferruginea Latreille.
Grapsidae: *Leptograpsus variegatus* (Fabricius)
Pachygrapsus transversus (Gibbes)
Ptychognathus easteranus Rathbun
Plagusia dentipes (De Haan).

The Heyerdahl Expedition of 1955–1956 collected a single brachyuran on Easter Island. Not hitherto reported, it is included herewith:

Grapsidae: *Geograpsus crinipes* (Dana).

The Medical Expedition to Easter Island (METEI) visited the island in 1964–1965. Collections of brachyuran crabs were made from late December to early February at the following localities: on the north side of the island at Anakena Bay; on the west side of the island at Hanga-Roa, Hanga-piko, and Mataveri (inland from Hanga-piko); on the south side of the island at Vaihu. Most of the collecting was intertidal, but that at Anakena was in water of 20–25 foot depth. Specimens were collected by rotenone poisoning at Vaihu, and the stomach of a large starfish from an unknown locality yielded crabs of the genus *Trapezia*, usually associated with corals. Except where noted, as in the case of children and islanders, who provided native names for crabs, all collecting was done by Ian E. Efford and Jack A. Mathias.

Fourteen species of brachyuran crabs are included in the METEI collection, a number double that obtained by earlier expeditions. Among the 14 are all previously collected species except *Pseudoliomera remota*, obtained by the *Albatross* Expedition, and *Geograpsus crinipes*, obtained by the Heyerdahl Expedition. A second specimen of *Ptychognathus easteranus* of the opposite sex from the unique holotype was collected. The number of crab families known from Easter Island was increased from two to four with the addition of the Dromiidae and Portunidae; the number of genera was increased from seven to twelve with the addition of *Dromidia*, *Portunus*, *Carpilius*, *Chlorodiella*, and *Cyclograpsus*; and among the seven species new to the island is a second species of *Plagusia* new to science.

The Expedición Isla de Pascua (EIP) of the Instituto Central de Biología, Universidad de Concepción, Chile, visited the island in August, 1972. Collections of brachyuran crabs were made intertidally at Anakena Bay, Hanga-Roa, and Hotu-Iti by H. I. Moyano, at Tahai by T. Cekalović, and by diving in 8–10 meters by V. A. Gallardo. Specimens were sent to the author for identification in November, 1972, by M. A. Retamal, who has kindly permitted incorporation of the new records in the present manuscript.

Included in the EIP collection are twelve species of brachyuran crabs. Among them are five species also collected by the METEI and one species collected by the Heyerdahl Expedition. The remaining six species include five widely ranging Indo-west Pacific species not previously known from Easter Island and one that appears to be new to science. The number of genera known from Easter Island is increased from twelve to sixteen with the addition of *Thalamita*, *Etisus, Liomera* (= *Carpilodes*), and *Lophozozymus*. Description of the new species will appear subsequently in a Chilean journal, at Professor Retamal's request.

The astute carcinologist will note that two large groups of Brachyura, the Oxystomata and the Oxyrhyncha, are lacking from Easter Island collections made to date, the list being composed entirely of Dromiacea and Brachyrhyncha. It may be confidently predicted that when present terrestrial and intertidal collecting is extended to include the subtidal, representatives of these groups will be added; for while a few oxystomatous and oxyrhynchous crabs occur in weeds and among corals in the tropical Pacific, more are to be found by shallow dredging.

Historical Note

Through the research of Dr. L. B. Holthuis of the Royal Netherlands Museum of Natural History, Leiden, I am able to mention what is probably the oldest observation of crabs on Easter Island. It is found in the account of Don Juan Hervé, first pilot or senior navigating officer of the *San Lorenzo*, one of two vessels comprising the expedition to the islands under Don Felipe González in 1770 (Hervé, 1908, p. 122), as reprinted in the Works of the Hakluyt Society, transcribed and edited by B. G. Corney. In the description of the small, rocky islets at the southwest tip of the island, now known as Needle Rock or Motu-kaokao and Flat Rock or Motu-nui, is the statement: "We passed on to the outer one, where we succeeded in landing, and on which we found two large masses of seaweed, many black flints, some sea urchins and small crabs, eggs of seagulls and their fledglings . . ." It is tempting to speculate, in the light of METEI findings, what these small crabs might have been.

Acknowledgments

When preparing the account of the brachyuran decapod Crustacea of Chile a decade and a half ago (Garth, 1957) it was realized that this work was incomplete in that coverage of the Chilean Isla de Pascua, as Easter Island is known to the Spanish-speaking world, was lacking. Since no new specimen material was then available, as in the case of Juan Fernandez Island, it was thought better to await the arrival of fresh collections than to redescribe the older ones. Such an opportunity presented itself with the extensive collections made by Ian E. Efford and Jack A. Mathias on the Medical Expedition to Easter

Island, and to them the author is indebted for the privilege of extending his knowledge of the Chilean fauna to this island outpost of the Pacific.

Inclusion in the present report of the single specimen of brachyuran crab collected at Easter Island by the Heyerdahl Expedition of 1955–1956 was made possible through the courtesy of Mr. Nils Knaben of the Oslo Museum, with Dr. L. B. Holthuis of the Leiden Museum facilitating arrangements.

Inclusion in the present report of the Easter Island collections of the Instituto Central de Biología, Universidad de Concepción, Chile, was made possible through the kindness of Prof. M. A. Retamal.

The writer is indebted to Mme. Danièle Guinot of the Muséum National d'Histoire Naturelle, Paris, for identifying the *Chlorodiella* species from Easter Island, and to Dr. T. Sakai of Kamakura, Japan, for confirming the identity of *Plagusia dentipes* from Easter Island with Japanese specimens. He wishes to thank Dr. C. B. Goodhart of the Museum of Zoology of Cambridge University, Cambridge (see Garth, 1971), for permission to examine specimens of *Pseudoliomera remota* and *P. lata* from the Indian Ocean, and Dr. L. B. Holthuis of the Rijksmuseum van Natuurlijke Historie, Leiden, and Mr. J. Forest of the Muséum National d'Histoire Naturelle, Paris, for permission to examine the type-specimens of *Plagusia* species at their respective institutions.

Consultation of type-specimens in European museums was made possible by a grant from the National Science Foundation (GB-3849). Illustration of the new species of *Plagusia* was provided by a grant from the Research and Publication Fund (National Defense Education Act) of the University of Southern California.

The sponge covering of *Dromidia* was identified by Dr. Gerald J. Bakus of the University of Southern California. The coral hosts of *Trapezia* species were identified by Dr. John W. Wells of Cornell University and the star fish from the stomach of which *Trapezia* species were recovered was identified by Mr. James Clark of Harvard University. Dr. F. A. Chace, Jr. of the U. S. National Museum reviewed the manuscript and made valuable suggestions.

ACCOUNT OF SPECIES

RESTRICTION OF SYNONYMIES. The synonymies that follow are restricted to the original description, the first use of the name in its present combination, a good illustration if not included in the above two, the first record from Easter Island, and, in order to provide documentation for the zoogeographical discussion to follow, records from adjacent Pacific islands from which the species might have migrated to Easter Island. In cases of involved synonymies, reference is made to one of the regional monographs, such as Alcock (1900), Edmondson (1922, 1954, 1959, 1962), Forest & Guinot (1961), Ihle (1913), Rathbun (1906, 1918, 1930), or Sakai (1936, 1939).

List of Species

	Albatross 1904–1905	Heyerdahl 1955–1956	METEI 1964–1965	EIP 1972
DROMIACEA				
DROMIIDAE				
Dromidia unidentata (Rüppell).			X	
BRACHYGNATHA-BRACHYRHYNCHA				
PORTUNIDAE				
Portunus pubescens (Dana)			X	
Thalamita				X
XANTHIDAE				
Carpilius convexus (Forskål)			X	
Liomera rugata (Milne Edwards)				X
Actaea parvula (Krauss)				X
Pseudoliomera remota (Rathbun)	X			
Lophozozymus dodone (Herbst)				X
Etisus electra (Herbst)				X
Chlorodiella cytherea (Dana)			X	X
Trapezia areolata Dana			X	X
Trapezia cymodoce (Herbst)			X	X
Trapezia danai Ward (= *maculata* Dana)				X
Trapezia ferruginea Latreille	X		X	
Species incertae sedis.[2]			X	X
GRAPSIDAE				
Geograpsus crinipes (Dana)		X		X
Leptograpsus variegatus (Fabricius)	X		X	X
Pachygrapsus transversus (Gibbes)	X		X	
Ptychognathus easteranus Rathbun	X		X	
Cyclograpsus longipes Stimpson			X	
Plagusia dentipes De Haan	X		X	
Plagusia integripes Garth, new species			X	
	6	1	14	12

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[2] One small xanthid obtained by the METEI is unreported pending further study.

Section BRACHYURA

Subsection DROMIACEA

Superfamily Dromiidea

Family Dromiidae

Dromidia unidentata unidentata (Rüppell).

Dromia unidentata Rüppell, 1830, p. 16, pl. 4, fig. 2; pl. 6, fig. 9 (Red Sea); Alcock, 1900, p. 139, literature; Chilton, 1911, p. 554 (Kermadec Islands).

Dromidia unidentata, Kossmann, 1880, p. 67; Ihle, 1913, p. 31 (New Guinea), synonymy; Sakai, 1936, p. 13, pl. 6, fig. 2; text-figs. 2a, b (Japan).

Material examined. Anakena, Easter Island, METEI Station F 85, 20–25 feet, 15 January 1965, 1 male, Ian E. Efford and Jack A. Mathias. The crab was covered by a sponge identified as *Hymeniacidon* species by Dr. Gerald J. Bakus.

Measurements. Male specimen: length of carapace 13.4 mm., width 11.3 mm.

Distribution. From Red Sea and East Africa to New Guinea and Japan; Kermadec Islands and, as subspecies *D. u. hawaiiensis* Edmondson (1922, p. 34), Hawaii.

Remarks. The Easter Island specimen allies itself with the widely distributed Indo-west Pacific subspecies, rather than with the Hawaiian subspecies described by Edmondson (1922, p. 34). The only other South Pacific record is from Meyer Island in the Kermadec Islands (Chilton, 1911), which lie northeast of New Zealand in Latitude 30° S., a few degrees more southerly than Easter Island. Other islands lying south of the Tropic of Capricorn and, together with Rapa Nui (Easter) and Sala y Gomez, completing an arc to San Felix and San Ambrosio off the coast of Chile are Rapa, Morotiri (Bass), Pitcairn, Henderson, and Ducie.

Subsection BRACHYGNATHA

Superfamily Brachyrhyncha

Family Portunidae

Portunus pubescens (Dana).

Lupa pubescens Dana, 1852b, p. 274; 1855, pl. 16, fig. 9 (Sandwich Islands).

Portunus pubescens, Rathbun, 1906, p. 870, pl. 14, fig. 1; Edmondson, 1923, p. 22 (Palmyra); Stephenson and Campbell, 1959, p. 99, figs. 2C, 3C, pl. 1, fig. 3; pls. 4C, 5C, synonymy.

Neptunus pubescens, Sakai, 1934, p. 303 (Japan).

Neptunus tomentosus Haswell, 1882, p. 547 (Australia).

Material examined. Hanga-Roa, near camp, January 1965, 1 female, Ian E. Efford and Jack A. Mathias.

Measurements. Female specimen: length of carapace 28.0 mm., width including lateral spines 44.6 mm., without spines 39.0 mm.

Distribution. Australia, Japan, Hawaii, and Line Islands (Palmyra). The early record from Port Jackson, New South Wales, is based on Stephenson and Campbell's synonymy of *Neptunus tomentosus*.

Remarks. The occurrence at Easter Island of *Portunus pubescens*, until recently known only from the north Central Pacific and Japan, becomes more plausible with the establishment of its identity with the Australian *P. tomentosus* and its recognition as a southern hemisphere species, Easter Island being in the Latitude of Brisbane. It is probable that *P. pubescens* occurs widely throughout the South Pacific but has not been reported because of insufficient collecting. Traces of reddish brown color remain on the metagastric and epibranchial regions after three and a half years in alcohol.

Family Xanthidae

Carpilius convexus (Forskål).

Cancer convexus Forskål, 1775, p. 88 (Red Sea).
Carpilius convexus Rüppell, 1830, p. 13, pl. 3, fig. 2; pl. 6, fig. 6 (Tahiti); Dana, 1852b, p. 159; 1855, pl. 7, fig. 5 (Sandwich Islands); Rathbun, 1907, p. 37 (Tuamotu); Boone, 1934, p. 89, pls. 43–45, synonymy; Barnard, 1950, p. 205 (Durban); Edmondson, 1962, p. 223, fig. 1b; Garth, 1965, p. 16, figs. 8 (male pleopods), 13 (Clipperton Island).

Material examined. Anakena, Station M 5, 1 meter, 23 December 1964, 2 females, collected by islanders. Mataveri, Station M 41, 21 January 1965, 1 female, Ian E. Efford and Jack A. Mathias.

Mesurements. Specimens, all females, measured 62.8 × 85.4, 70.7 × 95.1, and 73 × 96 mm. in length and width of carapace, respectively.

Distribution. From the Red Sea and South Africa to Hawaii, Tahiti, and Tuamotu. Clipperton Island.

Remarks. The color of the Easter Island specimens resembled nothing that this writer has encountered previously with this or any other brachyuran species. It was as if each specimen had been dipped, like an Easter egg, in a series of dyes: orange, pink, and blue, while being held each time by a different appendage. The result was a piebald appearance of utmost irregularity that could not be called a pattern. Suspecting some artifact in the preserving process, the writer queried Ian E. Efford, but was assured that this was their natural coloring before preservation. The native name for this spectacular crab is Pikea Tutuau.

Widely distributed throughout the Indo-west Pacific, *Carpilius convexus* has now been reported twice from the eastern Pacific, once at Clipperton Island and now at Easter Island, in the same Longitude, 109° W. Some 37° of Latitude, or 2,200 nautical miles, separate the two localities. The genus occurs also in the western Atlantic, but is absent from the American west coast.

Liomera rugata (Milne Edwards).

Carpilodes rugatus, A. MILNE EDWARDS, 1865, p. 230, pl. 12, figs. 3, 3a, 3b; ORTMANN, 1893, p. 468 (Tahiti); ODHNER, 1925, p. 20, pl. 1, fig. 16 (Gilbert Islands); EDMONDSON, 1962, p. 249, fig. 9a, synonymy.

Carpilodes monticulosus, RATHBUN, 1906, p. 884 (Hawaii); 1907, p. 37 (Tuamotu). [Not *C. monticulosus* A. Milne Edwards.]

Liomera rugatus, BARNARD, 1950, p. 237.

MATERIAL EXAMINED. Hotu-iti, 8 August 1972, one female, H. I. Moyano, EIP.

MEASUREMENTS. Female specimen, length of carapace 12.2 mm., width 21.4 mm.

DISTRIBUTION. From Red Sea and Mauritius to Tahiti, Tuamotu, and Hawaii.

REMARKS. This common Indo-west Pacific species has been confused with *Liomera monticulosa* (A. Milne Edwards) by such authorities as Borradaile (1902) and Rathbun (1907), according to Odhner (1925), whose figure is the basis for our identification.

Actaea parvula (Krauss).

Menippe parvulus KRAUSS, 1843, p. 34, pl. 2, figs. 2, a–c (Natal).

Actaea parvula, LENZ, 1910, p. 549 (Madagascar); ODHNER, 1925, p. 51, pl. 3, fig. 13 (Galle, Ceylon; Fiji; Marquesas); BARNARD, 1950, p. 234, text-fig. 43, g, h (Delgoa Bay), synonymy.

MATERIAL EXAMINED. Anakena Bay, 9 August 1972, 2 males, one ovigerous female, H. I. Moyano, University of Concepción, Chile.

MEASUREMENTS. Male specimens, 8.9 × 11.7 and 10.5 × 14.1 mm.; ovigerous female specimen 11.5 × 15.5 mm. in length and breadth of carapace, respectively.

COLOR IN ALCOHOL. Carapace yellow, with red-orange blotches on gastric and hepatic regions (three blotches in all). Chelipeds and legs yellow, fingers white with brown pigment visible beneath the surface. Hairs golden.

REMARKS. Easter Island specimens were compared with a 9.3 × 12.5 mm. female collected by the writer at Galle, Ceylon, in 1964, which had in turn been compared with specimens in the British Museum (Natural History), also from Galle, Ceylon, identified by T. Odhner. The salient, tridentate tooth on the immovable finger of the chela is characteristic of the species.

Pseudoliomera remota (Rathbun).

Actaea remota RATHBUN, 1907, p. 43, pl. 1, fig. 9; pl. 7, fig. 1 (Easter Island); 1911, p. 217 (Salomon, Coetivy); ODHNER, 1925, p. 63 (Hilo, Hawaii); SAKAI, 1939, p. 490, pl. 93, fig. 4 (Tosa Bay); GUINOT, 1962, p. 237, figs. 8, 9 (Maldive Islands).

Actaea nana KLUNZINGER, 1913, p. 86 (Koseir, Red Sea).
Pseudoliomera remota, GUINOT, 1967, p. 561; 1969, p. 228.

PREVIOUS COLLECTION. Easter Island, shore, 20 December 1904, 1 male, *Albatross* (Rathbun, 1907).

MATERIAL EXAMINED. None from among METEI collections. Through the kindness of Dr. C. B. Goodhart of the University Museum of Zoology, Cambridge, it was possible to examine the young female from Salomon collected by the *Sealark*.

MEASUREMENTS. Young female: length of carapace 4.0 mm., width 4.6 mm. The holotype male (USNM no. 32849) measures 6.0 mm. in length and 8.7 mm. in width of carapace (Rathbun, 1907).

DISTRIBUTION. Red Sea and western Indian Ocean to Japan, Hawaii, and Easter Island. The west Australian record (Guinot, 1962, fig. 9) is an error of provenience resulting from a confusion of names between the Eastern Islands of the Houtman Abrolhos group in the eastern Indian Ocean and Easter Island (Île de Pâques) in the eastern South Pacific. A Christmas Island also exists in both eastern Indian and central Pacific oceans further to confound the zoogeographer.

REMARKS. As noted from the Indian Ocean specimen examined, *Pseudoliomera remota* is a patterned species with the inner protogastric areoles broadly continuous with the front and the outer protogastric areoles discontinuous with the inner orbital areoles. The fingers resemble those of *Pseudoliomera lata* (Borradaile) from the Maldive Islands (see Garth, 1971), also seen at Cambridge University (*cf.* Guinot, 1962, figs. 6 and 8). The synonymy of *Actaea nana* Klunzinger (*cf.* Odhner, 1925) permits the inclusion of the Red Sea in the already extended longitudinal range of the species.

Lophozozymus dodone (Herbst).

Cancer dodone HERBST, 1801, p. 37, pl. 52, fig. 5 (East Indies).
Atergatis elegans HELLER, 1862, p. 519; 1865, p. 7, pl. 1, fig. 3 (Tahiti).
Lophozozymus dodone, ALCOCK, 1898, p. 108 (Andaman); BALSS, 1938, p. 39 (Fiji, Tahiti). FOREST and GUINOT, 1961, p. 54, text-figs. 39a, b (Tahiti), synonymy.

MATERIAL EXAMINED. Anakena Bay, shore, 9 August 1972, 1 male, H. I. Moyano, University of Concepción Expedition.

MEASUREMENTS. Male specimen: length of carapace 6.1 mm., width 9.2 mm.

DISTRIBUTION. From South Africa to Hawaii and Tahiti.

REMARKS. The Easter Island specimen was compared with a specimen from Hawaii of like size and sex. The slight discrepancies noted are believed to lie within the normal range of variation for this widely ranging Indo-west Pacific species.

Etisus electra (Herbst).

Cancer electra HERBST, 1801, p. 34, pl. 51, fig. 6 (East Indies).
Etisus rugosus JACQUINOT, 1852, pl. 4, fig. 2; 1853, p. 33 (Tuamotu).
Etisodes sculptilis A. MILNE EDWARDS, 1873, p. 236, pl. 9, fig. 2 (New Caledonia).
Etisodes electra, NOBILI, 1907, p. 390 (Tuamotu); RATHBUN, 1907, p. 42 (Tuamotu, Gilbert Islands); FOREST and GUINOT, 1961, p. 89, figs. 82a, b (Tahiti), synonymy.
Etisus electra, BARNARD, 1950, p. 245, figs. 45a, b (South Africa); GUINOT, 1964, p. 59.
Etisus (Etisodes) electra, HOLTHUIS, 1953, p. 21 (Marianas, Gilbert Islands).

MATERIAL EXAMINED. Anakena Bay, sand, 9 August 1972, 1 male, 1 young, H. I. Moyano, University of Concepción, Chile.

MEASUREMENTS. Male specimen, length of carapace 5.4 mm., width 6.8 mm.

DISTRIBUTION. From the Red Sea and Mozambique (Delgoa Bay) to Tahiti and Tuamotu (Manga Reva).

REMARKS. The Easter Island specimens compare with the figure of *Etisodes sculptilis* A. Milne Edwards, a synonym of *Etisus electra* (Herbst), according to Guinot (1964). The far-flung distribution of this small xanthid makes it a likely colonizer of island outposts like Easter.

Chlorodiella cytherea (Dana).

Chlorodius cytherea DANA, 1852a, p. 79; 1852b, p. 213; 1855, pl. 12, figs. 2a–c (Tuamotu and Hawaii).
Chlorodiella cytherea, HOLTHUIS, 1953, p. 14 (Marianas and Gilbert islands); FOREST and GUINOT, 1961, p. 95, figs. 90–92, 98a, b (Tahiti), synonymy.

MATERIAL EXAMINED. Hanga-piko, tide pool, Station M 10, 31 December 1964, 1 ovigerous female, Ian E. Efford and Jack A. Mathias. Anakena Bay, on the beach, 9 August 1972, 1 young male, H. I. Moyano, EIP.

MEASUREMENTS. Female specimen: length of carapace 6.1 mm., width 9.6 mm.

DISTRIBUTION. From the Red Sea and Madagascar to Hawaii, Tahiti, and Tuamotu.

REMARKS. With the recognition by Holthuis (1953) of *Chlorodiella cytherea* among Pacific coral atoll collections and its reestablishment by Forest and Guinot (1961) upon firm morphological characters, it becomes possible to distinguish four common *Chlorodiella* species in the Indo-west Pacific, the others being *C. laevissima* (Dana), with which the present species was formerly confused, *C. nigra* (Forskål), and *C. barbata* (Borradaile). The Easter Island specimen was seen and its identification confirmed by Mme. D. Guinot of the Paris Museum.

Trapezia areolata Dana.

Trapezia areolata DANA, 1852a, p. 83; 1852b, p. 259; 1855, pl. 15, fig. 8a (Tahiti); FOREST and GUINOT, 1961, p. 135, fig. 133 (Hikueru).
Trapezia ferruginea areolata, ORTMANN, 1897, p. 206, synonymy.
Trapezia reticulata STIMPSON, 1858, p. 37.

MATERIAL EXAMINED. Hanga-piko, 2 February 1965, 2 males, 2 ovigerous females, collected by Norma (METEI). No station or date, 2 males, from the stomach of a large starfish collected by Ian E. Efford and Jack A. Mathias and identified as *Leiaster leachii* by James Clark of Harvard University. SCUBA diving, coral reef, 8–10 meters, 8–9 August 1972, 1 male, V. A. Gallardo, EIP.

MEASUREMENTS. Males measure 9.3 × 10.7, 9.5 × 10.8, 9.6 × 10.9, and 12.1 × 13.7 mm., ovigerous females 9.8 × 12.2 and 12.1 × 15.0 mm. in length and width, respectively.

DISTRIBUTION. From Ceylon and the Nicobar Islands to Tahiti and Tuamotu (Hikueru = Melville Island).

REMARKS. The large starfish from whose stomach the two males were collected, along with four specimens of *Trapezia ferruginea* Latreille, was presumably feeding on the corals with which the *Trapezia* species are invariably associated throughout their extensive range.

Trapezia cymodoce (Herbst).

Cancer cymodoce HERBST, 1801, p. 22, pl. 51, fig. 5 (East Indies).

Trapezia cymodoce, GERSTAECKER, 1857, p. 125; ORTMANN, 1897, p. 203, synonymy; EDMONDSON, 1923, p. 20 (Palmyra).

Grapsillus cymodoce, RATHBUN, 1906, p. 685, pl. 11, fig. 6 (Hawaii).

Trapezia hirtipes JACQUINOT and LUCAS, 1853, p. 44, pl. 4, fig. 14 (Marquesas).

MATERIAL EXAMINED. Hanga-piko, 2 February 1965, 1 ovigerous female without chelipeds, collected by Norma (METEI).

MEASUREMENTS. Ovigerous female: length of carapace 8.5 mm., width 10.8 mm.

DISTRIBUTION. From the Red Sea and Dar-es-Salaam to Tahiti and the Marquesas. Hawaii and the Line Islands (Palmyra).

REMARKS. Although no mention is made of an invertebrate host, the *Trapezia* species are customarily collected by cracking large heads of *Pocillopora* coral, of which three species, *P. damicornis*, *P. danae*, and *P. diomedae*, occur at Easter Island, according to Dr. John W. Wells of Cornell University. *Trapezia cymodoce* is most readily distinguished from *T. ferruginea* by the fine woolly hair on the outer side of the palm of the cheliped. In the absence of chelipeds, reliance may be placed in the lateral teeth of the carapace, which are pointed even in grown specimens, according to Ortmann (1897).

Trapezia danai Ward.

Trapezia maculata DANA, 1852b, p. 256 (part); 1855, pl. 15, fig. 4d (not 4a–c); STIMPSON, 1860, p. 219 (Socorro Island). [Not *Grapsilius maculatus* MacLeay.]

Trapezia danae WARD, 1939, p. 13, figs. 17, 18. [Name substituted for *T. maculata* Dana, preoccupied by *T. maculata* (MacLeay).]

Trapezia aff. *danai*, SERÈNE, 1969, p. 136, figs. 14A, 14B, 15, 16, 21, 22, 24.

MATERIAL EXAMINED. Easter Island, 8–10 meters, SCUBA diving, 9–10 August 1972, one female, V. A. Gallardo, EIP.

MEASUREMENTS. Female specimen, length of carapace 8.5 mm., width 10.8 mm.

DISTRIBUTION. Western Pacific at Samoa, Tahiti, and Hawaii; eastern Pacific doubtfully at Socorro Island; specimens sent to Stimpson by John Xantus probably were from Hawaii also.

REMARKS. Since Dana's material probably contained more than one species (Serène, 1969), it is with some hesitation that the name now applied to one of them is used here, as it is by no means certain that the Easter Island specimen, a female, is identical with either the Hawaiian or Tahitian specimens figured by Dana (1855). For the present, it can only be said that Easter Island supports a finely spotted species of *Trapezia* resembling both *T. danai* Ward and *T. wardi* Serène, yet differing in some particulars from each of them. A series of specimens, including males, will be needed to resolve the question.

Trapezia ferruginea Latreille.

Trapezia ferruginea LATREILLE, 1825, p. 695 (Red Sea); ORTMANN, 1897, p. 205, synonymy.
Trapezia cymodoce ferruginea, RATHBUN, 1907, p. 58 (Easter Island); 1930, p. 557, pl. 228, figs. 1, 2 (Clarion Island); BOONE, 1927, p. 240, text-fig. 88 (Galápagos Islands); HERTLEIN and EMERSON, 1957, p. 5 (Clipperton Island).
Trapezia miniata JACQUINOT and LUCAS, 1853, p. 43, pl. 4, fig. 10 (Marquesas).

PREVIOUS COLLECTION. Easter Island, shore, 20 December 1904, 1 male, 1 ovigerous female, *Albatross* (Rathbun, 1907).

MATERIAL EXAMINED. Easter Island, without precise locality or date, 3 males, 1 ovigerous female, from the stomach of a large starfish collected by Ian E. Efford and Jack A. Mathias and identified as *Leiaster leachii* by James Clark.

MEASUREMENTS. Males measure from 7.5 × 8.4 to 12.3 × 14.4 mm., ovigerous female 8.7 × 11.4 mm. in length and width, respectively.

DISTRIBUTION. From the Red Sea and Zanzibar to Hawaii and the Marquesas in the western Pacific; Clarion, Clipperton, Easter, and Galápagos islands in the eastern Pacific; from the Gulf of California to Colombia on the American mainland.

REMARKS. *Trapezia ferruginea* is one of two Indo-Pacific species of *Trapezia* known to occur on the west coast of tropical America, *T. digitalis* Latreille being the other (Rathbun, 1930). Both are inhabitants of the *Pocillopora* coral colony but, whereas *T. ferruginea* is bright red, *T. digitalis* is a somber brown. The latter species was not found among METEI collections, nor has it been reported from Easter Island. Rathbun, (1907), who considered *T. ferruginea* a subspecies of *T. cymodoce* (Herbst), noted that the chelipeds of Easter Island specimens were covered with fine spots.

Family GRAPSIDAE

Geograpsus crinipes (Dana).

Grapsus crinipes DANA, 1851, p. 249; 1852b, p. 341; 1855, pl. 21, figs. 6a–d (Sandwich Islands).
Geograpsus crinipes, ORTMANN, 1894, p. 706 (Samoa); DE MAN, 1895, p. 83, pl. 28, figs. 17a–c; EDMONDSON, 1923, p. 10 (Fanning, Palmyra); 1959, p. 162, fig. 4a; SAKAI, 1939, p. 652, pl. 107, fig. 2 (Japan), synonymy.

MATERIAL EXAMINED. Poike, eastern peninsula of Easter Island, in a hole at an altitude of 250 m., 24 February 1956, 1 male, Thor Heyerdahl, collector (Oslo Museum). Tahai, 4 August 1972, T. Cekalović, EIP.

MEASUREMENTS. Male specimens: 38.7 × 45.1 and 47 × 55 mm., in length and breadth of carapace, respectively.

DISTRIBUTION. Throughout the Indo-west Pacific from the Red Sea and Zanzibar to Japan, Samoa, Hawaii, and the Line Islands (Fanning, Palmyra).

REMARKS. The male specimen collected by the Heyerdahl Expedition lived for 19 days, or until 14 March 1956. It is not known whether the hole in which it was found contained water, or if so, whether this was fresh or brackish. The altitude at which the Easter Island specimen was collected serves to underscore the terrestriality of the species. In the Marshall Islands, which are low islands, *Geograpsus crinipes* occurs among litter on the forest floor and is seldom seen by day except when accidentally disturbed.

The Oslo Museum specimen was identified by Dr. L. B. Holthuis of the Leiden Museum, who kindly forwarded the essential information for inclusion.

Leptograpsus variegatus (Fabricius).

Cancer variegatus FABRICIUS, 1793, p. 450.
Leptograpsus variegatus, MILNE EDWARDS, 1853, p. 172; RATHBUN, 1907, p. 29 (Easter Island); 1918, p. 234, pl. 36; GARTH, 1957, p. 94 (synonymy).
Leptograpsus ansoni MILNE EDWARDS, 1853, p. 171 (Juan Fernandez Island).

PREVIOUS COLLECTIONS. Easter Island, shore, 16, 20 December 1904, 3 males, 5 females. La Pérouse Bay, 17 December 1904, 7 males, 5 females, *Albatross* (Rathbun, 1907). The single male reported by Rathbun (1907) with the date of 21 December 1899, is not presently on record at the U. S. National Museum and may have been part of a collection not involving the *Albatross*, which on the date in question was at sea between Fiji and Funafuti in the Ellice Islands on an earlier cruise that did not stop at Easter Island (F. A. Chace, Jr., personal communication).

MATERIAL EXAMINED. Near Hanga-Roa, Station F 42, 25–26 December 1964, 2 males, 1 female, collected by children. Vaihu, Station F 94, 25 January 1965, rotenone collection in 6 to 10 feet of water, 1 male, soft shell, Ian E. Efford and Jack A. Mathias. Hanga-Roa, 5 February 1965, 1 female, without chelipeds, Ian E. Efford and Jack A. Mathias. Hanga-Roa Tai, 5 August 1972, 1 male, H. I. Moyano.

Measurements. Males measure from 21.8 × 24.5 to 43.5 × 50.5 mm., ovigerous female 30.1 × 34.2 mm., non-ovigerous female 44.2 × 49.8 mm. in length and width of carapace, respectively.

Distribution. Australia and New Zealand in the western Pacific; Easter Island and Juan Fernandez Island in the eastern Pacific; Peru and Chile on the west coast of South America.

Remarks. In sub-tropical southern hemisphere areas from which *Grapsus grapsus* (Linnaeus) is absent, its dominance of the upper intertidal of rocky shores is assumed by *Leptograpsus variegatus*. It is therefore probable that the crabs observed in 1770 by Don Juan Hervé (1908, p. 122) and mentioned in the introduction of this paper were of this species, although the fact that he referred to them as small crabs might indicate *Pachygrapsus transversus* (Gibbes) instead. Unlike *Grapsus grapsus*, which keeps to the supra-tidal level, *Leptograpsus variegatus* was reported by Lund University Chile Expedition collectors both in rocky crevices around high water level and in quiet water between boulders in the lower part of the littoral (Garth, 1957). Its presence in from 6 to 10 feet of water at Easter Island would support the latter observation.

Pachygrapsus transversus (Gibbes).

Grapsus transversus Gibbes, 1850, p. 181.

Pachygrapsus transversus, Gibbes, 1850, p. 182; Rathbun, 1902, p. 279 (Galápagos); 1907, p. 29 (Easter Island); 1918, p. 244, pl. 61, figs. 2, 3, synonymy.

Previous collection. Easter Island, shore, 16 December 1904, 1 female, *Albatross* (Rathbun, 1907).

Material examined. Hanga-Roa, 23 December 1964, 1 male, Ian E. Efford and Jack A. Mathias. Hanga-piko, tide pool, Station M 10, 31 December 1964, 2 males, Ian E. Efford and Jack A. Mathias. Vaihu, tide pool, 3 January 1965, 3 males, 2 females, Ian E. Efford and Jack A. Mathias.

Measurements. Males measure from 5.2 × 6.3 to 11.8 × 14.5 mm., females 5.2 × 6.6 and 6.0 × 7.7 mm. in length and width of carapace, respectively.

Distribution. West coast of America from Gulf of California to Peru; Galápagos Islands; Easter Island. East coast of America from Florida to Uruguay; Bermuda. West coast of Africa from Mediterranean to northern Angola; Cape Verde Islands.

Remarks. Since the Indo-west Pacific species of *Pachygrapsus*, *P. planifrons* De Man and *P. minutus* A. Milne Edwards, were encountered by the Scripps International Geophysical Year (IGY) Expedition at Clipperton Island (Garth, 1965), it was with interest that the writer verified from freshly collected METEI material the Easter Island record (Rathbun, 1907) of the amphi-American species, *P. transversus* (Gibbes). Thus, in the eastern North Pacific, as at Clipperton and Clarion islands, it is the western Pacific *Pachygrapsus* species that have gained foothold; in the eastern South Pacific, as at Galápagos and Easter islands, it is a New World *Pachygrapsus* species that has established itself.

Ptychognathus easteranus Rathbun.

Ptychognathus easterana RATHBUN, 1907, p. 31, pl. 2, fig. 4; pl. 7, figs. 4, 4a (Easter Island).

PREVIOUS COLLECTION. Easter Island, shore, 20 December 1904, 1 male, *Albatross* (Rathbun, 1907).

MATERIAL EXAMINED. Hanga-piko, tide pool, Station M 10, 31 December 1964, 1 young female, Ian E. Efford and Jack A. Mathias.

MEASUREMENTS. Young female: length of carapace 4.2 mm., width 5.0 mm. The male holotype (USNM No. 32845) measured 10.6 mm. in length and 12.7 mm. in width of carapace (Rathbun, 1907).

DISTRIBUTION. Known only from Easter Island, where it was first collected by the U. S. Fish Commission Steamer *Albatross* in 1904. The genus ranges throughout the Indo-west Pacific.

REMARKS. The single young female collected by the METEI differs from the male holotype in being more straight-sided, thereby increasing its resemblance to *Ptychognathus polleni* De Man (1895, p. 94, pl. 28, fig. 20a), and would not have been recognized as the same species as the male except for the external maxilliped, which is identical with the figure of Rathbun (1907).

Cyclograpsus longipes Stimpson.

Cyclograpsus longipes STIMPSON, 1858, p. 105 (Bonin Islands); DE MAN, 1896, p. 355, pl. 32, figs. 43a–c (Atjeh); RATHBUN, 1907, p. 36 (Tahiti, Tuamotu); SAKAI, 1939, p. 690, synonymy; CAMPBELL and GRIFFIN, 1966, p. 139, key.

MATERIAL EXAMINED. Shore above Vaihu, 25 January 1965, 2 males, 1 female, Ian E. Efford and Jack A. Mathias.

MEASUREMENTS. Male specimens: 4.6 × 5.7 and 5.4 × 7.0 mm.; female specimen: 7.0 × 8.8 mm.

DISTRIBUTION. Sumatra (Atjeh = Achin), Bonin Islands, Fiji Islands, Tahiti, and Tuamotu.

REMARKS. According to Campbell and Griffin (1966), *Cyclograpsus longipes* is distinguished from other *Cyclograpsus* species with entire anterolateral margins by having the lateral margins of the carapace straight and markedly divergent posteriorly, the epigastric lobes prominent, and the suborbital ridge interrupted two or three times. The Easter Island female differs from the two males in lacking the felted patch on the propodus of the second pair of walking legs and in having the suborbital ridge entire. In this respect it agrees with a larger series of eight males and three females from the Marshall Islands in the collections of the Allan Hancock Foundation.

Plagusia dentipes De Haan.

Plagusia dentipes De Haan, 1835, p. 58, pl. 8, fig. 1 (Japan); Rathbun, 1907, p. 36 (Easter Island); Sakai, 1939, p. 79, fig. 3, synonymy.

Previous collection. Easter Island, shore, 21 December 1904, 2 males, 1 female, *Albatross* (Rathbun, 1907).

Material examined. Easter Island, near camp, January 1965, 1 male, 1 female, Ian E. Efford and Jack A. Mathias.

Measurements. Male specimen: length of carapace 38.5 mm., width 41.6 mm.; female specimen: length 34.4 mm., width 36.7 mm.

Distribution. Japan and Formosa. Easter Island. Any continuity between the two regions must be assumed, as records from intermediate localities are lacking.

Remarks. The Easter Island specimens, while large, are not as large as a male from Simoda, length of carapace 44 mm., width 59.5 mm. (Sakai, 1939). Easter Island specimens were seen by Dr. Sakai, who confirmed their identity with Japanese specimens. The writer also had the privilege of examining two male and one female syntypes of von Siebold's collecting in the collections of the Leiden Museum.

Plagusia integripes Garth, new species.

(Figures 1–6.)

Type. Female holotype (AHF No. 6511), from shallow water off Hanga-Roa, Easter Island, 2 February 1965, Ian E. Efford and Jack A. Mathias, collectors (METEI).

Measurements. Female holotype: length of carapace 30.2 mm., width of carapace 31.1 mm., of front 6.2 mm., between inner orbital spines 12.2 mm., between exorbital spines 19.7 mm., length of chela 15.0 mm., of dactyl 8.4 mm.

Diagnosis. Carapace tuberculate; three teeth behind external orbital angle. Coxae of walking legs entire; meri smooth anteriorly, a single spine subterminally. Exognath of outer maxilliped without a flagellum.

Description. Carapace roughened everywhere by low scabrous tubercles arranged in transverse rows and becoming more prominent on the slopes of the major elevations; intervening depressions free of tubercles but filled with a tomentum of short, stout, hooked hairs directed forward and inward. Larger tubercles distributed as follows: two pairs on the front, forming a square; one behind the orbit, one outer branchial, and one post lateral, each with one or more subordinate tubercles. Front with about eight tubercles on each side arranged in a forward-curving arc, the anterior three independent, the posterior five coalesced; a blunt tooth on outer slope of inner orbital lobe. Anterolateral border with four strong teeth, including the exorbital tooth; teeth acute, directed forward, upward, and slightly inward, separated by broad U-shaped sinuses, and decreasing in size from first to last; last tooth considerably smaller than the

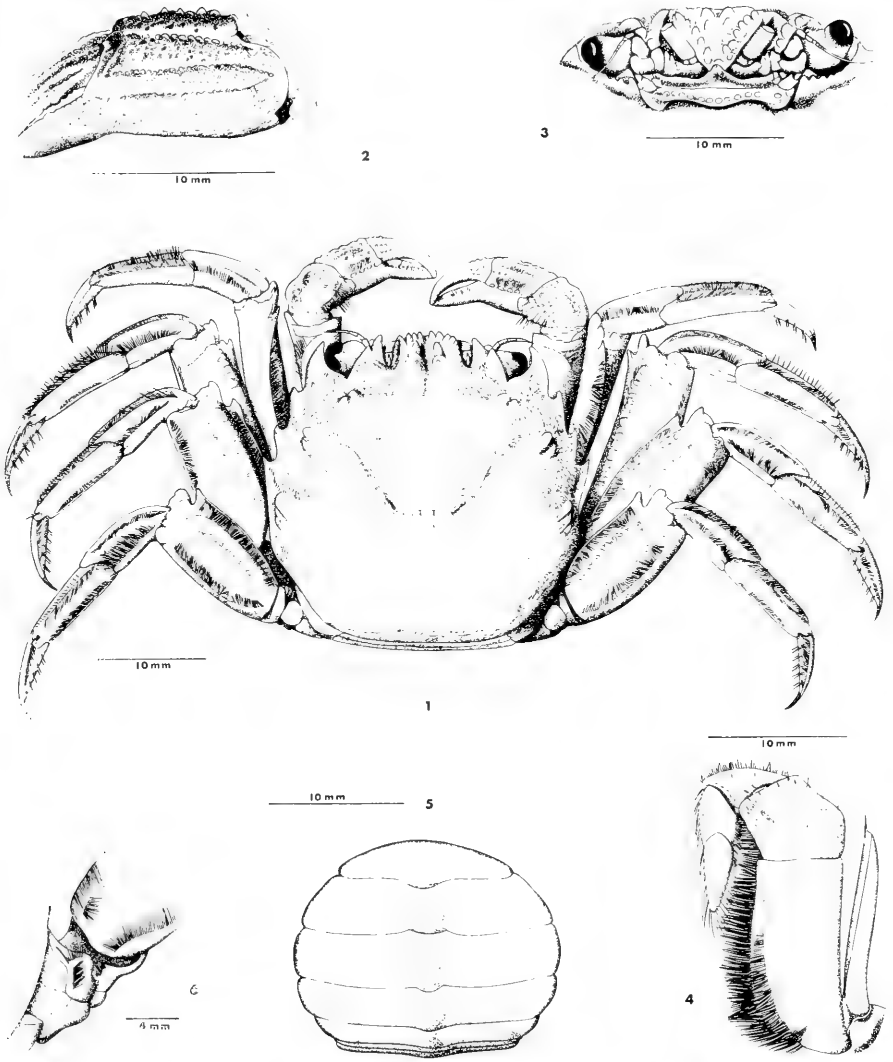

Figure 1. *Plagusia integripes* Garth, new species, female holotype (AHF No. 6511), dorsal view. Figure 2. Same, outer view of left cheliped. Figure 3. Same, frontal view of orbital region. Figure 4. Same, left outer maxilliped. Figure 5. Same, abdomen, restored. Figure 6. Same, coxa of right third leg. Drawings by Carl Petterson.

preceding tooth. Lower orbital margin continuous with epistome and similarly denticulate; epistome not readily divisible into lobes. Merus of outer maxilliped with a groove parallel to obliquely truncated anteroexternal margin; exognath lacking a flagellum.

Chelipeds of the female (the male is not known) moderately robust, equal, tuberculate, and hairy; tubercles forming a weak crest backed by feathered setae along inner margins of merus, carpus, and manus, irregularly arranged on upper surface of carpus and manus, and forming rows along ridges leading to the dactyls on outer surface of palm; dactyls basally tuberculate, movable finger grooved, tips hollowed and meeting with a slight gape; hooked hairs in depressions of carpus and manus.

Merus of walking legs with anterior crest entire, terminating in an acute spine or tubercle, fringed with plumose setae, and paralleled by a superior row of low tubercles; carpus and propodus similarly crested and fringed but lacking subterminal spine; dactylus short, curved, a double row of bristles internally, fringing hairs externally. Coxal lobes entire.

Abdomen of unique female holotype crushed, but clearly showing the 7-segmented arrangement as restored in figure 5.

REMARKS. The new species from Easter Island allies itself with *Plagusia depressa* (Fabricius), *P. glabra* Dana, and *P. speciosa* Dana in having the meri of the walking legs smooth anteriorly and culminating in a single spine. Like them also it lacks the flagellum of the exognath of the third maxilliped found in *Plagusia capensis* De Haan and *P. dentipes* De Haan but in its place carries a tuft of setae. It may be distinguished from *Plagusia depressa* in all its forms by the denticulate lower margin of the orbit and inner margins of the merus, carpus, and propodus of the cheliped, the corresponding surfaces in that species being entire; by the flatter, more squarish carapace with clusters of sharp tubercles separated by patches of hooked setae, rather than low squamiform tubercles fringed with soft hair; and by the more robust chelae, at least in the female sex, the male of the species being unknown; and from *P. d. depressa* by the entire coxa of the walking legs (fig. 6), that of the nominate form being bidentate (*cf.* Rathbun, 1918, text-fig. 154a).

The ♀ holotype from Easter Island has been compared with each of the following:

TYPE MATERIAL.

Plagusia chabrus (Linnaeus), ♀ neotype from Cape of Good Hope, H. B. van Horstok;
Plagusia capensis De Haan, ♀ lectotype from Cape of Good Hope, H. B. van Horstok; the above one and the same specimen in the Leiden Museum. (*cf.* Griffin, 1968)
Plagusia gaimardi Milne Edwards, ♂ type from Tongatabu, Quoy and Gaimard;
Plagusia tomentosa Milne Edwards, 3♂ and 1♀ syntypes, Cape of Good Hope, attributed to Latreille; 1♀ syntype, Cape of Good Hope, Delalande; both in the Paris Museum. [The above three probably synonyms of *Plagusia chabrus*.]
Plagusia dentipes De Haan, 2♂ and 1♀ syntypes, Japan, P. F. von Siebold, in the Leiden Museum.

OTHER MATERIAL.

Plagusia capensis De Haan, ♂ and ♀ from Long Reef, Collaroy, New South Wales;
Plagusia dentipes De Haan, ♂ and ♀ from Easter Island;
Plagusia depressa (Fabricius), ♂ and ♀ from Cubagua Island, Venezuela;

Plagusia depressa immaculata Lamarck, ♂ and ♀ from Cocos Island, Costa Rica;
Plagusia depressa tuberculata Lamarck, ♀ from Iheya Shima, Ryukyu Islands;
Plagusia speciosa Dana, ♀ from Apra Harbor, Guam; ♀ from Clipperton Island. The above are in the collections of the Allan Hancock Foundation.
Plagusia glabra Dana, ♂ and ♀ from Cogee, near Sydney, New South Wales. The above courtesy of The Australian Museum, Sydney.

ZOOGEOGRAPHY

The study of the Brachyura of the METEI clearly establishes Easter Island as the most easterly outpost of the Indo-west Pacific marine fauna in the South Pacific. As such it is comparable to Clipperton Island, an atoll at the same Longitude in the North Pacific, a relationship developed through the study of the Brachyura of the Scripps IGY Expedition (Garth, 1965).

Easter Island species with ranges extending westward to the western margins of the Indian Ocean are the following:

Dromidia unidentata (Rüppell)	Red Sea, East Africa
Carpilius convexus (Forskål)	Red Sea, South Africa
Liomera rugata (Milne Edwards)	Red Sea, Mauritius
Actaea parvula (Krauss)	Red Sea, Natal
Lophozozymus dodone (Herbst)	East Africa, Mauritius
Etisus electra (Herbst)	Red Sea, Mozambique
Chlorodiella cytherea (Dana)	Red Sea, Madagascar
Trapezia cymodoce (Herbst)	Red Sea, Dar-es-Salaam
Trapezia ferruginea Latreille	Red Sea, Zanzibar
Geograpsus crinipes (Dana)	Red Sea, Madagascar.

Species with range extending westward to the Central Indian Ocean are the following:

Pseudoliomera remota Rathbun	Coetivy, Salomon
Trapezia areolata Dana	Ceylon, Nicobar Islands
Trapezia danai Ward.	

Species with ranges extending westward to the western margins of the Pacific Ocean are the following:

Portunus pubescens (Dana)	Australia, Japan
Thalamita species	
Leptograpsus variegatus (Fabricius)	Australia, New Zealand
Cyclograpsus longipes Stimpson	Sumatra, Bonin Islands
Plagusia dentipes De Haan	Japan, Formosa.

Species apparently endemic to Easter Island but representing Indo-west Pacific or Pan-tropical genera are the following:

Ptychognathus easteranus Rathbun
Plagusia integripes Garth, new species

Species with ranges extending eastward to the shores of the Americas are the following:

Trapezia ferruginea Latreille	Galápagos Islands, Bay of Panama
Leptograpsus variegatus (Fabricius)	Juan Fernandez Island, Chile
Pachygrapsus transversus (Gibbes)	Galápagos Islands, Peru

It will be noted that the largest single segment are those that have negotiated the distance from the Red Sea to Easter Island, representing 210° of Longitude, or three-fifths of the circumference of the globe; also that the second largest segment are those that have negotiated the distance from Australia to Easter Island, representing 95° of Longitude, or one quarter of the circumference of the globe. On the other hand, only three species have successfully negotiated the distance from Chile to Easter Island, representing but 40° of Longitude, or one-ninth the circumference of the globe, and of these only one species, *Pachygrapsus transversus* (Gibbes), appears to have made the crossing from east to west, since it alone has incontestible New World affinities. That the migration has proceeded predominantly in an easterly direction is apparent by the increasing impoverishment of Pacific islands in Asiatic species from west to east, without a corresponding enrichment in American species. In the case of the *Pachygrapsus* species, which are susceptible to transport by ships' hulls and condensors, chance has determined the arrival and survival of *P. transversus* at Galápagos and Easter Island, as also of the western Pacific *P. planifrons* De Man and *P. minutus* A. Milne Edwards at Clarion and Clipperton in the northern hemisphere (Garth, 1965), again underscoring the randomness of insular dispersal.

The nearest islands to the west from which brachyuran species may have reached Easter Island are Tahiti and Tuamotu. Fortunately, the fauna of these islands is comparatively well known through the recent monograph of Forest and Guinot (1961).

Species common to islands immediately to the west of Easter Island are the following:

Carpilius convexus (Forskål)	Tahiti, Tuamotu
Thalamita	
Liomera rugata (Milne Edwards)	Tahiti, Tuamotu (Fakarava)
Actaea parvula (Krauss)	Marquesas
Lophozozymus dodone (Herbst)	Tahiti
Etisus electra (Herbst)	Tahiti, Tuamotu (Manga Reva)
Chlorodiella cytherea (Dana)	Tahiti, Tuamotu
Trapezia areolata Dana	Tuamotu (Hikueru = Melville)
Trapezia cymdoce (Herbst)	Tahiti, Marquesas
Trapezia ferruginea Latreille	Tahiti, Marquesas
Cyclograpsus longipes Stimpson	Tahiti, Tuamotu.

There remain to be considered three species known only from localities remote from Easter Island, rather than from adjacent islands. These are *Dromidia unidentata* (Rüppell), known in the Pacific from Japan, Hawaii, and the Kermadec Islands; *Portunus pubescens* (Dana), known from Japan, Hawaii, the Line Islands, and Australia; and *Plagusia dentipes* De Haan, known from Japan and Formosa. The Marquesas Islands, mentioned above, suggest a possible migration route, since they lie northwest of Easter Island along an axis which, if projected, leads through the Line Islands (Christmas, Fanning, Washington, and Palmyra) to Johnston and Midway islands, west of Hawaii. Such a direct dispersal route seems highly improbable, however, since it cuts across major ocean currents. The writer is inclined to favor, at least for the first two species mentioned, a southern hemisphere dispersal route eastward from Australia and would suggest a series of island stepping-stones for current-borne larval stages lying south of the Tropic of Capricorn: Lord Howe, Norfolk, Kermadec, Rapa, Morotiri (Bass), Pitcairn, Henderson, and Ducie. This island arc is completed to South America by Sala y Gomez, San Felix, and San Ambrosio. Juan Fernandez Islands, lying south as well as east of Easter Island, have but one brachyuran species found also at Easter Island, according to Balss (1924): *Leptograpsus variegatus* (Fabricius). The southern hemisphere island arc is much more probably involved in its trans-Pacific distribution than the hypothetical southern continent to which Balss (1924), following Arldt (1907, p. 114), took recourse. Evidence is constantly mounting to show that planktonic larvae of benthonic species, propelled by powerful currents, span greater oceanic distances than were once believed possible (Garth, 1966; Briggs, 1967; Scheltema, 1968). Certainly, of all Pacific islands, with the possible exception of Clipperton in the north Pacific, the sweepstakes route to Easter Island puts this hypothesis to its severest test.

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TWO NEW STONEFISHES (PISCES, SCORPAENIDAE) FROM THE INDO-WEST PACIFIC, WITH A SYNOPSIS OF THE SUBFAMILY SYNANCEIINAE

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Abstract. Two new stonefishes are described and placed tentatively in the genus *Synanceia.* A discussion of the limits of the subfamily Synanceiinae is given, and six genera (*Synanceia*, *Erosa*, *Dampierosa*, *Trachicephalus*, *Leptosynanceia*, and *Pseudosynanceia*) are recognized. Related genera are discussed as are nomenclatural problems. Brief descriptions and illustrations are provided for the species referable to the scorpionfish subfamily Synanceiinae.

Introduction

The common name 'stonefishes' is applied here to all members of the scorpionfish subfamily Synanceiinae, although the name is more commonly used only for the fishes of the genus *Synanceia.* Species of the genus *Synanceia* are the most venomous of fishes, capable of causing death in man (see Halstead, 1970). Despite the interest in stonefishes, the species are poorly known, and it is of interest that two new species have been found. The new species are referred tentatively to the genus *Synanceia*, and their large venom glands suggest that they may be just as venomous as the better-known and larger-sized species *Synanceia horrida* and *S. verrucosa.* Generic allocation of the new species necessitated an examination of other genera and species believed to be related to the genus *Synanceia.* The genera referable to the subfamily Synanceiinae contain few species and most of the species (nine or ten) are rarely encountered, so that it was thought desirable to provide a brief synopsis of the subfamily. Fishes of the subfamily Synanceiinae are restricted to the warm waters of the Indo-West Pacific faunal region. Some species are found on reefs, but other members of the subfamily occur on muddy or sandy bottoms in marine and brackish waters.

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METHODS

Methods follow those used by Eschmeyer (1969). Most scorpionfishes have the last two elements in the dorsal and anal fins united or close together at their bases and usually they are supported by a single pterygiophore. In the subfamily Synanceiinae, however, species of some genera have the last element single, well separated from the previous ray, and supported by its own pterygiophore. To distinguish between these two conditions the addition of "½" or the statement "last double" implies that the last soft ray is a double one and the absence of "½" or the statement "last single" indicates that the last element is separate soft ray. In these fishes there is no depression or pit where the premaxillaries join, so measurements originating from the anterior end are taken from the symphysis of the premaxillaries.

Subfamily Synanceiinae

The limits of this subfamily are in doubt. Bleeker (1874) included *Pelor* [=*Inimicus*], *Synanceia, Leptosynanceia*, and *Polycaulus* [=*Trachicephalus*] in a family Synanceiidae (his "Synanceioidei"). J. L. B. Smith (1958) included the genera *Minous, Inimicus, Choridactylus, Synanceia*, and *Synanceichthys* in the family Synanceiidae (his "Synanciidae") for western Indian Ocean species. De Beaufort (*in* Weber and de Beaufort, 1962) included *Synanceia, Leptosynanceia, Polycaulus, Inimicus*, and *Minous* in the family Synanceiidae (his "Synanceidae") for Indo-Australian species. Matsubara (1943) treated *Minous* as a separate subfamily Minoinae, *Inimicus* as a separate subfamily Pelorinae, and studied only *Synanceia verrucosa* as a representative of the subfamily Synanceiinae. The genus *Erosa* is thought by us to be related to *Synanceia*; Matsubara (1943) treated the genus *Erosa* as a separate subfamily Erosinae. Non-Japanese genera were not studied by Matsubara.

At the present time we suggest the following allocation of these genera and their synonyms (see also generic synonymies in text for additional synonyms):

Synanceiinae: *Synanceia* (including *Synanceichthys*), *Leptosynanceia, Trachicephalus* [*Polycaulus* a synonym], *Pseudosynanceia, Erosa*, and *Dampierosa*.
Inimicinae (synonym Pelorinae): *Inimicus* [*Pelor* a synonym] (including *Chorismopelor*), *Choridactylus* (including *Choridactyloides*).
Minoinae: *Minous* (including *Corythobatus, Decterias, Lysodermus*, and *Paraminous*).

Species of the subfamily Minoinae are characterized externally by the presence of a free lower pectoral ray in each fin, while the species in the subfamily Inimicinae have two (*Inimicus*) or three (*Choridactylus*) free pectoral rays. (The monotypic genus *Cheroscorpaena* (Mees, 1964) has three free pectoral fin rays; subfamilial placement of this genus is uncertain, but it probably belongs near the distinctive genus *Apistus*.) Species of the subfamilies Minoinae and Inimicinae will be treated in subsequent articles.

One feature which might prove to be important in the classification of these fishes at the subfamilial level and below is the presence of what appear to be skin glands or organs. These apparently pored structures tend to be scattered over the body in fishes of the subfamily Synanceiinae. They are present in rows (usually above the anal fin or below the dorsal fin) in some genera, and in *Synanceia, Erosa*, and *Dampierosa* they are reflected as warts. In the subfamily Inimicinae these glands are concentrated in a widely spaced row above the lateral line and in a patch behind the head. In the subfamily Minoinae, and presumably in other scorpaenoid fishes, they are absent. Frequently the glands contain a brown, hardened, wax-like substance in preserved specimens. A tiny buried scale accompanying each gland can be seen in alizarin-stained specimens. We do not know the function of these glands and have not studied them in detail.

The following trends are noted for the subfamily Synanceiinae:

1. Dorsal spines increase from 12 to 17 (occasionally 11 spines in those species which normally have 12 spines).
2. Dorsal soft rays decrease from 9 (10) to 4, but increase to 12–14 in one genus.
3. Fin spines change from firm and strong to flexible.
4. Pelvic rays are reduced from I + 5 to I + 3.
5. Pectoral fin rays decrease from about 18 or 19 to 11.
6. Eyes move to the dorsal surface of head; eyes become smaller.
7. Mouth shifts to a superior position.
8. Swimbladder is lost.
9. Vertebrae increase from 24 to about 30.

The definition of genera within the subfamily Synanceiinae is difficult, particularly because of the (probably 'rapid') evolution of certain features listed above as trends. For example, *Synanceia* is sometimes restricted to *S. horrida*, and *Synanceichthys* to *S. verrucosa* (as *verrucosus*) (Smith, 1958, p. 173). These 2 species and a presumed (by de Beaufort) hybrid (*S. platyrhynchus*) were treated in the genus *Synanceia* by de Beaufort (*in* Weber and de Beaufort, 1962); Whitley (1930) placed '*platyrhynchus*' in its own subgenus *Nofua*. The two new species described here further complicate this. One of the new species has 11 pectoral rays, and the other normally 14 rays, while '*platyrhynchus*' has 17, '*horrida*,' 15–17, and '*verrucosa*,' 18–19. Furthermore, one of the new species has the pelvic rays reduced to I + 4, as do some specimens referable to '*horrida*.' Given certain trends which occur in the subfamily, we do not feel that these differences are so important and we have expanded the genus *Synanceia*. We treat the genera *Erosa*, *Dampierosa*, *Trachicephalus*, *Pseudosynanceia*, and *Leptosynanceia* as monotypic, although more than one nominal species exists for some of these genera. Subsequent workers may wish to unite *Erosa* and *Dampierosa* in one genus.

SUBFAMILY DIAGNOSIS. Scales absent; no free pectoral rays; skin glands present (appearing as 'warts' in some genera); dorsal spines 11–17, dorsal soft rays 4–14 (last single or double); anal spines normally 2–4 (difficult to distinguish spines from soft rays in some species), anal soft rays 4–14, total anal spines and rays 7–16; pelvic rays I + 5, I + 4, or I + 3; pectoral rays 11–19;

second suborbital bone (= third infraorbital) broad, not T-shaped, attached to preopercle; third and fourth suborbital (fourth and fifth infraorbital) bones absent; vertebrae 23 to 30.

Key to the Genera and Species of the Subfamily Synanceiinae

1. Mouth terminal, only slightly oblique; eyes placed laterally on head, directed outwards 2
Mouth vertical or superior; eyes on dorsal surface of head, directed outwards and upwards or completely upwards 3
2. Dorsal spines 14; dorsal soft rays 5½ to 6½, usually 6½; anal spines 3; anal soft rays 5½ to 6½, usually 5½; pectoral fin rays 14–16, usually 15 .... *Erosa erosa*
Dorsal spines 12 (possibly 13); dorsal soft rays 9½ (possibly 8½); anal spines 2; pectoral fin rays 12 (11 or 13 should be expected) .... *Dampierosa daruma*
3. Dorsal spines 16 or more 4
Dorsal spines 11–14 5
4. Pelvic fin with 1 spine and 3 soft rays .... *Pseudosynanceia melanostigma*
Pelvic fin with 1 spine and 4 soft rays .... *Leptosynanceia asteroblepa*
5. Anal fin with 3 spines and 4½ (5) to 6½ (7) soft rays, total anal fin elements 7–10 6
Anal fin with 2 spines and 12–14 soft rays, total anal fin elements 14–16 .... *Trachicephalus uranoscopus*
6. (3 choices) Pectoral fin rays 11 (10 or 12 should also be expected) .... *Synanceia alula*
Pectoral fin rays 14, rarely 15 (13 should be expected; one type specimen with 15 on left, 16 on right) .... *Synanceia nana*
Pectoral fin rays 15 or more (if 15 or 16, eyes will have a crest above them) 7
7. Pectoral fin rays 18–19; no bony crest above eye .... *Synanceia verrucosa*
Pectoral fin rays 15–17; bony crest present above eye 8
8. Ridge connecting eyes across interorbit continuous, with no break in middle .... *Synanceia horrida*
Eyes nearly connected by a bony ridge across interorbit but with a concavity at center [a species of uncertain status] .... *Synanceia platyrhynchus*

Genus **Synanceia** Bloch and Schneider

Synanceia Bloch and Schneider, 1801, p. xxxvii (brief description; listed species; type-species *Scorpaena horrida* Linnaeus by subsequent designation of Jordan, 1919, p. 58).

Synanceja Bloch and Schneider, 1801, p. 194 (brief description; species descriptions; misprint for *Synanceia* [corrected in corrigenda on p. 573, see 'Nomenclatural remarks']).

Synanchia Swainson, 1839, pp. 61, 180–181 (unjustified emendation of *Synanceia* [see 'Nomenclatural remarks']; three subgenera).

Bufichthys Swainson, 1839, p. 268 [but not pp. 180–181] misprint for *Synanchia* [see 'Nomenclatural remarks']).

Synancidium Müller, 1843, p. 302 (type-species *Scorpaena horrida* Linnaeus by subsequent designation of Swain [see 'Nomenclatural remarks']; Müller proposed the genus for "*Synanceia* mit Vomerzähnen").

Synancydium, Agassiz, 1845, p. 63 (unjustified emendation of *Synancidium* Müller).

Synanceichthys Bleeker, 1863, p. 234 (type-species *Synanceia verrucosa* = *Synanceia brachio* by original designation).

Emmydrichthys Jordan and Rutter *in* Jordan, 1896, pp. 221–222 (type-species *Emmydrichthys vulcanus* Jordan and Rutter by monotypy).

Nofua Whitley, 1930, p. 24 (as a subgenus of *Synanceja* [sic]; type-species *Synanceia platyrhynchus* Bleeker by original designation).
Deleastes Seale, 1906, pp. 80–81 (type-species *Deleastes daector* by original designation).

Nomenclatural remarks. Much confusion exists over the spelling of this genus and its various synonyms, as well as the subfamily spelling. The genus is spelled *Synanceja* by many recent authors (e.g., Smith, Whitley, de Beaufort), but the correct spelling is clearly *Synanceia*. In the original description Bloch and Schneider, on page xxxviii, spell the name as *Synanceia*, on page 194 they spell it *Synanceja*, and in plate 45 *Synanceia*; in their "corrigenda" on page 573 they state "[page] 194. genus 50. scribe: *Synanceia*." Subsequent workers who have commented on this problem missed the corrigenda (e.g., Briggs, 1961, p. 164).

Gill (1905, p. 221, *et seqq.*) said of the problem of the genus *Synanceia* and some other genera, "Complication has resulted by reason of the intrusion of the incompetent Swainson into the field." Swainson (1839) did add considerable confusion, but this uncertainty easily can be resolved. As discussed by Gill, Swainson attempted to reclassify the "Synanceines" and named three subgenera, but in three places (1839: pp. 61, 180–181, and 268) Swainson variously interchanged names and diagnoses. Gill summarized the equivalent categories as follows:

p. 61	*pp. 180–181*	*p. 268*
Erosa	= *Bufichthys*	= *Synanchia* Cuvier (species *erosa*)
Synanchia	= *Synanchia*	= *Bufichthys* (species *horrida* and *grossa*)
Trichophasia	= *Trachicephalus*	= *Trachicephalus* (species *elongatus*)

Gill allocated the individual treatments by Swainson to the genera *Synanceia* and *Erosa* of other authors. *Trichophasia* and *Trachicephalus* were synonymized by Gill and he serves as first revisor selecting *Trachicephalus* over *Trichophasia*. Problems remain only for Swainson's subgenera *Erosa*, *Synanchia*, and *Bufichthys*. Authors, e.g. Swain (1882), Jordan and Starks (1904), Jordan (1919), and Whitley (1930), as well as Gill, consider Swainson's *Synanchia* an emendation of *Synanceia*, although Bleeker (1874, pp. 4,11) indicated that the species '*erosa*' could be placed in *Synanchia* of Swainson. *Synanchia* is an unjustified emendation and cannot be used as a separate genus for the species '*erosa*' as by Bleeker (see Gill, 1905). It is clear from Swainson's text (but not from p. 268) that he intended first *Erosa* and then *Bufichthys* for the species '*erosa*.' It therefore appears that on page 268 Swainson switched the two headings *Bufichthys* and *Synanchia* (compare particularly his diagnosis and subgeneric categories on pp. 180–181 with p. 268).

Swain (1882, p. 277), in his review of Swainson's genera, dealt only with the entries on Swainson's pages above 200 (*i.e.*, p. 268 but not pp. 61 or 180–

181) and was therefore not aware of the switched headings. Unlike Gill, Swain referred *Bufichthys* to *Synancia* [*Synanceia*] and selected '*horrida*' as the type-species of *Bufichthys*. But *Bufichthys* p. 268 is really *Synanceia* while *Bufichthys* on p. 181 is really *Erosa*. Swain's selection of '*horrida*' as the type of *Bufichthys* of p. 268 does not affect the type-species for *Bufichthys* on p. 181. The type-species of *Bufichthys* is really '*erosa*' by monotypy. (It does appear that Swain was in fact the first to select the type-species '*horrida*' for *Synancidium* Müller; see Swain's footnote 4 on p. 277; Jordan, 1919, also regarded '*horrida*' as the type-species of *Synancidium* Müller.)

Bufichthys Swainson (on p. 181) is the original generic description of *Bufichthys*, and Gill (1905, p. 223) serves as the first revisor selecting the genus *Erosa* Swainson (p. 61) over *Bufichthys*. This interpretation seems to have been the aim of Swainson and corresponds to current usage.

GENERIC DIAGNOSIS. Dorsal fin normally with 13–14 spines and 4½–5 to 7½–8 soft rays (last ray usually double); anal fin normally with 3 spines and 4½–5 to 6½–7 soft rays (last soft ray usually double); pectoral fin rays 11–19; pelvic fin rays I + 5, or I + 4 in some specimens and in one species; mouth vertical; eyes directed mostly upwards; vertebrae usually 24; swimbladder absent; body covered with warts.

REMARKS. The limits of the genus *Synanceia* are discussed in the subfamily section and reasons for placing some of the nominal genera in the synonymy of *Synanceia* are discussed above.

The genus *Emmydrichthys* Jordan and Rutter was based on a specimen of *S. verrucosa* with an abnormal dorsal fin. *Deleastes* was established by Seale for a species which he thought had shorter pelvic fins, pelvic fins located more posteriorly, and a smoother skin (see our account of *S. verrucosa*).

Synanceia nana Eschmeyer and Rama Rao, new species.

(Figures 1–2; tables 1, 3–5.)

No literature applies to this species.

HOLOTYPE. USNM 209417 (a specimen 73.2 mm. in standard length), Red Sea, Israel, northwest coast of the Gulf of Aqaba, bay at El Himeira, depth of capture to 18 meters, Victor G. Springer and assistants, 1100–1230 and 1315–1415 hours, 16 July 1969.

PARATYPES. CAS 14991 (1, 47.8), taken with the holotype; CAS 14992 (2, 21.3–39.7) and HUJ uncatalogued (1, 70.5), Red Sea, Israel, Gulf of Aqaba, bay at El Himeira, in 9–12 meters, Victor G. Springer and assistants, 0945–1215 hours, 8 September 1969; USNM 209418 (1, 24.0), Red Sea, Israel, Gulf of Aqaba, between Marset Mahash el Ala and Marset Abu Samra, 32 kilometers as road goes south of Marine Laboratory, in depths to 3.5 meters, Victor G. Springer and assistants, 1030–1300 hours, 2 September 1969; USNM 209419

FIGURE 1. *Synanceia nana*, holotype, USNM 209417, 73 mm. S.L., Red Sea.

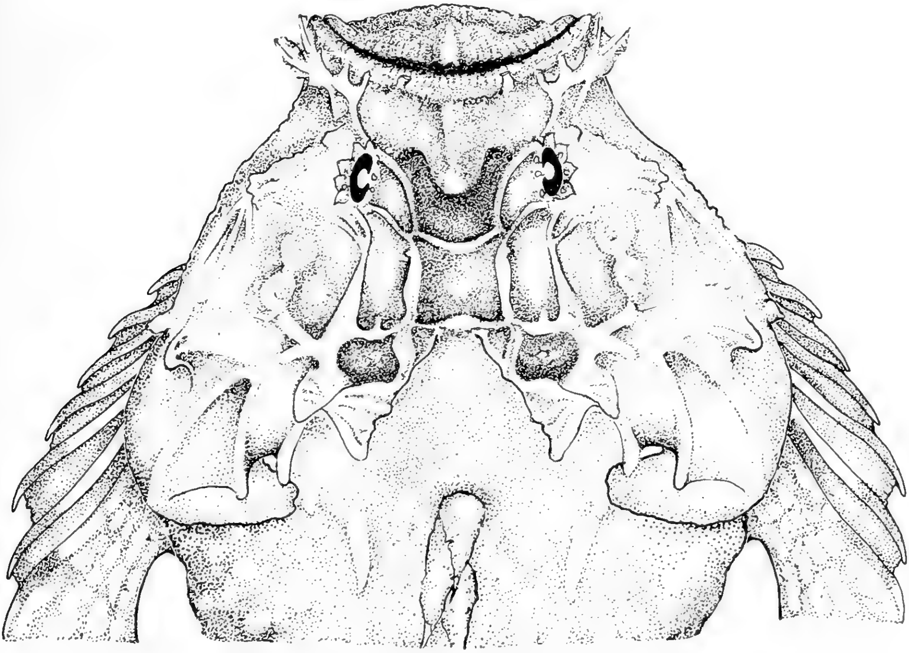

FIGURE 2. Drawing of head of *Synanceia nana*, based mostly on the holotype, 73 mm. S.L.

(1, 52.8), Red Sea, Gulf of Suez, Et-Tur, Sinai Peninsula, 100 kilometers north of Sharm el Sheikh as road goes, depths to 9 meters, Victor G. Springer and assistants, 1015–1315 hours, 27 September 1969; CAS 14993 (1, 71.5), Red Sea, Gulf of Suez, off Port Safâga, 27°16′15″N., 33°47′30″E., in 3 meters, H. A. Fehlmann and H. K. Badwi, 6 January 1965; AMNH 18385 (1, 102), Saudi Arabia, Persian Gulf, Tarut Bay, near Ras Tanura spit, R. Bowen, July 1947.

DISTINGUISHING FEATURES. Dorsal XIV–XV (usually XIV) + 5; anal III + 4 to 6 (usually III + 5); pectoral 14–15(16), usually 14; pelvic I + 5; head broad, depressed, with pits; no large pit below eye; deep depression between eyes; rectangular depression on occiput.

DESCRIPTION. Dorsal fin with 14 spines (15 in one specimen); all spines short, nearly the same length, with thick skin covering the venom glands. Dorsal soft rays 5, all unbranched. Anal fin with 3 spines, first very short. Anal soft rays 4–6, usually 5, last single, all unbranched. Pectoral fin rays 14–15 (16 on one side in 1 specimen), usually 14, all unbranched. Pelvic fin with 1 spine and 5 unbranched soft rays. Gill rakers rudimentary, total 7–10, 0–2 on upper arch, 7–8 on lower arch. Lateral line with 10–12 tubes (including one on caudal), lateral line pores paler than nearby 'warts' in smaller specimens. Vertebrae 24 (7 specimens), or 23? (1), or 25 (1).

Table 1. *Counts and measurements for the type specimens of* Synanceia nana *(measurements are in mm., percent standard length in parentheses).*

	Holotype USNM 209417	CAS 14991	CAS 14992	CAS 14992	CAS 14993	USNM 209418	USNM 209419	HUJ uncat.	AMNH 18385
Standard length	73.2	47.8	21.3	39.7	71.5	24.0	52.8	70.5	102.0
Dorsal rays	XIV+5	XIV+5	XIV+5	XIV+5	XIV+5	XIV+5	XIV+5	XIV+5	XV+5
Anal rays	III+5	III+5	III+5	III+5	III+5	III+5	III+5	III+4	III+6
Pectoral rays	14,14	14,14	14,14	14,14	14,14	14,14	14,14	14,14	15,16
Pelvic rays	I+5,I+5	I+5,I+5	I+5,I+5	I+5,I+5	I+5,I+5	I+5,I+5	I+5,I+5	I+5,I+5	I+5,I+5
Vertebrae	24	24	24	24	24	24	23?	24	25
Head length	29.0 (40)	18.0 (38)	8.0 (38)	13.7 (35)	28.0 (39)	9.1 (38)	20.0 (38)	26.2 (37)	42.3 (41)
Body depth	28.0 (38)	17.2 (36)	7.0 (33)	13.2 (33)	23.5 (33)	8.4 (35)	18.2 (35)	23.0 (33)	39.6 (39)
Orbit diameter	3.6 (05)	2.3 (05)	0.8 (04)	1.4 (04)	3.1 (04)	1.5 (06)	2.8 (05)	2.5 (04)	4.7 (05)
Snout length	6.5 (09)	4.2 (09)	1.3 (06)	2.7 (07)	5.5 (08)	1.5 (06)	5.0 (09)	5.0 (07)	11.5 (11)
Interorbital width	7.5 (10)	4.8 (10)	2.0 (09)	3.3 (08)	8.2 (11)	2.8 (12)	4.8 (09)	6.8 (10)	12.8 (13)
Jaw length	13.1 (18)	8.0 (17)	3.5 (16)	7.0 (18)	12.5 (18)	3.5 (15)	9.2 (17)	12.3 (18)	19.0 (19)
Predorsal fin length	22.5 (31)	14.0 (29)	6.2 (29)	12.1 (30)	21.0 (29)	7.0 (29)	15.6 (30)	20.5 (29)	32.0 (31)
Pectoral fin length*	43.0 (58)	25.7 (54)	10.5 (49)	20.0 (50)	37.1 (52)	10.6 (44)	28.0 (53)	34.6 (49)	59.5 (58)
Pelvic fin length	22.5 (31)	13.0 (27)	6.8 (32)	11.3 (29)	20.0 (28)	7.5 (31)	16.5 (31)	20.8 (30)	31.1 (30)

* from base of lower ray to tip of fin

Body shape and coloration as in figure 1. Head (fig. 2) broad, depressed. Eyes elevated, directed up and out. Posterior interorbital area as a deep pit, bordered behind by a ridge which forms anterior edge of shallow rectangular occipital pit. No deep pit before and below eyes. Low crest on upper posterior corner of orbit. Most head spines difficult to distinguish; preorbital bone with main spine pointing down and slightly forward, two lumps or ridges on anterior edge. Supplemental and 4 preopercular spines present, all short. Other spines absent or developed as lumps or ridges. Body covered with warts. Small teeth on jaws and vomer; none on palatines.

Head and body pallid to tan, with darker brown areas, most notably dark on back between posterior part of spinous dorsal fin and anterior half of anal fin and at base of caudal fin. Pale irregular spots on a tan background on outside and inside of pectoral fin, fin pale in middle and dark distally. Other fins, except spinous dorsal, dark distally with tips of rays or margins white. Smallest specimens with posterior part of body and caudal and anal fin darker than in larger specimens.

Described from nine specimens. Probably a small species, largest available 102 mm. in standard length.

Comparisons. This species most resembles *S. verrucosa* in body and head shape but differs from it by having a lower pectoral ray count (14–15 versus 18–19) and a different dorsal ray count (usually XIV + 5 versus usually XIII + 6½). *Synanceia nana* lacks a pit below the eye, unlike *S. verrucosa*, *S. platyrhynchus*, and especially *S. horrida*. *Synanceia nana* has a rectangular depression on the occiput which is absent in *S. verrucosa*. *Synanceia nana* has a higher pectoral ray count than *S. alula* (14 or more versus 11). Other differences are given in the key or may be found by comparing 'Distinguishing features' sections.

Remarks. The single specimen from outside the Red Sea (Saudi Arabia, AMNH 18385, 102 mm. S.L.) has higher counts of dorsal, anal, and pectoral rays and one more vertebra (table 1), and is darker brown in coloration than the Red Sea specimens. It also has the tips of the inner pelvic rays joined to each other by skin rather than having the tips of the inner rays attached to the body. It is about 30 mm. longer in standard length than our largest Red Sea specimen. We feel it is referable to *S. nana*, but study of additional specimens from outside the Red Sea would be desirable.

Distribution. *Synanceia nana* is known from the type material from the Gulf of Suez and the Gulf of Aqaba in the Red Sea and from Saudi Arabia. Depths of capture range from about 3 to 10 m.

Name. The specific name '*nana*' is a Latin noun meaning dwarf or pygmy, alluding to the small size of this species.

Synanceia alula Eschmeyer and Rama Rao, new species.

(Figures 3–4; tables 2–5.)

Synanceia verrucosa, Keegan et al., 1964, fig. 26 (good photograph of a specimen from the Solomon Islands).

Holotype. SU 14673 (a specimen 85.0 mm. in standard length), Nicobar Islands, Nancouri Island, 8°N., 93°40′E., shore collection, *R.I.M.S. Investigator* station 615, 27 October 1921.

Paratypes. ZSI 289/2 (1, 72.0), taken with the holotype; USNM 209420 (2, 30.0–48.5), Solomon Islands, New Georgia, Munda Pier, in old coral, collected by W. Chapman, 7 May 1944; USNM 209421 (1, 27.8), Solomon Islands, New Georgia, Munda lagoon, collectors Chapman and Cheyne, 19 June 1944.

Distinguishing features. Dorsal XIII + 5½–6½; anal normally III + 4½–5½ (last soft ray usually double); pectoral 11; pelvic I + 4; head broad, depressed, large pit below eye.

Description. Dorsal fin with 13 spines; spines nearly same length, first shortest, second and third longest, covered by thick skin; venom glands prominent, on distal half of spines. Dorsal soft rays 5½–6½, branched distally, last ½ ray virtually a distinct separate ray (without dissection soft rays probably would be counted as 6–7). Anal fin with 3 spines (4 in one specimen) and 5½ (normally) or 4½ soft rays; first anal spine about half length of second; last anal soft ray usually double (but appearing as two close-set rays); anal rays branched distally except in small specimens. Pectoral rays 11, all rays branched at tips in largest 2 specimens. Pelvic fin with 1 spine and 4 soft rays, but 3 soft rays on left side of holotype. Gill rakers rudimentary, total 7–8, 0–1 on upper arch, 7 on lower arch. Lateral line tubes difficult to distinguish from 'warts,' about 11 lateral line scales. Vertebrae 24 (4 specimens).

Body shape and coloration as in figure 3. Head (fig. 4) broad, depressed; eyes elevated, with crest at upper posterior corner. Large pit below eye, largest in largest specimens; deep pit below parietal and nuchal spines. Occipital pit shallow or nearly absent. Most head spines developed as lumps or ridges, poorly defined. Preorbital bone prominent, main spine as a broad lump pointing down, with lateral ridges pointing anteriorly. Supplemental preopercular spine absent or fused with first preopercular spine; four preopercular spines present. Small teeth on jaws and vomer, none on palatines.

Head and body tan or brown, with darkest areas on back and between posterior portion of spinous dorsal fin and anal fin; a broad dark band at base of caudal fin. Dorsal fin brown in holotype (possibly discolored), paler in other specimens.

Described from 5 specimens. Probably a small species, largest available 85.0 mm. in standard length.

Figure 3. *Synanceia alula*, holotype, SU 14673, 85 mm. S.L., Solomon Islands.

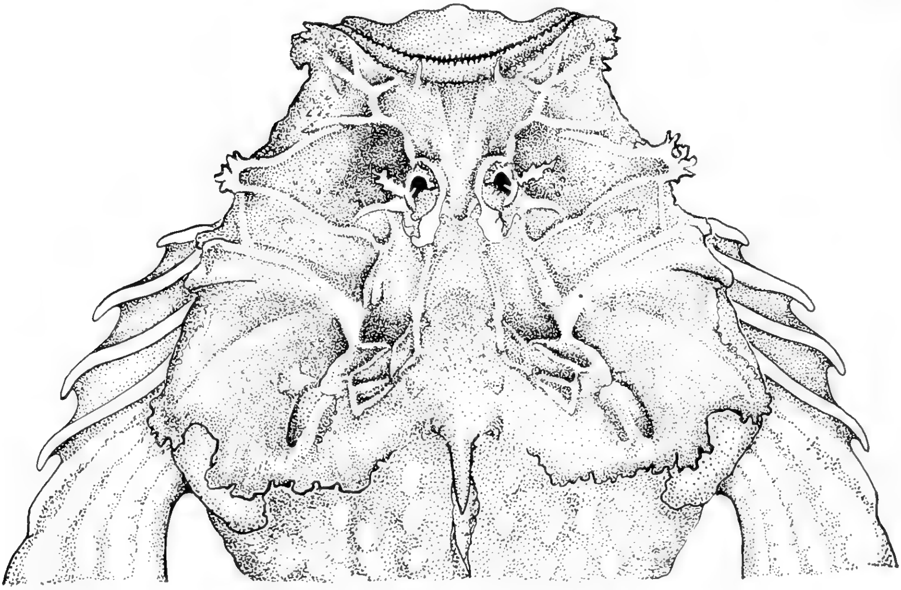

FIGURE 4. Drawing of head in holotype of *Synanceia alula*, 85 mm. S.L.

TABLE 2. *Counts and measurements for type specimens of* Synanceia alula *(measurements in mm., percent standard length in parentheses).*

	Holotype SU 14673	Paratypes			
		ZSI 289/2	USNM 209420	USNM 209420	USNM 209421
Standard length	85.0	72.0	30.0	48.5	27.8
Dorsal rays	XIII+5½	XIII+6½	XIII+5½	XIII+6½	XIII+5½
Anal rays	III+5	III+5½	IV+4½	III+5½	III+4½
Pectoral rays	11,11	11,11	11,11	11,11	11,11
Pelvic rays	I+3,I+4	I+4,I+4	I+4,I+4	I+4,I+4	I+4,I+4
Vertebrae	24	—	24	24	24
Head length	35.4 (42)	—	11.8 (39)	19.2 (40)	11.5 (41)
Body depth	31.8 (37)	—	11.0 (37)	17.0 (35)	10.0 (36)
Orbit diameter	4.2 (05)	—	1.6 (05)	2.4 (05)	1.7 (06)
Snout length	8.3 (10)	—	3.0 (10)	4.8 (10)	2.8 (10)
Interorbital width	4.6 (05)	—	2.2 (07)	4.0 (08)	1.8 (06)
Jaw length	16.8 (20)	—	5.5 (18)	9.0 (19)	4.7 (17)
Predorsal fin length	23.4 (28)	—	8.3 (28)	13.5 (28)	7.8 (28)
Pectoral fin length*	39.5 (47)	—	13.3 (44)	22.4 (46)	12.0 (43)
Pelvic fin length	23.5 (28)	—	8.8 (30)	14.8 (30)	8.0 (29)

* from base of lower ray to tip of fin

Table 3. *Frequency distributions of number of dorsal fin rays in species of the subfamily Synanceiinae.*

	Spines							Soft rays											Total dorsal rays							
	11	12	13	14	15	16	17	3½ –4	4½ –5	5½ –6	6½ –7	7½ –8	8½ –9	9½ –10	10½ –11	11½ –12	12½ –13	13½ –14	18½ –19	19½ –20	20½ –21	21½ –22	22½ –23	23½ –24	24½ –25	25½ –26
S. alula	—	—	5	—	—	—	—	—	—	3	2	—	—	—	—	—	—	—	3	2	—	—	—	—	—	—
S. nana	—	—	—	8	1	—	—	—	9	—	—	—	—	—	—	—	—	—	8	1	—	—	—	—	—	—
S. horrida	—	—	20	1	—	—	—	—	—	—	21	—	—	—	—	—	—	—	—	20	1	—	—	—	—	—
S. platyrhynchus	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
S. verrucosa	—	1	19	2	—	—	—	—	—	2	18	2	—	—	—	—	—	—	3	16	3	—	—	—	—	—
E. erosa	—	—	—	16	—	—	—	—	—	1	15	—	—	—	—	—	—	—	—	1	15	—	—	—	—	—
D. daruma	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—
L. asteroblepa	—	—	—	—	—	4	—	—	4	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—
P. melanostigma	—	—	—	—	—	5	2	4	1	2	—	—	—	—	—	—	—	—	—	2	3	2	—	—	—	—
T. uranoscopus	1	7	1	—	—	—	—	—	—	—	—	—	—	—	—	6	3	1	—	—	—	—	—	7	2	1

Table 4. *Frequency distributions of number of anal fin rays in species of the subfamily Synanceiinae.*

	Spines			Soft rays										Total anal rays									
	2	3	4	4½ –5	5½ –6	6½ –7	7½ –8	8½ –9	9½ –10	10½ –11	11½ –12	12½ –13	13½ –14	6½ –7	7½ –8	8½ –9	9½ –10	10½ –11	11½ –12	12½ –13	13½ –14	14½ –15	15½ –16
S. alula	—	4	1	3	2	—	—	—	—	—	—	—	—	—	2	3	—	—	—	—	—	—	—
S. nana	—	8	—	1	7	—	—	—	—	—	—	—	—	1	8	—	—	—	—	—	—	—	—
S. horrida	2	17	—	—	19	—	—	—	—	—	—	—	—	—	2	17	—	—	—	—	—	—	—
S. platyrhynchus	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
S. verrucosa	—	22	—	—	21	1	—	—	—	—	—	—	—	—	—	21	1	—	—	—	—	—	—
E. erosa	—	16	—	—	15	1	—	—	—	—	—	—	—	—	—	15	1	—	—	—	—	—	—
D. daruma	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
L. asteroblepa	—	1	3	3	1	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
P. melanostigma	—	7	—	—	—	5	2	—	—	—	—	—	—	—	—	—	5	2	—	—	—	—	—
T. uranoscopus	10	—	—	—	—	—	—	—	—	—	1	8	1	—	—	—	—	—	—	—	1	8	1

COMPARISONS. *Synanceia alula* resembles *S. horrida* in many respects, particularly by having a deep pit below the eye, but *S. alula* differs from *S. horrida* and all other species of the genus in having a very low pectoral ray count (11 versus 14 to 19). Other differences are given in the key or may be found by comparing 'Distinguishing features' sections.

DISTRIBUTION. *Synanceia alula* is known only from the type specimens from the Solomon Islands in the western Pacific Ocean and from the Nicobar Islands in the northern Indian Ocean. The specimen figured by Keegan *et al.* (1964) also was from the Solomon Islands.

NAME. The specific name '*alula*' (al′-ū-la), meaning little wing, is a Latin feminine noun, the diminutive of *ala* (wing), alluding to the very low pectoral ray count in this species.

Synanceia horrida (Linnaeus).

(Figures 5–6; tables 3–5.)

(A partial synonymy pertinent to the scope of the study.)

Scorpaena horrida LINNAEUS, 1766, p. 453 (original description; type locality East Indies).

Scorpaena "*alepidota*" BLOCH, 1787, pp. 106–108, pl. 183 ([see 'Remarks' below]).

Synanceia horrida, BLOCH and SCHNEIDER, 1801, pp. xxxvii, 194, 573 (misspelled genus as *Synanceja* on p. 194, corrected on p. 573; brief description and synonymy); CUVIER *in* Cuvier and Valenciennes, 1829, pp. 440–446 (lengthy description; review of earlier literature); BLEEKER, 1849, pp. 4, 9 (synonymy; brief description; range); 1852a, pp. 230, 237, 242 (compiled range); 1874, pp. 4, 11–13, fig. 1 on pl. 1 (synonymy; description; distribution); 1879, fig. 7 on pl. CCCCXVII (figure from Bleeker, 1874); HERRE, 1951, pp. 479–480 (synonymy; description; Philippines); DE BEAUFORT *in* Weber and de Beaufort, 1962, pp. 95–97 (synonymy; description; distribution).

Synanceia grossa GRAY, 1830, pl. 97 (plate only, plus caption; type locality Singapore).

Synanceia trachynis RICHARDSON, 1842, pp. 385–389 (original description; type locality Port Essington, Northern Territory, Australia).

Synancidium horridum, GÜNTHER, 1860, pp. 144–146 (brief synonymy; description of skeleton; BMNH specimens); KNER, 1865, p. 119 (description; Java); DAY, 1875, p. 162, fig. 3 on pl. XXXIX (synonymy; description); FOWLER, 1928, pp. 297–298 (compiled).

Scorpaena monstrosa GRAY, 1854, p. 117 (after Gronovius and '*horrida*' of Linnaeus).

Synanceja horrida, MCCULLOCH, 1929, p. 392 (synonymy; Australia); WHITLEY, 1930, pp. 24–25 (synonymy; comparisons with *S. trachynis*).

Synanceja trachynis, WHITLEY, 1930, pp. 25–26 (synonymy; Australian records; venom); 1932a, pp. 306–309, figs. 1–2 on pl. 4 (description; fresh coloration; Australia); 1960, pp. 1–6, 4 figs. (semi-popular account; habitat, coloration, venom); MUNRO, 1967, p. 540 (description; New Guinea).

REMARKS. References on venom and related subjects, as well as specimen figures, are given by Halstead (1970). Some Australian workers continue to recognize *S. trachynis* as a species distinct from *S. horrida*; we have not made an exhaustive study but our specimens seem to indicate that the two names are synonyms.

Scorpaena alepidota of Bloch (1787) originated through an inadvertent error. As evidenced by style in Bloch's work, a heading "*Scorpaena horrida*" before the words *Scorpaena alepidota* was omitted, giving the incorrect impression that '*alepidota*' was proposed as the scientific name. The plate was correctly labeled '*horrida*.' The name '*alepidota*' has no separate status nomenclaturally.

Material examined. (No counts were made on specimens which have standard length omitted.)

Singapore

SU 30873 (5 specimens, 67.8–134 mm. S.L.), Herre 1934 Pacific Expedition, A. W. Herre, 15 March 1934. SU 36001 (1, 151), Singapore market, A. W. Herre, February 1937. SU 32128 (1, 159), 8 February 1899.

Thailand

USNM 209422 (2, 147–190), Paton Bay, Patong Phuket, International Indian Ocean Expedition, *Anton Bruun* Cruise No. 1, 22 April 1963. CAS 15073 (1, 102), Rayong Province, SE. of Ban Phe Fisheries Station, 12°35′40″N., 101°25′43″E., Fehlmann and assistants, 28 April 1960. Plus ANSP 89676 (1).

Philippines

CAS 15074 (1, 136), Calaogao, Cauayan, Negros Island, collected among coral stones at night, 10°N., 122°30′E., Q. Akala, 18 May 1960. SU 34132 (1, 196), Sitankai, Sulu Island, Oriental Expedition 1936–37, A. W. Herre, 9 January 1937. SU 29780 (1, 158), Manila Bay, A. W. Herre, December 1933. SU 28363 (1, 95.0), Atimonan, Tayabas, Herre 1931 Philippine Expedition, A. W. Herre, 1931. SU 39137 (1, 111), Ragay Gulf, Luzon, A. W. Herre, 1940. Plus SU 28365 (2).

Batavia

ANSP 90442 (1), Baai.

New Guinea

SU 26744 (1, 160), Waigiu Island (= Waigeo Island), A. W. Herre, 7 June 1929.

Australia

USNM 174014 (5, 57.5–73.7), Northern Territory, reefs and tide pools off south entrance to lagoon, Groote Eylandt, Arnhemland Expedition, R. R. Miller and party, 19–25 March 1948.

Distinguishing features. Dorsal XIII–XIV (usually XIII) + 6½; anal II–III (usually III) +5½; pectoral 15–17, usually 16; pelvic I + 4–5, usually 5; all fin rays usually branched; head large, depressed, with deep pits; eyes elevated, with bony crest above posterior corner of orbit, joined between orbits; occiput depressed, forming a deep saddle behind orbits; a deep, mostly round pit below eye; deep pit below parietal and nuchal spines. Body covered with thick skin and warts.

FIGURE 5. *Synanceia horrida*, USNM 174014, sub-adult, 67 mm. S.L., Australia.

FIGURE 6. *Synanceia horrida*, CAS 15074, head of an adult, 142 mm. S.L., Philippines.

DESCRIPTION. Dorsal fin with 13 spines, occasionally 14; spines nearly same length, second to fourth longest, covered by thick skin. Dorsal soft rays 6½, branched distally. Anal fin with 3 spines (2 spines in 2 of 19 specimens) and 5½ soft rays, spines progressing in length from first to third, soft rays branched distally. Pectoral fin rays 15–17, usually 16, all rays branched at tips. Pelvic fin with 1 spine and 4 or 5, usually 5, soft rays [one specimen (SU 28363) abnormally with I + 3 on right and I + 5 on left]. Gill rakers rudimentary, total 13–15 in larger specimens, difficult to distinguish on upper arch in our specimens below 75 mm. S.L., larger specimens with 5–6 on upper arch, all

Table 5. *Frequency distributions of pectoral rays and pelvic soft rays in species of the subfamily Synanceiinae.*

	Pectoral rays (left side)									Pelvic soft rays (left side)		
	11	12	13	14	15	16	17	18	19	3	4	5
S. alula	5	—	—	—	—	—	—	—	—	1	5	—
S. nana	—	—	—	8	1*	—	—	—	—	—	—	9
S. horrida	—	—	—	—	3	14	2	—	—	—	2	17
S. platyrhynchus	—	—	—	—	—	—	1	—	—	—	—	1
S. verrucosa[1]	—	—	—	—	—	—	—	19	3	—	1**	21
E. erosa	—	—	—	1	14	1	—	—	—	—	16	—
D. daruma	—	1	—	—	—	—	—	—	—	—	1	—
L. asteroblepa	—	—	—	3†	1	—	—	—	—	—	4	—
P. melanostigma	—	—	—	3	5	—	—	—	—	7	—	—
T. uranoscopus	—	—	—	6	4	—	—	—	—	—	—	10

* 16 on right

** 5 on right

† one with 13 on right

[1] left and right pectoral ray counts for 24 additional specimens: 17+18 (1 specimen), 18+18 (22), 19+19 (1).

sizes with 8–9 on lower arch. Lateral line pores usually 10–12, difficult to distinguish from warts. Vertebrae 24.

Body shape and coloration as in figure 5. Head (fig. 6) broad, depressed; eyes elevated slightly, accentuated by large, mostly circular deep pit below eyes and large crests above eyes. Occipital area deep, forming saddle between eyes and beginning of dorsal fin; this area smooth, without warts. Deep pit also present behind eye below parietal and nuchal spines. Preorbital bone prominent, with broad spinous point directed downwards, with lateral ridges pointing anteriorly. Suborbital ridge with one large lump in middle. Supplemental preopercular spine usually present as a lump, first three preopercular spines usually present, first and second the largest. Other head spines indistinct or developed as lumps or absent. Small teeth on jaws and vomer, none on palatines.

Coloration of a small specimen as in figure 5. In preservative mostly brown; fins tend to be darker distally, except for spinous dorsal fin; caudal darkest at base, in middle, and distally; remaining areas of caudal fin streaked with white.

Comparisons. *Synanceia horrida* is most like *S. alula* in having a large pit below the eyes, but *S. horrida* is easily separated from *S. alula* by having more pectoral rays (15–17 versus 11), among other features. From the widespread *S. verrucosa*, *S. horrida* can be distinguished by having a large circular pit below the eye and high crests above the eyes which are joined, leaving no pit between the eyes. Other differences are given in the key and other 'Comparisons' sections.

Distribution. *Synanceia horrida* has a fairly wide range, occurring from

India eastwards to Java, New Guinea, Australia, the Philippines, and China. Unlike *S. verrucosa* it is apparently absent from the central Pacific and from western India to the Red Sea and Africa. It appears to be a continental and 'large island' species living on sandy or muddy bottom among rocks. (A record of this species from Saint Helena in the Atlantic (Günther, 1860, p. 145) was presumed (Eschmeyer, 1971, p. 503) to be based on incorrect locality information accompanying the specimen.)

Synanceia platyrhynchus Bleeker.

(Figure 7; tables 3–5.)

Synanceia platyrhynchus Bleeker, 1874, pp. 4, 11, 14–15, fig. 2 on pl. 1 (original description; type locality Amboina); 1879, fig. 2 on pl. CCCXVI (figure of type from Bleeker, 1874); de Beaufort *in* Weber and de Beaufort, 1962, p. 99 (examined type and one additional specimen with no locality data; thought to be a hybrid between *S. verrucosa* and *S. horrida*).

Synanceja (Nofua) platyrhynchus, Whitley, 1930, p. 24 (as type of a new subgenus).

Material examined. RMNH 5898 (1, 129 mm. S.L., 164 or 165 mm. T.L., holotype of *S. platyrhynchus*), Amboina. We could not locate the second specimen mentioned by de Beaufort *in* Weber and de Beaufort (1962, p. 99).

Remarks. De Beaufort gave the length of the two specimens he examined as 153 and 220 mm. and stated that one of them was the type. One of these measurements must be in error as the type in Leiden is 165 mm. T.L., the same length Bleeker gave in the original description.

The type specimen appears to us to be referable to *S. horrida*, but it seems to be abnormal in that the crests above the eyes are more poorly developed and are not joined between the eyes. This leaves a depression between the eyes which approaches somewhat the condition in *S. verrucosa*, although in *S. verrucosa* the pit is broader and the eyes farther apart. The type of *S. platyrhynchus* is very similar to *S. alula* with regard to head shape and location of crests and pits, but *S. alula* has far fewer pectoral rays (11 versus 17). We have kept *S. platyrhynchus* as a separate entry in this paper to draw attention to it in hopes that additional specimens may be found if it is in fact a species distinct from *S. horrida*.

Counting by the methods used in this paper, the type specimen has dorsal rays XIII + 6½, anal rays III + 5½, and pelvic rays I + 5. De Beaufort (*in* Weber and de Beaufort, 1962, p. 99) discusses the type specimen in more detail. A photograph of the type as it appears now is reproduced as figure 7.

Synanceia verrucosa Bloch and Schneider.

(Figure 8; tables 3–5.)

(A partial synonymy pertinent to the scope of the study.)

Synanceia verrucosa Bloch and Schneider, 1801, pp. XXXVII, 195, pl. 45 (original description; type locality India; spelling of genus on p. 194 corrected to *Synanceia* in Cor-

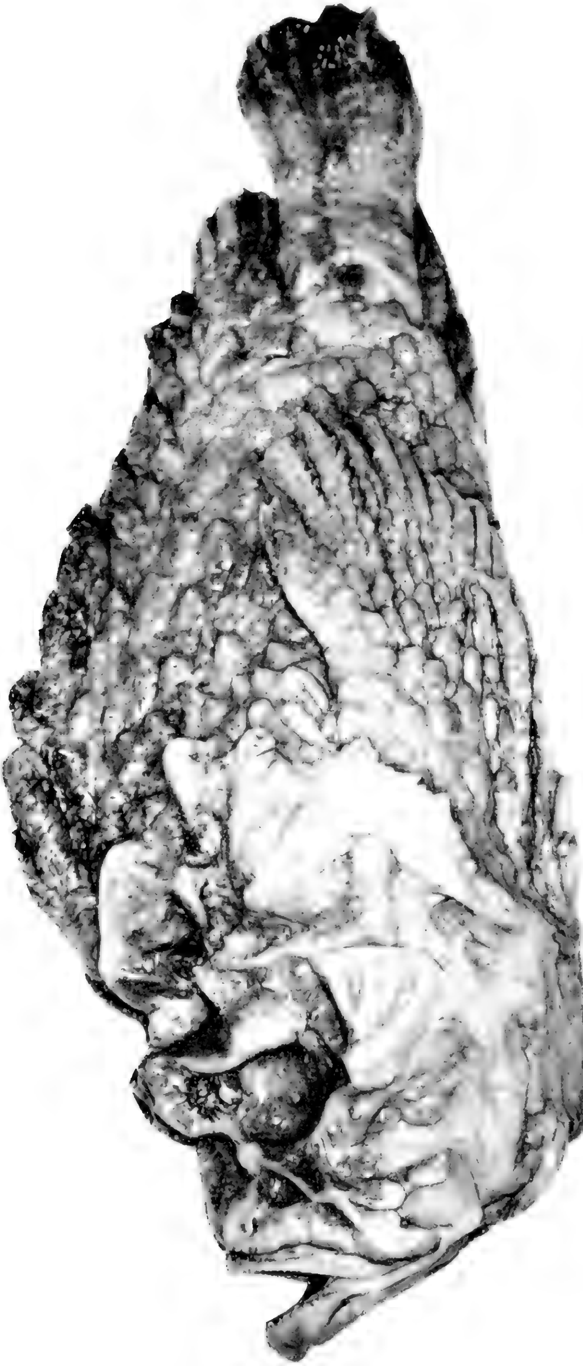

FIGURE 7. *Synanceia platyrhynchus*, RMNH 5898, holotype, 129 mm. S.L., Amboina.

rigenda, p. 573); Günther, 1860, p. 146 (synonymy; brief description; BMNH specimens); Bleeker, 1874, pp. 4, 11, 15–17 (synonymy; description; range); Day, 1875, pp. 162–163, fig. 4 on pl. XXXIX (synonymy; description; range); Bleeker, 1879, fig. 5 on pl. CCCCXVII (figure only); Herre, 1951, pp. 479–482 (synonymy; description; Philippines); de Beaufort *in* Weber and de Beaufort, 1962, pp. 95, 97–99 (synonymy; description; distribution).

Scorpaena bicirrata Lacépède, 1801, pp. 333, 349–350 (original description, from Commerson).

Scorpaena brachion Lacépède, 1801, pp. 333, 351–352, pl. 12 opposite p. 360 (original description, based on drawing from Commerson; no type locality).

Scorpaena Bicapillata Shaw, 1803, p. 273, pl. 40 (for Lacépède's *Scorpaena bicirrata*; description from Lacépède).

Scorpaena Brachiata Shaw, 1803, p. 274 (for Lacépède's *Scorpaena brachion*).

Synanceia brachio Cuvier *in* Cuvier and Valenciennes, 1829, pp. 447–454 (new spelling for *S. brachion* Lacépède; synonymy; long description; review of earlier literature); Bleeker, 1849, pp. 4, 9–10 (synonymy; description; range); 1852a, pp. 233, 236, 240 (listed; Ternate, Banda, Ceram, and Waigioe).

Synanceia bicapillata, Cuvier *in* Cuvier and Valenciennes, 1829, pp. 454–456 (synonymy; description; discussion); Bleeker, 1849, p. 4 (compiled range); 1852a, pp. 230, 242 (listed; Molucca).

Synanceia sanguinolenta Cuvier *in* Cuvier and Valenciennes, 1829, p. 447, footnote (original description from Ehrenberg MS and figure; no locality).

Synanceja verrucosa, Fowler, 1928, p. 299 (synonymy; remarks; range); McCulloch, 1929, 392–393 (synonymy; range).

Synanceichthys verrucosus, Bleeker, 1863, p. 234 (listed; Ternate); Whitley, 1932a, pp. 309–310 (rare on Great Barrier Reef; AMS specimens from other localities); Munro, 1967, p. 540 (description; New Guinea).

Emmydrichthys vulcanus Jordan and Rutter *in* Jordan, 1896, pp. 221–223, 562, pl. 26 (original description; type of new genus; type locality Society Islands).

Synanceia thersites Seale, 1901, pp. 121–122 (original description; type locality Marianas Islands [holotype BPBM 256, not found; paratype ANSP 91726]).

Deleastes daector Seale, 1906, pp. 80–81, fig. 22 (original description; type locality Tahiti; holotype BPBM 1360 [not found]).

Remarks. All the nominal species listed above have been recognized as synonyms of *S. verrucosa* by previous workers. *Emmydrichthys vulcanus* was based on a specimen with an abnormal dorsal fin. In the original description of *Deleastes daector,* Seale reported it differed from *Synanceia* by having shorter pelvic fins, pelvic fins located more posteriorly, and a smoother skin. The location and apparent size of the pelvic fins depend in part on the position of the hyoid arch on preservation, and we find that either of two conditions is common: the depth between the rear of the head and the pelvic fin will be shallow when the hyoid arch is not depressed or will be deep when the arch is depressed downward. The presence of warts was found to be somewhat variable. A more thorough study should be made.

Material examined. (No counts were made, except of pectoral rays, on specimens which have standard length omitted.)

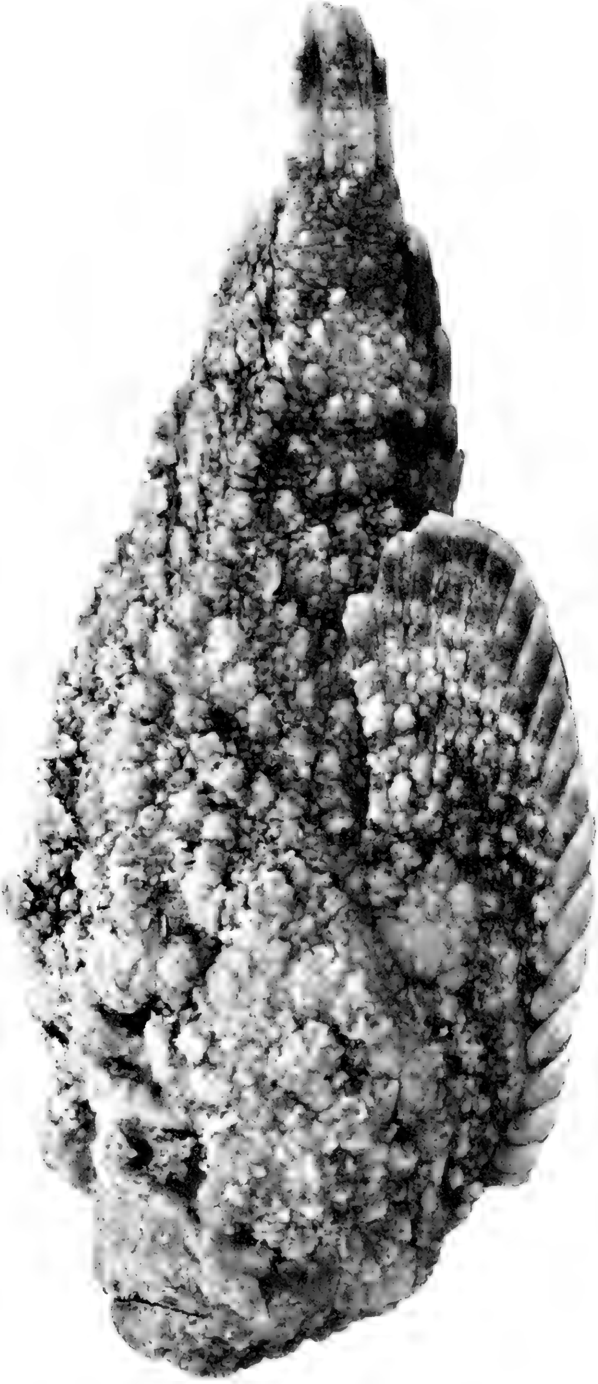

FIGURE 8. *Synanceia verrucosa*, CAS 13760, adult, 129 mm. S.L., Australia. (Specimen tilted slightly on left side.)

Western Indian Ocean

CAS 14943 (1 specimen, 123 mm. S.L.), Kenya, Andromache Reef just south of entrance to Port Kilindini of Mombasa Harbor, 4°05′05″S., 39°40′39″E., over flat reef with dead coral and sand, International Indian Ocean Expedition, *Anton Bruun* Cruise No. 9, sta. HA-1, 15 November 1964; SU 37205 (1, 154), southern Andaman Islands, south of Corbyn's Cove, Port Blair, under a coral stone in low water, D. D. Mukerji, 16 December 1933; Plus ANSP 107718 (1) and ANSP 107702 (1), Sechelles; USNM 19981 (1), Mauritius.

Ceylon

CAS 14969 (3), Trincomalee, outside harbor at coral cave, inside base of Royal Navy of Ceylon, depth to 1.5 meters, W. Smith-Vaniz, 27 June 1969.

Okinawa

USNM 71553 (1).

Philippines

SU 28362 (2, 121–187), Sitankai, Sulu Province, Herre Philippine Expedition, A. W. Herre, 12 August 1931. SU 28364 (1, 51.3), Dumaguete, Herre Philippine Expedition, A. W. Herre, 11 June 1931. Plus SU 34135 (1).

Micronesia

Palau Islands: CAS 14957 (1, 97.5), Auluptagel Island, Crocodile Cove, 7°17′ N., 134°29′E., Brittan *et al.*, 29 July 1956. CAS 14959 (1, 106), Angaur Island in Garangaoi Cove, south of Cape Nagaramudel, 6°53′50″N., 134°7′49″E., DeWitt and party, 22 October 1957. CAS 14956 (2, 119–133), Ngadarak Reef SW. of Auluptagel Island, 7°17′48″N., 134°28′37″E., Rikrik, 8 July 1956. Plus CAS 14953 (1), CAS 14954 (1), CAS 14958 (1), CAS 14960 (1), and CAS 14961 (1). *Mariana Islands*: CAS 14963 (1, 39.1), Guam, ca. ½ mile SW. of Agat village, sand flat off north side of Bangi point, 13°22′36″N., 144°38′53″E., Fehlmann, 12 October 1958. CAS 14965 (3, 54.2–121), Guam reef and sand flat north of Tringhera Beach in Agana Bay, 13°28′53″N., 144° 45′45″E., Fehlmann and Bronson, 7 April 1959. ANSP 91726 (1, 160, paratype of *S. thersites*), Guam, Agana, A. Seale, 12 July 1900. Plus CAS 14966 (2), CAS 14962 (1), and CAS 14964 (1). *Caroline Islands*: CAS 14947 (1, 126), Yap Island, inlet on east side of Yap Island, 9°29′48″N., 138°26′57″E., Bronson and Hermana, 27 December 1959. Plus CAS 14952 (3) and CAS 14948 (1).

Melanesia

Solomon Islands: CAS 15076 (1, 47.8), Bougainville, east side of Puk Puk Island, sea beach outside of Poison Lagoon, *Te Vega* Expedition, Cruise No. 6, Sta. 243, William P. Davis, 9 March 1965. SU 6034 (1, 154), Sikiana Island, Stewart group, Crocker Expedition, 16 May 1933.

POLYNESIA

Samoa: CAS 2228 (1, 115), A. Seale, 25 June 1929. CAS 2225 (2, 94.3–168), Pago Pago, A. Seale, May 1929. Plus SU 9041 (3) and CAS 14967 (1). *Fiji*: SU 21021 (1). *Tonga Islands*: CAS 14968 (1). *Society Islands*: SU 5357 (1, 187, holotype of *Emmydrichthys vulcanus*). CAS 14949 (1, 135), Tahiti, Tavavo, J. E. Randall, 21 April 1956. CAS 14955 (1, 47.4), Moorea, Faatoai village at entrance to Papetoai Bay, J. E. Randall and party, 30 June 1956. Plus CAS 14950 (3) and CAS 14983 (1). *Tuamotu Islands*: CAS 14946 (2) and CAS 14945 (1).

NEW CALEDONIA

USNM 208132 (1), Noumea.

NEW GUINEA

USNM 30516 (1).

AUSTRALIA

CAS 13760 (1, 129), Capricorn Islands, One Tree Island, west side, reef flat, caught under stone on reef crest, F. McMichael, 20 November 1969. Plus CAS 14944 (1), Fairfax Island.

RED SEA

HUJ uncataloged (101 mm. S.L.).

DISTINGUISHING FEATURES. Dorsal XII–XIV, usually XIII + 5½–7½, usually 6½; anal III + 5½–6½, usually 5½; pectoral 17–19, usually 18; pelvic I + 5; all soft rays usually branched, covered with thick skin; head depressed; eyes only slightly elevated, far apart, and with a deep depression between; occipital area elevated, bordered laterally by a pit lying behind each eye; small pit below and before eyes, pit smaller than orbit. Body covered with thick skin and warts.

DESCRIPTION. Dorsal fin normally with 13 spines; spines nearly same length, about third through fifth the longest, covered by thick skin. Dorsal soft rays 5½–7½, usually 6½, branched distally. Anal fin with 3 spines and 5½ (rarely 6½) soft rays, soft rays branched distally, spines progressing in length from first to third. Pectoral fin rays 18–19, usually 18; all rays branched distally but dissection may be necessary to discern in lower fleshy pectoral rays, rays unbranched in very small specimens. Pelvic fin with 1 spine and 5, or rarely 4, soft rays. Gill rakers rudimentary, total 8–11, 1–4 on upper arch, 6–8 on lower arch. Lateral line difficult to distinguish from warts, usually 8–10 pores present. Vertebrae 24.

Body shape and coloration as in figure 8. Head large, broad, and depressed; eyes very slightly elevated, far apart, and with a deep pit between them; occipital area elevated, without a pit; a pit present behind each eye lateral to occiput, deepest below parietal and nuchal spinous ridge; a small, more or less U-shaped pit, less than orbit diameter, below and in front of eyes. Preorbital bone covered by thick skin, usually with two diverging spines over maxillary. Suborbital ridge with one large lump in middle under eye. Supplemental preopercular spine usually absent, first and second preopercular spines large, third sometimes present, fourth and fifth absent. Other head spines indistinct, or developed as lumps or ridges, or absent. Small teeth on jaws, none on vomer or palatine.

Coloration variable. In preservative mostly brown (fig. 8). Pectoral, pelvic, and caudal fins tipped with white. Caudal fin with a subterminal dark band. Paler areas on body, usually well marked between soft dorsal and anal fin.

COMPARISONS. *Synanceia verrucosa* is most like *S. nana* in shape and location of pits on the head, but *S. verrucosa* is easily separated from *S. nana* by having more pectoral rays (18–19 versus 14). *Synanceia verrucosa* lacks vomerine teeth, while the other species of the genus have small teeth on the vomer. *Synanceia verrucosa* may be separated from the other species of the genus by the characters presented in the key.

DISTRIBUTION. *Synanceia verrucosa* is the most widespread stonefish and is known from throughout the Indo-West Pacific faunal region from the Red Sea, eastern Africa east to Tahiti, and from Australia north to Japan. It is found in shallow water among coral reefs and coral rubble.

Genus **Erosa** Swainson

Erosa SWAINSON, 1839, p. 61 (type-species *Synanceia erosa* Langsdorf, understood from text).

Bufichthys SWAINSON, 1839, p. 181 (type-species *S. erosa*, by monotypy [see 'Nomenclatural remarks']).

Synanchia, SWAINSON, 1839, p. 268, not pp. 61 or 280–281 (misidentification or misprint [see 'Nomenclatural remarks']).

Synanchia, BLEEKER, 1874, pp. 3–4 (as a genus for '*erosa*'; after Swainson, 1839, p. 268 [see 'Nomenclatural remarks']).

Erosa, JORDAN and STARKS, 1904, p. 156 (described as a "new genus" after Swainson; wrongly thought Swainson's name had no nomenclatural standing).

NOMENCLATURAL REMARKS. See 'Nomenclatural remarks' under the genus *Synanceia*.

GENERIC DIAGNOSIS. See 'Distinguishing features' under the species account.

Erosa erosa (Langsdorf).

(Figure 9; tables 3–5.)

Synanceia erosa Langsdorf *in* Cuvier and Valenciennes, 1829, pp. 459–460 (original description; type locality Japan); Cuvier, 1837, p. vii, fig. 3 on Ichthyology pl. 21 (color plate); Temminck and Schlegel, 1843, p. 45, fig. 1 on pl. xvii (brief description; Japan); Boeseman, 1947, pp. 54–55 (Burger and Von Siebold specimens from Japan; equals *Erosa erosa*).

Synanchia erosa, Swainson, 1839, p. 268 (name only; *Synanchia* in error for *Bufichthys* [see 'Nomenclatural remarks' under genus *Synanceia*]).

Synancidium erosum, Günther, 1860, p. 146 (brief description; BMNH specimens); Steindachner and Döderlein, 1884, p. 199 (short description; Tokyo and Kagoshima); Nyström, 1887, p. 19 (description; one specimen from Japan); Ishikawa and Matsüüra, 1897, p. 49 (listed; Kagoshima, Japan).

Erosa erosa, Jordan and Starks, 1904, pp. 156–158, fig. 16 (synonymy; description; variation in coloration; Japan); Franz, 1910, p. 74 (specimens from Japan); Jordan and Thompson, 1914, p. 276, fig. 46 (listed; Japan; figure from Jordan and Starks, 1904); McCulloch, 1921, pp. 177–178 (*E. iridea* a synonym; description; figure of holotype of *E. iridea*); Jordan and Hubbs, 1925, p. 275 (specimens from Japan); McCulloch, 1929, p. 392 (listed; *E. iridea* a synonym); Schmidt, 1931, p. 111 (specimen from Japan); Fowler, 1938b, p. 199 (listed from Malaya); Matsubara, 1943, pp. 422–424 (synonymy; description; internal features; specimens from Japan).

Erosa fratrum Ogilby, 1910a, p. 32 (original description; type locality Moreton Bay, coast of southern Queensland, Australia); McCulloch, 1929, p. 392 (listed; Australia); Whitley, 1964, p. 57 (listed; Australia).

Erosa iridea Ogilby, 1910b, p. 113 (original description; type locality 19 miles N., 30°W., from Double Island Point, in 33 fathoms, coast of southern Queensland, Australia).

Material examined. (Counts were not taken on specimens with standard length omitted and locality information abbreviated.)

Japan

SU 7385 (1, 98.3), Misaki, Jordan and Snyder. SU 7389 (1, 85.5), Nagasaki, Hizen, Jordan and Snyder. SU 7197 (3, 77.7–109), Odowara. FSUT 7550 (1, 94.7), Wakayama. FSUT 32013 (1, 111), Nagasaki. FSUT 32263 (1, 48.4), Nagasaki. FSUT 34630 (1, 131), Kochi. FSUT 34633 (1, 69.0), Kochi. Plus USNM 51342 (1), USNM 59714 (1), USNM 75919 (2), and USNM 57650 (1).

South China Sea

CAS 14800 (1, 91.0), 20°04′N., 111°58′E., R. L. Bolin, 20 July 1958. CAS 14797 (1, 85.2), 20°02′30″N., 113°32′E., F. D. Ommanney, 25 June 1958. CAS 14799 (1, 111), Formosa Strait, just south of Formosa Banks to Pescadores Island, about 30–50 meters, trawl, F. B. Steiner, 5 May 1972.

Philippines

USNM 168213 (1), southern Luzon.

AMBOINA

ZMK uncatalogued (1, 30.3), Bugten, in about 50 fathoms, T. Mortensen, 21 February 1922.

AUSTRALIA

QMB 13/1571 (about 97.0, ?holotype of *Erosa fratrum*), Moreton Bay, Queensland. AMS E2943 (1, 63.0, ?holotype of *Erosa iridea*), 19 miles N., 30° W. from Double Island Point, in 33 fathoms, Queensland.

DISTINGUISHING FEATURES. Dorsal XIV + 5½–6½, usually 6½; anal III + 5½–6½, usually 5½; pectoral 14–16, usually 15; pelvic I + 4; all fin rays usually branched; no palatine teeth; head very large, globular; mouth terminal, only slightly oblique; eyes large and on lateral surface of head; a strong bony ridge connects orbits, followed on occiput with a deep pit; warts behind head, not well marked on body posteriorly.

DESCRIPTION. Dorsal fin with 14 spines, all about same length. Dorsal soft rays 5½ or 6½, usually 6½ (without close examination would probably count 7 rather than 6½ soft rays). Anal fin with 3 spines, first short, second twice first, third longest. Anal soft rays 5½–6½, usually 5½ (appearing as 6). Pectoral fin short, 14–16 (usually 15) branched rays. Pelvic fin with 1 spine and 4 soft rays. Gill rakers rudimentary, total 10–13, 3–4 on upper arch and 7–9 on lower arch. Lateral line tubes 10–11, including one on caudal fin. Some warts on body, most conspicuous behind head. Vertebrae usually 25 (24–26).

Body shape and coloration as in figure 9. Head round; mouth terminal, slightly oblique; eyes not elevated, on side of head, pointing outwards. A strong ridge connects the orbits posteriorly; ridge followed by deep square to rectangular occipital pit; pit also present before ridge connecting orbits but occupied by ascending arms of premaxillaries. No pit below eyes or below parietal and nuchal spines. Preorbital bone with 2 broad spines over maxillary. Suborbital ridge without distinct spines, raised in middle. Five blunt preopercular spines present, plus 2 lumps on dentary and 3 spines near bases of upper preopercular spines. Large cleithral spine, two blunt opercular spines. Other spines indistinct, developed as lumps. Small teeth on jaws and vomer, none on palatines.

In preservative (fig. 9) body brown or black on a pallid background; area behind head and below soft dorsal fin darkest. Pectoral fin streaked and mottled with brown or black, most lines enclosing circles, a white patch at midheight of upper pectoral rays; anal fin mostly pallid with streaks and circular rings of dusky pigment; caudal fin pallid, crossed by about 6 vertical narrow dark bands (or double bands). Body most noticeably pallid at bases of middle dorsal spines and below middle of spinous dorsal fin.

COMPARISONS. The genus *Erosa* is most like *Dampierosa* in body shape and shares with it (but not with *Synanceia*) the following features: eyes lateral, mouth only slightly oblique, head globular and not depressed. *Erosa* differs

FIGURE 9. *Erosa erosa*, CAS 14799, adult, 111 mm. S.L., Formosa Strait.

from *Dampierosa* in having a lower soft dorsal fin ray count (5½–6½ versus 9½), 14 rather than 12 dorsal spines, and 3 rather than 2 anal spines.

DISTRIBUTION. *Erosa erosa* occurs from Japan south to Australia; specific localities represented by our material and records in the literature are Japan, the South China Sea area, the Philippine Islands, Amboina, and eastern Australia.

Genus **Dampierosa** Whitley

Dampierosa WHITLEY, 1932b, p. 346 (type-species *Dampierosa daruma* by original designation; monotypic).

GENERIC DIAGNOSIS. See 'Distinguishing features' under the species account below.

Dampierosa daruma Whitley.

(Figure 10; tables 3–5.)

Dampierosa daruma WHITLEY, 1932b, pp. 346–347, figs. 2–3 on pl. XXXVIII (original description; type locality northwestern Australia, dredged off Broome, 1931, collector R. Bourne; holotype AMS IA5116); 1964, p. 57 (listed).

Erosa daruma, MEES, 1960, p. 19 (one specimen from Roeburne, Western Australia; dorsal XIII + 8; anal I + 7 (or III + 5); pectoral 12; placed in genus *Erosa*).

MATERIAL EXAMINED. AMS IA5116 (97.2 mm. S.L., about 119 mm. T.L., holotype), locality as given above. Plus one specimen briefly examined, C.S.I.R.O. Marine Laboratory, Munroe Collection C2766 (53.0 mm. S.L.), from Exmouth Gulf.

DISTINGUISHING FEATURES. Dorsal XII + 9½ (?XIII + 8½); anal II + 6½; pectoral 12; pelvic I + 4; no palatine teeth; head large, globular; mouth terminal, slightly oblique; strong bony ridge connects orbits, followed on occiput by a deep pit; body with warts.

DESCRIPTION. (Based only on the holotype. A more complete description is given by Whitley.) Dorsal fin with 12 spines and 9½ soft rays (first soft ray segmented slightly, counted by Whitley (1932b) as a spine). Anal fin with 2 spines and 6½ soft rays. Dorsal and anal spines fairly weak. Pectoral fin short, with 12 rays. Pelvic fin with 1 spine and 4 soft rays. Gill rakers as given by Whitley: 7 or 8 short, rounded, thick gill rakers on first arch. Lateral line tubes 13. Body covered with warts. Vertebral count not available.

Body shape and coloration as in figure 10. Head globular; mouth terminal, slightly oblique; eyes not elevated, on side of head, directed outwards. A strong ridge connects the orbits; ridge followed by deep occipital pit. No pit below eyes or below parietal and nuchal spines. Preorbital bone with 2 large lumps over maxillary. Suborbital ridge without spines. Preopercle spines prominent. (No information available on other spines.) Small teeth on jaws and vomer, none on palatines.

FIGURE 10. *Dampierosa daruma*, holotype, AMS IA5116, 97 mm. S.L., Australia; figure from Whitley, 1932b.

Coloration as given by Whitley (1932b, p. 347) is as follows:

> "General colour in alcohol dark purplish-brown, irregular in tone and broken up by the lighter papillae and raised cephalic surfaces. Interorbital and pterotic regions white. Light brown mottling on lower surface of head and on parts of the body below the spinous and soft dorsal fins. Dorsal dark brown anteriorly, but mottled yellowish on the middle and posterior spines. Soft dorsal dark brownish with a narrow margin of yellow and a broad oblique median band of yellow. Anal similar to soft dorsal. Pectoral dark brownish with a yellowish band partly encircling its base, a broader band crossing the rays to form large ocelli below and a distal margin of yellowish. Ventrals dark brown with two bands of yellowish and a similarly coloured spot on the proximal part of the last ray. Caudal dark brown, crossed by a broad median band of yellowish and with a broad margin of the same colour."

Comparisons. See 'Remarks' below.

Distribution. *Dampierosa daruma* apparently is known only from three localities off northwestern Australia.

Remarks. The holotype was briefly examined by the first author. We believe that additional study will show that *Dampierosa* should be regarded as a synonym of *Erosa*, even though the species differ substantially in counts of dorsal and anal fin rays. The head shape is nearly identical, sharing the presence of a strong ridge joining the orbits, with a small pit before, and a large occipital pit after this ridge. The eyes and mouth are similarly located in the single species in each genus. In most scorpaenid fishes fin ray counts are fairly stable for a given genus, but in the stonefishes the counts are variable in apparently closely related species, and, as discussed under the subfamily section, there appears to be a trend towards an increase of dorsal spines at the expense of the dorsal soft rays in species of this subfamily. The presence of 2 anal spines in *Dampierosa* and 3 (the usual condition in scorpaenids) in *Erosa* is not regarded as a major difference; in *Dampierosa* the third anal spine has become a segmented ray. Mees (1960, p. 19) gives anal rays as I + 7 or III + 5 for 1 specimen of *Dampierosa*. A clarification of the dorsal and anal fin ray counts in available specimens of *Dampierosa* is needed, and internal features of *Erosa* and *Dampierosa* should be compared.

Genus **Pseudosynanceia** Day

Pseudosynanceia Day, 1875, p. 163 (type-species *Pseudosynanceia melanostigma* Day, by monotypy).

Generic diagnosis. See 'Distinguishing features' under the species account below.

Pseudosynanceia melanostigma Day.

(Figure 11; tables 3–5.)

Pseudosynanceia melanostigma Day, 1875, p. 163, fig. 6 on pl. LV (original description; excellent figure of holotype; type locality Karachi, Pakistan; holotype ZSI 1761).

Leptosynanceia melanostigma, DAY, 1888, p. 788 (placed in genus *Leptosynanceia*); BLEGVAD and LØPPENTHIN, 1944, p. 193 (brief description; coloration; specimens from Iranian Gulf); KHALAF, 1961, p. 125 (description; counts as follows: dorsal XV–XVI + 5–6, anal III + 7, pectoral 14–15, ventral I + 2; wrongly states no lateral line; from Fao, Iraq).

MATERIAL EXAMINED.

PERSIAN GULF

USNM 196472 (1, 51.6), ESE. of Abu Ali, C. E. Dawson, sta. 13, 13 October 1956.

WEST PAKISTAN

USNM 199671 (1, 90), near Karachi, received from El Husseini, 24 January 1966. ZSI 1761 (1, 127, holotype of *Pseudosynanceia melanostigma*), Karachi. AMS B8183 (1, about 115), Karachi, purchased from Day in 1885 [This specimen listed as type in AMS records but it is not]. SU 62409 (1, 75.7), vicinity of Karachi, M.A. El Husseini, 1963.

INDIA

CAS 14801 (1, 77.8), western India, north side of Okha Point, tide pool, International Indian Ocean Expedition, *Anton Bruun* Cruise No. 1, 9 March 1963. USNM 209423 (1, 53.9), western India, 22°54′N., 68°36′E., in 15.5 meters, International Indian Ocean Expedition, *Anton Bruun* Cruise No. 4B, sta. 223A, 19 November 1963.

DISTINGUISHING FEATURES. Dorsal XV–XVII + 4–6, usually XVI + 4; anal III + 7–8; pectoral 14–15; pelvic I + 3; all soft rays including pectoral rays unbranched; head depressed; eyes on dorsal surface, pointing mostly upwards; mouth superior; no deep pits on head; body without prominent warts.

DESCRIPTION. Dorsal fin with 15–17 spines, all spines slender but with prominent venom glands, all about same length. Dorsal soft rays 4–6, last single. Anal fin with 3 spines of nearly same length. Anal soft rays 7–8, last single. Pectoral fin long, reaching to over anal fin spines, with 14–16 (usually 15) unbranched rays. Pelvic fin small, with 1 spine and 3 unbranched soft rays. Gill rakers rudimentary, total 7–10, with 1–3 on upper arch and 6–7 on lower arch. Lateral line not visible to unaided eye (with magnification a subsurface canal usually can be seen at the normal location of the lateral line or slightly above; small raised papillae with pores are also scattered on the body, some forming a row below the dorsal fin, another group usually can be seen above the anal fin, parallel to the lateral line).

Body shape and coloration as in figure 11. Head depressed, with mouth superior; eyes small, on dorsal surface, pointing mostly upwards, at least 4 eye diameters apart. Head with scattered low ridges, no deep pits on head. Head spines poorly developed. Preorbital bone with 2 lumps over maxillary. Four

FIGURE 11. *Pseudosynanceia melanostigma*, adult, SU 62409, 76 mm. S.L., West Pakistan. (Specimen tilted on left side.)

preopercular spines present. Other spines developed as ridges or absent. Small teeth on jaws and vomer, none on palatines. Vertebrae 26 (2 specimens) or 27 (1).

Coloration in preservative (fig. 11) brown or gray to black on a pallid background, lighter ventrally. Body darkest on caudal peduncle, then abruptly white at base of caudal fin. A broad subterminal brown or black bar on caudal fin, otherwise this fin pallid. A clear area on anterior part of soft dorsal fin extending onto body. Soft dorsal fin dark distally. Spinous dorsal fin with dusky pigment concentrated near distal part of spines. Pectoral fin mostly pallid with a broad dark bar distally, fin rays tipped with white. Pectoral axil mostly pallid, with a few dark specks or reticulations usually present. Anal fin mostly dusky, darkest posteriorly. Pelvic fin rays pallid below, dark distally, with tips of rays pallid. In life, pallid areas are yellow, according to Blevad and Løppenthin (1944) and Khalaf (1961).

Comparisons. See the 'Comparisons' section for *Leptosynanceia asteroblepa.*

Distribution. This species is restricted in distribution; it is known only from the Persian Gulf to western India. It is a marine and estuarine species living on mud bottom.

Genus **Trachicephalus** Swainson

Trachicephalus Swainson, 1839, pp. 181, 268 (type-species *Synanceia elongatus* by original designation).

Trichophasia Swainson, 1839, p. 61 (type-species *Synanceia elongatus* implied from text [see 'Nomenclatural remarks'].

Polycaulus Günther, 1860, p. 175 (proposed as a replacement name for *Trachicephalus* Swainson); Bleeker, 1874, p. 19 (description; nomenclature).

Uranoblepus Gill, 1861, footnote on p. 5 (proposed as a replacement name for *Trachicephalus* Swainson).

Nomenclatural remarks. As discussed by Gill (1905, p. 224) the replacement names *Polycaulus* and *Uranoblepus* were proposed because of the similarity of *Trachicephalus* and the earlier *Trachycephalus* (e.g., the reptile genus *Trachycephalus* Tschudi, 1838). Under the *Rules of Zoological Nomenclature* the two are etymologically different and *Trachicephalus* is not preoccupied.

Both *Trichophasia* and *Trachicephalus* were proposed by Swainson (1839) for the same category as evidenced from the text (p. 61, pp. 180–181, and p. 268) (see also our 'Nomenclatural remarks' under the genus *Synanceia*). Gill (1905, p. 224) appears to be the first to mention both names, and he selected *Trachicephalus* over *Trichophasia.*

Diagnosis. See 'Distinguishing features' in the species account below.

Trachicephalus uranoscopus (Bloch & Schneider).

(Figure 12; tables 3–5.)

Synanceja uranoscopa Bloch and Schneider, 1801, p. 195 (original description; type locality

Tranquebar, India; spelling of genus on p. 194 corrected to *Synanceia* on p. 573); CUVIER *in* Cuvier and Valenciennes, 1829, pp. 458–459 (brief description; remarks).

Uranoscopus indicus KUHL and VAN HASSELT *in* Cuvier and Valenciennes, 1829, p. 456 (nomen nudum); BLEEKER, 1849, p. 10 (as synonym of *Synanceia elongata*).

Synancya elongata CUVIER *in* Cuvier and Valenciennes, 1829, pp. 456–458 (original description; type locality Pondichery, India, and Java); BLEEKER, 1849, pp. 4, 10 (synonymy; brief description; range); 1861b, p. 72 (listed; Penang).

Synanceia elongata, CUVIER, 1837, p. viii, fig. 3 on Ichthyology pl. 27 (color plate).

Trachicephalus elongatus, SWAINSON, 1839, p. 268 (as type of *Trachicephalus*).

Synanceia breviceps RICHARDSON, 1845, pp. 71–72 (original description; type locality China); WHITEHEAD, 1969, pp. 205, 207 (types lost).

Aploactis breviceps, RICHARDSON, 1846, p. 212 (placed in *Aploactis*; location of specimens).

Synancia elongata, CANTOR, 1850, p. 1029 (synonymy; description; range).

Uranoscopus adhæsipinnis BLYTH, 1860, p. 142 (original description; type locality India, from Calcutta fish market [some counts of fin rays low, probably inaccurate]).

Polycaulus elongatus, GÜNTHER, 1860, p. 174 (synonymy; description; osteology; collection data); KNER, 1865, p. 120 (synonymy; description; range); BLEEKER, 1874, pp. 20–21, fig. 1 on pl. 2 (description; synonymy; range); 1879, fig. 2 on pl. CCCCXV (figure from Bleeker, 1874); SEALE, 1910, p. 286 (specimens from Borneo).

Polycaulis uranoscopus, DAY, 1875, p. 164, fig. 6 on pl. XXXIX (synonymy; description; range; good figure); HERRE and MYERS, 1937, p. 34 (2 specimens [SU 30872] from Singapore).

Trachicephalus uranoscopus, RUTTER, 1897, p. 81 (good description; specimens from China [SU 1758]); FOWLER, 1929, p. 613 (listed; 4 specimens from Hong Kong); 1931, p. 305 (specimens from Hong Kong; coloration; status of *Trachicephalus*).

Polycaulus uranoscopus, FOWLER, 1935, p. 153 (one specimen from Bangkok, Thailand; "agrees with Bleeker's figure of *Polycaulus elongatus*"); DE BEAUFORT *in* Weber and de Beaufort, 1962, pp. 102–103, fig. 29 (synonymy; description; distribution).

Trachycephalus uranoscopus, FOWLER, 1938a, p. 36 (two specimens from Tai Po, China, and two from Hong Kong).

MATERIAL EXAMINED.

CHINA

SU 1758 (6, 44.8–56.5), Swatow, A. M. Fielde. SU 25743 (2, 70.7–80.0), Canton, A. W. Herre.

HONG KONG

SU 9853 (2, 47.0–63.1), P. L. Jouy. SU 39608 (2, 63.5–67.2), Aberdeen Fish Market, A. W. Herre, 1 June 1937. Plus USNM 143296 (1).

SINGAPORE

SU 30872 (2, 19.6–53.8), A. W. Herre, 3 March 1934. SU 34090 (7, 37.0–62.3), A. W. Herre, 8 May 1937. SU 39472 (1, 59.0), Siglap, A. W. Herre, 18 October 1940. Plus USNM 142947 (1).

THAILAND

USNM 119657 (1, 40.5), Laem Sing, at mouth of Chanthaburi River, H. M. Smith, 17 July 1928.

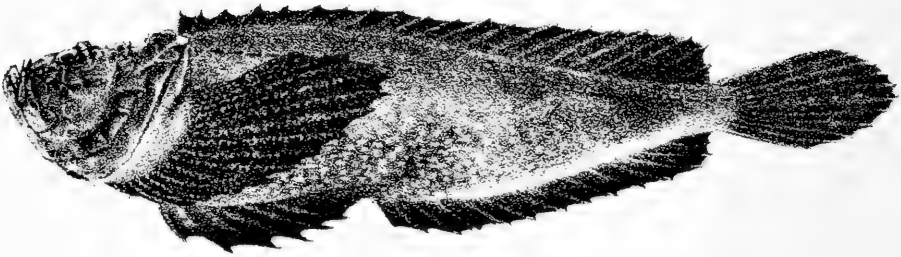

FIGURE 12. *Trachycephalus uranoscopus*, adult, India; figure from Day, 1875, fig. 6 on pl. 39.

INDIA

SU 14671 (2, 36.0–45.0), Marmagao Bay, S. Kemp. SU 14672 (2, 68.8–72.2), Madras, Ennur Fisheries Station, A. W. Herre, 6 January 1941; MNHN A905 (3, 52.3–54.0, syntypes of *S. elongata*), Coramandel Coast, collected by Leschenault.

DISTINGUISHING FEATURES. Dorsal XI–XIII + 12–14, usually XII + 12; anal II + 12–14, usually II + 13; pectoral 14–15; pelvic I + 5; all soft rays including pectoral rays unbranched; head depressed; eyes on dorsal surface of head, pointing mostly upwards; mouth superior; no deep pits on head; body without prominent warts.

DESCRIPTION. Dorsal fin with 12 (11–13) spines, all spines about same length, flexible, difficult to distinguish from soft rays. Dorsal soft rays 12–14, usually 12, with last single. Pectoral fin moderate, reaching to level of anal spines, with 14–15 unbranched rays. Anal fin with 2 spines and 12–14, usually 13, soft rays, last soft ray single. Pelvic fin base very long, reaching to level of vent, with 1 spine and 5 unbranched soft rays. Gill rakers rudimentary, total 7–8, 2–3 on upper arch, 5 on lower arch. Lateral line difficult to observe without microscope, runs high up on flanks; total tubes about 12–14, anterior ones more prominent and with small bilobed flaps; additional papillae (with pores?) scattered on body, a row present on body above anal fin and another above lateral line.

Body shape and coloration as in figure 12. Head depressed, with superior mouth; eyes small and on dorsal surface of head, pointing upwards and outwards, about 3 eye diameters apart. Head with scattered low ridges; two ridges run medially from eye, shallow occipital pit bordered by ridges, pit present between eyes but occupied by ascending arms of premaxillaries; another ridge passes under eye; no deep pits on head. Head spines poorly developed. Preorbital bone with 2 or 3 short spines over maxillary. Preopercular bone with 4 blunt spines. Other spines developed as lumps, ridges, or absent. Small teeth on jaws and vomer, none on palatines. Vertebrae 28–30, mostly 29.

Body mostly tan or brown in preservative (figure 12). Lateral line pores and other pores on body sometimes surrounded by white. Distal portions of soft dorsal, anal, caudal, and pectoral fins darker brown except caudal fin tipped with white and with pale area on dorsal and on ventral margin of caudal at about middle of fin (better marked in small specimens).

COMPARISONS. See the 'Comparisons' section under *Leptosynanceia asteroblepa.*

DISTRIBUTION. *Trachicephalus uranoscopus* occurs from western India to China and south in the Malay Archipelago to Borneo. This species is associated with mud bottom areas and some captures have been in estuaries.

Genus **Leptosynanceia** Bleeker

Leptosynanceia BLEEKER, 1874, p. 17 (type-species *Synanceia asteroblepa* Richardson by monotypy).

DIAGNOSIS. See 'Distinguishing features' under the species account below.

Leptosynanceia asteroblepa (Richardson).

(Figure 13; tables 3–5.)

Synanceia asteroblepa RICHARDSON, 1845, pp. 69–71, figs. 1–3 on pl. 39 (original description; type locality New Guinea; compared with species of *Synanceia*); BLEEKER, 1849, p. 4 (listed; New Guinea); 1852a, p. 242 (listed; New Guinea); 1852b, pp. 419–420 (description; rivers and estuaries of Borneo); GÜNTHER, 1860, p. 147 (compiled); 1868, p. 265 (listed; Sarawak); VINCIGUERRA, 1926, p. 539 (synonymy; listed; muddy rivers of Sarawak; range).

Leptosynanceia asteroblepa, BLEEKER, 1874, pp. 17–18, fig. 2 on pl. 4 (as type of a new genus; description; specimens from Borneo; good figure); 1878, p. 49 (listed; New Guinea); 1879, fig. 6 on pl. CCCCXVI (figure from Bleeker, 1874); FOWLER, 1928, p. 298, fig. 51 (brief synonymy and description; *L. greenmani* as a synonym); HERRE and MYERS, 1937, p. 34 (description; specimen from Sumatra, 100 miles west of Singapore [SU 30870]); MUNRO, 1967, p. 539 (in key; New Guinea).

Leptosynanceia greenmani FOWLER, 1905, pp. 507–510, fig. 12 (original description; type locality Borneo; compared with *Leptosynanceia asteroblepa*; [holotype ANSP 114884, 2 paratypes ANSP 114885-6]).

MATERIAL EXAMINED.

BORNEO

ANSP 114884 (1 specimen, 117 mm. S.L., holotype of *L. greenmani*), Baram, Borneo, A. C. Harrison, Jr., and H. M. Hiller, 1897; ANSP 114885 (1, 103, paratype of *L. greenmani*), and ANSP 114886 (1, 87.2, paratype of *L. greenmani*), Baram, Borneo, W. H. Furness, 1898.

SUMATRA

SU 30870 (1, 49.7), 100 mi. west of Singapore, A. W. Herre, 27 March 1934.

DISTINGUISHING FEATURES. Dorsal XVI + 5; anal III–IV + 5–6; pectoral 13–15, usually 14; pelvic I + 4; all soft rays including pectoral rays unbranched;

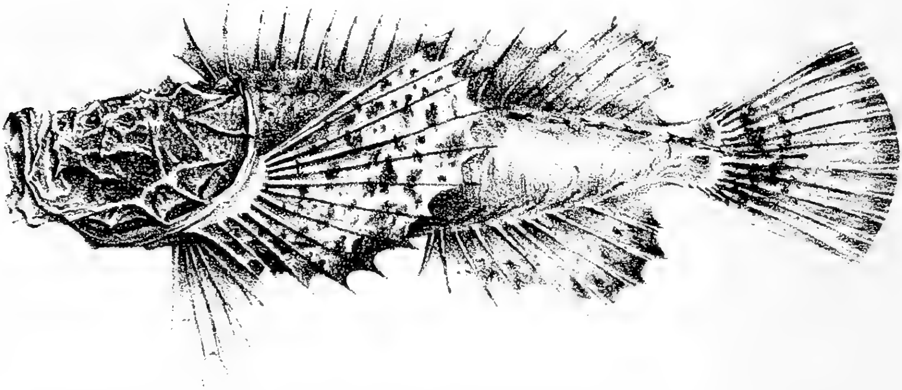

FIGURE 13. *Leptosynanceia asteroblepa*, adult, New Guinea; figure from Richardson, 1844, fig. 1 on pl. 39.

head depressed; eyes on dorsal surface, directed mostly upwards; mouth superior; no deep pits on head; body without prominent warts.

DESCRIPTION. Dorsal fin with 16 spines, all spines about same length, firm but of small diameter, with small venom glands at about midheight of spines. Dorsal soft rays 5, unbranched, last single. Anal fin with 3–4 spines and 5–6 unbranched soft rays, last single. Pectoral fin reaching to over anal spines, upper rays the longest, with 13–15 rays, all unbranched. Pelvic fin short, with 1 spine and 4 unbranched soft rays. Gill rakers rudimentary, 3 on upper arch, 8 or 9 on lower arch (in one specimen). Lateral line runs high up on back, with 11 tubes, last on caudal fin; additional papillae (with pores?) visible on body with microscope, a row of them present above anal fin.

Body shape and coloration as in figure 13. Head depressed, with mouth superior; eyes small and on dorsal surface of head, eyes pointing mostly upwards, about 3 eye diameters apart. Head with scattered low ridges; shallow pits present but none prominent. Most head spines poorly developed. Preorbital bone with 2 lumps over maxillary. Preopercular bone with 5 well marked spines. Opercular spines well defined. Other spines developed as lumps or ridges or absent. Small teeth on jaws, none on vomer and palatines. Vertebrae 28 (1 specimen).

Specimens available to us mostly faded. Fowler (1905) reports body pale brown, scarcely paler below, head finely mottled or marbled with darker brown, and back and sides with numerous large deep brownish blotches. Fins also similarly marked. Soft dorsal, anal, and caudal darker distally but with a white margin. Bleeker (1874) illustrates a brownish-yellow fish, mottled with large dark areas, fins dark distally, tinge of pink on fins.

COMPARISONS. The genera *Pseudosynanceia*, *Trachicephalus*, and *Leptosynanceia* each contain a single species. These species are more elongate (and resemble uranoscopid fishes in outward appearance) than the other more globular species treated in this paper. The pelvic rays are I + 3 in *Pseudosynanceia*, I + 4 in *Leptosynanceia*, and I + 5 in *Trachicephalus*. *Pseudosynanceia* resembles *Leptosynanceia*, and differs from *Trachicephalus*, in having a high dorsal spine count (usually XVI + 4 in *Pseudosynanceia*, XVI + 5 in *Leptosynanceia*, and XII + 12 in *Trachicephalus*). Significant differences in anal counts are also found (III + 7–8 in *Pseudosynanceia*, II + 12–14 in *Trachicephalus*, and usually IV + 5 in *Leptosynanceia*). These external differences are extensive and serve to distinguish the species from each other. A more detailed study is needed, but it would appear that these differences warrant separate genera for these species.

DISTRIBUTION. We know this species only from Singapore, Sumatra, Borneo, and New Guinea. It is reported to inhabit estuaries and rivers.

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GOGOLIA FILEWOODI, A NEW GENUS AND SPECIES OF SHARK FROM NEW GUINEA (CARCHARHINIFORMES: TRIAKIDAE), WITH A REDEFINITION OF THE FAMILY TRIAKIDAE AND A KEY TO TRIAKID GENERA

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INTRODUCTION

On the night of July 18–19, 1970, Mr. Komet Kisokau handlined a peculiar small shark in Astrolabe Bay, off the Gogol River near Madang, New Guinea. Mr. Kisokau and Mr. R. T. Gibson (Fisheries Officer, Madang, and a former shark fisherman) recognized the unusual nature of the specimen and sent it to Mr. L. W. Filewood (Biologist-In-Charge of the Department of Agriculture, Stock and Fisheries, Konedobu, Papau-New Guinea), who is currently studying the elasmobranchs of the New Guinean region. Mr. Filewood discovered that the specimen represented a new genus and species of triakid and intended to describe it in collaboration with the present writer. Unfortunately Mr. Filewood was unable to participate in this task and generously relinquished both it and the specimen to me.

Gogolia Compagno, new genus

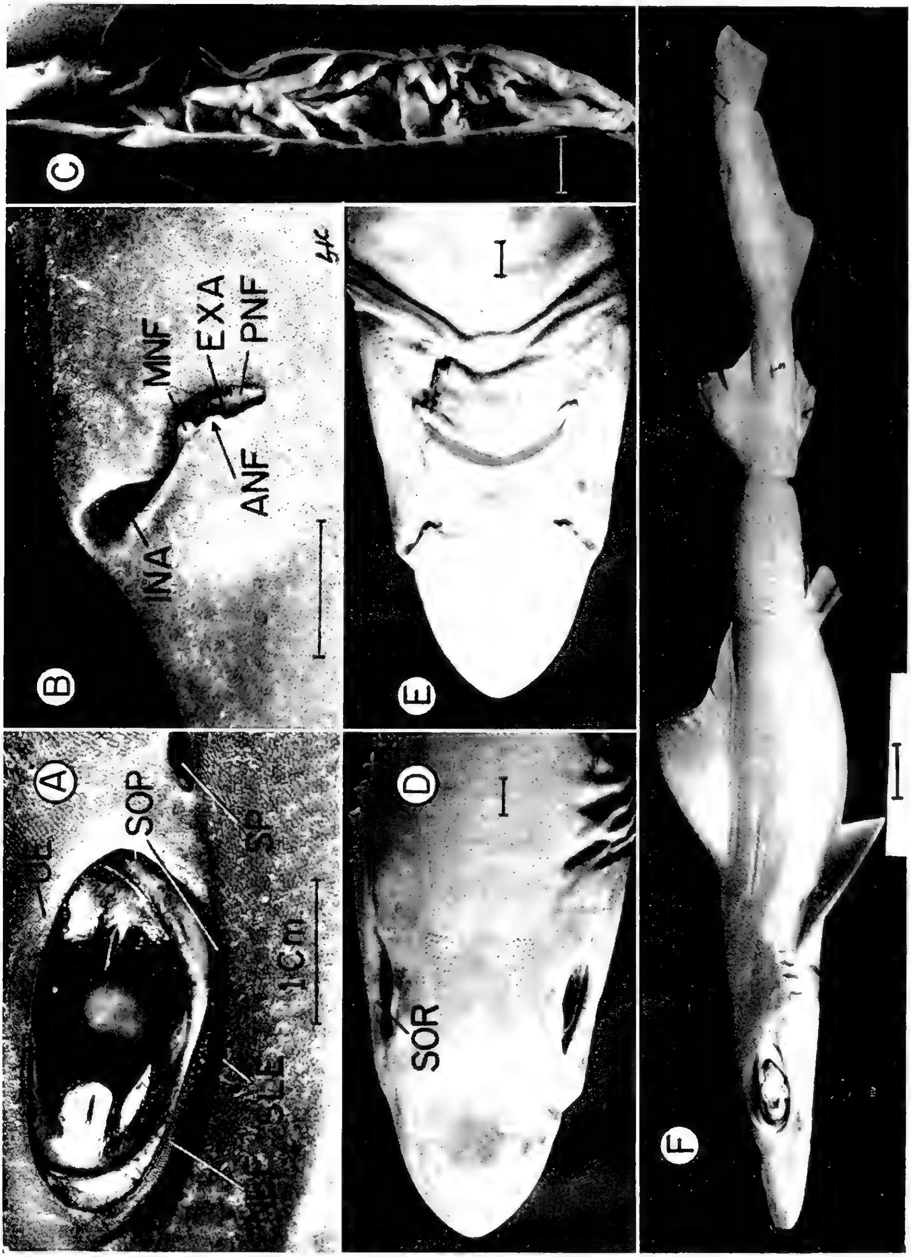
TYPE SPECIES. *Gogolia filewoodi* Compagno, new species.

DERIVATION OF NAME. *Gogolia* (considered feminine), from the Gogol River of Northern New Guinea.

FIGURE 1. *Gogolia filewoodi* Compagno, new genus and species. Lateral view of holotype, 739 mm. adult female, Australian Museum no. I. 16858–001.

GENERIC DEFINITION. (Terminology follows Compagno, 1970; Compagno and Springer, 1971; and Compagno, 1973a.). Triakid sharks with a moderately long head, length from snout tip to level of 5th gill openings about 1.4–1.5 times the distance between the dorsal fin bases and about 22–24 percent of total length. Head and snout acutely wedge-shaped and blunt-tipped in lateral view (figs. 1, 2F). Outline of snout bell-shaped in dorsoventral view (fig. 2D–E) and parabolic in front of nostrils. Snout very long, preoral length (distance from snout tip to upper symphysis) about 1.6–1.7 times mouth width and 2.1–2.2 in head length. Subocular ridges very strong and prominently visible in dorsal view of head (fig. 2D: SOR) and blocking off view of eyes ventrally (fig. 2E). Eyes very large, elliptical, and about twice as long as high. Nictitating lower eyelid external and having a diagonal edge (fig. 2A: NLE). Subocular pouch shallow and entirely covered with denticles. Gill openings very small, width of 3rd about 2.2–5.2 in eye length. Anterior nasal flaps very low and virtually vestigial (fig. 2B: ANF), not barbel-like or greatly expanded. Posterior ends of anterior nasal flaps well forward of mouth (fig. 2E). No nasoral grooves. Nasal cavities communicating to the exterior only by narrow incurrent and excurrent apertures (fig. 2B: INA and EXA), not exposed ventrally. Internarial width about 2.0 times nostril widths. Nostrils about 2.5 times farther from the snout tip than from the mouth. Mouth arcuate in shape (fig. 2E). Mouth very short, its length from level of upper symphysis to level of mouth corners 2.5–3.0 in width of mouth between corners. Lower jaw very flat, with its sides hardly protruding or not showing below ventral surface of head in lateral view (figs. 1, 2F). Upper labial furrows extending anteriorly to level of upper symphysis.

Tooth-row counts 40–41/35 (2). 2–3/2–4 series of teeth functional. Premedial edges of most teeth convex and undifferentiated, but in adult the medials and some upper anteroposteriors have premedial cusplets or strong serrations (figs. 3C–D, 4A). Primary cusps very strong on all teeth except for the last lower posteriors (fig. 4B: teeth nos. 14–15). Postlateral edges of crowns strongly notched in all cusped teeth, these differentiated basally into postlateral cusplets or blades. Roots of teeth relatively low (fig. 3C–H: RT). Teeth strongly compressed, sharp-edged, and blade-like, but not molariform. Teeth not enlarged at symphysis to form a knob and not extending onto edges and ventral surface of lower jaw. Tooth-row groups poorly differentiated and including medials (fig. 4: M) and anteroposteriors (fig. 4A, teeth nos. 1–20; and fig. 4B, teeth nos. 1–15) in both jaws. Medials have erect or semioblique cusps and relatively higher and narrower crowns than the lower, broader, oblique-cusped anteroposteriors. Dignathic heterodonty strong in anteroposteriors near symphysis, but much weaker near the ends of the dental bands. In an adult these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parasymphysial anteroposteriors have premedial cusplets or serrations, narrow cusps, prominent transverse ridges or striations, and more postlateral cusplets in the upper jaw, while lower teeth have no premedial cusplets and very few postlateral ones, broader cusps, and no ridges (compare fig. 3C–E with F–H).

Interdorsal ridge present in adult and absent in fetus. Caudal peduncle short, its length from second dorsal insertion to upper caudal origin about ⅘ of second dorsal base. Lateral trunk denticles from dorsum below first dorsal fin with teardrop-shaped crowns that are considerably longer than wide and have rudimentary lateral cusps or none (fig. 3A–B).

Longest distal radials of pectoral fin skeleton about 1.6 times as long as longest proximal radials (fig. 5A–B: DRA and PRA). Anterior margins of pelvic fins about ⅗ as long as pectoral anterior margins.

First dorsal origin far anterior, varying from over pectoral insertions to about over pectoral midbases. Free rear tip of first dorsal slightly posterior to pelvic origins. First dorsal base extremely long (figs. 1, 2F), its length almost equal to length of dorsal caudal margin, 2.3–3.2 times the first dorsal height, and 1.3–1.4 times the distance between dorsal bases. Second dorsal much smaller than first, its height about ⅔ of first dorsal height and its base length less than half of first dorsal base. Anal fin smaller than second dorsal, its height 0.5–0.6 of second dorsal height and its base 0.5–0.7 of second dorsal base. Anal insertion slightly anterior to second dorsal insertion by a distance about 0.1–0.2 of second dorsal base.

Caudal fin with a short but strong ventral caudal lobe in adult but a weak one in a fetus (figs. 1, 2F). Postventral caudal margin shallowly indented but not deeply notched. Length of terminal caudal sector from subterminal notch to tip of caudal about 3.1–3.8 in length of dorsal caudal margin.

Cranium with a long rostrum, with the length of the medial rostral cartilage from its base to the anterior edge of the rostral node about 1.4–1.9 in nasobasal length (distance from the base of the medial rostral cartilage to the posteroventral edge of the occipital centrum, here used as an independent variable for cranial proportions). Bases of lateral rostral cartilages connected by a ridge (fig. 6A, C: RRF) to the edge of the anterior fontanelle. Nasal capsules trans-

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Figure 2. *Gogolia filewoodi.* A–E, photographs from 739 mm. holotype. A, left eye in lateral view. B, left nostril in ventral view. C, valvular intestine cut longitudinally to show spiral valve. D, head, dorsal view. E, head, ventral view. F, photograph in lateral view of 224 mm. fetus, CAS–27588. All scale lines equal 1 centimeter. Abbreviations: ANF, anterior nasal flap; EXA, excurrent aperture; INA, incurrent aperture; MNF, mesonarial flap; NLE, nictitating lower eyelid; PNF, posterior nasal flap; SLE, secondary lower eyelid; SOP, subocular pouch; SOR, subocular ridge; SP, spiracle; UE, upper eyelid.

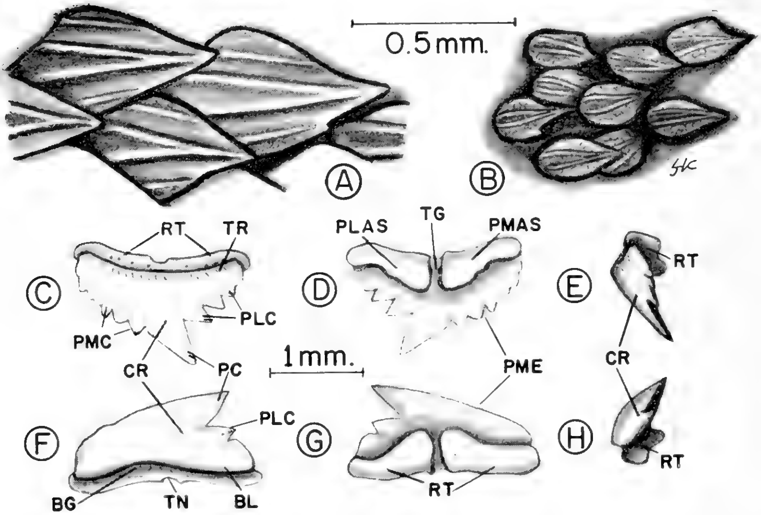

FIGURE 3. *Gogolia filewoodi.* A, crowns of lateral trunk denticles from dorsum below first dorsal fin, 739 mm. holotype. B, same from 224 mm. fetus. C–E, teeth from 739 mm. holotype. Labial (C), lingual (D), and lateral (E) views of tooth from 4th upper anteroposterior row (numbered from symphysis). Labial (F), lingual (G), and lateral (H) views of tooth from 4th lower anteroposterior row. Abbreviations: BG, basal groove; BL, basal ledge; CR, crown; PC, primary cusp; PLAS, postlateral attachment surface of root; PLC, postlateral cusplets; PMAS, premedial attachment surface of root; PMC, premedial cusplets; PME, premedial edge; RT, root; TG, transverse groove; TN, transverse notch; TR, transverse ridges.

versely elongated and anteriorly flattened, not circular (fig. 6: NC). Nasal fontanelles delimited anteriorly from nasal apertures (fig. 6B: NA and NF). Nasal openings of orbitonasal canals inside nasal capsules and well behind posterior edges of nasal fontanelles. Thickened ridges or ectethmoid condyles (fig. 6B–C: ECN) present on nasal capsules and articulating with the orbital processes of the palatoquadrates (fig. 7B–C). A depression or subethmoid fossa (fig. 6B: SEF) present on the ventral surface of the cranium between the ectethmoid condyles. Basal plate very narrow across orbital notches (fig. 6B: NP), its transverse width there about 3.0 in nasobasal length. Two pairs of arterial foramina present on basal plate, one for the internal carotid arteries and one for the stapedial or orbital arteries (fig. 6B: FC and FS). Least width across supraorbital crests (transverse to the long axis of the cranium) about 2.4 in nasobasal length. Postorbital processes short and shallowly notched distally (fig. 6: PT). Suborbital shelves narrow and not laterally expanded, ear-shaped, fenestrate, or notched. Greatest width across suborbital shelves (perpendicular to the long axis of cranium) about 1.7 in nasobasal length.

Total vertebral counts 180 (2). No stutter zone of alternating long and short centra in vertebral column. Thoracic vertebral centra with strong diagonal calcified lamellae (fig. 5D–E: DCL).

Other characteristics of *Gogolia* those of the family Triakidae and of the single species (see below).

FAMILIAL CLASSIFICATION OF *GOGOLIA*

Gogolia is a genus that, with *Hemitriakis* and *Iago*, stands midway between the families Carcharhinidae and Triakidae (or their equivalents) as defined by Garman (1913), White (1936, 1937), Bigelow and Schroeder (1948), and Garrick and Schultz (1963). According to these workers, triakids have several functional series of small, molariform or blade-like and multicuspidate teeth and 'nictitating folds,' whereas carcharhinids have not more than 1 or 2 series of small to large, blade-like teeth and 'nictitating membranes.' The failure of these characters to distinguish the two families is discussed elsewhere (Compagno, 1970). *Gogolia* itself has a 'nictitating fold' but has small, blade-like teeth in 2–4 functional series.

Previously I resolved the problem of triakid-carcharhinid intergradation by the unsatisfactory expedient of merging the two families (Compagno, 1970). Subsequent work on a revision of carcharhinoid genera indicated that a group of genera partially corresponding to the family Triakidae of White (1937) could be separated from the Carcharhinidae.

Part of the difficulty in separating the families Carcharhinidae and Triakidae of White (1937) and Bigelow and Schroeder (1948) was that each of the two families contained genera closer to the type genus of the other family than to its own type genus. Thus *Triaenodon* has many external, cranial, pectoral fin skeleton, and cephalic myological characters that ally it closely with typical carcharhinids such as *Carcharhinus*, but the strong cusplets on its teeth led many workers to place *Triaenodon* incorrectly in the Triakidae. *Galeorhinus* has often been placed in the Carcharhinidae but it similarly has many characters that indicate close affinities with the Triakidae. Also, *Galeorhinus* is linked with the genera *Triakis* and *Mustelus* by a group of roughly intermediate forms (*Gogolia*, *Hypogaleus*, *Iago*, *Furgaleus*, and *Hemitriakis*).

The reinstated family Triakidae includes the genera *Mustelus* Linck, 1790; *Galeorhinus* Blainville, 1816; *Triakis* Müller and Henle, 1838a; *Scylliogaleus* Boulenger, 1902; *Hemitriakis* Herre, 1923; *Furgaleus* Whitley, 1951; *Hypogaleus* J. L. B. Smith, 1957a; *Iago* Compagno and Springer, 1971; *Allomycter* Guitart, 1972; and *Gogolia*. *Triaenodon* Müller and Henle, 1837 is transferred to the Carcharhinidae (see also Gohar and Mazhar, 1964, and Kato, Springer, and Wagner, 1967, for discussion of the familial position of *Triaenodon*). The "scyliorhiniform triakoids" (Compagno, 1970) have often been placed in the family Triakidae or its equivalents and included in the genus *Triakis*. However, these genera, including *Proscyllium* Hilgendorf, 1904, *Eridacnis* H. M. Smith, 1913, *Ctenacis* Compagno, 1973a, and *Gollum* Compagno, 1973a, are sufficiently distinct from triakids to require a separate family, Proscylliidae (elevation of subfamily Proscylliinae Fowler, 1941). *Leptocharias* A. Smith, *in* Müller and Henle, 1838a is difficult to place but probably is best placed in its own family, Leptochariidae (elevation of tribe Leptochariana Gray, 1851) owing to its morphological distinctness from other carcharhinoids. *Leptocharias* has often been grouped with the triakids in proximity to *Triaenodon*, but these two genera are not closely related.

The Triakidae can be defined as follows:

Family TRIAKIDAE Gray, 1851, new rank

Subfamily Musteli BONAPARTE, 1838, p. 199 (Family Squalidae. Type genus: *Mustelus* Cuvier, 1817, equals *Mustelus* Linck, 1790.). Preoccupied in Mammalia by families Mustelini Fischer, 1817 and Mustelidae Swainson, 1835 (Type genus: *Mustela* Linnaeus, 1758); references for mammalian families in Simpson (1945).

Family Galei MÜLLER and HENLE, 1839, p. 57 (Type genus: *Galeus* Cuvier, 1817, a junior synonym of *Galeorhinus* Blainville, 1816; not *Galeus* Rafinesque, 1809.).

Family Scylliodontes MÜLLER and HENLE, 1839, p. 63 (Not based on a type genus.).

Tribe Triakiana GRAY, 1851, p. 39 (Family Squalidae. Type genus: *Triakis* Müller and Henle, 1838a.). The family Triakidae was independently proposed by White (1936a, 1936b, 1937).

Family Galeorhinoidae GILL, 1862b, p. 393 (Type genus: *Galeorhinus* Blainville, 1816.).

Family Scylliogaleidae WHITLEY, 1940, p. 68 (Type genus: *Scylliogaleus* Boulenger, 1902.). The family Scylliogaleidae was independently proposed by Smith (1957b).

Family Emissolidae WHITLEY, 1940, p. 68 (Type genus: *Emissola* Jarocki, 1822, probably a junior synonym of *Mustelus* Linck, 1790.).

Family Eugaleidae GURR, 1962, p. 428 (Type genus: *Eugaleus* "Rafinesque, 1810", equals Gill, 1864, *not* Rafinesque, 1809–1810; a junior synonym of *Galeorhinus* Blainville, 1816.).

Carcharhinoid sharks with the head not expanded laterally into a wing-like blade. Eyes high on sides of head, with their ventral edges above the nostrils. Eye length 1.5–2.5 or more times eye height. Nictitating lower eyelid variably external, transitional, or internal (Compagno, 1970). Small to moderately large spiracles present, with their greatest widths about 3–10 in eye length. Labial furrows long and present on both jaws. Labial cartilages well developed.

Tooth-row groups poorly differentiated or absent, with medials often present but no symphysials, anteriors, or well defined posteriors. Posterior teeth not comb-like. Gynandric heterodonty absent or poorly developed as far as is known (data not available for *Scylliogaleus*, *Gogolia*, and *Allomycter*). Tooth-row counts 18–94/27–94. Teeth with strong basal ledges and grooves.

Precaudal pits absent. Pectoral fin skeleton with its radials projecting half of pectoral anterior margin length or less into fin (fig. 5A). Distal pectoral radials with parallel edges and truncate or distally rounded tips. Longest distal radials 1–2 times as long as longest proximal radials.

First dorsal fin with distinct apex and separate anterior and posterior margins, not arcuate-edged and keel-like. First dorsal base anterior to pelvic bases. Length of first dorsal base usually much shorter than dorsal caudal margin, but subequal to it in *Gogolia*. No undulations in dorsal caudal margin.

Neurocranium with bases of lateral rostral cartilages well separated. Nasal capsules not greatly depressed or transversely expanded (fig. 6). Large nasal fontanelles present and broadly continuous anteriorly with the nasal apertures (fig. 6B: NA and NF). Nasal openings of orbitonasal canals inside the nasal cavities, located at the posterior edges of the nasal fontanelles or behind them. Ectethmoid condyles, when present, without foramina for the anterior facial veins (ectethmoid foramina). Internasal septum a high, compressed plate. Arterial foramina on the basal plate usually include two pairs of stapedial and internal carotid foramina (fig. 6B: FS and FC), but *Furgaleus* has a single pair of common foramina apparently formed by the merging of the stapedials and internal carotids on each side. Parietal fossa single. Supraorbital crest present (fig. 6: SC).

Wedge-like intermedialia strongly developed in vertebral centra of adults and subadults (fig. 5E) but often absent or poorly developed in fetuses or newborn specimens (fig. 5D).

Valvular intestine with a spiral valve of 5–11 turns. Levator palatoquadrati muscles small, with their origins not expanded anterior to the postorbital processes (fig. 7C: MLP).

Triakidae is distinguished from the families Scyliorhinidae, Pseudotriakidae, and Sphyrnidae of Bigelow and Schroeder (1948) by many characters that need not be detailed here. The Proscylliidae as delimited above differ from the Triakidae in having rudimentary nictitating lower eyelids; very short labial furrows (sometimes absent in *Eridacnis*); comb-like posterior teeth; transverse grooves absent from teeth; distal pectoral radials much shorter than the proximal radials; and wedge-like intermedialia absent from the vertebral centra. The Leptochariidae differ from the Triakidae in having teeth without transverse grooves; strongly developed gynandric heterodonty; nasal openings of the orbitonasal canals not in the nasal cavities but posterior to them and penetrating the suborbital shelves; no supraorbital crest; and 14–16 turns in the spiral intestinal valve.

The family Carcharhinidae is restricted to the "advanced carcharhinids" of Compagno (1970) and includes *Carcharhinus* Blainville, 1816; *Scoliodon* Müller and Henle, 1837; *Galeocerdo* Müller and Henle, 1837; *Triaenodon* Müller and Henle, 1837; *Loxodon* Müller and Henle, 1838a; *Hypoprion* Müller and Henle, 1839; *Prionace* Cantor, 1849; *Aprionodon* Gill, 1862a; *Isogomphodon*

Gill, 1862b; *Lamiopsis* Gill, 1862b; *Rhizoprionodon* Whitley, 1929; and *Negaprion* Whitley, 1940. The "intermediate carcharhinids" of Compagno (1970) are sufficiently distinct from the Carcharhinidae to rate a family, Hemigaleidae (family Hemigalei or Hemigaleus of Hasse, 1879), that includes the genera *Hemipristis* Agassiz, 1843; *Hemigaleus* Bleeker, 1852 (including *Negogaleus* Whitley, 1931); *Dirrhizodon* Klunzinger, 1871 (including *Heterogaleus* Gohar and Mazhar, 1964); *Chaenogaleus* Gill, 1862b; and *Paragaleus* Budker, 1935. *Dirrhizodon* is usually synonymized with the fossil *Hemipristis* but is separable by differences in tooth histology (Compagno, 1973b).

The Carcharhinidae and Hemigaleidae differ from the Triakidae in having stronger monognathic heterodonty; precaudal pits present; pectoral fin skeleton extending into the distal parts of the fins; distal pectoral radials with pointed tips and tapering edges; longest distal radials over 3 times the length of the longest proximal radials; lateral undulations present in the dorsal caudal margin (irregular in *Scoliodon* and in some specimens of *Triaenodon*); nasal fontanelles either separated from the nasal apertures by a cartilaginous bridge (hemigaleids, *Galeocerdo* and *Loxodon*) or absent; no supraorbital crest; and levator palatoquadrati muscles greatly expanded anteriorly, with their origins extending in front of the postorbital processes and onto the sides and dorsal surface of the cranial roof (Moss, 1972, and unpublished data). The Hemigaleidae additionally differ from the Triakidae in having two pairs of foramina for the lateral aortae and efferent hyoidian arteries on the basal plate. Carcharhinids differ from triakids also in having weak or no basal ledges on their teeth; ectethmoid foramina present on the ectethmoid condyles; and scroll intestinal valves.

COMPARISON WITH OTHER GENERA

Gogolia is separable from all other triakids by its unusually high ratio of preoral length to mouth width (this is below 1.5 in other genera); very short mouth (approached in this only by *Furgaleus*); very small gill openings; heterodonty pattern in adult (fig. 4); extreme anterior position of its first dorsal origin (*Iago* is similar in this but other genera have the first dorsal origin posterior to the pectoral insertions); very long and low first dorsal fin (other genera have the first dorsal base ⅔ of the dorsal caudal margin or less and the fin height over half of the base length); and high total vertebral counts (*Triakis acutipinna* has 175–176 centra, but other triakids usually have fewer than 160).

Gogolia is distinguished from other triakids in a key to the genera of Triakidae provided below. In this key the genera *Galeorhinus*, *Hypogaleus*, and *Hemitriakis* are restricted to the species listed in Compagno (1970). *Triakis* comprises the species placed in it by Compagno (1973a): *T. scyllium* Müller and Henle, 1839, including *Hemigaleus pingi* Evermann and Shaw, 1927; *T. megaloptera* (A. Smith, 1849), including *Mustelus nigropunctatus* J. L. B.

Smith, 1952; *T. semifasciata* Girard, 1854, including *Mustelus felis* Ayres, 1854; *T. maculata* Kner and Steindachner, 1866, including *Mustelus nigromaculatus* Evermann and Radcliffe, 1917; and *T. acutipinna* Kato, 1968. The poorly known genus *Allomycter* is tentatively placed in the Triakidae and included in the key. *Allomycter* (with a single species, *A. dissutus*) was described from photographs of a unique specimen of shark from Cuba, but this specimen was lost before its describer could examine it (Guitart, 1972).

Family Triakidae. Key to genera

1a. Nostrils with broad nasoral grooves. Anterior nasal flaps very large, meeting each other at midline of snout and overlapping mouth posteriorly. ...... *Scylliogaleus* Boulenger, 1902.

1b. Nostrils without nasoral grooves. Anterior nasal flaps small to absent, when present separated from each other and not reaching mouth ...... 2.

2a. Preoral length 1.6–1.7 times mouth width. First dorsal fin with its base length almost equal to length of dorsal caudal margin and 2.3–3.2 times the first dorsal height ...... *Gogolia* Compagno, new genus.

2b. Preoral length less than 1.5 times mouth width. First dorsal with its base length ⅔ or less of the dorsal caudal margin length and about 1.2–1.7 times the first dorsal height .. 3.

3a. Anterior nasal flaps absent. Nasal cavities widely open to the exterior ...... *Allomycter* Guitart, 1972.

3b. Anterior nasal flaps present. Nasal cavities not widely open to the exterior but communicating with it through restricted incurrent and excurrent apertures ...... 4.

4a. Teeth markedly unlike in upper and lower jaws. Anterior nasal flaps formed into slender barbels ...... *Furgaleus* Whitley, 1951.

4b. Teeth not markedly unlike in upper and lower jaws. Anterior nasal flaps not barbel-like ...... 5.

5a. Origin of first dorsal far forward, over pectoral bases ...... *Iago* Compagno and Springer, 1971.

5b. Origin of first dorsal farther back, over inner margins of pectorals or posterior to them ...... 6.

6a. Second dorsal fin about as large as anal fin, with its height ⅖ or less of first dorsal height and its base about half as long as first dorsal base. Terminal sector of caudal about half as long as dorsal caudal margin ...... *Galeorhinus* Blainville, 1816.

6b. Second dorsal fin noticeably larger than anal fin, its height ½ to virtually equal to first dorsal height and its base ⅔ to about equal to second dorsal base. Terminal sector of caudal about ⅓ as long as dorsal caudal margin ...... 7.

7a. Nostrils narrow and far apart, internarial space about 2.5–3.0 times nostril width. Teeth formed into compressed cutting blades. Medials present at symphysis of both jaws .... 8.

7b. Nostrils wider and closer together, internarial space about 1.0–2.0 times nostril width. Teeth molariform to semibladelike, not greatly compressed. No differentiated medials at symphysis ...... 9.

8a. Eyes fusiform in shape and over 2 times as long as high. Mouth broadly arched. Second dorsal over ⅔ of height of first dorsal. Ventral caudal lobe very short ...... *Hemitriakis* Herre, 1923.

8b. Eyes pear-shaped and less than twice as long as high. Mouth triangular. Second dorsal about half as high as first dorsal. Ventral caudal lobe very long ...... *Hypogaleus* J. L. B. Smith, 1957.

9a. Snout bluntly rounded in dorsoventral view, thick and blunt in lateral view. Mouth arcuate in shape, lower jaw with convex edges. Teeth of lower jaw hardly overlapping or not extending onto its ventral surface, not enlarged at symphysis or forming a knob .... *Triakis* Müller and Henle, 1838.

9b. Snout bluntly parabolic to subtriangular in dorsoventral view, bluntly to narrowly pointed in lateral view. Mouth subtriangular or triangular in shape, lower jaw with straight or nearly straight edges. Teeth of lower jaw prominently overlapping onto its ventral surface, more or less enlarged at symphysis to form a knob resembling those of rays of the genus *Rhynchobatus* .... *Mustelus* Linck, 1790.

Gogolia is closest to *Galeorhinus*, *Hypogaleus*, and *Hemitriakis* within the Triakidae and is intermediate in some characters between *Hemitriakis* and the other genera. Thus *Gogolia* resembles *Hemitriakis* in having strong subocular ridges, external nictitating lower eyelids, shallow subocular pouches, and poorly developed lateral cusps on the trunk denticles, but agrees with *Galeorhinus* and *Hypogaleus* in eye shape, greatly reduced anterior nasal flaps and protruding mesonarial flaps, and size disparity between first and second dorsal fins. The premedial cusplets on the upper parasymphysial teeth of *Gogolia* recall similar cusplets on upper and lower anteroposteriors of the Eocene fossil "*Galeus recticonus*" (as described and illustrated by Leriche, 1905). However, the teeth of "*G. recticonus*" have heavier cusps, larger and more regular premedial cusplets, less compressed crowns and roots, and stronger transverse notches than in those of *Gogolia*. Living *Galeorhinus* species also have a few irregular premedial cusplets on anteroposteriors closest to the symphysis, but these are less prominent than the premedial cusplets of *Gogolia* and "*G. recticonus*."

Gogolia filewoodi Compagno, new species.

HOLOTYPE. A pregnant adult female, 739 mm. total length, with 2 fetuses (1 retained by Mr. L. W. Filewood), Australian Museum (Sydney) no. I. 16858–001. The remaining fetus, a 224 mm. male, is cataloged as CAS–27588.

TYPE LOCALITY. Astrolabe Bay, Northern New Guinea, about 1 mile north of the Gogol River mouth at 40 fathoms depth; about 5° 18′ S. Latitude and 145° 50′ E. Longitude.

SPECIES NAME. Named for Mr. L. W. Filewood in recognition of his work on the poorly known elasmobranch fauna of New Guinea.

MEASUREMENTS AND PROPORTIONS. These are given as percentages of total length for the adult female holotype and the male fetus (table 1).

DESCRIPTION (based on the adult female and fetal male). Head broad, width at spiracles about half head length. Head moderately depressed and trape-

→

FIGURE 4. *Gogolia filewoodi.* Set of detached teeth from left jaw half of 739 mm. holotype in labial view, with anteroposterior teeth numbered sequentially from medial row at symphysis (M) to last row at end of dental band. A, upper teeth. B, lower teeth.

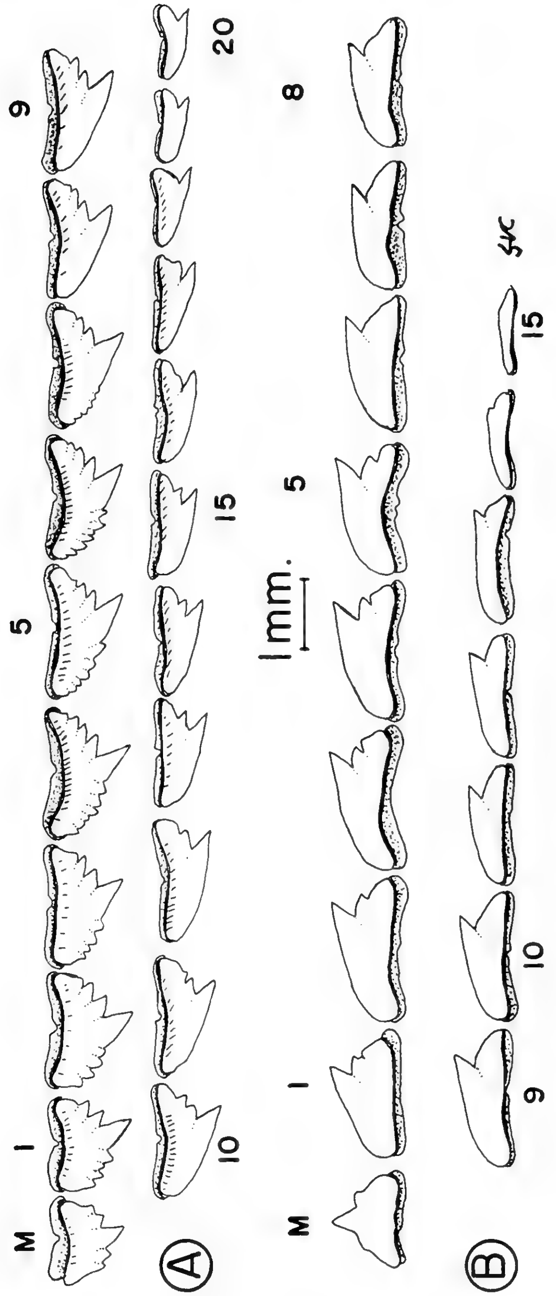
A
M
1
5
9
10
15
20
1 mm.
B
M
1
5
8
9
10
15

TABLE 1. *Measurements of two specimens of* Gogolia filewoodi.

Measurement	Adult female	%	Male fetus	%
Total length:	739 mm.	—	224 mm.	—
Tip of snout to:				
Nostrils.	45	6.1	15	6.7
Upper symphysis.	72	9.8	25	11.2
Eyes.	57	7.7	20	8.9
Spiracles.	94	12.7	33	14.7
1st gill openings.	133	18.0	46	20.6
5th gill openings.	158	21.5	53	23.7
Pectoral origins.	152	20.1	51	22.8
1st dorsal origin.	173	23.4	62	27.7
2nd dorsal origin.	434	57.7	138	61.6
Pelvic origins.	336	45.5	106	47.3
Anal origin.	445	60.2	140	62.5
Upper caudal origin.	560	75.8	172	76.8
Vent.	353	47.8	106	47.4
Distance between:				
Vent and caudal tip.	386	52.2	118	52.6
1st and 2nd dorsal bases.	119	16.1	35	15.6
Pectoral and pelvic bases.	162	21.9	44	19.7
Pelvic and anal bases.	81	11.0	28	12.5
2nd dorsal base and upper caudal origin.	58	7.9	14	6.3
Anal base and lower caudal origin.	58	7.9	14	6.3
2nd dorsal and anal origins.	17	2.3	3	1.3
2nd dorsal and anal insertions.	11	1.5	2	0.9
Eyes:				
Length.	26	3.5	13	5.8
Height.	13	1.8	6	2.7
Transverse distance between anterior corners.	52	7.0	20	8.9
Nostrils:				
Width.	16	2.2	6	2.7
Internarial space.	33	4.5	12	5.6
Spiracles:				
Diameter.	4	0.5	2	0.9
Mouth:				
Length.	14	1.9	6	2.7
Width.	42	5.7	15	6.7
Labial furrows:				
Length upper furrows.	17	2.3	6	2.7
Length lower furrows.	9	1.2	3	1.3
Gill opening widths:				
1st.	11	1.5	3	1.3
2nd.	12	1.6	3	1.3
3rd.	12	1.6	2.5	1.1
4th.	10	1.4	2	0.9
5th.	8	1.1	1.5	0.7

TABLE 1. *Continued.*

Measurement	Adult female	%	Male fetus	%
Head:				
Width at anterior corners of eyes.	66	8.9	25	11.2
Height at anterior corners of eyes.	35	4.7	11	4.9
Trunk:				
Width at pectoral insertions.	68	9.2	18	8.0
Height at pectoral insertions.	78	10.6	20	8.9
Caudal peduncle:				
Width at 2nd dorsal insertion.	24	3.2	6	2.7
Height at 2nd dorsal insertion.	26	3.5	7	3.1
Pectoral fins:				
Length anterior margins.	118	16.0	31	13.8
Length posterior margins.	84	11.4	18	8.0
Length bases.	44	6.0	13	5.8
Distance from origin to free rear tip.	81	11.0	24	10.7
Length inner margins.	45	6.1	14	6.3
Claspers:				
Length outer margins.	—	—	3	1.3
Pelvic fins:				
Length anterior margins.	46	6.2	13	5.8
Length bases.	43	5.8	10	4.5
Distance from origin to free rear tip.	59	8.0	17	6.7
Height.	33	4.5	7	3.1
Length inner margins.	30	4.1	8	3.6
1st dorsal fin:				
Length anterior margin.	121	16.4	32	14.3
Length base.	157	21.3	49	21.9
Height.	67	9.1	15	6.7
Length inner margin.	32	4.3	8	3.6
2nd dorsal fin:				
Length anterior margin.	76	10.3	22	9.8
Length base.	72	9.7	20	8.9
Height.	46	6.2	11	4.9
Length inner margin.	23	3.1	6	2.7
Anal fin:				
Length anterior margin.	51	6.9	13	5.8
Length base.	50	6.8	10	4.5
Height.	27	3.7	6	2.7
Length inner margin.	19	2.6	6	2.7
Caudal fin:				
Length dorsal margin.	167	22.6	51	20.9
Length preventral margin.	57	7.7	18	8.0
Length lower postventral margin.	21	2.8	5	2.2
Length upper postventral margin.	77	10.4	21	9.4
Length subterminal margin.	32	4.3	11	4.9
Length terminal margin.	58	7.9	10	4.5
Length terminal sector.	64	8.7	16	7.2

zoidal in transverse section at eyes. Outline of head in lateral view slightly convex ventrally and undulated dorsally, with a slight concavity in front of eyes and a convexity above them (figs. 1, 2F). Head outline with prominent notches just anterior to nostrils when viewed dorsoventrally (fig. 2D–E). Dorsal surface of suborbital ridges with depressions over the nostrils and in front of eyes. Eyes dorsolaterally situated on head, without eye notches. Ends of nictitating lower eyelid attached to upper eyelid (fig. 2A). Secondary lower eyelid sharp-edged and extending below the entire length of the eye. Kinetics and morphology of the nictitating lower eyelids, secondary lower eyelids, subocular pouches, and levator nictitans muscles (see below) indicate that *Gogolia* may not be able to completely close its eyes with its nictitating lower eyelids. Spiracles large, oval, and about $1/7$ as long as eyes. Spiracles positioned posterior to eyes by about their own lengths and about opposite the nictitating lower eyelids. No papillose gill rakers on gill arches. Small lobes or mesonarial flaps (fig. 2B: MNF) present on the bases of the anterior nasal flaps above their tips and protruding from the nasal apertures (as in *Galeorhinus*). Low posterior nasal flaps present (fig. 2B: PNF). Mouth width about $3/5$ of width of head at mouth corners. No large buccal papillae in mouth. Upper labial furrows about twice as long as lower ones, with their anterior ends slightly in front of eye pupils.

Teeth showing strong gradient monognathic heterodonty in anteroposterior teeth of both jaws of adult. Teeth become proportionately longer, lower, smaller, and more oblique-cusped towards the ends of the dental bands (fig. 4). Postlateral cusplets are reduced and replaced by postlateral blades in this direction in both jaws, while premedial cusplets are replaced by undifferentiated premedial edges in the upper jaw. Ontogenic heterodonty apparently similar to that of *Hemitriakis* (Compagno, 1970), with the fetus lacking cusplets and having postlateral blades only on all of its anteroposterior teeth. Teeth not forming a pavement and hardly protruding when mouth is closed.

Body moderately slender, with trunk high and subtriangular in section at first dorsal base in adult but lower in fetus. Caudal peduncle short and nearly oval in section, not greatly compressed and without lateral dermal keels. No predorsal or postdorsal ridges present. Lateral trunk denticles with strong medial cusps and a pair of medial ridges in fetus and adult, but with lateral ridges also present in adult (fig. 3A–B). Denticle crowns have reticulated depressions on their dorsal surfaces, much as in *Iago* (Compagno and Springer, 1971, fig. 6) and many other carcharhinoids.

Pectoral fins broad and subangular, with slightly convex anterior margins, narrowly rounded apices, slightly concave posterior margins, and broadly rounded free rear tips and inner margins. Pectorals slightly smaller than first dorsal. Origins of pectorals about under 3rd gill openings. Apex of pectoral posterior to its free rear tip when fin is elevated and appressed to body.

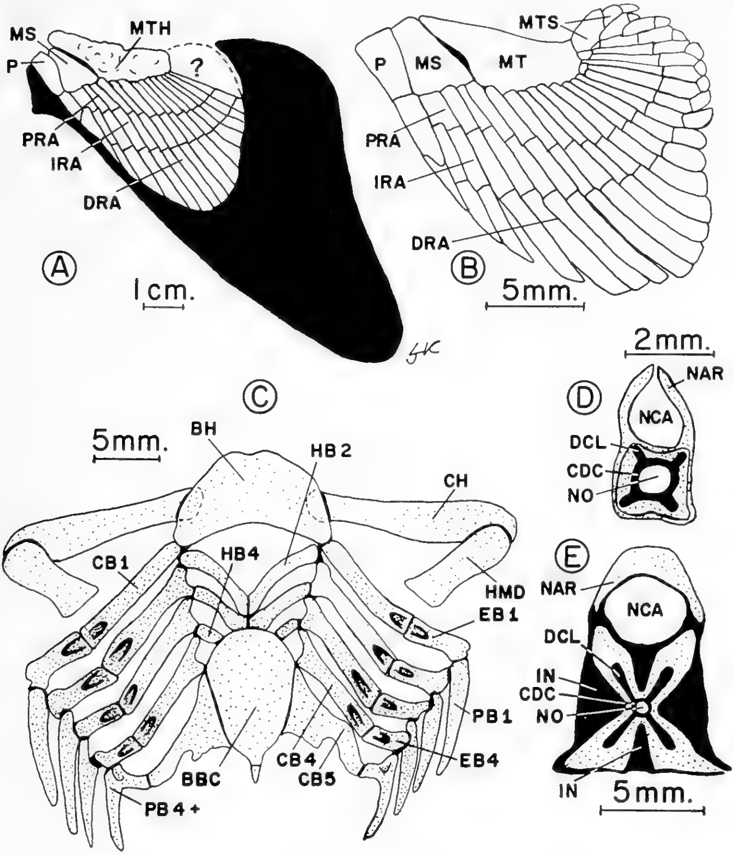

Figure 5. *Gogolia filewoodi.* A, pectoral fin skeleton of 739 mm. holotype, traced from radiograph (details of the axial segments of the metapterygium could not be distinguished), with outline of pectoral fin indicated in black. B, dissection of pectoral fin skeleton from 224 mm. fetus. C, hyobranchial skeleton (excluding hyobranchial rays and extravisceral cartilages) from 224 mm. fetus. D–E, transverse sections of MP vertebral centra from below first dorsal fin base, with sections cut through the apices of the calcified double cones of each centrum; calcified structures are in heavy black and cartilage stippled. D, centrum from 224 mm. fetus. E, centrum from 739 mm. holotype. Abbreviations: BBC, basibranchial copula; BH, basihyoid; CB 1–5, 1st to 5th ceratobranchials; CDC, calcified double cone; CH, ceratohyal; DCL, diagonal calcified lamella; DRA, distal radial segments; EB 1–4, 1st to 4th epibranchials; HB 2–4, 2nd to 4th hypobranchials (1st absent); HMD, hyomandibula; IN, intermedialia; IRA, intermediate radial segments; MS, mesopterygium; MT, basal segment of metapterygium (lightly calcified in fetus); MTH, basal segment of metapterygium (heavily hypercalcified and irregular in shape in adult); MTS, distal segments of metapterygium (metapterygial axis); NAR, neural arch; NCA, neural canal; NO, notochordal canal; P, propterygium; PB 1–4 +, 1st to 4th pharyngobranchials (4th one probably a compound element); PRA, proximal radial segments.

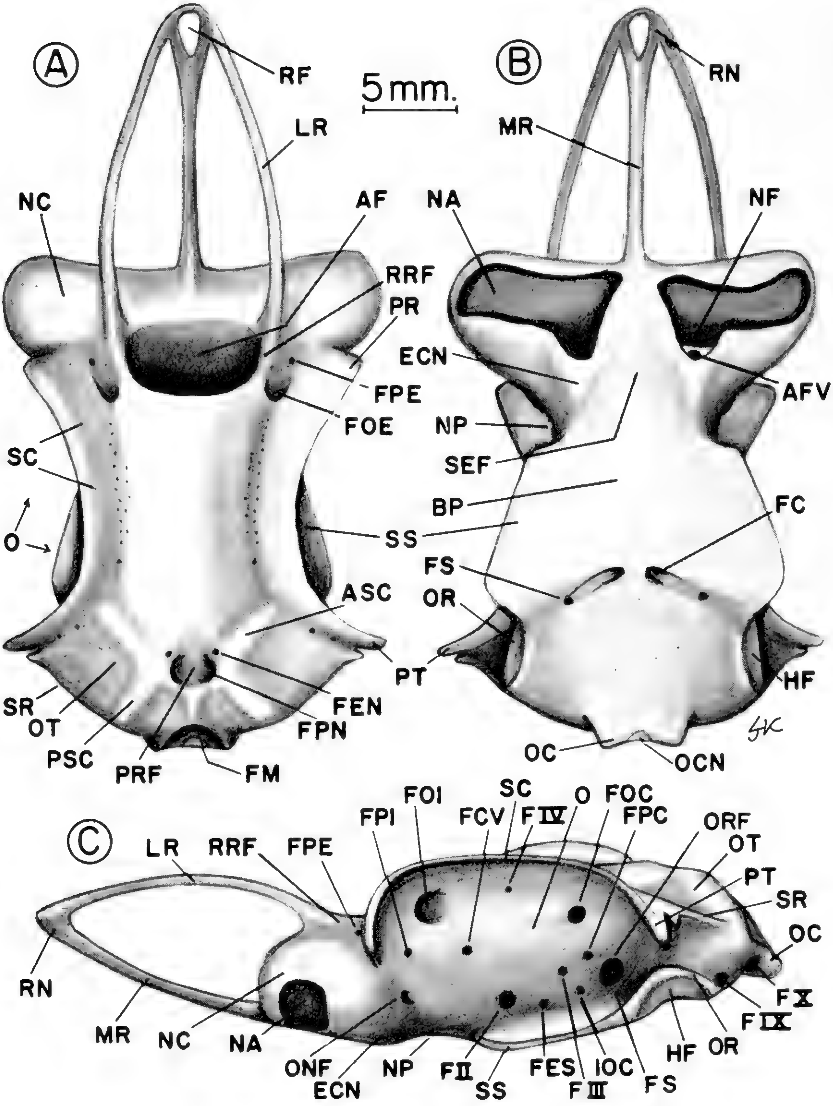

Figure 6. *Gogolia filewoodi.* Neurocranium dissected from 224 mm. fetus, in dorsal (A), ventral (B), and lateral (C) views. Abbreviations: AF, anterior fontanelle; AFV, position of anterior facial vein in nasal fontanelle; ASC, anterior semicircular canal; BP, basal plate; ECN, ectethmoid condyle; F II, optic nerve foramen; F III, oculomotor nerve foramen; F IV, trochlear nerve foramen; F IX, glossopharyngeal nerve foramen; F X, vagus nerve foramen; FC, foramen for internal carotid artery; FCV, foramen for anterior cerebral vein; FEN, foramen for endolymphatic duct; FES, foramen for efferent spiracular artery; FM, foramen magnum; FOC, orbitocerebral foramen for superficial ophthalmic nerve; FOE and FOI, preorbital and orbital foramina for supraorbital canal through supraorbital crest,

Pectoral fin skeleton with 1 radial on propterygium, 4–5 on mesopterygium, and about 15–16 on metapterygium (including segmented axis of metapterygium). Radials mainly divided into 3 segments: proximal, intermediate, and distal. Metapterygium (exclusive of segmented axis) densely hypercalcified and irregularly expanded in adult but not in fetus (fig. 5A–B).

Pelvic fins triangular, short, and about as large as anal fin. Pelvic anterior margins slightly convex, apices subacute, posterior margins straight, free rear tips pointed, and inner margins nearly straight. Inner margins, free rear tips, and posterior margins of pelvics forming a broad triangle.

First dorsal broadly triangular, with convex to undulated anterior margin, narrowly rounded apex, concave posterior margin, acute and attenuate free rear tip, and concave inner margin. Midpoint of first dorsal base varying from about equidistant between pectoral and pelvic bases (fetus) to about 1.6 times farther from pelvic bases than pectorals (adult). First dorsal insertion slightly anterior to pelvic origins by a distance somewhat less than the lengths of the pelvic bases. First dorsal insertion far posterior to apex of first dorsal.

Second dorsal much narrower-based and more acutely triangular than first dorsal, with undulating anterior margin, broadly rounded apex, moderately concave posterior margin, acutely pointed and attenuate free rear tip, and concave inner margin. Second dorsal origin anterior to anal origin by a distance less than ¼ of second dorsal base length.

Anal fin a low triangle, with undulated to slightly convex anterior margin, round apex, shallowly concave posterior margin, acute free rear tip, and nearly straight posterior margin.

Dorsal caudal margin convex to undulated, without a crest of enlarged denticles. Preventral margin slightly convex, tip of ventral lobe narrowly rounded, upper and lower postventral margins and subterminal margin nearly straight, and terminal margin slightly concave. Subterminal margin about 0.6–1.1 times

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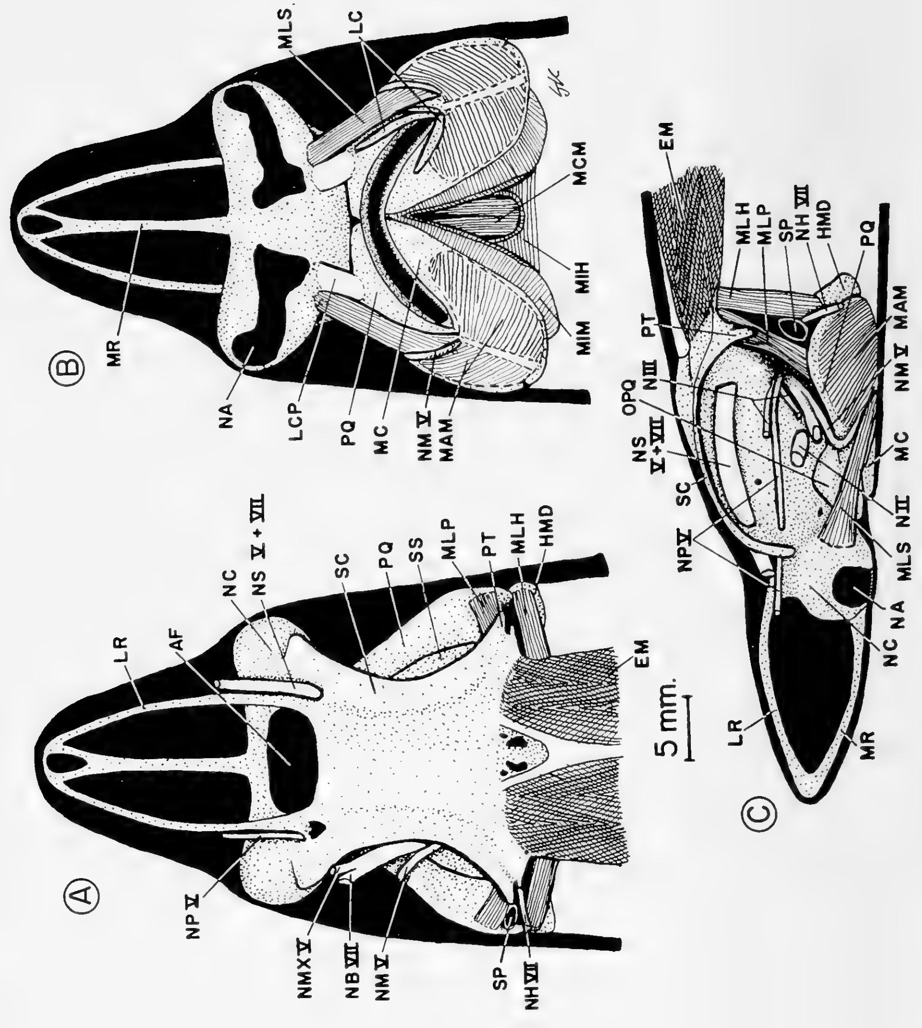
containing superficial ophthalmic nerve; FPC, orbitocerebral foramen for deep ophthalmic nerve; FPE and FPI, preorbital and orbital foramina for canal transmitting deep ophthalmic nerve through supraorbital crest; FPN, fenestra for the perilymphatic canal; FS, foramen for the stapedial or orbital artery; HF, hyomandibular facet; IOC, interorbital canal; LR, lateral rostral cartilage; MR, medial rostral cartilage; NA, nasal aperture; NF, nasal fontanelle; NP, orbital notch; O, orbit; OC, occipital condyle; OCN, occipital centrum; ONF, orbital foramen for orbitonasal canal (nasal foramen or ectethmoid chamber for the canal is inside nasal capsule); OR, opisthotic ridge; ORF, orbital fissure; OT, otic capsule; PR, preorbital process; PRF, parietal fossa; PSC, posterior semicircular canal; PT, postorbital process; RF, rostral fenestra; RN, rostral node; RRF, ridge between base of lateral rostral cartilage and edge of anterior fontanelle; SC, supraorbital crest; SEF, subethmoid fossa; SR, sphenopterotic ridge; SS, suborbital shelf.


A
LR
AF
NC
NS V + VIII
SC
PQ
SS
MLP
PT
MLH
HMD
EM
NP V
NMX V
NB VII
NM V
SP
NH VII
5 mm.
B
MR
NA
LCP
PQ
MC
NM V
MAM
MLS
LC
MCM
MIH
MIM
C
EM
MLH
MLP
SP
NH VII
HMD
PQ
PT
NIII
OPQ
NS V+VIII
SC
NP V
MC
MAM
NM V
NII
MLS
NA
NC
LR
MR

terminal margin, relatively shorter in adult than fetus. Vertebral axis of caudal noticeably raised.

Total vertebral counts 180 (2). Counts of monospondylous precaudal (MP) centra 27.2 percent, counts of diplospondylous precaudal (DP) centra 35.0–36.7 percent, and counts of diplospondylous caudal (DC) centra 35.0–36.7 percent of total counts. Ratios of DP/MP counts 1.3–1.4, DC/MP counts 1.3–1.4, A ratios (length of penultimate MP centrum/length of first DP centrum × 100) 150–160, and B ratios (length/width of penultimate MP centrum × 100) 67–68 (methods of counting and ratios follow Springer and Garrick, 1964, and Compagno, 1970). Transition between MP and DP centra over region of pelvic fin bases. Last few MP centra before MP–DP transition not greatly enlarged.

Vertebral calcification patterns studied from transverse sections of MP centra below first dorsal base (terminology from Ridewood, 1921). Diagonal calcified lamellae very long in adult but short in fetus. Dorsal, ventral, and lateral intermedialia are present in the adult but not in the fetus (fig. 5D–E). Notochordal canal very small at apices of calcified double cones in adult (unlike adults of *Iago*) but large in fetus.

Neurocranium was dissected in the fetus (fig. 6) and studied by stereoradiographs in the adult. Cranial terminology is modified from Gegenbaur (1872), Allis (1923), Holmgren (1941), Gilbert (1967), and Compagno (1973a and b). The cranium of *G. filewoodi* is most similar to those of *Hemitriakis*, *Galeorhinus*, and *Hypogaleus*, and less like those of other triakids (the neurocranium was dissected and examined by the writer from all triakid genera except *Allomycter*). Rostral cartilages slender and not hypercalcified in adult, fused at their tips to form a fenestrate rostral node. Nasal capsules slightly wider than long, greatest transverse width across them 1.1–1.3 in nasobasal length. Anterior fontanelle horizontally oval, with its width about 3.4–3.7 in nasobasal length.

←

Figure 7. *Gogolia filewoodi*. Head of 224 mm. fetus in dorsal (A), ventral (B), and lateral (C) views, dissected to show relation of neurocranium to jaws, jaw and hyoid muscles, and cranial nerve roots. Head outline in black. Abbreviations: AF, anterior fontanelle; EM, epibranchial myomeres; HMD, hyomandibula (distal end); LC, labial cartilages; LCP, cushioning ligament between ectethmoid condyle and orbital process of palatoquadrate; LR, lateral rostral cartilage; MAM, adductor mandibulae muscle; MC, Meckel's cartilage; MCM, coracomandibular muscle; MIH, interhyoid muscle; MIM, intermandibular muscle; MLH, levator hyomandibuli muscle; MLP, levator palatoquadrati muscle; MLS, levator labii superioris or preorbitalis muscle; MR, medial rostral cartilage; N II, optic nerve; N III, oculomotor nerve; NA, nasal aperture; NB VII, buccal ramus of facial nerve; NC, nasal capsule; NH VII, hyomandibular ramus of facial nerve; NM V, mandibular ramus of trigeminal nerve; NMX V, maxillary ramus of trigeminal nerve; NP V, deep ophthalmic ramus of trigeminal nerve; NS V + VII, supraorbital trunk or superficial ophthalmic ramus of trigeminal and facial nerves; OPQ, orbital process of palatoquadrate; PQ, palatoquadrate; PT, postorbital process; SC, supraorbital crest; SP, spiracle; SS, suborbital shelf.

Dorsal lip of fontanelle not anteriorly flared and without an epiphysial foramen. Cranial roof broadly arched between orbits. Orbital notches very prominent (fig. 6B: NP). No keels on basal plate. Internal carotid foramina closer to each other than to the stapedial foramina. Edge of supraorbital crests arcuate in dorsal view. Orbit oval in lateral view, with contents indicated in fig. 6C. No ledges between nasal capsules and suborbital shelves. Otic capsules not greatly expanded or inflated, their lengths about 3.3 in nasobasal length and the greatest transverse width across them about 1.9 in nasobasal length. Hyomandibular facets small and horizontally elongate. Occipital condyles short, with a single occipital centrum between them (fig. 6B–C: OC and OCN).

The hyobranchial skeleton was studied in the fetus by dissecting it out, staining it with methylene blue by Van Wijhe's method (Gray, 1954), and clearing it with the tricresyl phosphate-tributyl phosphate clearing solution of Groat (1941). It resembles comparable structures in other carcharhinoids examined (*Leptocharias* and *Scoliodon*) but has an unusually large and broad basihyoid and basibranchial copula (fig. 5C: BH and BBC). The hyomandibulae are short and moderately stout, the ceratohyals long and stout, and 3 pairs of hypobranchials (apparently nos. 2–4) are present.

Jaws and musculature associated with them are relatively weak (terminology for muscles follows Lightoller, 1939). Palatoquadrates and Meckel's cartilages flat and weak, with low orbital processes on palatoquadrates. The orbital processes articulate with the ectethmoid condyles on the nasal capsules and are attached to them by cushioning ligaments (fig. 7B–C: LCP and OPQ). Levator labii superioris or preorbitalis muscles small and single-headed, their origins on the sides of the nasal capsules lateral to the ectethmoid condyles and their insertions on the adductor mandibulae muscles near the mouth angles. Levator palatoquadrati muscles very slender, originating at the bases of the postorbital processes and inserting on the posterodorsolateral ends of the palatoquadrates. Levator hyomandibuli muscles very slender, originating on the sides of the otic capsules below the sphenopterotic ridges and inserting on the dorsolateral ends of the hyomandibulae. Levator nictitans short and poorly differentiated (not shown in fig. 7). Coracomandibular (fig. 7B: MCM), coracohyoid, and coracobranchial muscles very large, but branchial constrictors could not be found in the specimen examined.

Stomach divided into a moderately large fundus and a long, slender pylorus. The fundus extends posteriorly about half the length of the pleuroperitoneal cavity then reverses direction as the pylorus nearly to the base of the liver, where it connects with the valvular intestine. The intestine (fig. 2C) has 7 turns in its spiral valve. The rectum has a bulbous rectal gland attached to it by a stalk. Liver moderately large, irregularly bilobate, and extending posteriorly over ¾ of the length of the pleuroperitoneal cavity. Liver not obscuring other viscera entirely in ventral view. Spleen elongate and not nodular, with an irregularly thickened part opposite the end of the fundus and a slender anterior part extending along the pylorus. Pancreas small, located at junction of spiral intestine and pylorus. Ovary present on right side only, with follicles up to 6 mm. in diameter present. Both oviducts are developed, each having a moderately large nidimental gland.

Development ovoviviparous. The 2 fetuses (probably full-term or nearly so) were carried one to an oviduct and lacked placental connections to the mother.

Color of adult dark gray tinged with brown on dorsum, fins, and underside of head, light gray or gray-cream on abdomen and flanks. Dorsal fin edges dusky or blackish and posterior margin of pectorals light. Fetus is gray-brown above, lighter below, and dusky finned.

Summary

Gogolia filewoodi, new genus and species, is described from two specimens of triakid shark from northern New Guinea. The genus differs from other triakids in having an unusually high ratio of preoral length to mouth width, very short mouth, small gill openings, extremely long first dorsal base, and high vertebral counts. The family Triakidae is resurrected, redefined, and limited to the genera *Mustelus, Galeorhinus, Triakis, Scylliogaleus, Hemitriakis, Furgaleus, Hypogaleus, Iago, Allomycter*, and *Gogolia*. The family Carcharhinidae is confined to the genera *Carcharhinus, Scoliodon, Galeocerdo, Triaenodon, Loxodon, Hypoprion, Prionace, Aprionodon, Isogomphodon, Lamiopsis, Rhizoprionodon*, and *Negaprion. Hemipristis, Hemigaleus, Dirrhizodon, Chaenogaleus*, and *Paragaleus* are referred to the family Hemigaleidae, *Leptocharias* tentatively to its own family, Leptochariidae, and the 'scyliorhiniform triakoid' genera *Proscyllium, Eridacnis, Ctenacis*, and *Gollum* to the family Proscylliidae.

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Introduction

The present study was undertaken to make available for future reference the detailed muscular anatomy of the forelimb of this remarkable marine mammal, *Enhydra lutris*.

The sea otter has a limited southern range of approximately 140 miles along the coast of California from the Monterey Peninsula on the north to Morro Bay on the south. It is estimated by aerial and shoreline survey, that 1,000 individuals make up the population in this area.

The sea otter rarely comes on shore in this area, preferring the sanctuary of the abundant kelp beds for its home. Food preference is exclusively the many invertebrates found in this area, such as the various kinds of crabs, shellfish, and sea urchins. Since this food is mainly on the ocean floor, the animals dive to obtain it but return to the surface to consume it while floating on their backs using the chest as a dinner table. Divers, observing otters gathering their food, note that it is carried either in a bimanual manner or under one arm in the axillary area where a fold of skin assists in securing the object.

On occasions, an animal will bring up a rock and, placing it on its abdomen, use it as an anvil against which it can break shellfish. In so doing the animal holds the food between its forepaws and rapidly strikes it against the rock. In view of this habit, the otter has been classified as a tool user.

We are concerned, therefore, with the work this animal has to do with the forelimbs in an aquatic environment, and the structural anatomy he has with which to accomplish these tasks.

Over the past several years, the author has observed these animals in their natural habitat, noting the high degree of specialized use of the forelimbs in eating, grooming, and caring for the young. Based on these observations it would appear that the 'hand' of this animal should be extremely dextrous, yet when observed at close range, the anatomical characteristics show marked resemblance to the forepaw of mammals which use the forelimb mainly for land propulsion.

Many references in the literature describe how the otter uses its forelimbs. It seemed of interest, therefore, to study the 'hand' in some detail from an anatomical standpoint. To do so necessitated the study of the entire forelimb since the hand, to be effective, must be positioned by the forelimb and positional stability maintained when the hand itself is in use.

The material for this study consisted of one fresh specimen on which the range of motion measurements were made, and one preserved specimen used for recording the detail of the muscular anatomy. The method used for this latter study was to make a series of anatomical dissections, photograph each, and then from the projected slides make accurate line drawings. In this way, the relative size and relationship of each muscle could be portrayed.

The forelimb muscles can be grouped in various ways: by their innervation, by their action (such as extensors and flexors), by their origin (pre- and post-axial), or by where they make their attachments. Examples of the last would be muscles connecting the trunk to the limb, muscles connecting the scapula to the humerus, etc.

In this treatise a fixed method of presentation is not used, but rather the muscles are described as they are encountered in a dissection going from the proximal to the distal areas. Each muscle is numbered and retains this number wherever it appears. A gross description of each muscle is given with its origin and insertion and a notation as to its action or actions if the muscle were to be activated as a single unit. This situation, of course, never happens in the living specimen, as each voluntary motion of any part of the limb is a complicated interplay between the many muscles, some relaxing, some serving to stabilize the joints, and some serving as prime movers for any given motion.

For further clarification, plates of the forearm skeleton have been added and the areas of origin and insertion of muscles designated.

Observations Of Joint Mobility

In a fresh specimen, by means of passive motions, some idea of the range of motion of the forelimb could be observed and for some joints the range of motion could be actually recorded.

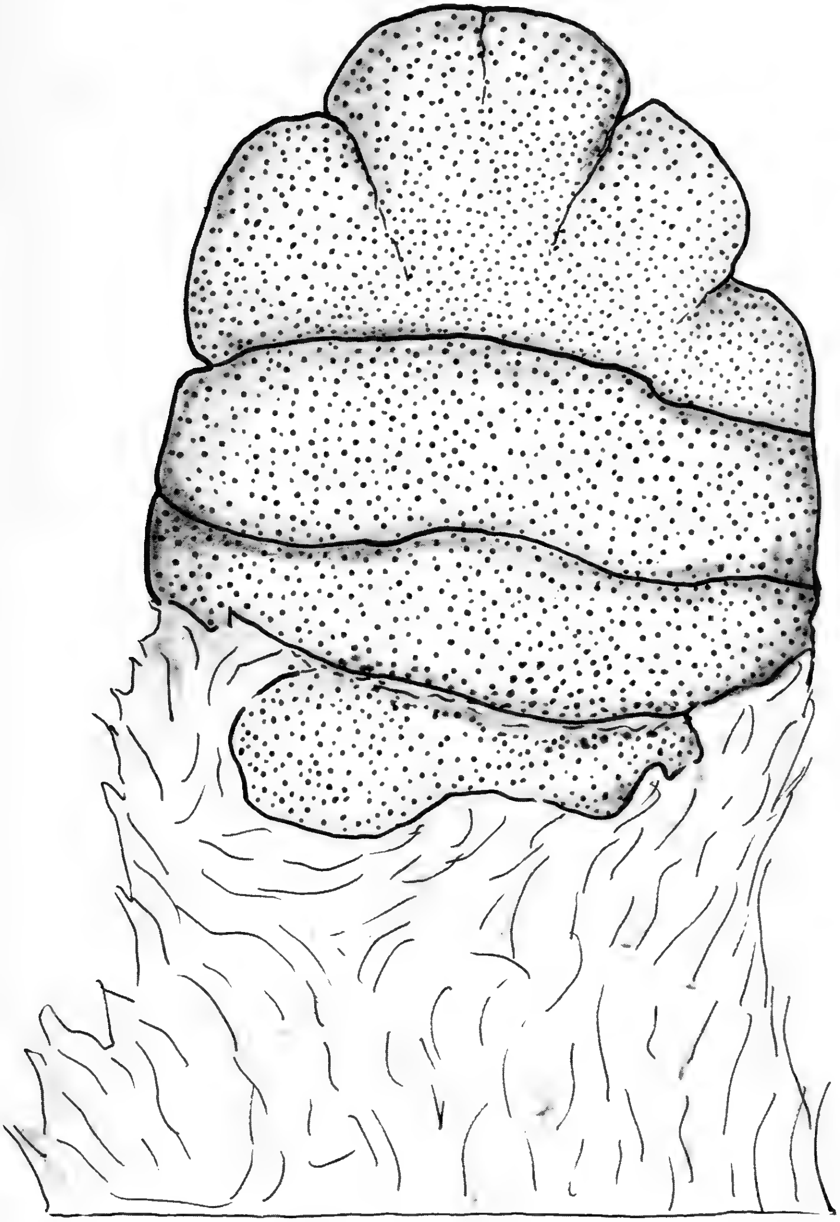

FIGURE 1. An anterior or palmar view of the forefoot to show the disposition of the palmar pads. The major crease lines are transverse and quite deep. Distally, shallow incomplete crease lines suggest interdigitation, but such is not the case to any practical degree. The pads appear to bulge slightly and are turgid, and the covering skin is thick with a pebbly roughness.

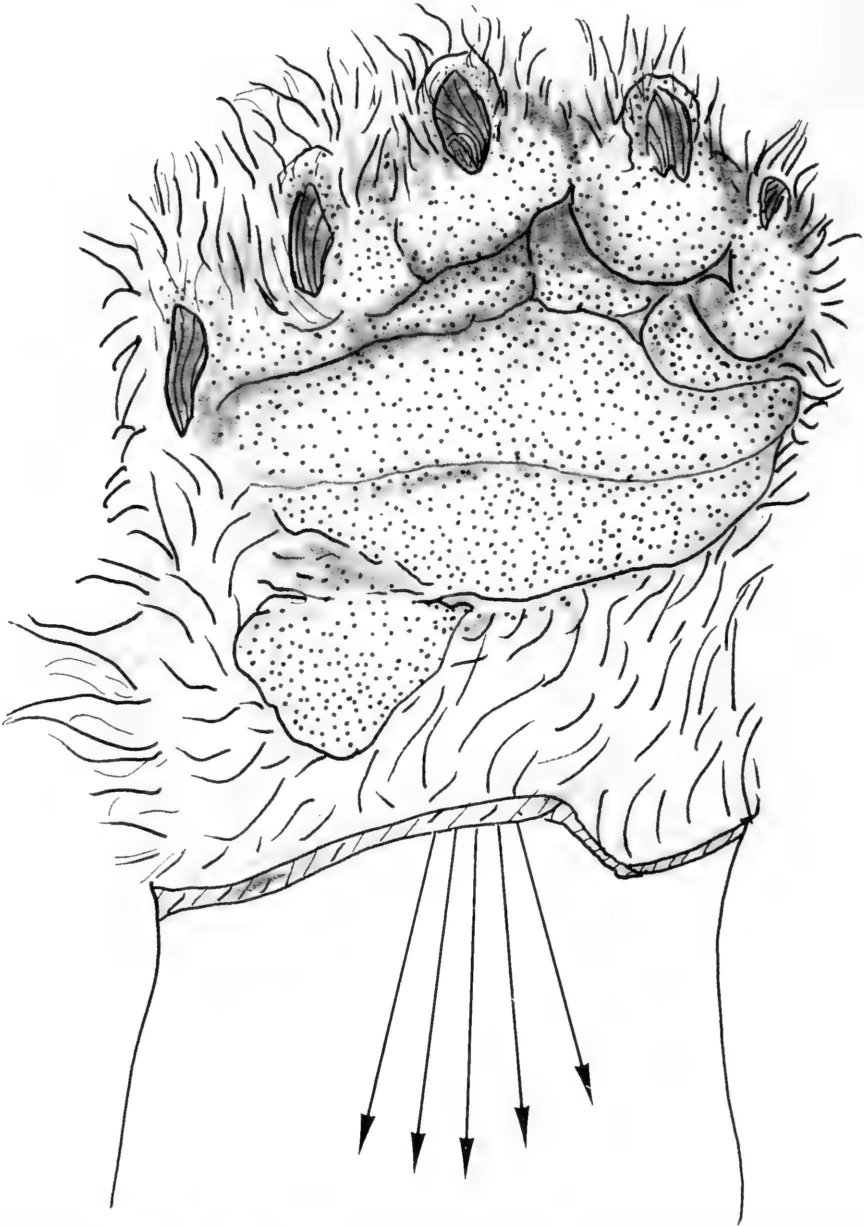

FIGURE 2. Anterior or palmar view of the forefoot while all long digital flexors are being pulled strongly in the forearm. Although there is cupping of the palm, the pad so fills the palm that there is little space in which to retain objects. Note that the claws now appear, as all interphalangeal and metacarpal phalangeal joints come into maximum flexion.

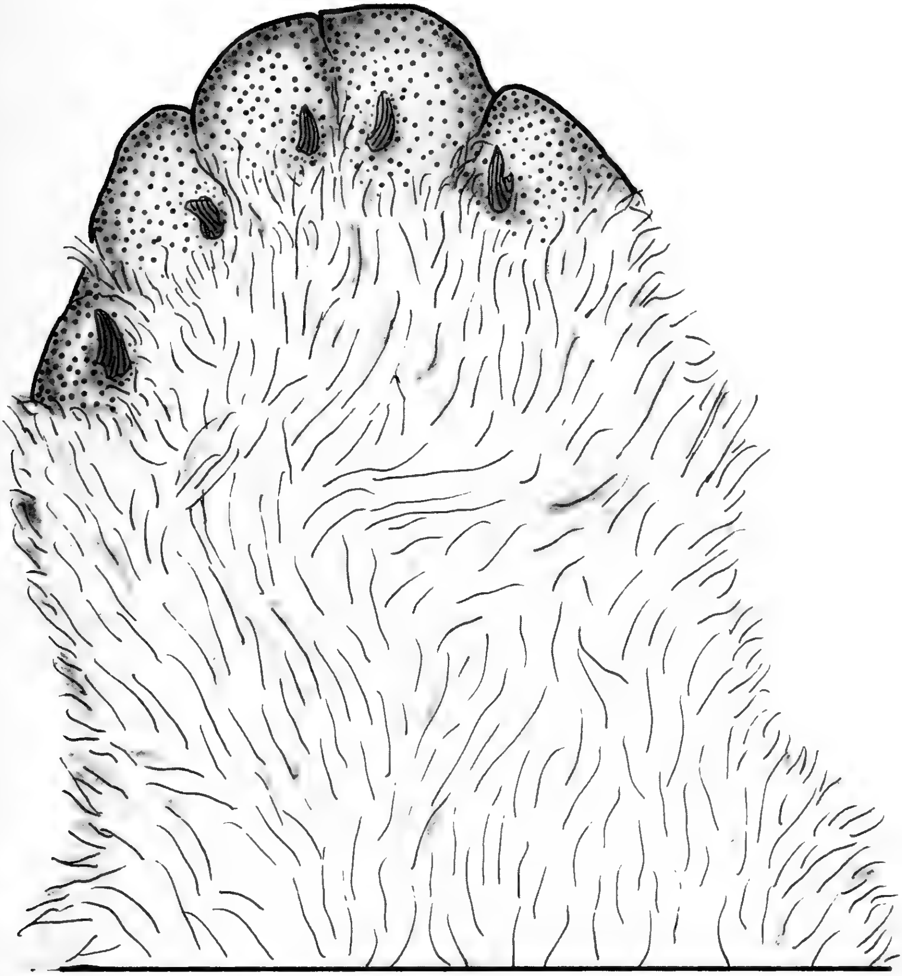

Figure 3. In this posterior or dorsal view of the forefoot the hair has been trimmed away to show the position of the claws which, in the unflexed hand, are visible only in this view. Since the claws are closely associated with, and move only with, the terminal phalanx, their position indicates a marked degree of hyperextension of the terminal digital joints.

As there is no clavicle in this animal, the pectoral girdle, which consists of the scapula only, is extremely mobile on the chest wall, being limited only by the muscles attaching the girdle to the trunk. Thus, in a transverse plane, the pectoral girdle could be moved to near the midline dorsally and ventrally, and in the longitudinal plane an equal, if not slightly greater, range of motion was present. A good range of motion in the shoulder joint was also present but technically it was not possible to get accurate measurements in degrees of abduction, adduction, flexion, extension, and rotation.

For the elbow, extension was to an angle of 145° and flexion to an angle of 40°.

For the forearm, pronation was to 30° beyond the midposition and supination to 45° beyond the midposition.

The wrist is very mobile. Palmar flexion of the wrist was to an angle of 82° beyond the straight line of the forearm, and dorsiflexion to an angle of 40°. Good lateral motion of the wrist was also present, radioflexion being to an angle of 30° and ulnaflexion to an angle of 50°.

For digits 2, 3, 4, and 5, the average range of motion of the individual joints as measured from the line of the metacarpal was as follows:

	Extension	Flexion
Metacarpal phalangeal joint	80°	45°
Proximal interphalangeal joint	52°	45°
Distal interphalangeal joint	170°	20°
For digit 1:		
Metacarpal phalangeal joint	80°	65°
Interphalangeal joint	170°	50°

From the above, it is to be noted that the digital joints have a greater range of extension than of flexion, which, in itself, would indicate the sacrificing of a gripping mechanism in favor of ambulatory functions.

This situation was even more evident when traction was made on the digital extensors and the flexor tendons in the forearm.

The digits of the 'hand' are not individualized, being held closely together by webbing and the first digit, or thumb, is in the same plane as the other digits. Without an established thumb web the first digit is unopposable and lateral motions of the other digits are of insignificant amount because of the webbing. In fact, a better term than "webbing" would be total syndactylism.

An effort was made to see if objects could be held in the hand by a grasp mechanism. When the long flexors were pulled upon strongly in the forearm an ordinary pencil, for example, could not be grasped firmly in the hand. Larger objects could be held but rather precariously in the absence of an opposable thumb. Part of the problem, as far as gripping objects is concerned, appears to be due to the large pads on the palmar surface which, on grasp, appear to fill the palm. When the digits were flexed to their limits, the terminal digital pads failed to touch the palmar pad by about 12 mm. However, there is sufficient flexion of the digits to allow the claws to be used against the flat opposing surface. Since palmar flexion of the wrist is extremely good, large objects of 8 or more cm. in diameter could be held between the hand and distal forearm.

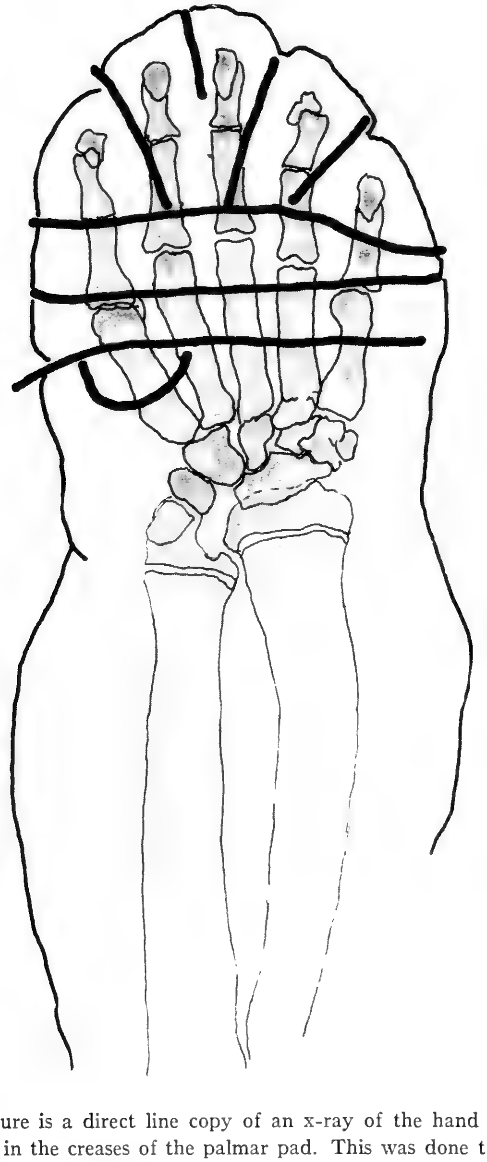

FIGURE 4. This figure is a direct line copy of an x-ray of the hand and wrist after soft iron wires were placed in the creases of the palmar pad. This was done to show the relationship of these crease lines to the underlying joints. The pad itself lies distal to the most proximal wire (heavy line). From this it is to be noted that the volar pad covers only the distal one-half of the metacarpals plus the phalanges. The main transverse creases are at metacarpal phalangeal joint level. Therefore when walking on this pad the otter does not walk on the flat of the hand as it appears, but rather on the metatarsal heads and the phalanges. This is readily understandable in view of the limited dorsiflexion of the wrist and the great degree of hyperextension of the metacarpal phalangeal joints.

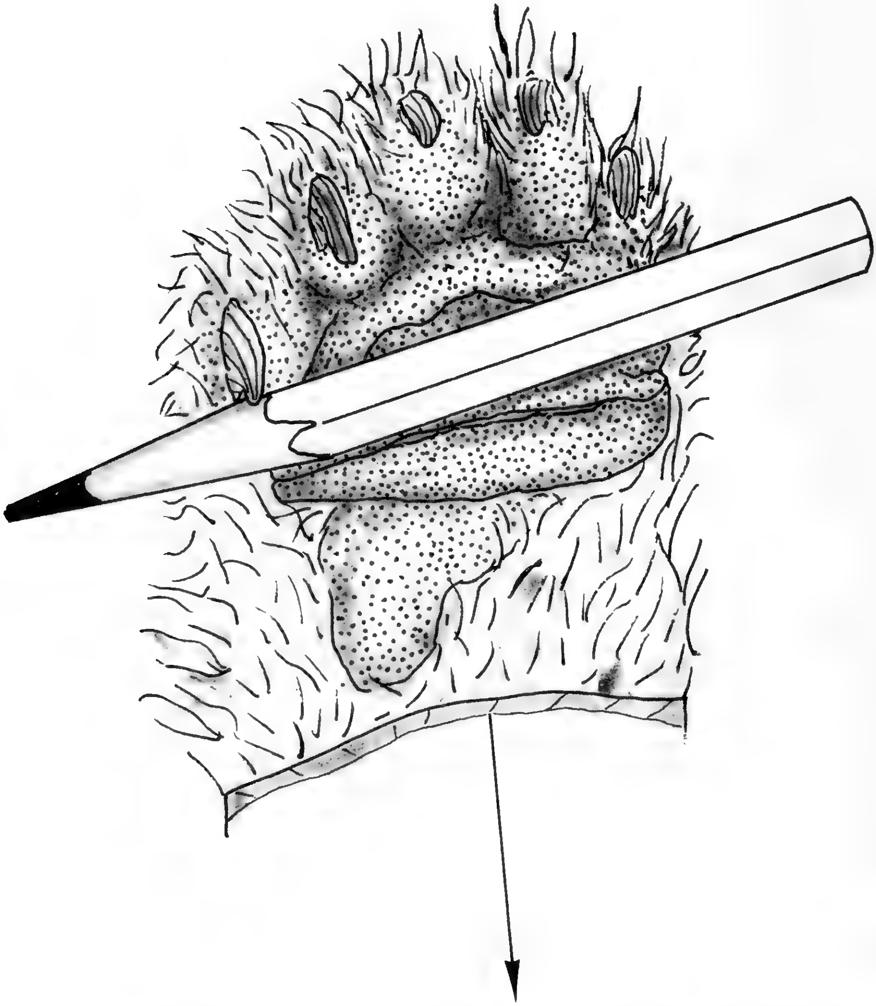

FIGURE 5. The grasp mechanism of the individual hand is markedly limited as shown in this figure. The long flexor tendons of the digits were pulled upon forcibly in an effort to demonstrate grasp of a pencil. This precarious grasp depended upon sufficient flexion of the finger joints to allow the claw of the fifth digit to become effective. Without a good claw (and the claws are frequently worn down to mere nubbins) it is doubtful that either of the objects shown in figures 5 and 6 could be held in the one hand. See also figure 6.

On the few occasions that the animal was observed on land, the forelimb functioned admirably for terrestrial progression. Underwater observers report that the forelimbs are not used for swimming, but are active in food gathering.

In light of these observations it is understandable why the animal performs

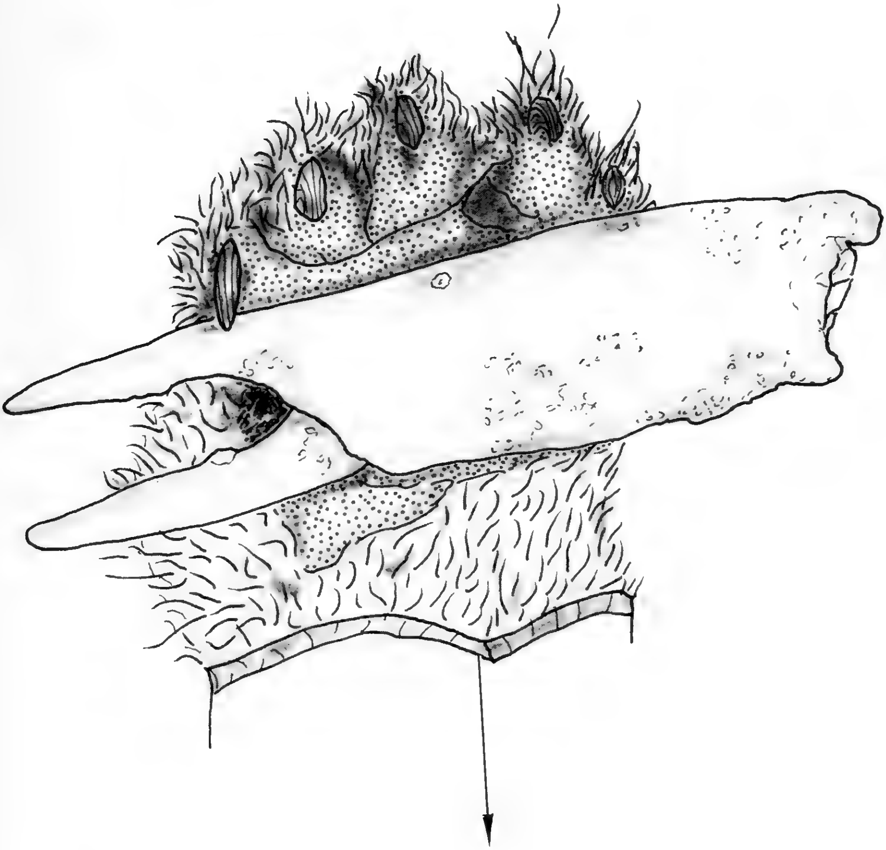

Figure 6. In this figure, a medium-sized crab leg has been substituted for the pencil of figure 5.

most of the forelimb functions in a bimanual manner. Anatomically, the hand is small, the digits are not individualized, and grasp function is poor. Therefore, to obtain the observed dexterity the forelimbs must be used together. One hand opposing the other provides what we would interpret as a 'thumb service.'

One is reminded of a bilateral human amputee who has lost both hands at wrist level, and in the absence of a prosthesis everything that can be done is done by opposing the two forearm stumps.

Thus it is interesting to speculate whether or not an otter could survive if one hand was lost. The probability seems good that he could, using the forearm stump against the opposite hand. However, to lose one extremity at elbow level would probably prove disastrous.

The anatomical study which follows was made on sea otter #222 (State of

California Fish and Game). The otter was an adult male with an overall body length (tip of nose to tip of tail) of 125 cm. The length of the upper arm was approximately 14 cm. and the lower arm was of equal length. The length of the forefoot (hand) was 7 cm. and the width was 5 cm. It must be kept in mind that only a single specimen was used and therefore variations and anomalies which are bound to occur between individual specimens are not recorded.

MUSCLES OF THE FORELIMB OF THE SEA OTTER

ALPHABETICAL LISTING OF MUSCLES

Muscle	No.	Muscle	No.
Abductor digiti quinti	49	Flexor digitorum sublimis ulnaris	48
Abductor digiti secundi	57	Flexor pollicis brevis	55
Abductor pollicis brevis	54	Infraspinatus	24
Abductor pollicis longus	38	Interossei	59
Acromiodeltoideus	17	Latissimus dorsi	15
Acromiotrapezius	2	Levator anguli scapulae	11
Adductor digiti quinti	52	Lumbricali	53
Adductor digiti secundi	57	Omotrachleon	6
Adductor pollicis	56	Opponens digiti quinti	50
Anconeus externus	23	Palmaris longus	40
Biceps brachii	28	Pectoantebrachialis	12
Brachialis	29	Pectoralis major	13
Brachioradialis	30	Pectoralis minor	14
Clavobrachialis	5	Pronator quadratus	46
Clavotrapezius	3	Pronator teres	44
Cleidomastoideus	4	Rhomboideus capitis	8
Dorsoepitrochlearis	19	Rhomboideus major	7
Extensor carpi radialis brevis	32	Rhomboideus profundus	9
Extensor carpi radialis longus	31	Serratus magnus	10
Extensor carpi ulnaris	35	Spinodeltoideus	18
Extensor digitorum communis	33	Spinotrapezius	1
Extensor digitorum lateralis	34	Subscapularis	27
Extensor pollicis et indicis longus	36	Supinator	37
Flexor carpi radialis	43	Supraspinatus	26
Flexor carpi ulnaris	39	Teres major	16
Flexor digitorum profundus, central head	45	Teres minor	25
Flexor digitorum profundus, humeral head	42	Triceps brachii caput lateralis	21
Flexor digitorum profundus, ulna head	41	Triceps brachii caput longus	20
Flexor digiti quinti brevis	51	Triceps brachii caput medialis	22
Flexor digitorum sublimis radialis	47		

DESCRIPTIONS OF MUSCLES

1. Spinotrapezius.

This muscle is the most posterior of the three muscles which make up the trapezius muscle complex. The spinotrapezius, with the acromiotrapezius and

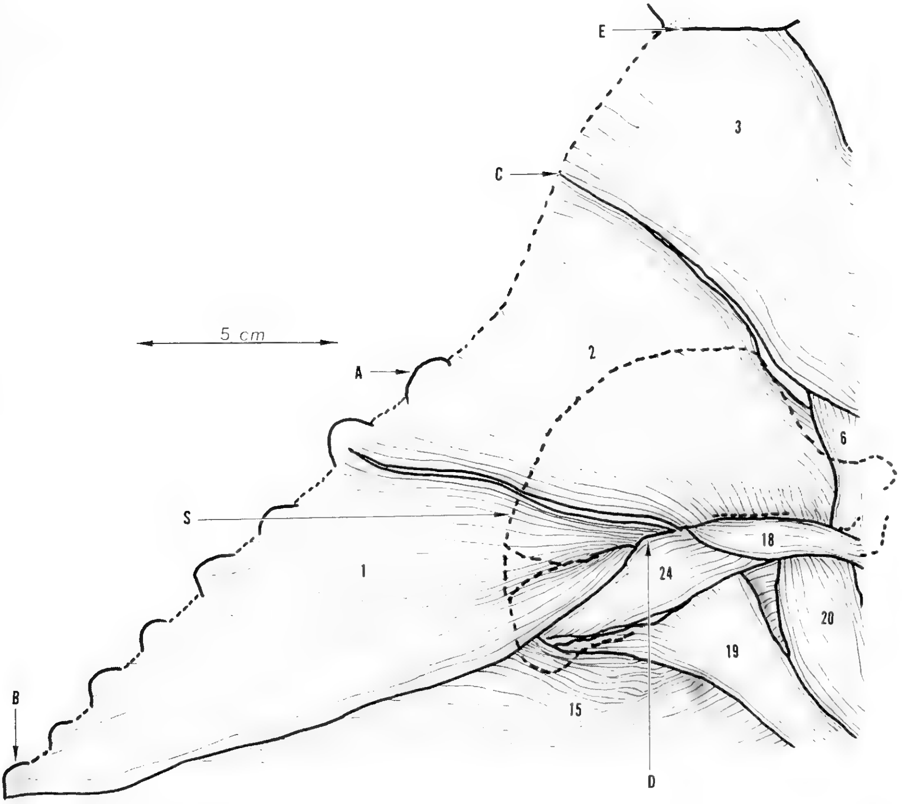

FIGURE 7. Lateral view of the right side of the trunk to show the superficial trapezius muscle complex, which consists of three muscles, the spinotrapezius (1), the acromiotrapezius (2), and the clavotrapezius (3). These muscles are vago-accessory, presumably having migrated posteriorly from the pharyngeal area. Together they form a broad dorsal sheet of muscle suspending the pectoral girdle and the forelimb from the middorsal line of the body. The scapula is outlined to show its relationship to the musculature. Key: 1, spinotrapezius; 2, acromiotrapezius; 3, clavotrapezius; 6, omotrachlean (levator scapulae ventralis); 15, latissimus dorsi; 18, spinodeltoideus; 19, dorsoepitrachlearis; 20, triceps brachii caput longus; 24, infraspinatus; A, spinous process of first dorsal vertebra; B, spinous process of eighth dorsal vertebra; C, middorsal line-cervical area; D, site of tuberosity on spine of scapula; E, lambdoid ridge of skull; S, outline of scapula.

the clavotrapezius, forms a broad superficial muscle sheath joining the axial skeleton to the scapula and forelimb. The muscle is thin and triangular in shape with the base along the middorsal line.

ORIGIN. Arising by fleshy fibers along the middorsal line and spinous processes from T-2 to T-8, the muscle triangulates toward the tuberosity of the scapular spine, where a short, flat tendon develops.

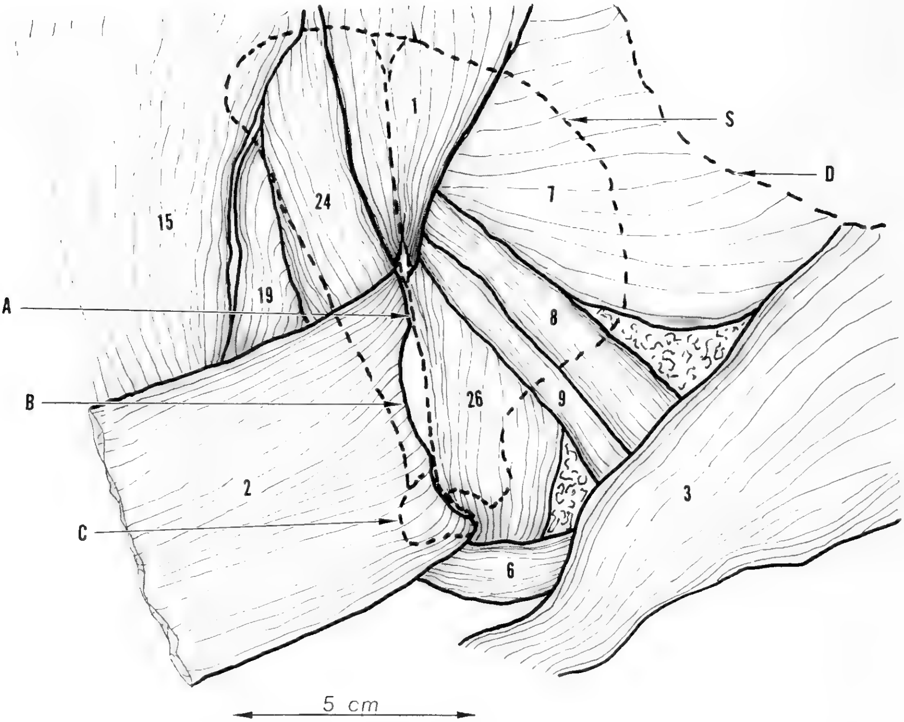

FIGURE 8. Lateral view of the right scapular area. The acromiotrapezius muscle (2) has been detached from its origin and reflected downward and posteriorly to show the detail of its insertion on the scapular spine and acromium process. Note the unattached raphe area (B). The deeper rhomboid muscles, (7), (8), (9), lying beneath the acromiotrapezius muscle are now exposed. Key: 1, spinotrapezius; 2, acromiotrapezius; 3, clavotrapezius; 6, omotrachlean (levator scapulae ventralis); 7, rhomboideus major; 8, rhomboideus capitis; 9, rhomboideus profundus; 15, latissimus dorsi; 19, dorsoepitrachlearis; 24, infraspinatus; 26, supraspinatus; A, scapula, spine; B, raphe—unattached to spine of scapula; C, scapula, acromion process; D, middorsal line, cervical area; S, outline of scapula.

INSERTION. The tendon inserts on the tuberosity of the spine of the scapula along the anterior and distal surface.

ACTION. The principal action is to support the scapula and forelimb and move these structures toward the middorsal line.

2. Acromiotrapezius.

This is the central muscle of the trapezius muscle complex being situated between the spinotrapezius posteriorly and the clavotrapezius anteriorly. The muscle is thin and broad, and rhomboid in shape.

ORIGIN. Arising by fleshy fibers from a broad base along the middorsal line extending from the midcervical area anteriorly to the spinous process of T-2 posteriorly. The muscle passes sheetlike toward the spine of the scapula. Here, the muscle fibers end in a crescent-shaped tendinous raphe in the central area and in short tendon fibers at the proximal end and fleshy fibers at the distal end.

Insertion. The proximal tendon fibers insert on the tuberosity of the spine of the scapula just distal to the tendon of the spinotrapezius. The distal fleshy fibers insert on the full length of the acromion process of the scapula. The tendinous raphe spans between the two insertions and is unattached to the spine of the scapula, although paralleling it. The distal insertion is crossed superficially by the omotrachleon muscle. The tendinous raphe gives origin to the spinodeltoideus muscle.

Action. This muscle assists in the support of the scapula and forelimb from the axial skeleton and can assist in rotating the scapula counterclockwise.

3. Clavotrapezius.

The anterior muscle of the trapezius muscle complex is also thin and broad and closely associated along its posterior border with the acromiotrapezius. The muscle is somewhat triangular in shape with a broad base dorsally.

Origin. The muscle arises by fleshy fibers from the middorsal line adjacent to the origin of the spinotrapezius in the cervical area. The origin extends anteriorly the length of the remaining cervical area to reach the skull at the external occipital crest. The origin then continues laterally along the lambdoid ridge of the skull approximately one-third the distance to the jugular process. From their origin the muscle fibers pass ventrally toward the shoulder, at which point the muscle divides into an anterior one-third and posterior two-thirds.

Insertion. The anterior one-third of the muscle continues toward the clavicular area inserting into the deep fascia at this site since there is no clavicle. The posterior two-thirds of the muscle divides about equally into two parts. The anterior portion joins with a remaining portion of the cleidomastoid muscle at this level to continue distally and eventually reaches the ulna. The posterior portion joins with the muscle fibers from the cleidomastoid muscle to form the clavobrachialis muscle, which in turn inserts more distally along the pectoral ridge of the humerus.

Action. With this somewhat complicated insertion the muscle acts, in addition to supporting the pectoral girdle and drawing it upwards and forward, to assist in flexion of both the shoulder and elbow.

4. Cleidomastoideus.

This long, thick, straplike muscle joins the skull to the upper extremity.

Origin. Arising by fleshy fibers from the anterior and inferior surface of

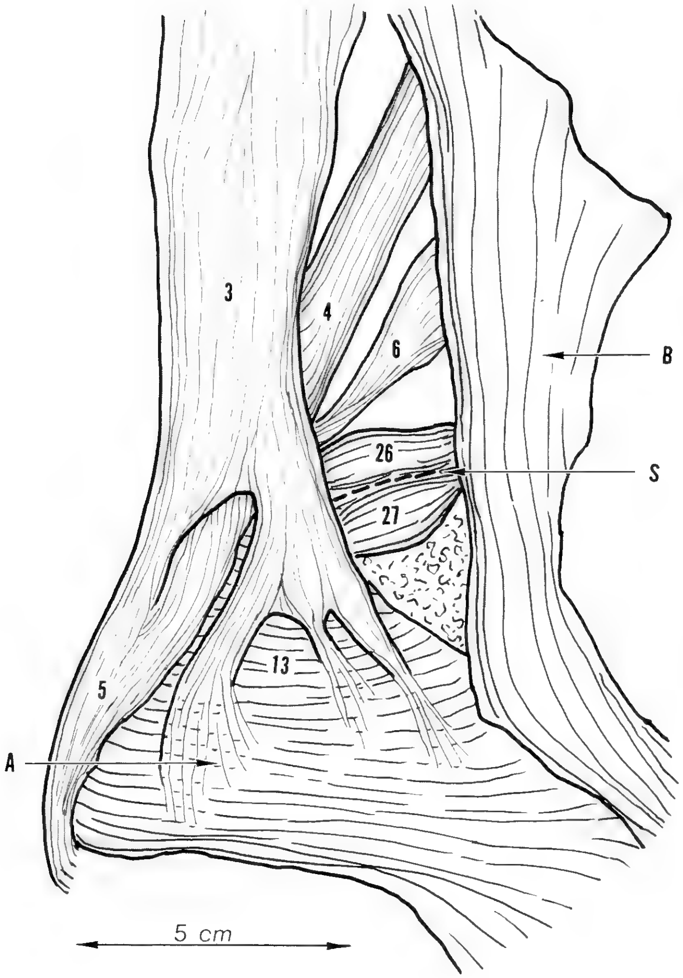

Figure 9. Anterolateral view of the right shoulder. The clavotrapezius—cleidomastoideus—and clavobrachialis complex. This somewhat complex muscle arrangement, occurring over the point of the shoulder, is depicted in figures 9, 10, and 11. The essential feature is an interchange of muscle fibers between the clavotrapezius (3) and the cleidomastoideus (4) resulting in the formation of the clavobrachialis muscle (5).

This view shows a division of the clavotrapezius (3) into an anterior one-third which spreads out to insert into the pectoral fascia, and a posterior two-thirds being joined by fibers of the cleidomastoideus (4) to form the clavobrachialis muscle (5). Not shown in this plate is the continuation of the cleidomastoideus (4) and its being joined by muscle fibers from the clavotrapezius (3); see figure 11 for this detail. Key: 3, clavotrapezius; 4, cleidomastoideus; 5, clavobrachialis; 6, omotrachlean (levator scapulae ventralis); 13, pectoralis major; 26, supraspinatus; 27, subcapularis; A, pectoral fascia; B, sternomastoideus muscle; S, scapula, superior border.

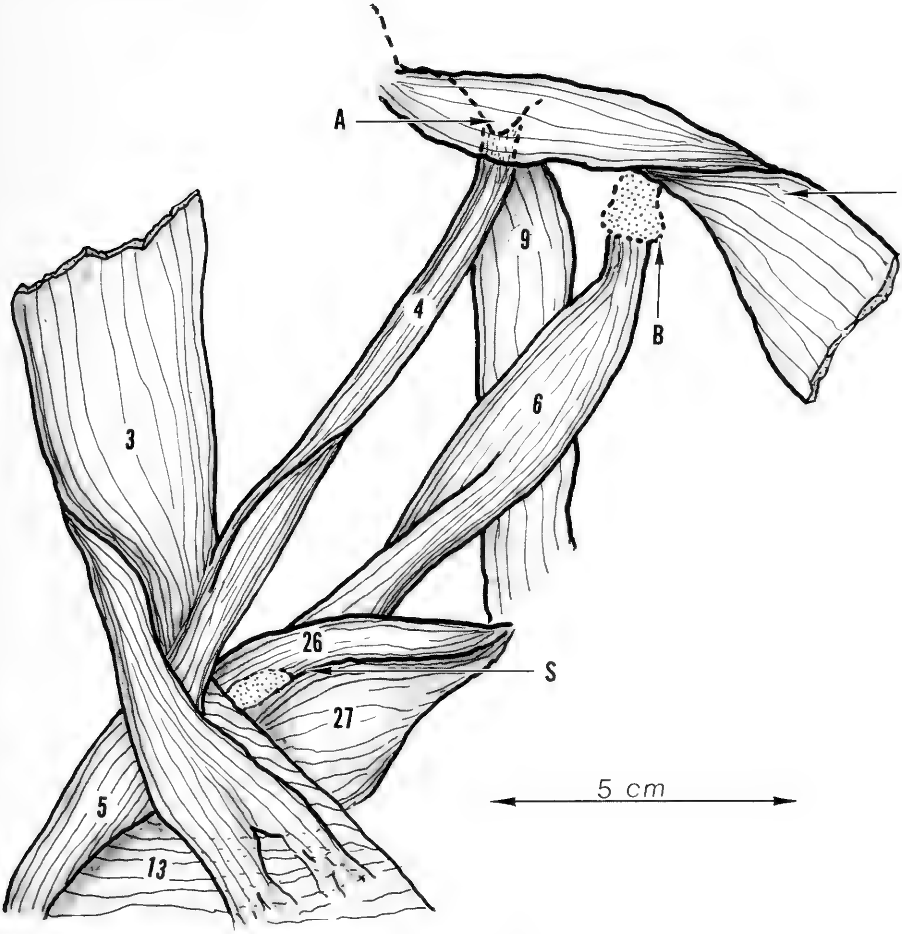

Figure 10. Anterolateral view of the right shoulder area identical to figure 8, except that the clavotrapezius muscle (3) has been detached from its origin and reflected laterally and posteriorly. The sternomastoideus muscle (C) has been reflected anteriorly. The muscle interchange to form the clavobrachialis (5) is again shown. Not shown (as in figure 9) is the continuation of the cleidomastoideus muscle (4). Key: 3, clavotrapezius; 4, cleidomastoideus; 5, clavobrachialis; 6, omotrachlean (levator scapulae ventralis); 9, rhomboideus profundus; 13, pectoralis major; 26, supraspinatus; 27, subscapularis; A, mastoid process of the skull; B, transverse process of the first cervical vertebra; C, sternomastoideus muscle; S, scapula, superior margin.

the mastoid process of the skull, the muscle passes in uniform diameter under the clavotrapezius and over the omotrachleon toward the shoulder at which point the muscle splits into a posterior one-fourth and an anterior three-fourths.

Insertion. The posterior one-fourth joins with the muscle fibers from

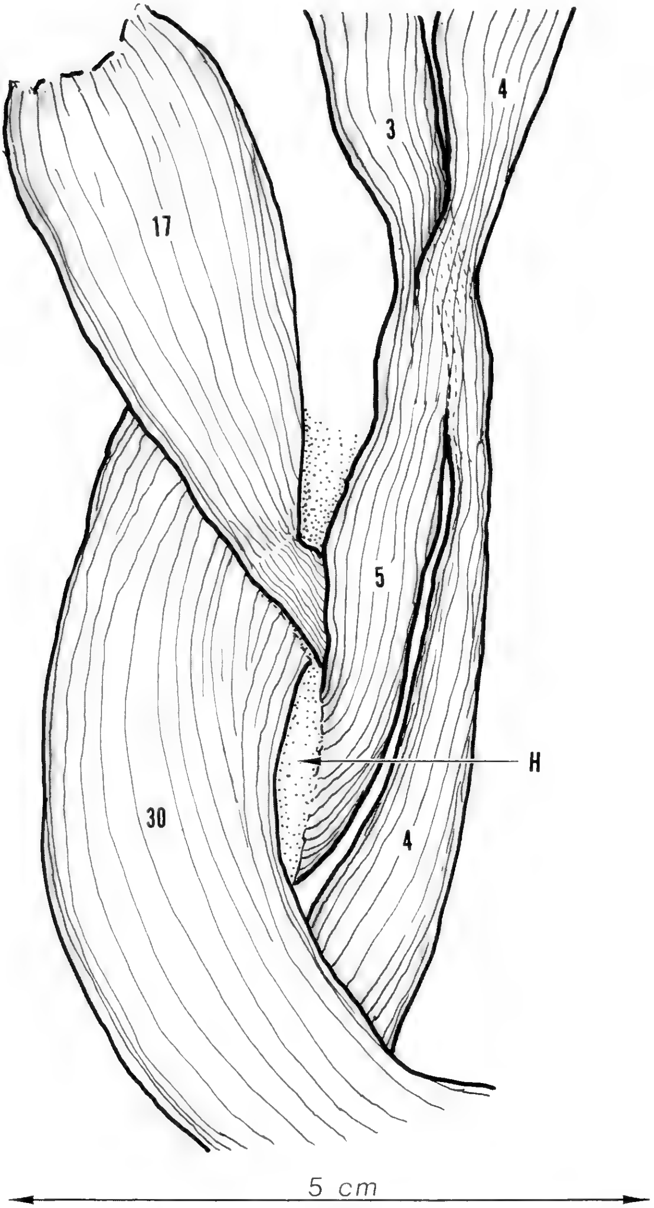

FIGURE 11. An enlarged view of the right shoulder area and upper humerus to show the continuation of the cleidomastoideus muscle (4) and its receiving of muscle fibers from the clavotrapezius (3) (depicted by dotted line). Also shown is the insertion of the clavobrachialis (5) and the acromiodeltoideus (17). Key: 3, clavotrapezius; 4, cleidomastoideus; 5, clavobrachialis; 17, acromiodeltoideus; 30, brachioradialis; H, humerus.

the clavotrapezius to form the clavobrachialis muscle. The anterior three-fourths joins with the remaining muscle fibers of the clavotrapezius. Thus reinforced, this combined muscle continues distally into the anterior cubital area of the elbow where it joins with the pectoantebrachialis muscle which, in turn, inserts into the ulna.

Action. With this somewhat complicated insertion it would be difficult to analyze the specific action of this muscle. From its position the muscle could assist in both flexion of the elbow and shoulder and drawing of the forelimb forward and dorsally.

5. Clavobrachialis.

This is a rather small flat muscle passing over the shoulder area.

Origin. This muscle is made up of fibers from the clavotrapezius and the cleidomastoideus as described in the description of each. The newly formed muscle converges to a longitudinal linear configuration.

Insertion. The muscle fibers insert into the humerus along the pectoral ridge at its junction with the deltoid ridge. The insertion is adjacent to and just posterior to the insertion of the pectoralis major muscle and just distal to the insertion of the spinodeltoideus and acromiodeltoideus muscles.

Action. This small muscle, by virtue of its position, could assist in abduction and flexion of the humerus.

6. Omotrachleon (levator scapulae ventralis).

This is a long, flat, ribbonlike muscle connecting the scapula to the spine.

Origin. This muscle arises by fleshy fibers from the anteromedial surface of the transverse process of the first cervical vertebra. At its point of origin it overlies the origin of the rhomboideus profundus muscle. The muscle passes obliquely posteriorly across the neck toward the acromion process of the scapula.

Insertion. About one-fourth of the fibers split off anteriorly just before reaching the acromion process of the scapula. These fibers join the panniculus carnosus muscle of the forelimb. The remaining fibers insert into the posterior border of the acromion process of the scapula.

Action. This muscle serves to support the scapula and rotate it counterclockwise.

7. Rhomboideus major.

This thin, flat, triangular muscle lies beneath the trapezius muscle complex and connects the scapula with the axial skeleton.

Origin. Fleshy fibers arise from the middorsal line of the cervical area starting just posterior to the external occipital crest and continue posteriorly the full length of the cervical spine into the thoracic area to terminate at the

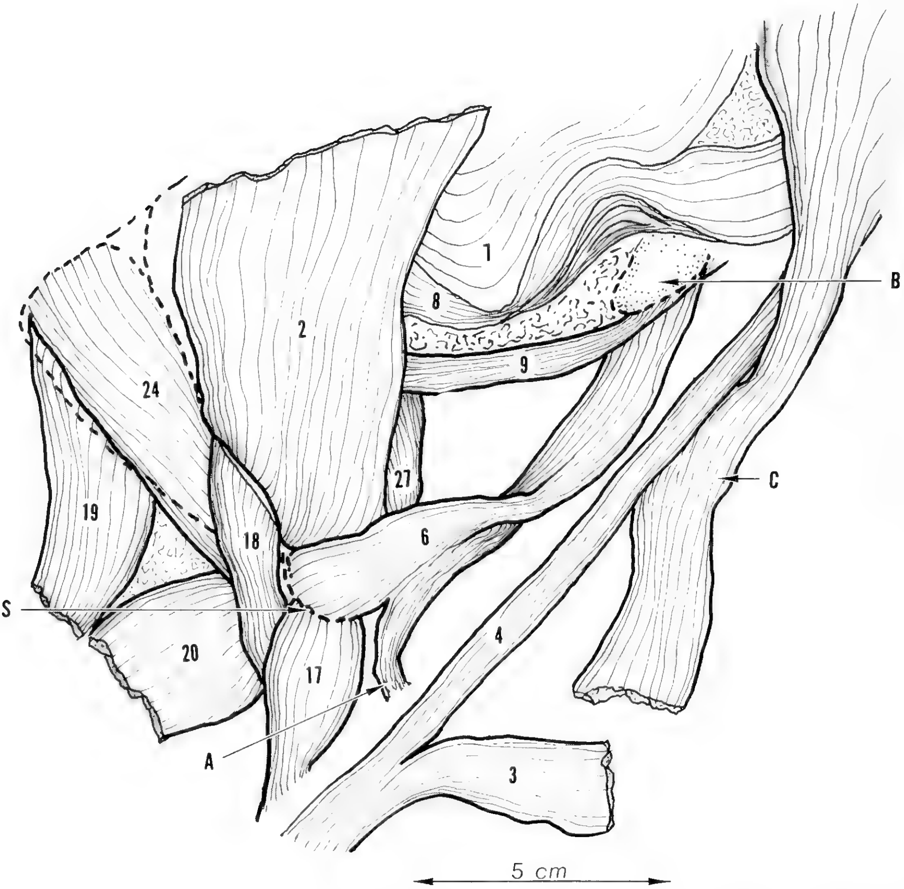

Figure 12. Lateral view of the right shoulder and neck area to show origin and insertion of omotrachlean muscle (levator scapulae ventralis) (6) and its relation to the other muscles in the area. The rhomboideus major (7) and the rhomboideus capitis (8) have been reflected dorsally. The clavotrapezius (3) detached at its origin, is reflected anteriorly for clear exposure of the underlying musculature. The spinotrapezius has been removed. Key: 2, acromiotrapezius; 3, clavotrapezius; 4, cleidomastoideus; 6, omotrachlean (levator scapulae ventralis); 7, rhomboideus major; 8, rhomboideus capitis; 9, rhomboideus profundus; 17, acromiodeltoideus; 18, spinodeltoideus; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 24, infraspinatus; 27, subscapularis; A, to the panniculus carnosus; B, transverse process of first cervical vertebra; C, sternomastoid muscle; S, scapula, acromion process.

dorsal spine of T-3. From its origin the muscle triangulates toward the posterior portion of the vertebral border of the scapula.

Insertion. Fleshy and tendinous fibers insert along the vertebral border of the scapula, starting at the inferior angle and extending anteriorly to the origin of the scapular spine. At this point, a tendinous raphe is formed which

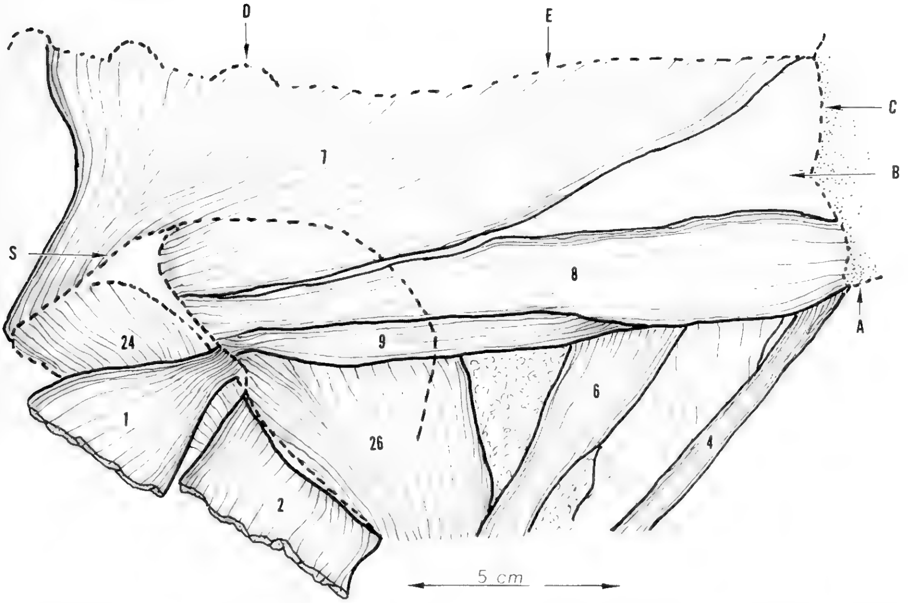

Figure 13. Dorsolateral view of right cervical and scapular to show the rhomboid muscle complex. This group of three muscles, the rhomboideus major (7), capitis (8), and profundus (9), form a sheet-like layer beneath the trapezius muscle group. In this plate the spinotrapezius (1) and the acromiotrapezius (2) have been detached at their origins and reflected ventrally. The clavotrapezius has been removed. As noted from their origins and insertions, these three rhomboid muscles act to support the pectoral girdle drawing it forward and rotating it clockwise. Key: 1, spinotrapezius; 2, acromiotrapezius; 4, cleidomastoideus; 6, omotrachlean (levator scapulae ventralis); 7, rhomboideus major; 8, rhomboideus capitis; 9, rhomboideus profundus; 24, infraspinatus; 25, supraspinatus; A, mastoid process of skull; B, deep cervical musculature; C, lambdoid ridge of skull; D, spinous process of first dorsal vertebra; 5, middorsal line, cervical area; S, outline of scapular.

spans the area of origin of the spine, then joins the remaining fibers to insert along the anterior ridge of origin of the scapular spine. This latter portion overlies and more-or-less joins with the insertion of the rhomboideus capitis.

Action. This muscle pulls the scapula forward as in shrugging the shoulder. It can also rotate the scapula clockwise.

8. Rhomboideus capitis.

The second of the rhomboideus muscle group is a thin, flat, elongated muscle connecting the skull with the scapula. The muscle parallels to a degree the inferior border of the rhomboideus major and underlies the trapezius musculature in this area.

Origin. Arising by fleshy fibers from the lateral one-third of the lambdoidal

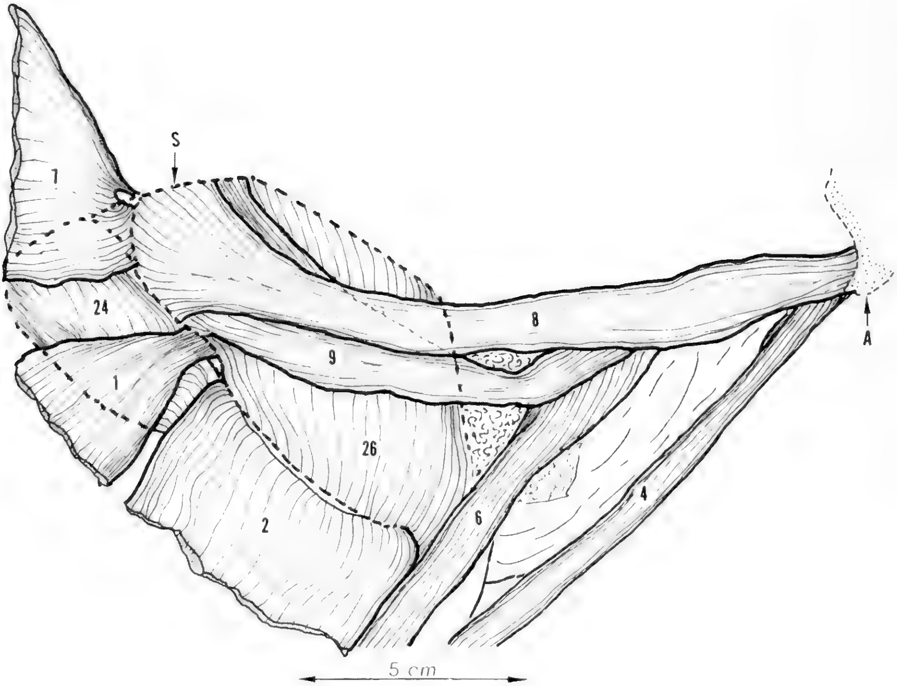

FIGURE 14. Dorsolateral view of cervical and scapular area identical with figure 13 except that the rhomboideus major (7) has been detached from its origin and reflected posteriorly at its insertion. The origin and insertion of the rhomboideus capitis (8) is shown. Key: 1, spinotrapezius—reflected; 2, acromiotrapezius—reflected; 4, cleidomastoideus; 6, omotrachlean; 7, rhomboideus major—reflected; 8, rhomboideus capitis; 9, rhomboideus profundus; 24, infraspinatus; 26, supraspinatus; A, mastoid process of the skull; S, outline of scapula.

crest and the jugular process of the skull, the muscle courses inferiorly to pass over the supraspinatus fossa of the scapula where it widens in a flare-type manner terminating in a thin, flat, tendinous, sheath.

INSERTION. This flat, thin tendon inserts along the spine of the scapula more or less fusing with the tendon of the rhomboideus major but also continues its insertion along the vertebral margin of the scapula superiorly approximately two-thirds of the distance to the first angulation of this margin.

ACTION. The muscle draws the scapula forward and acts to rotate the scapula clockwise.

9. **Rhomboideus profundus.**

The third and deepest of the rhomboid muscles underlies, for the most part, the rhomboideus capitis and connects the spine to the scapula.

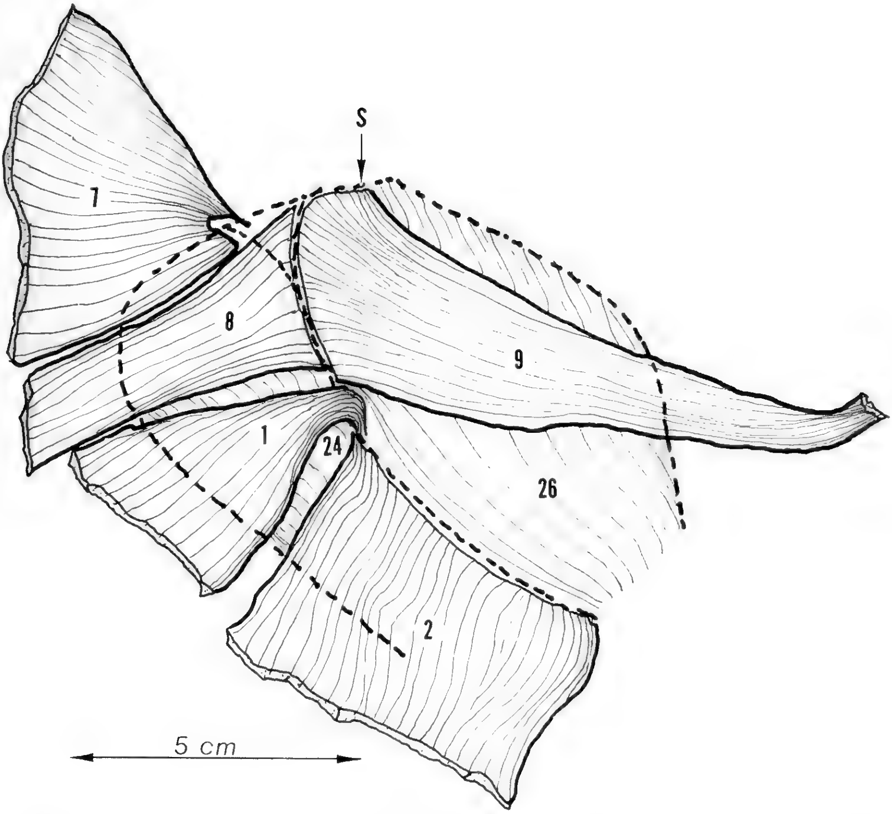

Figure 15. Lateral view of right scapula. The rhomboideus major (7) and the rhomboideus capitis (8) have been reflected posteriorly to show the detail of insertion of the rhomboideus profundus (9) on the scapula. Again, the spinotrapezius (1) and the acromiotrapezius (2) have been reflected as in the previous plate. Key: 1, spinotrapezius—reflected; 2, acromiotrapezius—reflected; 7, rhomboideus major—reflected; 8, rhomboideus capitis—reflected; 9, rhomboideus profundus; 24, infraspinatus; 26, supraspinatus; S, outline of scapula.

Origin. This muscle arises by fleshy fibers from the inferior surface of the transverse process of C-1 vertebra overlying the origin of the omotrachleon muscle. From this point the strap-type muscle passes obliquely inferiorly to underlie the rhomboideus capitis as it reaches the scapula area. Near its insertion the muscle spans out ending in a thin tendinous sheath in a manner similar to the rhomboideus capitis.

Insertion. The tendon of the rhomboideus profundus inserts with that of the rhomboideus capitis but extends more superiorly along the vertebral margin of the scapula to the first angulation of the vertebral border.

Action. This muscle's action is the same as that of the rhomboideus capitis, drawing the scapula forward and rotating it clockwise.

10. Serratus magnus.

This large, flat, interdigitated muscle connects the rib cage with the vertebral margin of the scapula, and is the posterior portion of a common suspensory sheet of muscle which includes superiorly the levator anguli scapulae. The muscle is best observed as the vertebral margin of the scapula is spread out from the rib cage.

Origin. Arising by fleshy digitations from ribs 1 to 6; starting on rib 1 near the spine the origin continues in an oblique line to rib 6 at about the level of the midlateral line of the chest. The muscle triangulates from its origin toward the vertebral margin of the scapula and, in doing so, the digitation is joined into a flat muscular sheath, the superior margin of which becomes continuous with the levator anguli scapulae.

Insertion. The serratus magnus portion of this muscle sheath inserts on the vertebral margin of the scapula starting at the inferior angle and extending superiorly to the level of origin of the scapular spine where it joins the levator anguli scapulae. The insertion is deep to that of the rhomboideus major.

Action. This muscle acts to hold the scapula against the chest wall and serves to suspend the trunk in weight bearing. It can also move the scapula in the line of its fibers.

11. Levator anguli scapulae.

This muscle is, in effect, the superior continuation of the serratus magnus and connects the cervical spine to the scapula.

Origin. Fleshy fibers arise from the transverse processes and intervening fascia of C-3 to C-7. A sheet of muscle is formed which triangulates toward the vertebral margin of the scapula. The inferior border approximates the superior border of the serratus magnus distally to form a common muscle.

Insertion. The levator anguli scapulae portion of the muscle sheath inserts superiorly to the serratus magnus in a similar manner along the vertebral margin of the scapula from the origin of the scapular spine halfway to the superior angle of the scapula.

Action. In view of the muscle's more dorsal origin, the action is to suspend the scapula and rotate the scapula clockwise. It also assists the serratus magnus muscle in holding the vertebral margin of the scapula to the chest wall.

12. Pectoantebrachialis.

This muscle is the most superficial of the pectoral muscle group. It is a large, strong, triangular muscle connecting the trunk to the forearm.

Figure 16. Dorsal view of right-shoulder area. The trapezius muscles have been removed. The rhomboideus major (7) is shown reflected outward from the vertebral margin of the scapula. The scapula has been spread outward from the body to disclose the serratus magnus (10) and the levator anguli scapulae (11) muscles. These broad, flat but thick and strong muscles act as a sling support for the trunk between the forelimbs. The two muscles form a common and continuous muscle sheath, their division being based on the site of origin, the levator anguli scapulae (11) from the cervical area, serratus magnus (10) from the rib cage. Key: 7, rhomboideus major—reflected; 10, serratus magnus; 11, levator anguli scapulae; 27, subscapularis; A, fifth rib; B, deep cervical musculature; C, middorsal line cervical area; D, transverse process of third cervical vertebra; S, scapula, vertebral margin.

Origin. Fleshy fibers arise from the superior part of the sternum starting at the upper border of the manubrium and reaching to between ribs 1 and 2. The muscle then courses obliquely inferiorly over the pectoral musculature toward the anterior cubital area where the muscle converges and, joined by

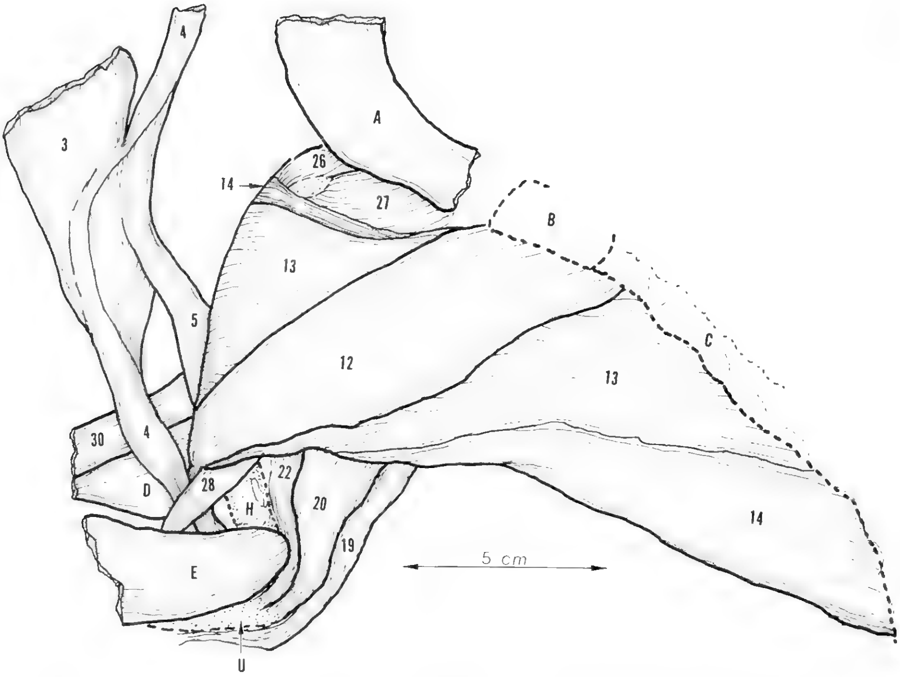

Figure 17. Anterior view of the right humerus and upper chest with the forelimb rotated externally. The cleidomastoideus (4) and clavotrapezius (3) are reflected laterally. The sternomastoid muscle (A) is detached at its insertion and reflected superiorly. The pectoral muscle complex is thus revealed. This complex consists of three flat, thick, and strong muscles arising from the anterior upper chest, connecting the trunk to the upper extremities. The most superficial is the pectoantebrachialis (12) which overlies the pectoralis major (13), which in turn overlies the pectoralis minor (14). This strong muscle group flexes and internally rotates the humerus. In addition, action of the pectoantebrachialis (12) is to assist in flexion of the elbow. Further detail of the relationship of these three muscles is shown in figures 18, 19, and 20. Key: 3, clavotrapezius—reflected; 4, cleidomastoideus—reflected; 5, clavobrachialis—reflected; 12, pectoantebrachialis; 13, pectoralis major; 14, pectoralis minor; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 22, triceps brachii caput medialis; 26, supraspinatus; 28, biceps brachii; 30, brachioradialis; A, sternocleidomastoid muscle—reflected; B, sternum, manubrium; C, sternum, corpus; D, extensor muscles of the forearm; E, flexor muscles of the forearm; H, humerus; U, ulna.

fibers from both the cleidomastoideus laterally and pectoralis major medially, forms a strong tendon.

Insertion. Passing deep to the tendon of insertion of the biceps, the heavy tendon of the pectoantebrachialis inserts on the medial ridge of the ulna at the conoid process just distal to the joint surface.

Action. Strong flexion of the elbow is accomplished plus assistance in flexion of the humerus.

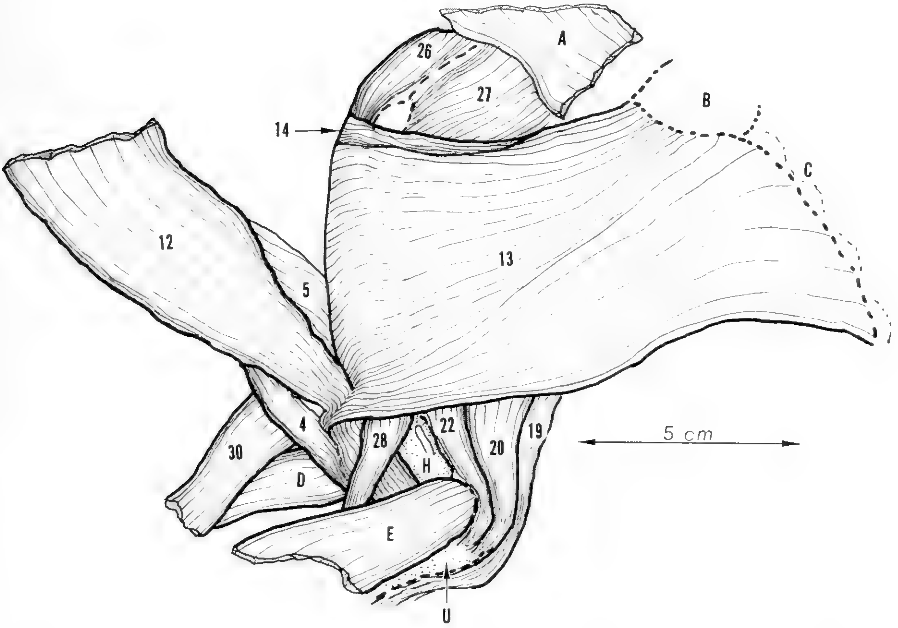

Figure 18. Anterior view of the right upper chest and humerus with the forelimb rotated externally. This is essentially the same view as figure 17 but with the pectoantebrachialis (12) reflected laterally to show the pectoralis major (13) and the lower fibers of the muscle joining with the pectoantebrachialis (12) which in turn joins the cleidomastoideus (4) for common insertion into the proximal ulna. The lower part of the pectoralis minor has been omitted in this drawing. Key: 4, cleidomastoideus; 5, clavobrachialis; 12, pectoantebrachialis—reflected; 13, pectoralis major; 14, pectoralis minor; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 22, triceps brachii caput medialis; 26, supraspinatus; 28, biceps brachii; 30, brachioradialis; A, sternocleidomastoid—reflected; B, sternum, manubrium; C, sternum, corpus; D, extensor muscles of forearm; E, flexor muscles of forearm; H, humerus; U, ulna.

13. **Pectoralis major.**

This strong, broad, rhomboid muscle of the pectoral group underlies the pectoantebrachialis and connects the sternum to the humerus. The muscle is heaviest superiorly.

Origin. There is a continuous origin of fleshy fibers from the top of the manubrium to the fourth rib level inferiorly. This forms the base of the muscle which then continues transversely as a broad sheet to the humerus. In so doing, the muscle overlies the pectoralis minor and bridges the anterior chest. Short thin tendinous fibers develop on the underside as the humerus is approached.

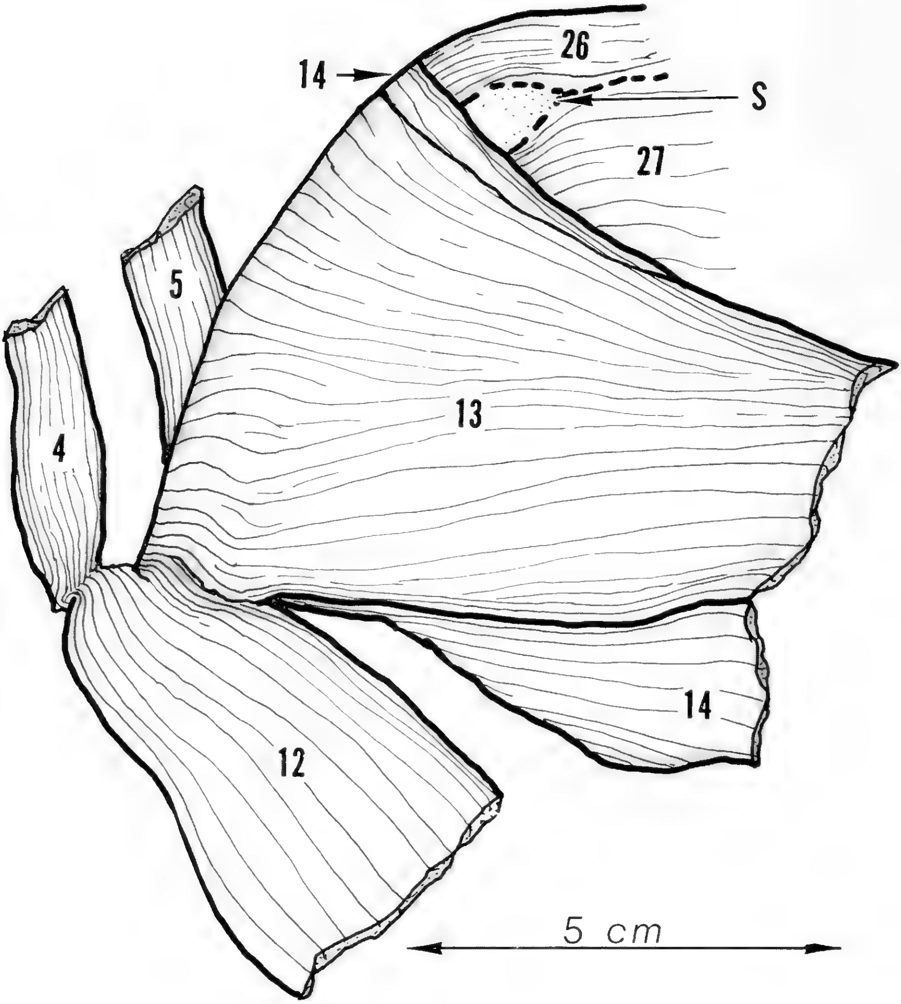

FIGURE 19. An anterior view of the right shoulder and upper arm musculature in a limited area. The pectoantebrachialis (12) has been detached from its origin and reflected inferiorly to show its contribution of muscle fibers to the pectoralis major (13) near its distal insertion on the humerus, and also the joining of the cleidomastoideus (4) with the pectoantebrachialis (12) to form a common tendon. Key: 4, cleidomastoideus; 5, clavobrachialis; 12, pectoantebrachialis; 13, pectoralis major; 14, pectoralis minor; 26, supraspinatus; 27, subscapularis; S, scapula, supraglenoid area of superior border.

INSERTION. The insertion of this muscle extends practically the entire length of the humerus, starting superiorly at the greater tuberosity at the margin of insertion of the supraspinatus tendon and extending distally along the lateral side of the pectoral ridge and humeral crest to the cubital fossa area.

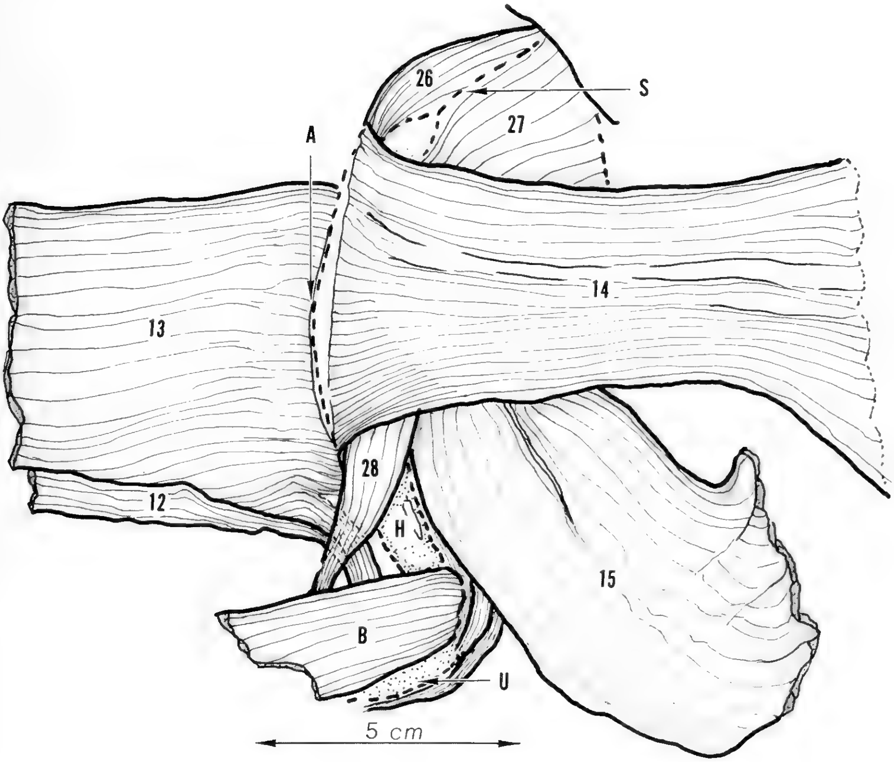

FIGURE 20. Anterior view of right shoulder area with the forelimb adducted and externally rotated. The pectoantebrachialis (12) and the pectoralis major (13) have been detached from their origins and reflected laterally, thus exposing the insertion of the underlying pectoralis minor (14). With adduction of the forelimb the latissimus dorsi (15) comes into view and overlies the triceps muscle group. Note raphe-type insertion of the upper part of the pectoralis major (13). Also shown are the pectoralis major (13) fibers joining the pectoantebrachialis (12). Key: 12, pectoantebrachialis; 13, pectoralis major; 14, pectoralis minor; 15, latissimus dorsi; 26, supraspinatus; 27, subscapularis; 28, biceps brachii; A, raphe-type insertion of pectoralis major; B, forearm flexor musculature; H, humerus; S, scapula, superior margin; U, ulna.

At the upper end, a tendinous raphe is present, and at the lower end some fleshy and tendinous fibers join the pectoantebrachialis muscle.

ACTION. This muscle is a strong flexor and internal rotator of the humerus, and it also assists in adduction of the forelimb.

14. **Pectoralis minor.**

This deepest muscle of the pectoral group underlies the pectoralis major and joins the trunk to the humerus.

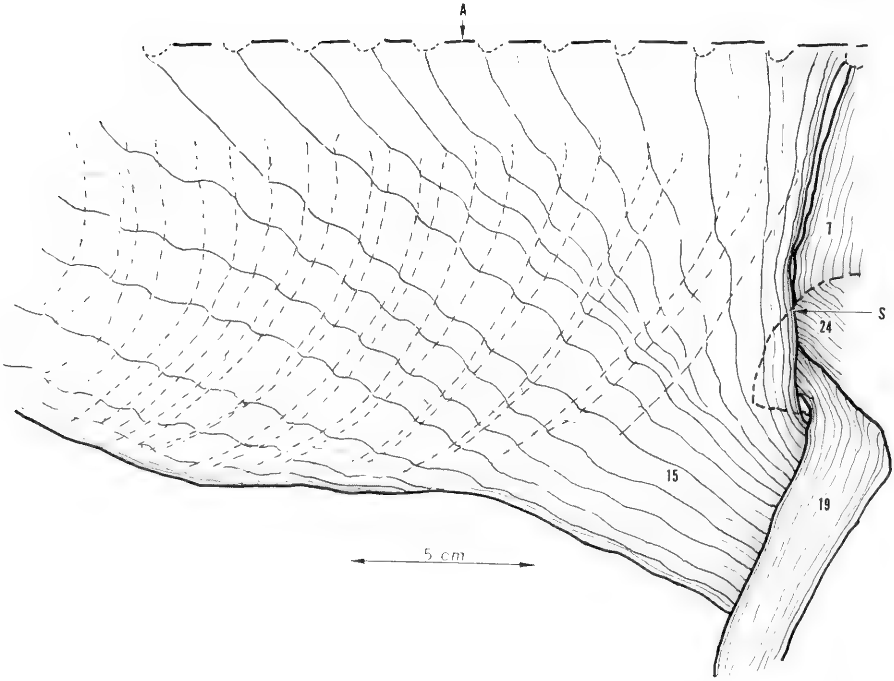

FIGURE 21. Lateral view of right thoracic and shoulder area to show origin of large and strong latissimus dorsi (15) muscle from the trunk, and its relation to the scapula and adjacent musculature. The spinotrapezius muscle which overlies the dorsal and anterior area of the latissimus dorsi (15) has been removed. Key: 7, rhomboideus major; 15, latissimus dorsi; 19, dorsoepitrochlearis; 24, infraspinatus; A, spinous process of eighth dorsal vertebra; S, outline of scapula.

ORIGIN. Arising by fleshy fibers from the border of the sternum, rib levels 2 to 7, this thin flat rectangular muscle courses toward the humerus under the pectoralis major and over the biceps muscle. There is a tendency towards clefting of the muscle in its upper part between ribs 2 and 3. Near the humerus a broad thin tendon develops.

INSERTION. The tendon inserts on the humerus just medial and parallel to the pectoralis major along the length of the pectoral ridge. The uppermost and more fleshy fibers insert on the greater tuberosity of the humerus just medial to the tendon of insertion of the supraspinatus. At the lower or most distal end the tendon is joined by fleshy and tendinous fibers of the anterior half of the split latissimus dorsi muscle for common insertion.

ACTION. Along with the pectoralis major this muscle flexes, internally rotates, and adducts the humerus.

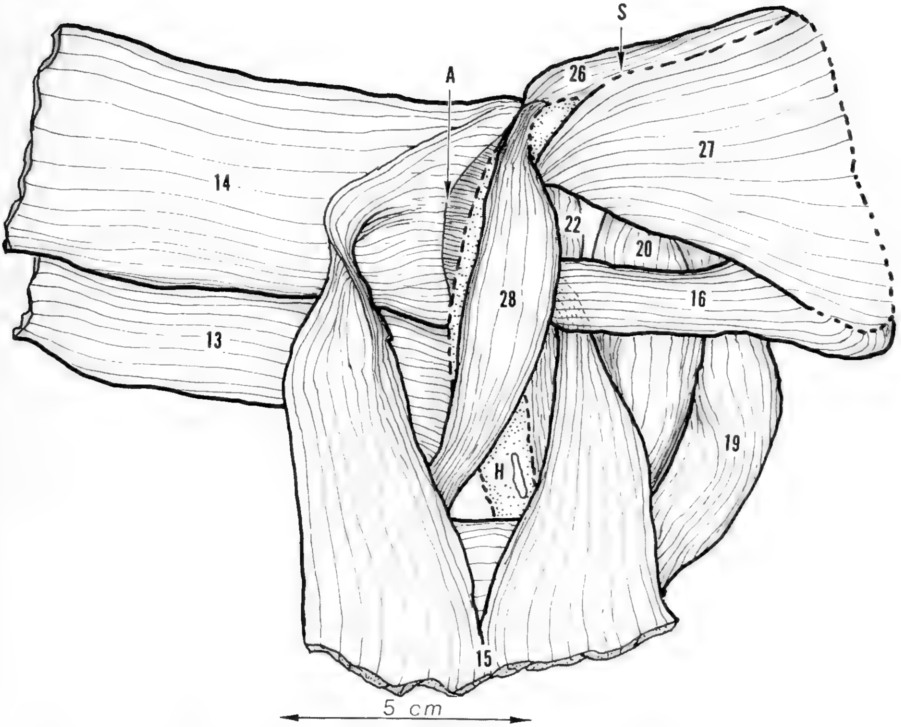

FIGURE 22. Anterior view of the right shoulder and humerus with the upper extremity in external rotation. The pectoral muscles (13) and (14) are reflected laterally exposing the biceps brachii (28) and the teres major (16). The biceps brachii is displaced a bit laterally. The latissimus dorsi (15) is now viewed as the two halves reach their insertion on the humerus. A common tendon of insertion is formed with the teres major and the pectoralis major. Key: 13, pectoralis major; 14, pectoralis minor; 15, latissimus dorsi; 16, teres major; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 22, triceps brachii caput medialis; 26, supraspinatus; 27, subscapularis; 28, biceps brachii; A, tuberosity of the humerus; H, humerus, S, scapula, superior margin.

15. Latissimus dorsi.

This is a large, flat, strong muscle, triangular in shape, covering most of the thorax from T-3 to T-12 and joining the trunk to the humerus.

ORIGIN. Arising by fleshy fibers from the middorsal line and spinous processes from T-3 to T-9 and then from the lumbar fascia to T-12 level inferiorly and ribs 10 and 11 level midlaterally. This large sheetlike muscle triangulates toward the inferior angle of the scapula, which it crosses to disappear under the dorsoepitrochlearis. At about this point the muscle divides into a dorsal, or proximal, two-fifths and a ventral, or distal, three-fifths, but both divisions con-

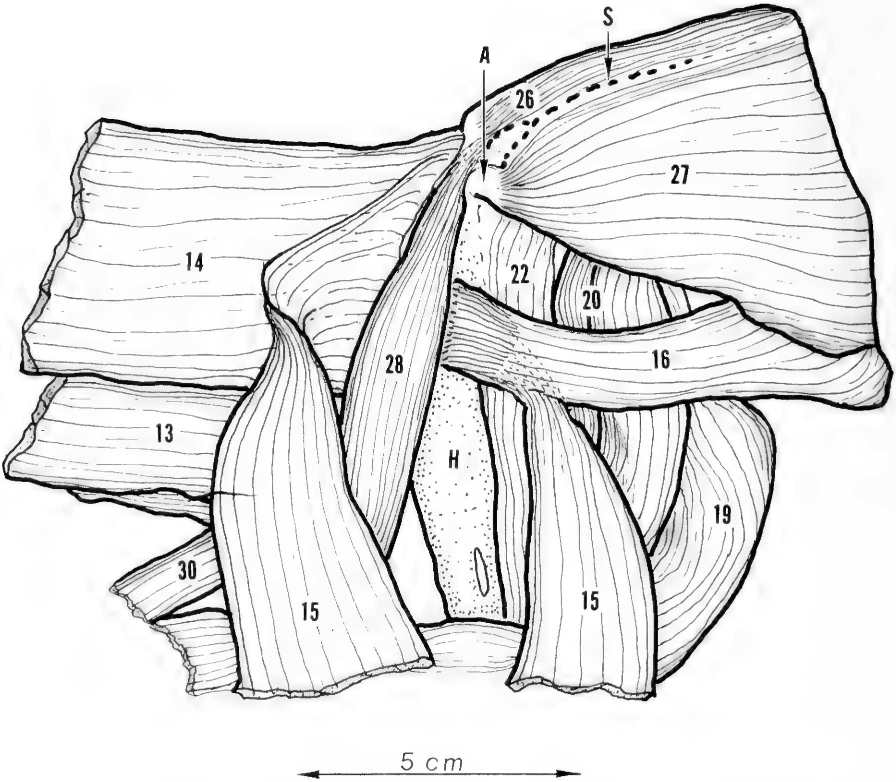

FIGURE 23. Anterior view of the right shoulder and humerus with upper extremity in external rotation. This is essentially the same view as in figure 22 except that the biceps brachii (28) is now displaced medially to disclose the detail of insertion of that portion of the latissimus dorsi (15) which joins the pectoralis minor (14). The pectoral muscles (13) and (14) are again reflected laterally. Key: 13, pectoralis major; 14, pectoralis minor; 15, latissimus dorsi; 16, teres major; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 22, triceps brachii caput medialis; 26, supraspinatus; 27, subscapularis; 28, biceps brachii; A, tendon fibers begin here; H, humerus; S, scapula, superior border.

tinue under the triceps musculature to gain access to the medial side of the humerus.

INSERTION. At this point, the proximal two-fifths portion narrows and flattens into a tendon which passes between the biceps brachii and the humerus to join that of the teres major for a common insertion on the humerus along the pectoral ridge and just under the insertion of the pectoralis minor. The distal three-fifths of the muscle passes as fleshy fibers anterior to the biceps brachii, then, spreading into flat tendinous fibers, joins the deep side of the tendon of the pectoralis minor for a common insertion with this tendon.

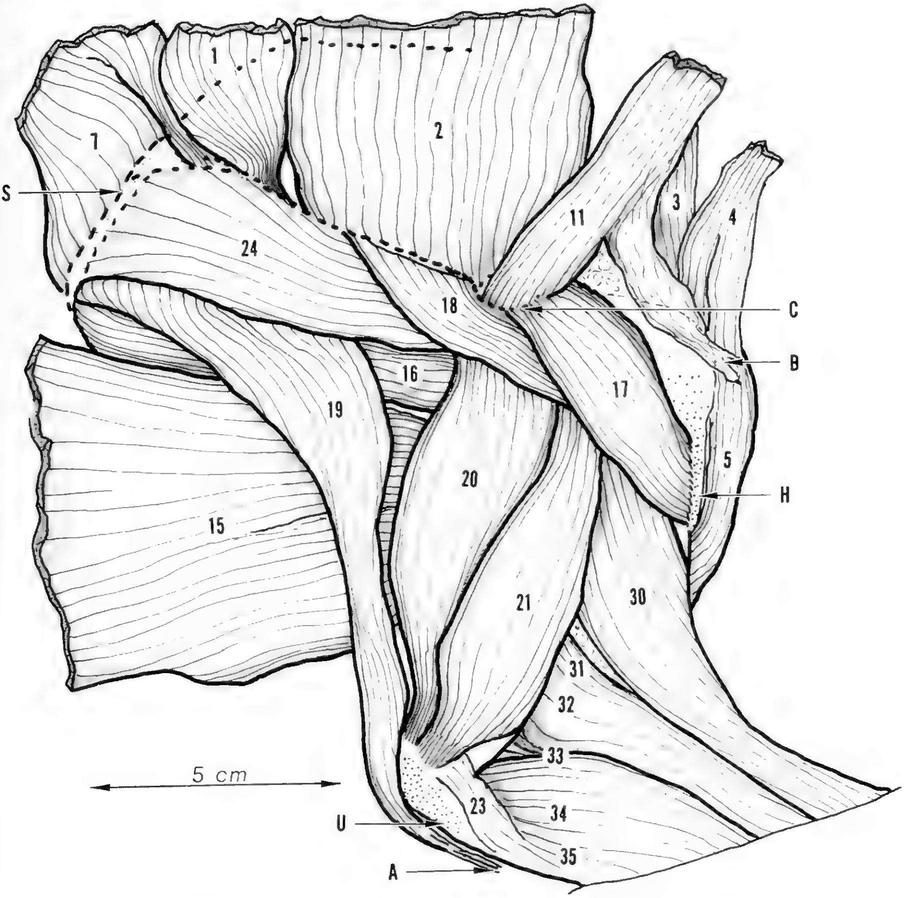

FIGURE 24. Lateral view of the right shoulder and forelimb. The relationship of the acromiodeltoideus (17) and the spinodeltoideus (18) is shown. Also, the insertion of the levator anguli scapulae (11) on the acromion process of the scapula is seen. The clavobrachialis (5) has been reflected anteriorly to show its tendinous insertion on the humerus. The relationship of the other muscles in this lateral view is to be noted. Key: 1, spinotrapezius; 2, acromiotrapezius; 3, clavotrapezius; 4, cleidomastoideus; 5, clavobrachialis; 7, rhomboideus major; 11, levator anguli scapulae; 15, latissimus dorsi; 16, teres major; 17, acromiodeltoideus; 18, spinodeltoideus; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 21, triceps brachii caput lateralis; 23, anconeus externus; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor carpi ulneris; A, forearm fascia; B, panniculus carnosa; C, scapula, acromion process; H, humerus; U, ulna; S, scapula, vertebral border.

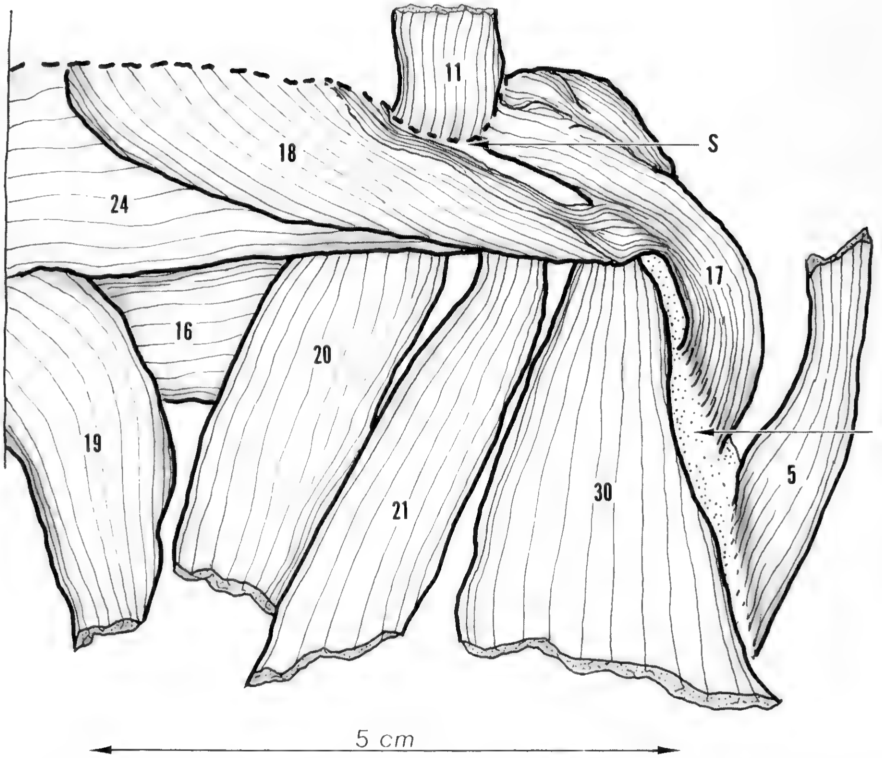

FIGURE 25. Enlarged localized lateral view of the right shoulder area to show detail of spinodeltoideus (18) joining acromiodeltoideus (17) to gain insertion on the humerus. To show this adequately the acromiodeltoideus (17) has been rotated anteriorly, thus exposing the undersurface where the juncture of the two muscles occurs. Key: 5, clavobrachialis; 11, levator anguli scapulae; 16, teres major; 17, acromiodeltoideus; 18, spinodeltoideus; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 21, triceps brachii caput lateralis; 30, brachioradialis; H, humerus; S, scapula, acromion process.

ACTION. This muscle is a strong extensor and internal rotator of the humerus.

16. Teres major.

This short but strong muscle connects the inferior border of the scapula with the humerus.

ORIGIN. Muscle fibers arise from the inferior angle and dorsal one-half of the inferior border of the scapula with some tendinous fibers from the fascia overlying the infraspinatus muscle in this area to form a somewhat cone-shaped muscle paralleling the inferior scapular border passing directly toward the hu-

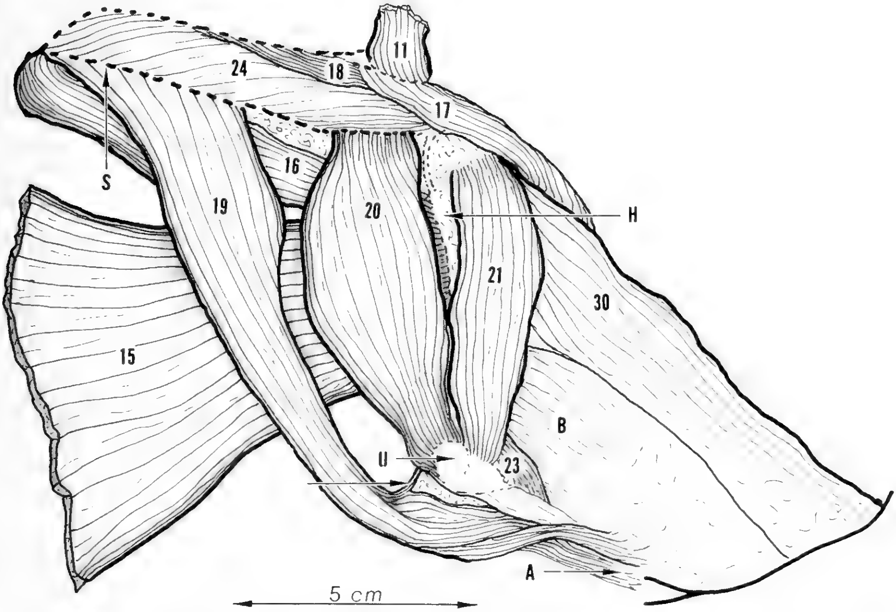

FIGURE 26. The triceps muscle complex is a group of strong muscles arising from the scapula or humerus with insertion on the olecranon process of the ulna to give extension of the elbow joint. The triceps musculature proper consists of the triceps brachii caput longus (20), lateralis (21), and medialis (22). The caput medialis has basically three divisions, having a somewhat complicated configuration and relationship to the caput lateralis (see figure 27). This triad of muscles is reinforced by the large dorsoepitrochlearis (19) which, due to its site of origin from the scapular margin, is responsible for the posterior webbing between the humerus and the scapula. Also, the small anconeus externus (23) is an accessory to this group (see figure 29).

This figure is a posterolateral view of the upper right extremity to show detail of the triceps brachii caput longus (20) and lateralis (21), and the dorsoepitrochlearis (19). Note a few tendon fibers (C) from the dorsoepitrochlearis (19) joining the tendon of the triceps brachii caput longus (20). Key: 11, levator anguli scapulae; 15, latissimus dorsi; 16, teres major; 17, acromiodeltoideus; 18, spinodeltoideus; 19, dorsoepitrochlearis; 20, triceps brachii caput longus; 21, triceps brachii caput lateralis; A, deep fascia of the forearm; B, forearm extensor musculature; C, tendon fibers, from (19) entering tendon of (20); H, humerus; S, outline of scapula, axillary border; U, ulna, olecranon process.

merus. Near the humerus the muscle is joined by muscle and tendon fibers of the superior portion of the latissimus dorsi. A flat strong tendon forms which passes under the biceps brachii.

INSERTION. This tendon now inserts into the humerus on the medial side and nearly parallel to the insertion of the pectoralis minor.

ACTION. Adduction and internal rotation of the humerus is accomplished by this muscle.

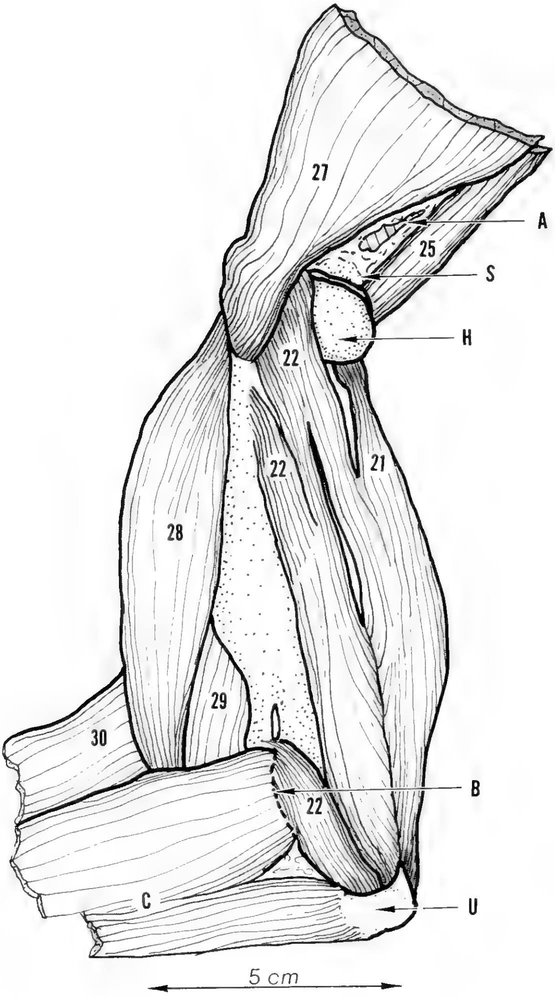

Figure 27. Medial view of the right forelimb and shoulder area with the forelimb in full external rotation to show the triceps brachii caput medialis (22), its various parts, and their relationships to each other and to the caput lateralis (21). The caput longus (20) of the triceps has been completely removed. The biceps brachii (28) is displaced anteriorly to visualize the deeper triceps brachii caput medialis (22).

Note the three (22) labels which mark the three parts of the medial head. The upper (22) label is the intermediate part (anconeus internus). The middle (22) label is the long part (anconeus medialis). The lower (22) label is the medial part (anconeus medialis). Key: 21, triceps brachii caput lateralis; 22, triceps brachii caput medialis; 25, teres minor; 27, subscapularis; 28, biceps brachii; 29, brachialis; 30, brachioradialis; A, site of origin of triceps brachialis, caput longus; B, medial epicondylar ridge of humerus; C, forearm flexor musculature; H, humerus, articular surface of head; S, scapula, infraglenoid area; U, ulna, olecranon process.

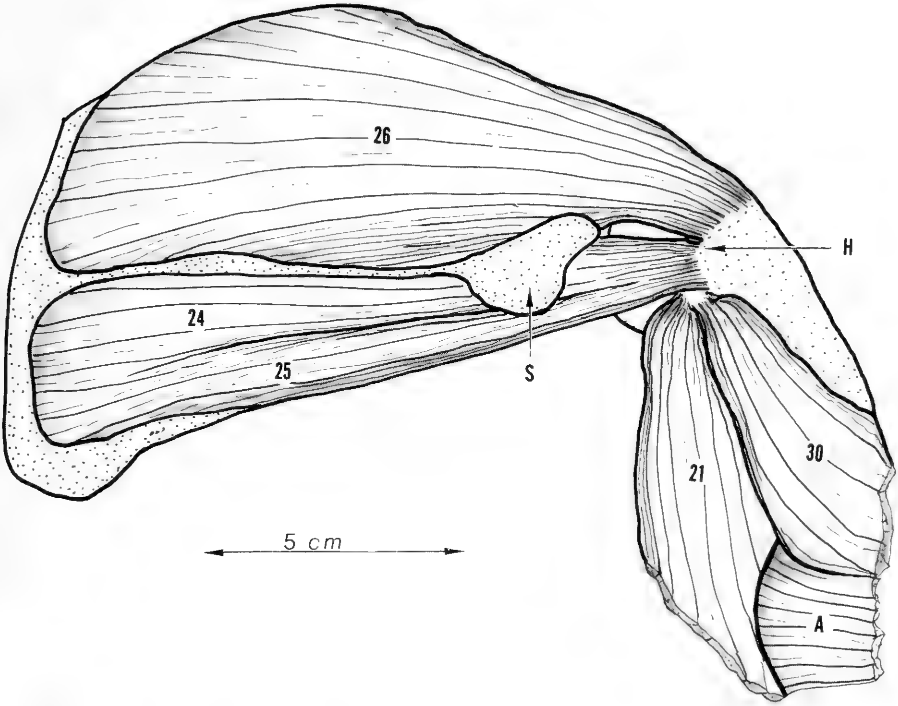

Figure 28. The shoulder cuff muscles of the scapula consist of the subscapularis (27), supraspinatus (26), infraspinatus (24), and teres minor (25). All four of these muscles arise from the surface of the scapula and terminate in a tendinous cuff about the shoulder which inserts on the humerus, stabilizing and activating this joint. The tendons are intimately associated with the shoulder joint capsule.

This right lateral view of the scapula and shoulder area has all muscles removed that attach to the scapula except for those arising from the scapular fossae (lateral surface). Key: 21, triceps brachii caput lateralis; 24, infraspinatus; 25, teres minor; 26, supraspinatus; 30, brachioradialis; A, extensor musculature of the forearm; H, humerus, greater tuberosity; S, scapula, acromion process.

17. Acromiodeltoideus.

Joining the scapula to the humerus, this small but stout triangular muscle overlies the point of the shoulder.

Origin. From the full width of the most distal margin of the acromion process muscle fibers arise on the undersurface and tendinous fibers on the outer surface to form a short muscle which then passes over the lateral aspect of the shoulder joint to the upper humerus.

Insertion. With tendinous fibers developing on the undersurface but fleshy fibers persisting on the outer surface, the muscle inserts into the distal area of the deltoid ridge after first receiving the tendinous and the fleshy fibers

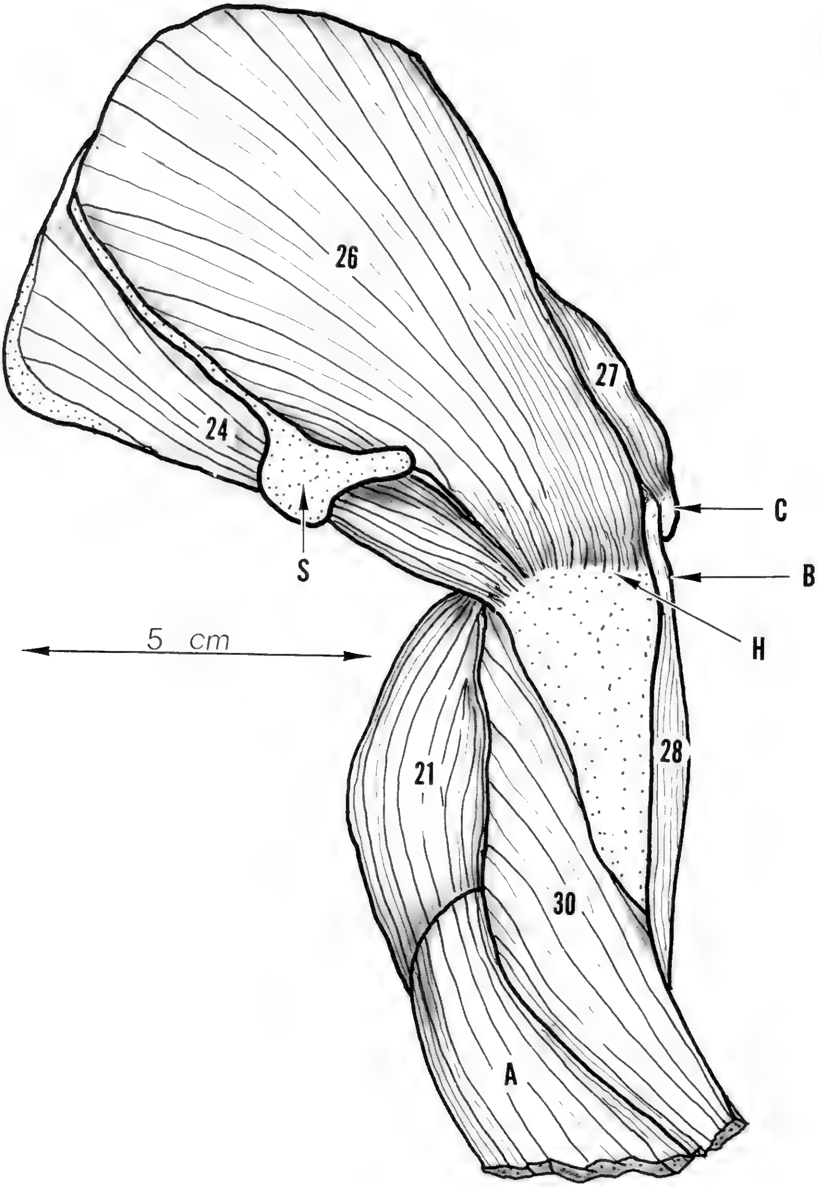

FIGURE 29. Anterolateral view of the right scapula and shoulder to show the detail of insertion of the supraspinatus (26) in relation to the bicipital groove and infraspinatus (24) and subscapularis (27) muscles. Key: 21, triceps brachii caput longus; 24, infraspinatus; 26, supraspinatus; 27, subscapularis; 28, biceps brachii; 30, brachioradialis; A, extensor musculature of the forearm; B, biceps brachii tendon in bicipital groove of humerus; C, humerus, lesser tuberosity; H, humerus, greater tuberosity; S, scapula, acromion process.

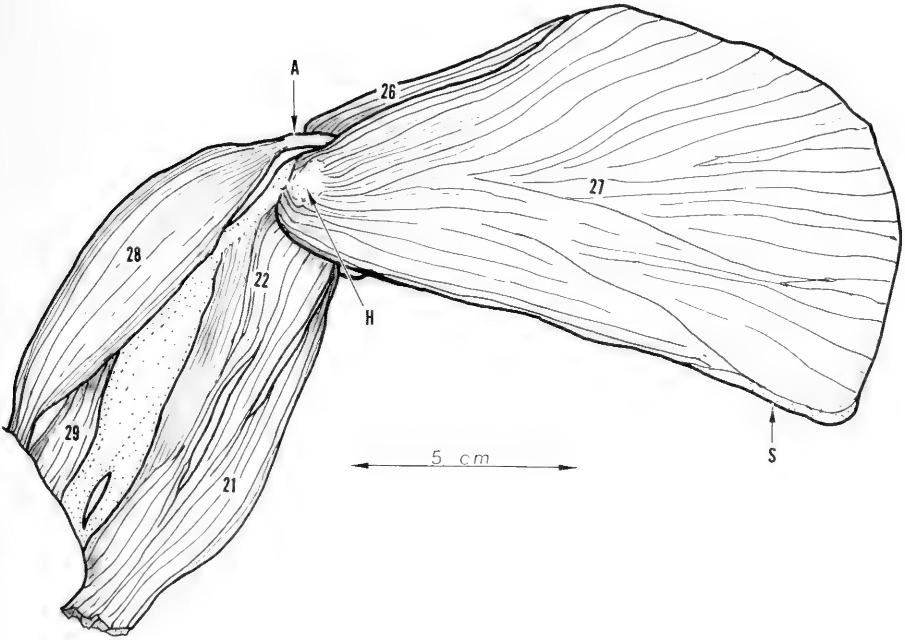

Figure 30. Medial view of the right scapula and shoulder to show the detail of subscapularis muscle (27). The biceps brachii (28) has been displaced somewhat anteriorly and the upper tendon lifted out of the bicipital groove of the humerus. Key: 21, triceps brachii caput lateralis; 22, triceps brachii caput medialis; 26, supraspinatus; 27, subscapularis; 28, biceps brachii; 29, brachialis; A, biceps brachii tendon out of bicipital groove; H, humerus, lesser tuberosity; S, scapula, axillary border.

of the spinodeltoideus muscle. The insertion is linear between the insertion of the pectoralis muscles and the origin of the brachioradialis.

Action. This muscle can abduct the humerus and possibly give slight external rotation as well.

18. **Spinodeltoideus.**

This small triangular muscle joins the spine area of the scapula to the humerus via the acromiotrapezius and courses with convergence toward the acromiodeltoideus muscle.

Insertion. Both fleshy and tendinous fibers join the undersurface of the acromiodeltoideus and proceed to a common insertion with this muscle on the humerus just proximal to the insertion of the clavobrachialis.

Action. Acting with the acromiodeltoideus some degree of abduction, extension, and external rotation of the humerus is accomplished.

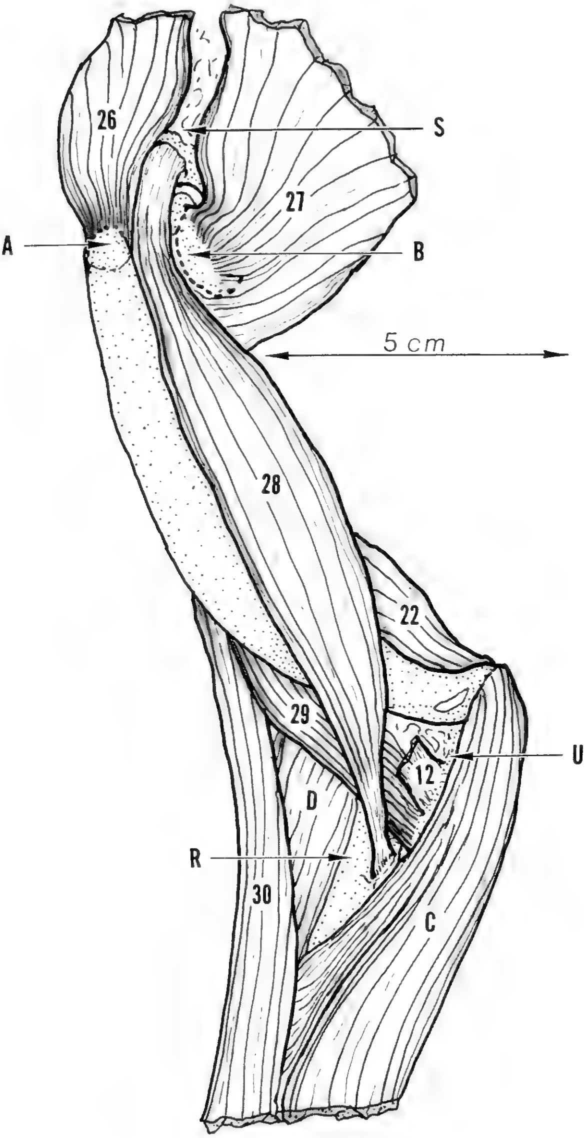

FIGURE 31. Anteromedial view of the right forelimb to show origin and insertion of the biceps brachii muscle (28). The supraspinatus muscle (26) and the subscapularis muscle (27) have been retracted sufficiently to disclose the upper border of the glenoid. The pectoantebrachialis (12) has been excised near its insertion. Key: 12, pectoantebrachialis; 22, triceps brachii caput medialis; 26, supraspinatus; 27, subscapularis; 28, biceps brachii; 29, brachialis; 30, brachioradialis; A, greater tuberosity of the humerus; B, lesser tuberosity of the humerus; C, forearm flexor musculature; D, forearm extensor musculature; S, scapula, supraglenoid area; R, radius; U, ulna.

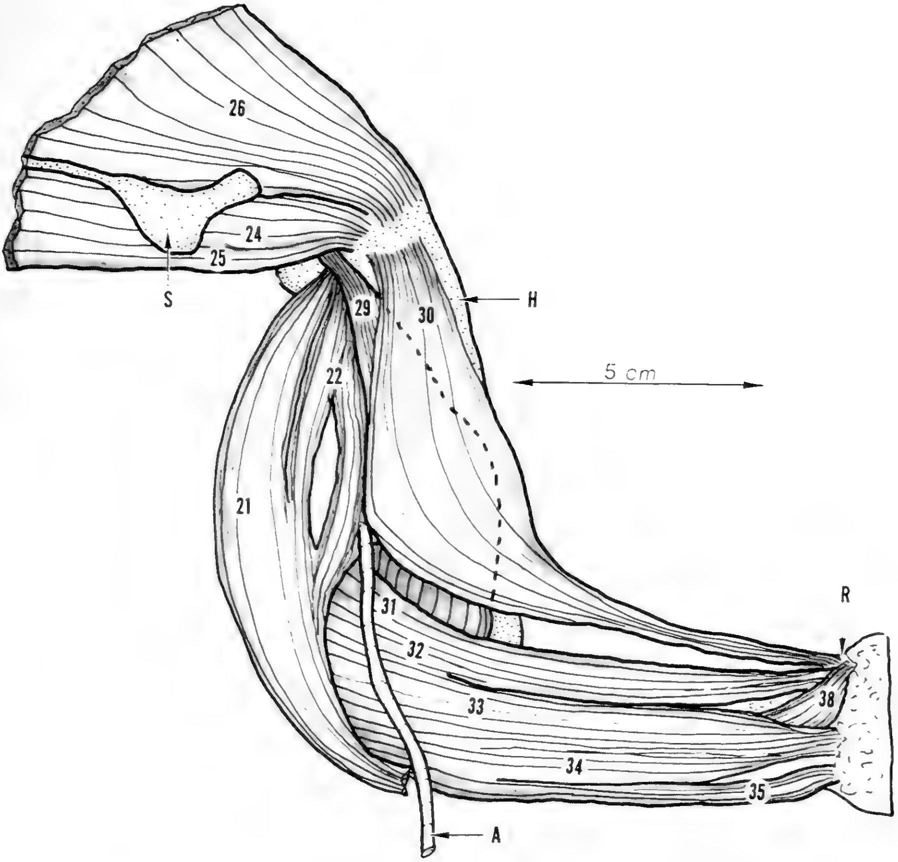

FIGURE 32. Lateral view of the right upper extremity to show the brachialis and the brachioradialis muscles. The triceps mechanism has been displaced posteriorly somewhat and the more superficial muscles of the upper arm and shoulder area have been removed. The superficial sensory branch of the radial nerve is shown displaced from its normal position between the brachioradialis (30) and the radial wrist extensors (31) (32). Key: 21, triceps brachii caput lateralis; 22, triceps brachii caput medialis; 24, infraspinatus; 25, teres minor; 26; supraspinatus; 29, brachialis; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor digitorum ulnaris; A, radial nerve; H, humerus; R, radius (radial styloid); S, scapula, acromion process.

19. **Dorsoepitrochlearis.**

This strong, somewhat flat and triangular, fleshy muscle connects the scapula to the forearm on the extensor surface, thus becoming a functional part of the triceps muscle complex.

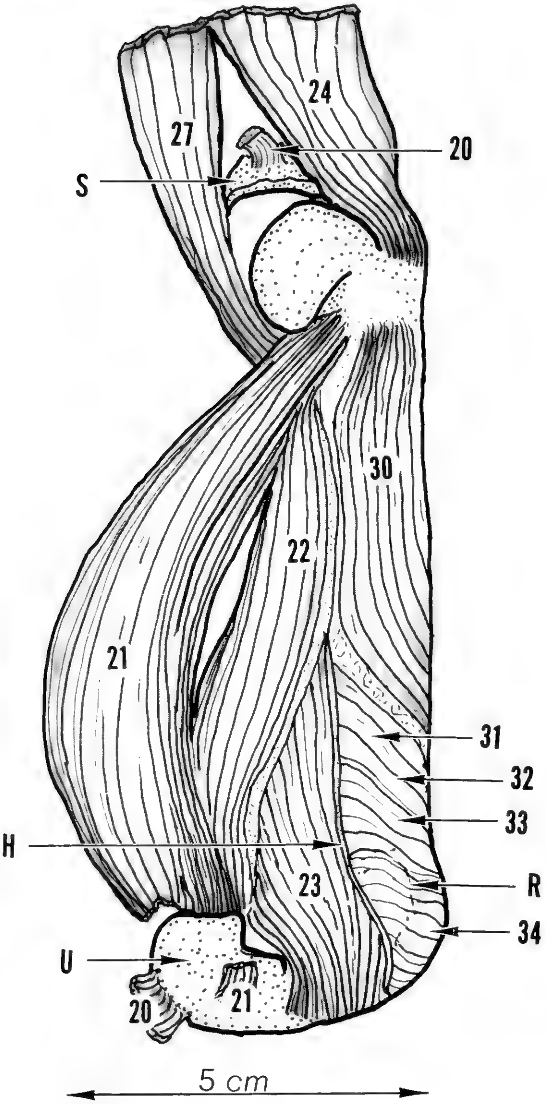

FIGURE 33. Posterior view of the right upper arm to show origin and insertion of anconeus externus (23). Triceps brachii caput lateralis (21) has been detached near its insertion and displaced medialward. The triceps brachii caput longus (20) has been removed except for its tendon of origin and insertion. The scapula is located presenting the axillary border. Key: 20, triceps brachii caput longus; 21, triceps brachii caput lateralis; 22, triceps brachii caput medialis; 23, anconeus externus; 24, infraspinatus; 27, subscapularis; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; H, humerus, lateral epicondylar crest; R, radius, radial head outline; S, scapula, infraglenoid area; U, ulna, olecranon process.

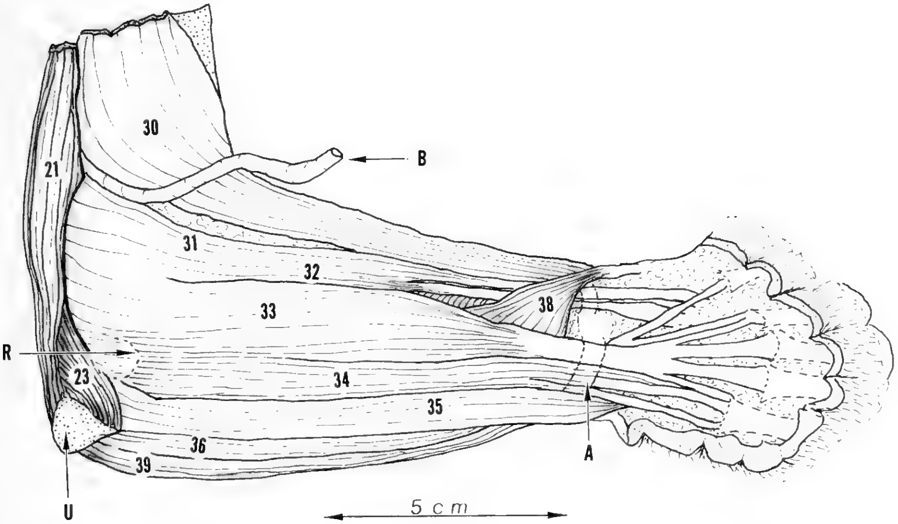

Figure 34. Lateral view of right forearm and elbow area to show relationship of the superficial dorsal musculature. Note the transverse dorsal carpal ligament at wrist level (A). Key: 21, triceps brachii caput lateralis; 23, anconeus externus; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor carpi ulnaris; 36, extensor pollicis et indicis longus; 38, abductor pollicis; 39, flexor carpi ulnaris; A, transverse dorsal carpal ligament; B, radial nerve, distal portion displaced from its bed; R, radius, outline of radial head; U, ulna, olecranon process.

Origin. The muscle arises by fleshy and tendinous fibers from the dorsal three-fifths of the inferior border of the scapula adjacent to and overlying the origin of the teres major muscle. From its origin, the muscle triangulates toward the point of the elbow paralleling the long head of the triceps brachii and overlying the latissimus dorsi.

Insertion. At the elbow a flat tendon forms which overrides the olecranon process. Except for a few short tendinous fibers which join the tendon of the long head of the triceps brachii, this muscle inserts into the deep fascia of the upper part of the forearm, mostly on the medial side.

Action. Strong extension of the elbow is accomplished.

20. **Triceps brachii caput longus.**

This strong spindle-shaped muscle with a tendon at each end joins the scapula to the ulna, and is part of the triceps muscle complex.

Origin. Arising as a heavy tendon with but few fleshy fibers from the inferior surface of the neck of the scapula adjacent to the glenoid, the muscle courses distally down the posterior surface of the humerus between the dorso-

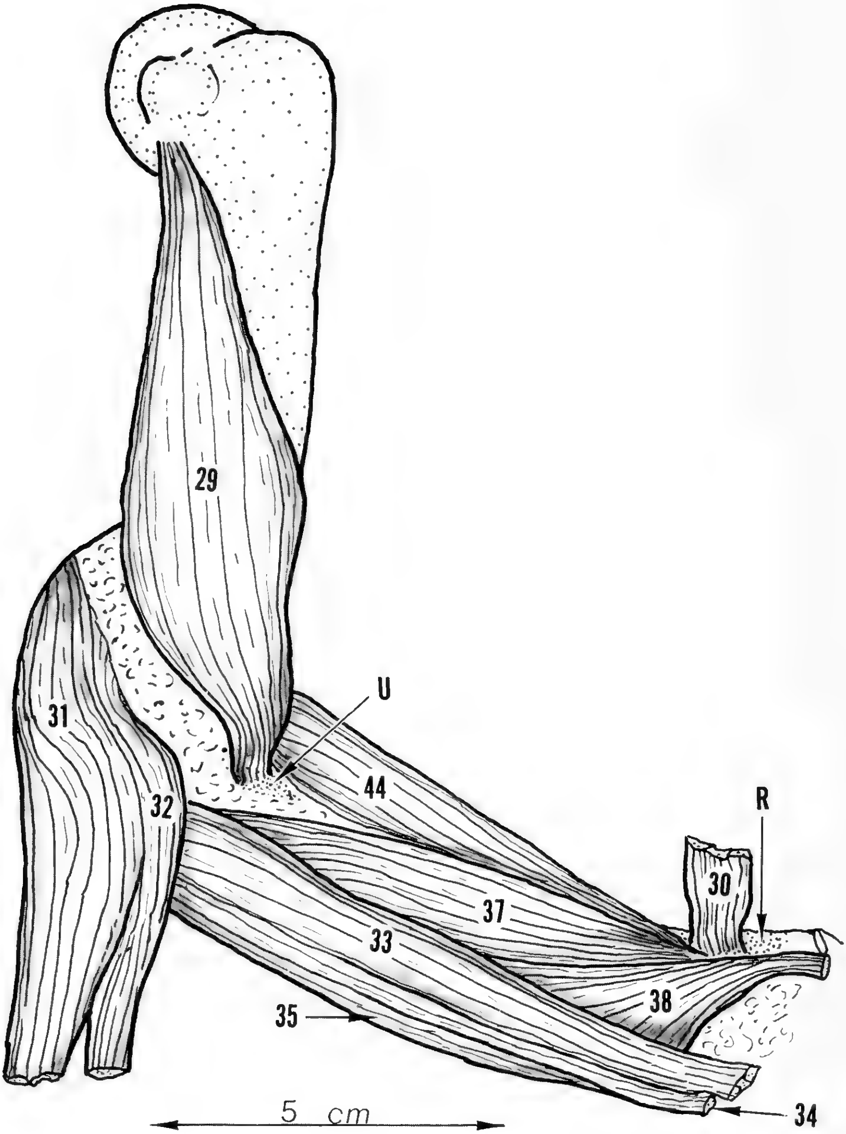

FIGURE 35. An anterolateral view of the right upper extremity to show the relationship of the brachialis (29) to the pronator teres (44) and the supinator (37) muscles. The radial carpal extensors (31) and (32) have been reflected at their origin and the brachioradialis (30) has been excised except for its insertion on the distal radius. The muscles overlying the brachialis (29) have been removed. Key: 29, brachialis; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor carpi ulnaris; 37, supinator, 38, abductor pollicis longus; 44, pronator teres; R, radius, radial styloid area; U, ulna, coronoid area.

epitrochlearis and the triceps brachii caput lateralis directly to the olecranon process of the ulna.

Insertion. A heavy tendon terminating this muscle inserts into the olecranon process of the ulna posteriorly and medially. Near its actual bony insertion it receives the tiny tendinous slip from the dorsoepitrochlearis muscle.

Action. Strong extension of the elbow results from contraction of this muscle.

21. **Triceps brachii caput lateralis.**

This is another strong fusiform muscle of the triceps muscle complex. This muscle connects the upper humerus with the ulna.

Origin. Fleshy and tendinous fibers arise from the medial surface of the neck of the humerus and adjacent shoulder capsule. The muscle thus formed courses distally to the lateral side of the elbow adjacent to the triceps brachii caput longus and overlies the origin of the brachialis muscle. In its midportion it receives muscle fibers from the medial head of the triceps brachii, and again in its distal portion more fibers from the medial head join in a tendinous raphe.

Insertion. The muscle terminates at the elbow in a short broad tendon which inserts on the posterolateral side of the olecranon process of the ulna adjacent to and just distal to the insertion of the long head of the triceps brachii.

Action. This muscle joins the other members of the triceps muscle complex to produce strong extension of the elbow joint.

22. **Triceps brachii caput medialis.**

This muscle is the lesser of the three triceps muscles and consists of three distinct parts, all of which are closely approximated to the humerus. The long (anconeus posterior) and the intermediate (anconeus internus) portions are more closely associated. The medial division (anconeus medialis) is more apart, much shorter, and much more distal.

Origin. The long portion arises from the posteromedial surface of the upper humerus by thin tendinous fibers from as far proximal as the level of the lesser trocanter. The intermediate portion arises to the lateral side of the long portion but takes origin by fleshy and tendinous fibers more proximally from the posteromedial surface of the neck of the humerus and adjacent capsule of the shoulder joint. Both portions progress distally and unite into a common single muscle belly after the intermediate portion first gives off muscle fibers to the caput lateralis triceps brachii. The medial portion (anconeus medialis) arises distally on the humerus from the posterior surface of the medial epicondylar flare and the fleshy fibers approach the elbow.

Insertion. The tendons of the caput medialis insert on the medial side of the olecranon process.

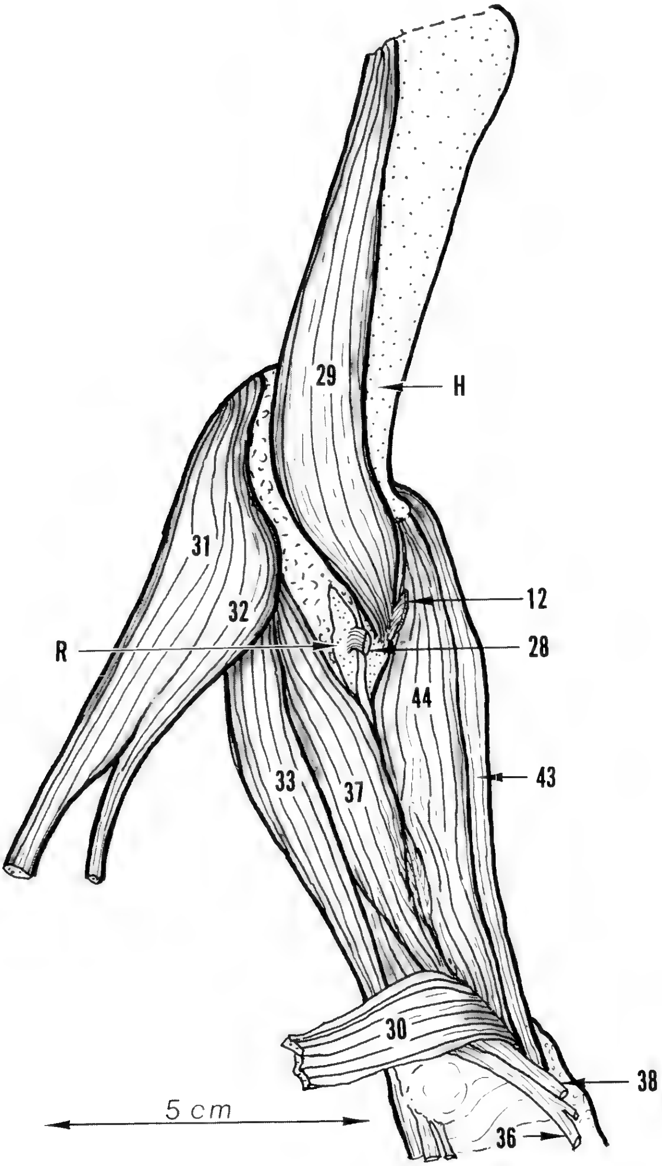

FIGURE 36. Anterior view of the right forearm in midposition to show the pronator (44) supinator (37) relationship. Insertions of the brachialis (29) and the pectoantebrachialis (12) are shown on the coronoid area of the ulna. Also seen is the insertion of the lower biceps tendon on the tubercle of the radius. The radial carpal extensors (31) (32) and the brachioradialis (30) muscles are reflected. Key: 12, pectoantebrachialis; 28, biceps brachii; 29, brachialis; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 36, extensor pollicis et indicis longus; 38, abductor pollicis longus; 44, pronator teres; 43, flexor carpi radialis; H, humerus; R, radius, tubercle.

Action. This muscle joins with others of the triceps muscle complex to give strong extension of the elbow joint.

23. Anconeus externus.

This short fleshy triangular muscle bridging the elbow joint is, in a sense, a counterpart of the anconeus internus (medial part of the caput medialis of the triceps brachii).

Origin. This muscle arises from the posterior surface of the lateral epicondylar flare of the distal humerus by fleshy fibers which then course distally to the lateral side of the olecranon.

Insertion. Fleshy and tendinous fibers insert laterally on the olecranon along the semilunar notch.

Action. This muscle probably assists in extension of the elbow.

24. Infraspinatus.

This flat muscle occupying the infraspinatus fossa of the scapula joins the scapula to the humerus.

Origin. Fleshy fibers arising from the infraspinatus fossa of the scapula triangulate toward the upper end of the humerus. The inferior part of the muscle shows a tendency to linear deviation from the remainder of the muscle mass to be designated as the teres minor muscle. At the shoulder the two are joined to form a heavy flat tendon forming part of the tendinous cuff of the shoulder joint.

Insertion. The tendon fibers insert into the lower posterior area of the greater tuberosity adjacent to and just below the tendon of the supraspinatus.

Action. The action is to abduct and externally rotate the humerus.

25. Teres minor.

This small muscle lying along the inferior scapular border is hardly distinguishable as separate from the infraspinatus muscle.

Origin. The common origin from the infraspinatus fossa with the infraspinatus muscle and a common tendon with this muscle indicates how close the association actually is.

Insertion. Tendon fibers join with those of the infraspinatus muscle to insert on the greater tuberosity of the humerus. The most distal fibers are those of the teres minor.

Action. The muscle contraction produces external rotation of the humerus with some assistance in abduction as well.

26. Supraspinatus.

This large muscle is a strong, flat, fleshy muscle connecting the scapula to the humerus over the top of the shoulder joint.

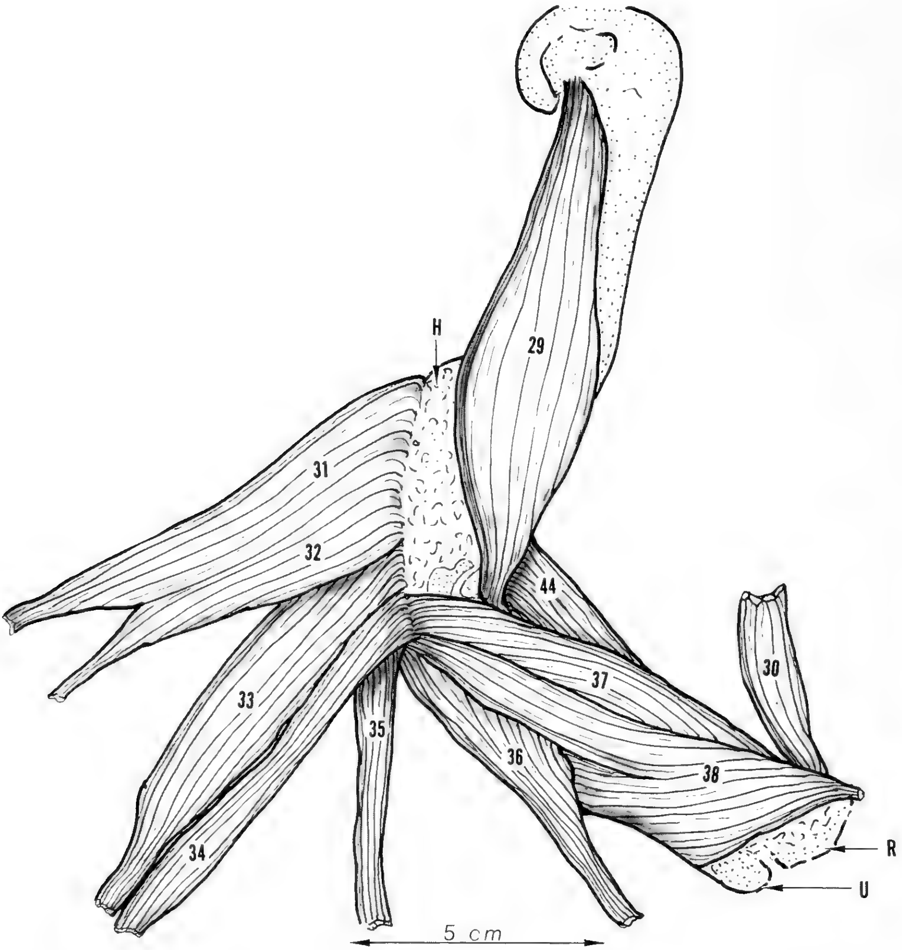

Figure 37. Lateral view of the right upper arm with the forearm in midposition to show origin in relationship of forearm extensor musculature. All muscles arising from the lateral epicondylar area have been reflected at their origins except for the supinator (37). Key: 29, brachialis; 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor carpi ulnaris; 36, extensor pollicis et indicis longus; 37, supinator; 38, abductor pollicis longus; 44, pronator teres; H, humerus, connective tissue overlying the bone; R, radius; U, ulna.

Origin. Muscle fibers arise from the entire supraspinatus fossa and converge toward the shoulder joint where a strong flat tendon develops bridging this joint as part of the tendinous cuff.

Insertion. Tendon fibers enter the greater tuberosity of the humerus ad-

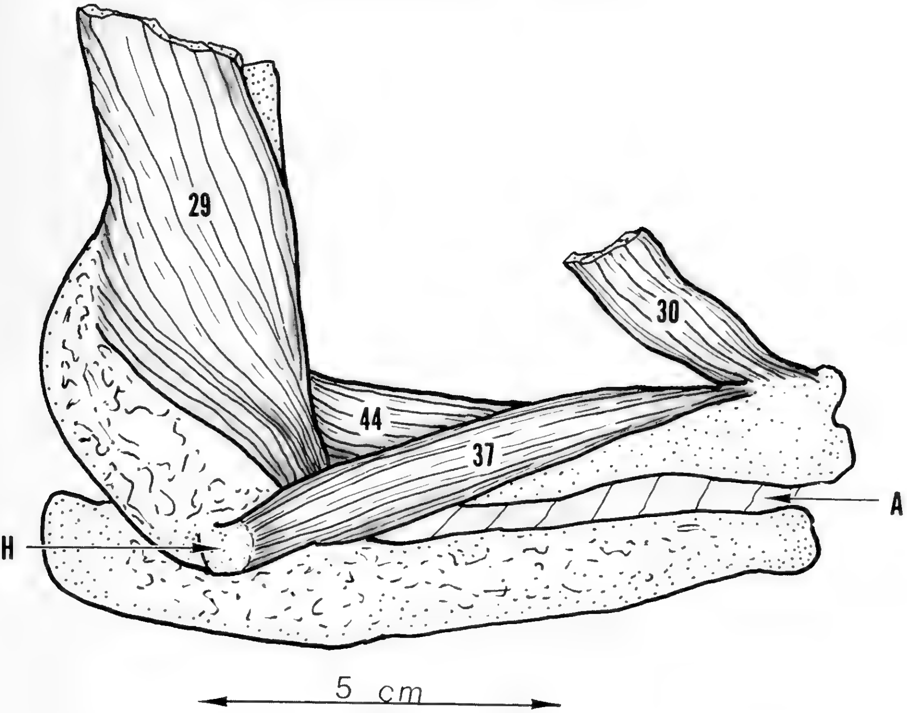

Figure 38. Lateral view of the right upper extremity with the forearm in midposition. All forearm extensor musculature has been removed to show origin of supinator muscle (37). The interossei membrane is shown spanning between the radius and ulna. Key: 29, brachialis; 30, brachioradialis; 37, supinator; 44, pronator teres; A, interossei membrane; H, humerus, lateral epicondyle.

jacent and superior to the tendon of the infraspinatus and extend to the margin of the bicipital groove.

Action. This muscle initiates abduction of the humerus.

27. Subscapularis.

This large triangular muscle lying on the underside of the scapula connects this bone with the humerus.

Origin. Arising as fleshy and tendinous fibers from the entire subscapular surface, the muscle triangulates toward the glenoid where, beyond the scapular spine, it parallels and approximates the supraspinatus muscle. The flat, heavy tendon which then forms bridges the shoulder joint as part of the tendinous cuff of this joint.

Insertion. The tendon fibers insert into the full width of the lesser tuberosity of the humerus.

Action. This muscle is a strong internal rotator of the humerus.

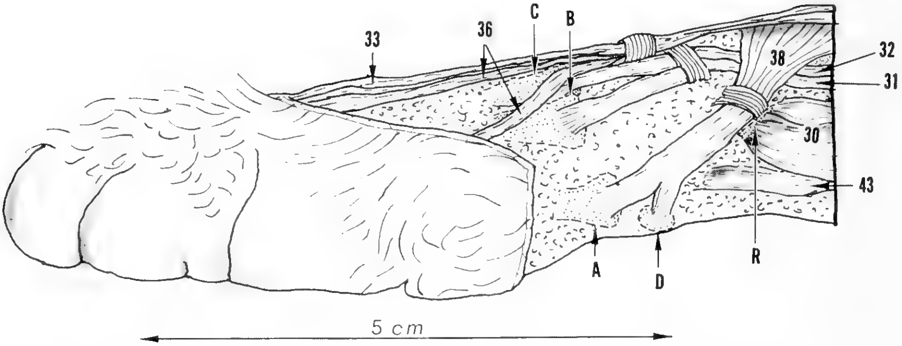

Figure 39. An enlarged view of the radial side of the wrist of the right upper extremity. Detail of insertion of the radial carpal extensors (31) and (32) and the abductor pollicis longus (38) is shown. Note dorsal ligamentous structures which hold tendons in position when wrist is dorsiflexed. Key: 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 36, extensor pollicis et indicis longus; 38, abductor pollicis; 43, flexor carpi radialis; A, metacarpal-1; B, metacarpal-2; C, metacarpal-3; D, radial sesamoid; R, radius, styloid area.

Note. The tendons of the subscapularis, supraspinatus, and infraspinatus (with the teres minor) are closely associated with the superior portion of the shoulder joint capsule and form a strong tendinous cuff about the joint. The articular surface of the humerus is thus held snuggly against the glenoid surface of the scapula.

28. **Biceps brachii.**

This single-bellied, spindle-shaped muscle with a well developed tendon at each end joins the scapula to the radius.

Origin. From the tubercle on the neck of the scapula at the superior border of the glenoid a heavy tendon arises which passes through the shoulder joint proper to enter the bicipital groove at the upper end of the humerus. From here the tendon expands into a spindle-shaped muscle lying along the anterior surface of the humerus to reach the anterior cubital fossa. The lower tendon now forms and passes across the elbow joint to the proximal radius.

Insertion. The distal tendon fibers insert into the bicipital tubercle of the radius.

Action. This muscle has the combined action of flexion of the elbow and supination of the forearm.

29. **Brachialis.**

This strong thick muscle underlies the brachioradialis muscle in the upper one-half of the humerus, and connects the humerus with the ulna.

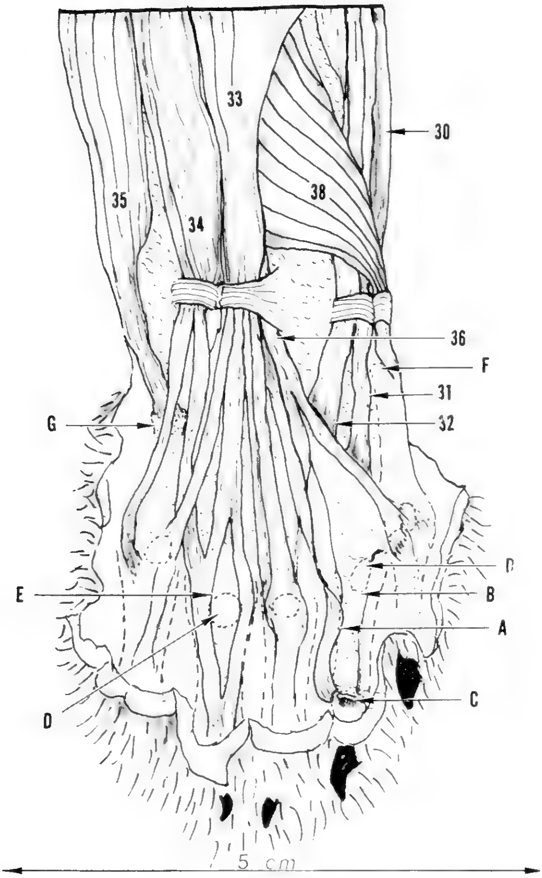

FIGURE 40. An enlarged view of the dorsal and the distal right forearm and hand to show relationship of extensor musculature of the wrist and digits. For digit 2, the extensor aponeurosis overlying the proximal phalanx has been split longitudinally and reflected (A) to show relationship to the sesamoid and proximal joint (metacarpal-phalangeal joint). Also, note ligamentous attachment (B) of sesamoid to base of proximal phalanx, thus causing the sesamoid to move with the proximal phalanx on flexion and extension. Distally, the extensor digitorum communis (33) and the index portion of the extensor pollicis et indicis (36) of the extensor aponeurosis have been divided transversely to show insertion into base of dorsum of the middle phalanx (C). For digit 4, the extensor aponeurosis and common digital extensors have been split longitudinally (E) and spread apart to show relationship to sesamoid. The insertion of the extensor carpi ulnaris (35) into the base of the fifth metacarpal and the abductor pollicis (38) into the base of the first metacarpal are shown. Also note the transverse overlying ligaments at wrist level. Key: 30, brachioradialis; 31, extensor carpi radialis longus; 32, extensor carpi radialis brevis; 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor carpi ulnaris; 36, extensor pollicis et indicis longus; 38, abductor pollicis; A, split extensor aponeurosis of digit 2; B, ligament attaching sesamoid to proximal phalanx; C, insertion of long extensor tendon on digit 2; D, sesamoid bone; E, split extensor tendon of digit 4; F, base of metacarpal 1; G, base of metacarpal 5.

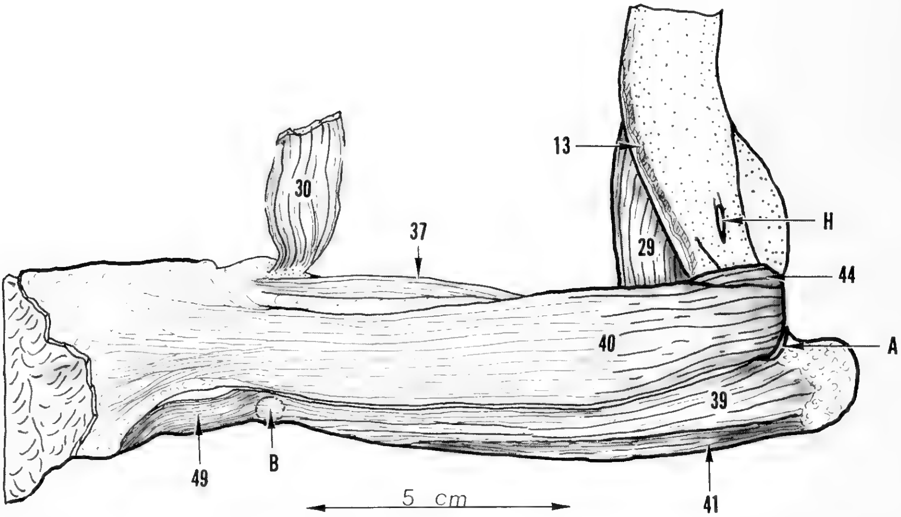

FIGURE 41. Medial view of right upper extremity with forearm in midposition, thus presenting its volar or flexor surface. This figure shows the origin and relationship of the superficial forearm flexor musculature. The abductor digiti quinti has been displaced outward from the shaft of the fifth metacarpal. Key: 13, pectoralis major, insertion; 29, brachialis; 30, brachioradialis; 37, supinator; 40, palmaris longus; 41, flexor digitorum profundus (ulnar head); 44, pronator teres; 49, abductor digiti quinti; A, elbow joint; B, pisiform bone; H, humerus, medial epicondylar foramen.

ORIGIN. Muscle fibers arise from almost the entire posteromedial surface of the humerus, from the neck of the humerus above to the lateral epicondylar ridge below. Entering the area of the cubital fossa a tendon is formed which bridges the elbow joint.

INSERTION. The tendon of the brachialis muscle inserts on the medial side of the proximal ulna adjacent to the insertion of the pectoantebrachialis tendon.

ACTION. This muscle is a strong flexor of the elbow joint.

30. **Brachioradialis.**

This is a long elbow-spanning fleshy muscle connecting the proximal humerus with the distal radius.

ORIGIN. Arising as thin flat tendinous fibers from the surface of the upper part of the brachialis muscle and from along the deltoid ridge of the humerus from the greater tuberosity to the humeral crest, a fleshy muscle belly promptly develops which spans the elbow joint anterolaterally then tapers gradually following the radial border of the forearm to the area of the radial styloid.

INSERTION. Tendon fibers developing on the underside of the muscle distally insert into the bone of the radial styloid.

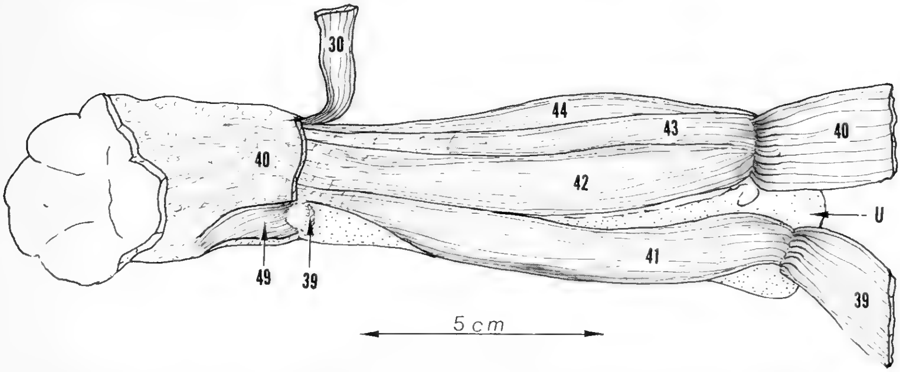

FIGURE 42. Volar view of right forearm in its distal portion and volar medial view of proximal portion as the forearm is in a slightly pronated position. The palmaris longus (40) and the flexor carpi ulnaris (39) have been divided and reflected to show origins and relationships of the deeper flexor musculature. The musculature of the flexor digitorum profundus can, by origin, be divided into three distinct portions, the more superficial humeral head (42) and the ulnar head (41), and the deeper central head (45). Not visible in this view, the central head has an ulnar, radial, and interosseus portion which will be shown later. Distally, all of the profundi group are joined together at the wrist as a broad tendinous structure from which separate the five profundi tendons, one passing to each digit. At wrist level the tendon passes under the deep carpal ligament. Also distally, and in addition to the main flexor tendon, the profundi give rise to the sublimi and lumbrical musculature which will be described later. Key: 30, brachioradialis; 39, flexor carpi ulnaris; 40, palmaris longus; 41, flexor digitorum profundus, ulnar head; 42, flexor digitorum profundus, humeral head; 43, flexor carpi radialis; 44, pronator teres; 49, abductor digiti quinti; U, ulna, olecranon area.

ACTION. This strong muscle has the double action of flexing the elbow and supinating the forearm.

31. Extensor carpi radialis longus.

This muscle is the more radial of the two radial carpal extensors.

ORIGIN. This muscle arises in common with the extensor carpi radialis brevis by muscular fibers from the proximal three-fourths of the lateral epicondylar ridge. The common muscle extends about half-way down the forearm before dividing into the longus and brevis portions. In the midforearm the longus portion lies between the brachioradialis muscle and the extensor digitorum communis muscle. At wrist level, the tendon passes through a groove on the dorsal surface of the radius adjacent to the styloid process. The overlying transverse dorsal carpal ligament forms a compartment for the tendon.

INSERTION. Bridging the wrist joint the tendon inserts at the base of metacarpal 2 into a tubercle on the dorsum and slightly to the radial side.

ACTION. This muscle is a strong dorsiflexor and radial flexor of the wrist joint.

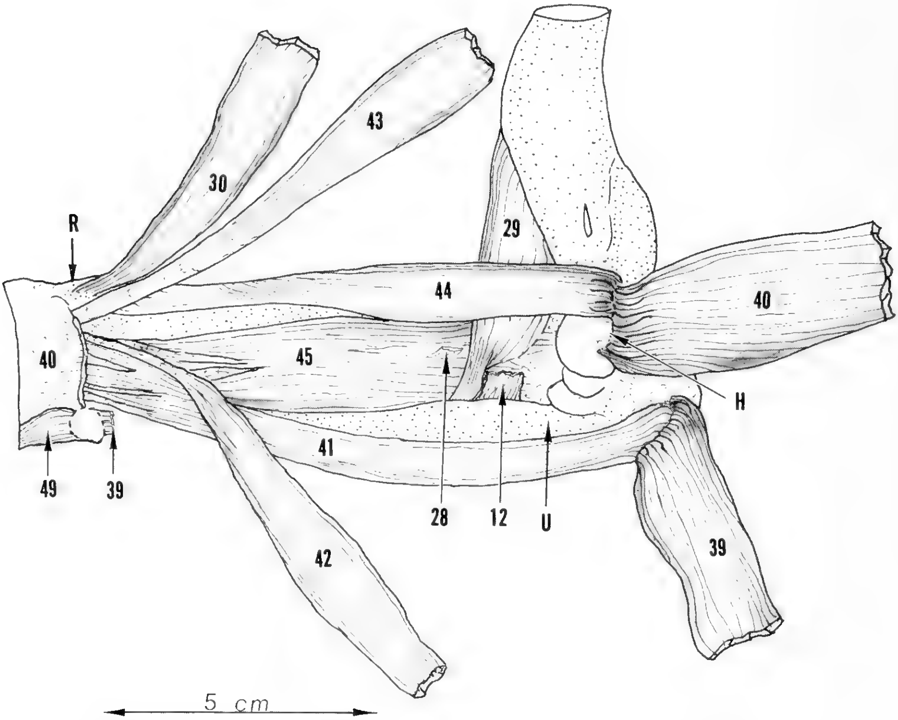

FIGURE 43. Volar view of right forearm with most of the flexor musculature reflected to show the deeply situated flexor digitorum profundus (central head) (45), with its fibers joining the ulna humeral divisions at near-wrist level. Also shown in this view are the insertions of the biceps tendon (28), the pectoantebrachialis tendon (12), and the brachialis muscle (29). The origin of the pronator teres (44) in relation to the palmaris longus (40) is visualized. Key: 12, pectoantebrachialis; 28, biceps brachii; 29, brachialis; 30, brachioradialis; 39, flexor carpi ulnaris; 40, palmaris longus; 41, flexor digitorum profundus (ulnar head); 42, flexor digitorum profundus (humeral head); 43, flexor carpi radialis; 44, pronator teres; 45, flexor digitorum profundus (central head); H, humerus, medial epicondyle; R, radius, styloid process; U, ulna.

32. **Extensor carpi radialis brevis.**

This muscle is a partner of the extensor carpi radialis longus and also connects the humerus to the hand.

ORIGIN. In common with the extensor carpi radialis longus from the lateral epicondylar ridge, this muscle represents the lower fibers of origin. The tendon forming in midforearm parallels that of the longus and passes with this tendon in the groove at the distal end of the radius.

INSERTION. Spanning the wrist joint the tendon inserts into the dorsum at the base of metacarpal 3.

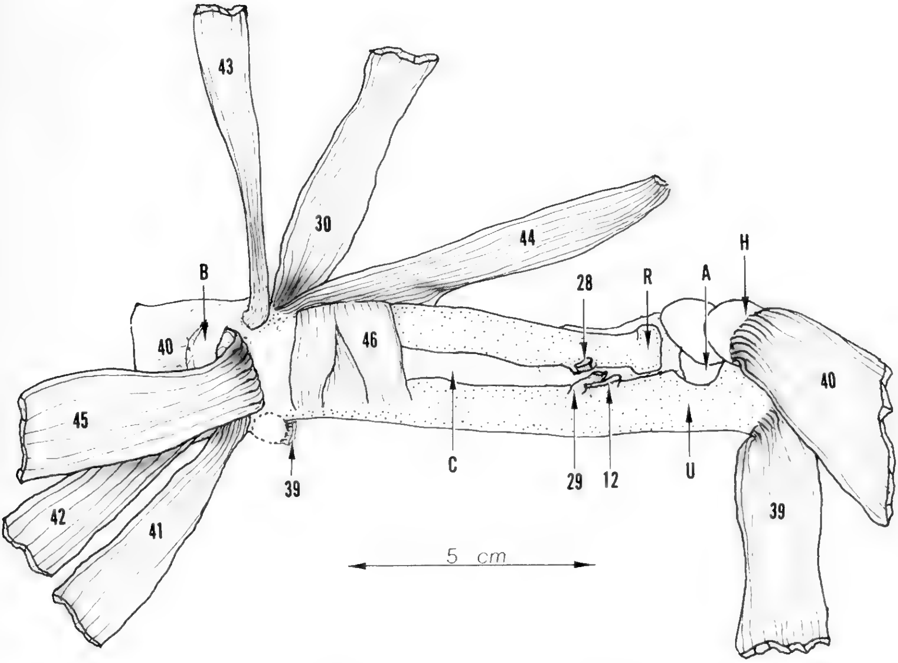

Figure 44. Volar view of right forearm. All flexor musculature has been reflected to expose the radius and ulna with intervening interosseus membrane. The flexor digitorum profundi musculature has been reflected distally where the tendons are entering the carpal canal beneath the deep carpal ligament. Distally, the pronator quadratus muscle (46) is shown spanning the two forearm bones. Note insertions of the biceps brachii (28), brachialis (29), and pectoantebrachialis (12). Key: 12, pectoantebrachialis; 28, biceps brachii; 29, brachialis; 30, brachioradialis; 39, flexor carpi ulnaris; 40, palmaris longus; 41, flexor digitorum profundus (ulnar head); 42, flexor digitorum profundus (humeral head); 43, flexor carpi radialis; 44, pronator teres; 45, flexor digitorum profundus (central head); 46, pronator quadratus; A, elbow joint; B, deep carpal ligaments; C, interosseus membrane; H, humerus, medial epicondyle; R, radius, head; U, ulna.

Action. Owing to its more central location and insertion, the brevis serves only to dorsiflex the wrist.

33. Extensor digitorum communis.

This muscle, along with the extensor digitorum lateralis, represents the long extensors of the digits except for the thumb. The musculature is in the forearm and the tendons extend distally to the middle phalanges.

Origin. The muscle arises in common with the extensor digitorum lateralis from the lateral epicondylar ridge of the humerus down to and including the lateral epicondyle. The extensor digitorum lateralis fibers are the more distal in origin. At its origin, the muscle overlies the extensor carpi radialis brevis and appears to share some fibers with this muscle. On the dorsum of the forearm the muscle lies between the radial-carpal extensors and the extensor digitorum lateralis. At wrist level four separate tendons develop and pass through a groove at the distal radius, following which they spread out and span to each of the digits 2, 3, 4, and 5. Over the metacarpal area small tendinous slips may develop which rejoin the same or adjacent tendon at the metacarpal-phalangeal joint area.

Insertion. At the metacarpal-phalangeal joint level each tendon expands and joins into the extensor hood and the extensor aponeurosis mechanism, but the central fibers continue down the dorsum of the proximal phalanx to insert at the base of the middle phalanx. At the metacarpal-phalangeal joint level a light fibrous attachment is noted to the sesamoid at this site. The sesamoid, however, is more associated with the joint capsule than with the extensor tendon.

Action. The primary action of the tendon is to extend the metacarpal-phalangeal joint through the hood mechanism. However, with the metacarpal-phalangeal joint stabilized so that hyperextension does not occur, the central fibers then act to extend the proximal interphalangeal joint.

34. **Extensor digitorum lateralis.**

This partner of the extensor digitorum communis muscle provides an extra long extensor tendon for the fourth and fifth digits.

Origin. The muscle arises in common with the extensor digitorum communis representing the more distal portion of this origin, the lateral humeral epicondyle and epicondylar ridge. Separation from the communis occurs on the ulnar side of this muscle and near the wrist two individual tendons develop which pass through a separate compartment in a groove of the distal radius. From here, the more radial of the two tendons passes beneath the communis tendon of digit 5 to the midmetacarpal area to join with the communis tendon of digit 4 at the extensor hood level. The more ulnar tendon parallels the common extensor tendon of digit 5 to join into the extensor hood of this digit on the ulnar side.

Insertion. Joining with the communis extensor tendon the insertion is the same; namely, the base of the middle phalanx of digits 4 and 5.

Action. The action is the same as that of the communis tendon for the fourth and fifth digits.

35. **Extensor carpi ulnaris.**

This strong muscle joins the humerus with the hand and serves to balance the action of the radial carpal extensors.

Origin. This muscle arises from the lateral epicondyle just radial to the

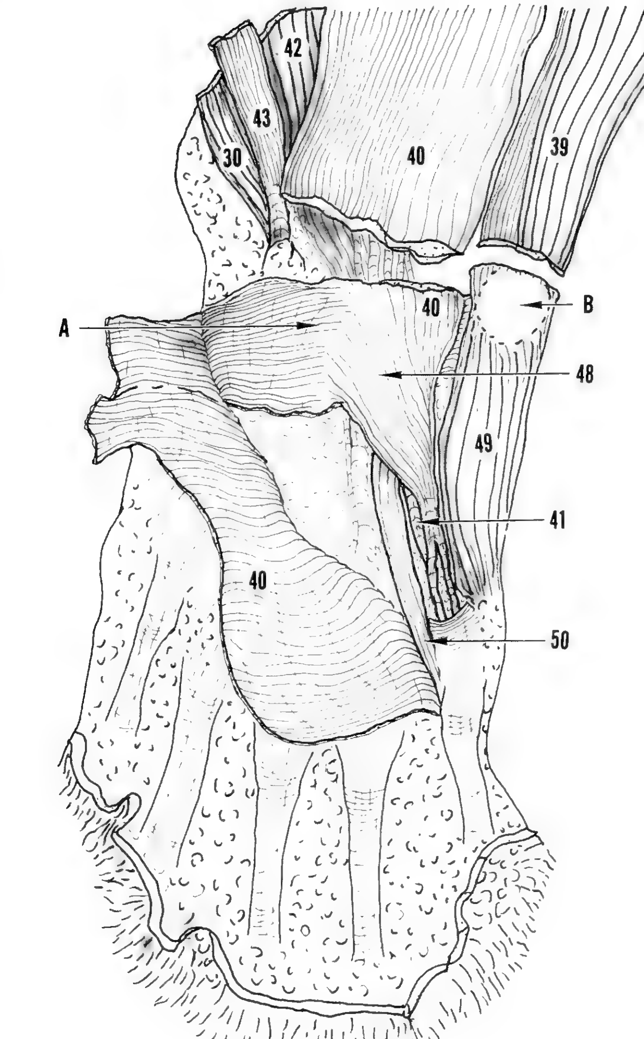

FIGURE 45. An enlarged view of the volar surface of the right forepaw. The volar pad has been removed and the palmaris longus tendon (40) divided. Distally, the palmaris longus fascial expansion (palmar fascia) has been reflected radialward to disclose the origin of the sublimis muscle (48) for digit 5. Note the continuation of deep muscle fibers from the underside of the palmaris longus joining with muscle fibers arising from the deep transverse carpal ligament to form the sublimis muscle of this fifth digit. Key: 30, brachioradialis; 39, flexor carpi ulnaris; 40, palmaris longus; 41, flexor digitorum profundus, tendons from the ulnar head; 42, flexor digitorum profundus (humeral head); 43, flexor carpi radialis; 48, flexor digitorum sublimis for digit 5; 49, abductor digiti quinti; 50, opponens digiti quinti; A, transverse carpal ligament; B, pisiform bone.

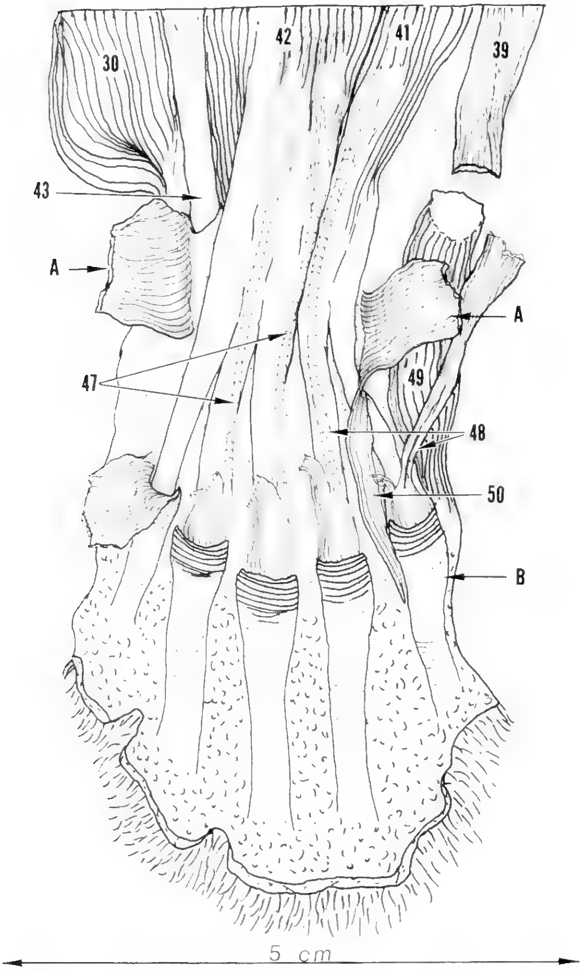

FIGURE 46. Enlarged view of volar surface of the right hand. The palmar fascia has been completely removed except for the groups of distal fibers which reinforce the sublimi tendons. The flexor tendon sheath has been resected a bit distally for digits 2, 3, 4, and 5 to show the broadening of the sublimis to completely cover the profundus tendon at this site. Note again, there is no sublimis tendon for digit 1. The palmaris longus fibers for this digit attach to the rim of the flexor tendon sheath. The transverse carpal ligament (A) has been divided and reflected to show the origin of the sublimis of digits 2, 3, and 4. The sublimis of digit 5 has been reflected from its origin and displaced ulnaward. Also shown are the profundi flexor tendons of all digits and how these tendons arise from the proximal musculature. Key: 30, brachioradialis; 39, flexor carpi ulnaris; 41, flexor digitorum profundus (ulnar head); 42, flexor digitorum profundus (humeral head); 43, flexor carpi radialis; 47, flexor digitorum sublimis (radial); 48, flexor digitorum sublimis (ulnar); 49, abductor digiti quinti; 50, opponens digiti quinti; A, transverse carpal ligament; B, fibrous flexor tendon sheath.

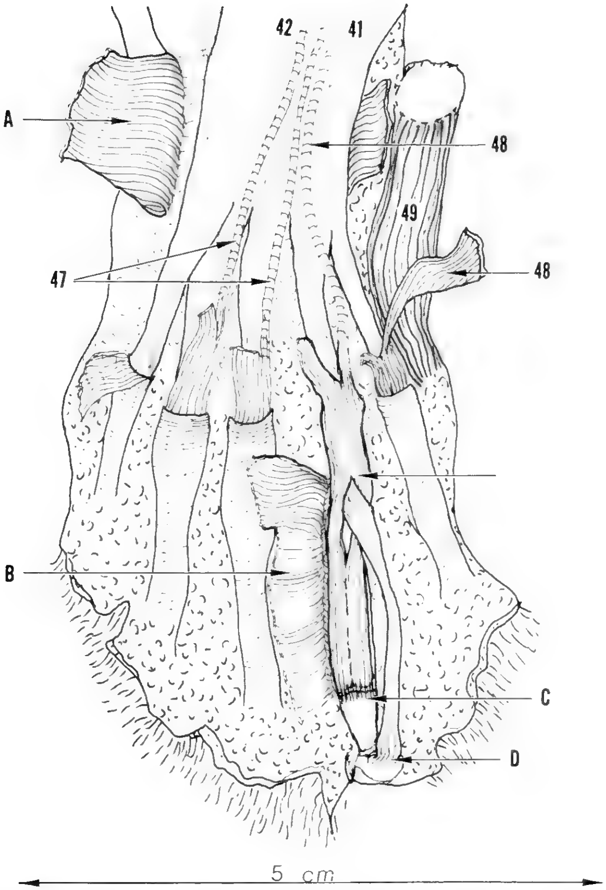

FIGURE 47. Enlarged view of the volar aspect of the right hand. On digit 4 the fibrous flexor tendon sheath (A) has been divided along the ulnar margin and reflected radialward to show the contents of the flexor tunnel. The concentration of transverse fibers on the flexor tendon sheath provides the pulley mechanism of the sheath, thus preventing bowstringing of the flexor tendons when activated. Note the division and rejoining of the sublimis tendon to allow the profundus to come through. The sublimis then continues distally to insert in the base of the middle phalanx (B). The profundus flexor tendon continues in this sheath to the distal interphalangeal-joint level, inserting at the base of the terminal phalanx which is in a hyperextended position at rest. The deep transverse carpal ligament (D) has been divided and reflected. This broad ligament has its radial attachment mainly to the radial sesamoid and volar wrist joint capsule along the radial side of the navicular-lunate bone. On the ulnar side, attachment is mainly along the base of the pisiform with attachment also to the wrist joint capsule in the area of the triquetrum. Key: 41, flexor digitorum profundus (ulnar head); 42, flexor digitorum profundus (humeral head); 47, flexor digiti sublimis (radial); 48, flexor digiti sublimis (ulnar of the fifth digit); 49, abductor digiti quinti; A, transverse carpal ligament; B, fibrous tendon sheath of digit 4, reflected; C, insertion of sublimis flexor tendon; D, insertion of profundus flexor tendon.

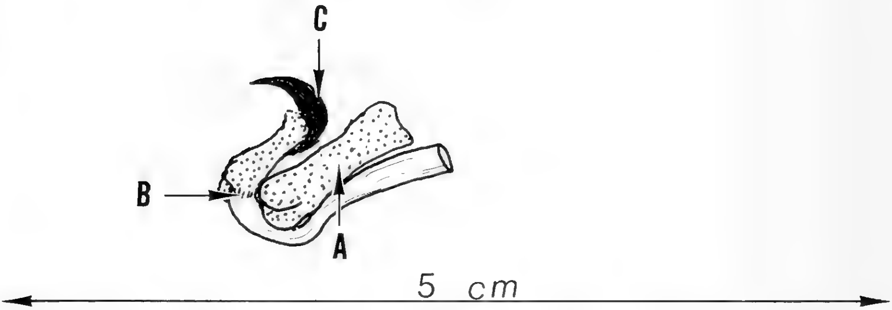

FIGURE 48. Enlarged ulnar view of the middle and distal phalanges of digit 4 to show the hyperextended position of the terminal phalanx and the insertion of the profundus flexor tendon. Note the close approximation of the claw to the terminal phalanx. Key: A, middle phalanx; B, insertion of profundus flexor tendon on distal phalanx; C, claw.

origin of the supinator muscle adjacent and distal to the extensor digitorum lateralis muscle. The muscle passes along the ulnar border of the dorsum of the forearm adjacent to the extensor digitorum lateralis. Near the wrist a strong tendon is formed which broadens and passes over the distal ulna with an interposed bursa between the tendon and the bone.

INSERTION. Spanning the carpal area, the tendon continues distally to the ulnar side of the base of the fifth metacarpal where it inserts into a slight bony protuberance at this site.

ACTION. The direct action of this muscle is to ulnaflex the wrist but, if this motion is opposed, the action becomes one of dorsiflexion of the wrist joint.

36. **Extensor pollicis et indicis.**

This muscle provides long extensor action for the thumb and an assistance to the communis extensor tendon of digit 2.

ORIGIN. The muscle arises entirely from the proximal two-thirds of the ulna, beginning at the articular notch level and extending distally along the ulnar crest. The origin is just posterior to that of the abductor pollicis longus muscle. The muscle underlies the extensor digitorum communis muscle and the tendon which forms passes through the same compartment at the distal radius as the communis tendons. Just distal to the wrist, the tendon divides into two separate tendons which continue radiusward. The more radial one goes directly to the base of the thumb, the other underlies the communis tendon to reach the ulnar side of digit 2.

INSERTION. The pollicis tendon inserts into the base of the proximal phalanx of digit 1 after spreading out somewhat in a hoodlike manner at the metacarpal-phalangeal joint level. The indicis tendon, which is approximately twice the size of the communis tendon of this digit, joins into the extensor hood on the

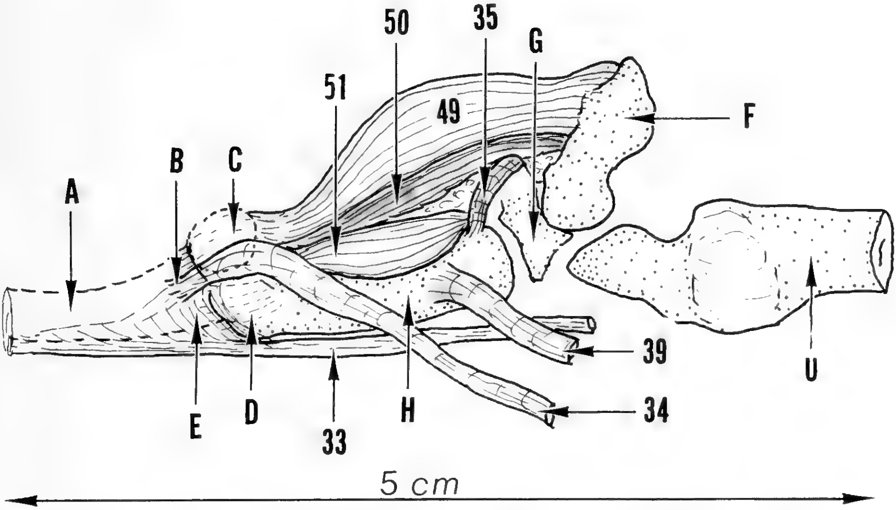

FIGURE 49. Enlarged ulnalateral view of ulna border of the right hand to show relationship of muscles of tendons about the fifth metacarpal (H). Note insertion of the extensor digiti lateralis (34) is mainly into the base of the proximal phalanx, the communis extensor, forming the main extensor aponeurosis. Although in close proximity the base of the fifth metacarpal does not articulate with the joint surface on the triquetrum but rather more radial on the hamate. The pisiform bone has been reflected outward a bit for a cleared view of the ulna carpal extensor and flexor tendons. Key: 33, extensor digitorum communis; 34, extensor digitorum lateralis; 35, extensor carpi ulnaris; 39, flexor carpi ulnaris; 49, abductor digiti quinti; 50, opponens digiti quinti; 51, flexor digiti quinti brevis; A, proximal phalanx; B, insertion of extensor digitorum lateralis; C, sesamoid bone; D, collateral ligament at the metacarpal phalangeal joint; E, extensor hood at the metacarpal phalangeal joint; F, pisiform; G, triquetrum; H, metacarpal (fifth); U, ulna, distal end.

ulnar side of the communis tendon, then joins with the communis tendon for the remainder of its course.

ACTION. The pollicis portion extends the metacarpal-phalangeal joint of the thumb and acts as an adductor of the thumb as well. The indicis portion has the identical action to that of the comunis tendon of digit 2.

37. **Supinator.**

This deep, somewhat flat forearm muscle joins the humerus to the radius.

ORIGIN. Heavy tendinous fibers arise from the small area on the distal and most prominent part of the lateral humeral epicondyle just ulnaward of the origin of the extensor carpi ulnaris muscle. From its origin the muscle passes directly toward the radius and promptly begins its insertion.

INSERTION. Insertion is into the proximal three-fourths of the radius start-

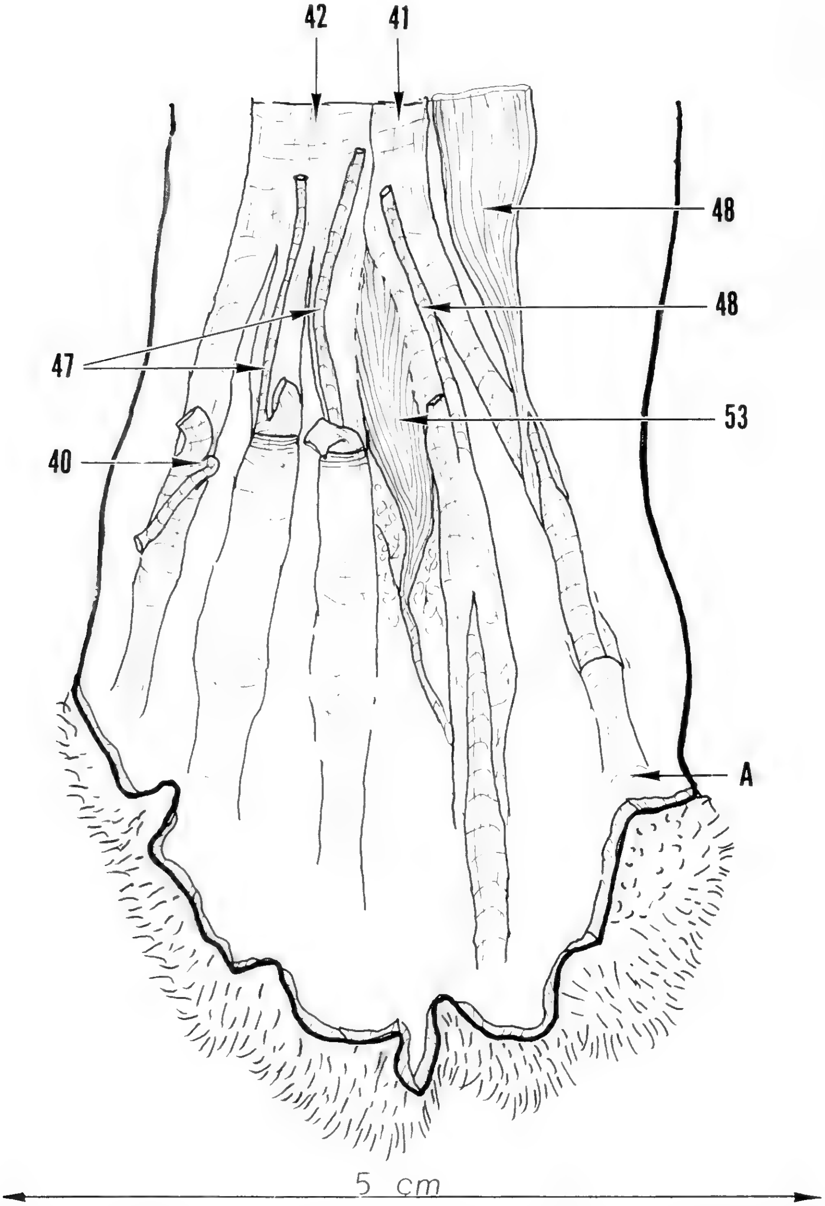

FIGURE 50. Palmar view of the right hand to show specifically the origin and insertion of the single lumbricale muscle in this specimen (53). In this plate, the entire flexor sheath has been removed from digit 4 and the proximal one-half removed from digit 5. For digit 1, the palmar fascia attached to the rim of the flexor sheath has been split and reflected (40). Key: 40, palmaris longus; 41, flexor digiti profundus (ulnar head); 42, flexor digiti profundus (humeral head); 47, flexor digitorum sublimis (radial); 48, flexor digitorum sublimis (ulnar); A, digit 5.

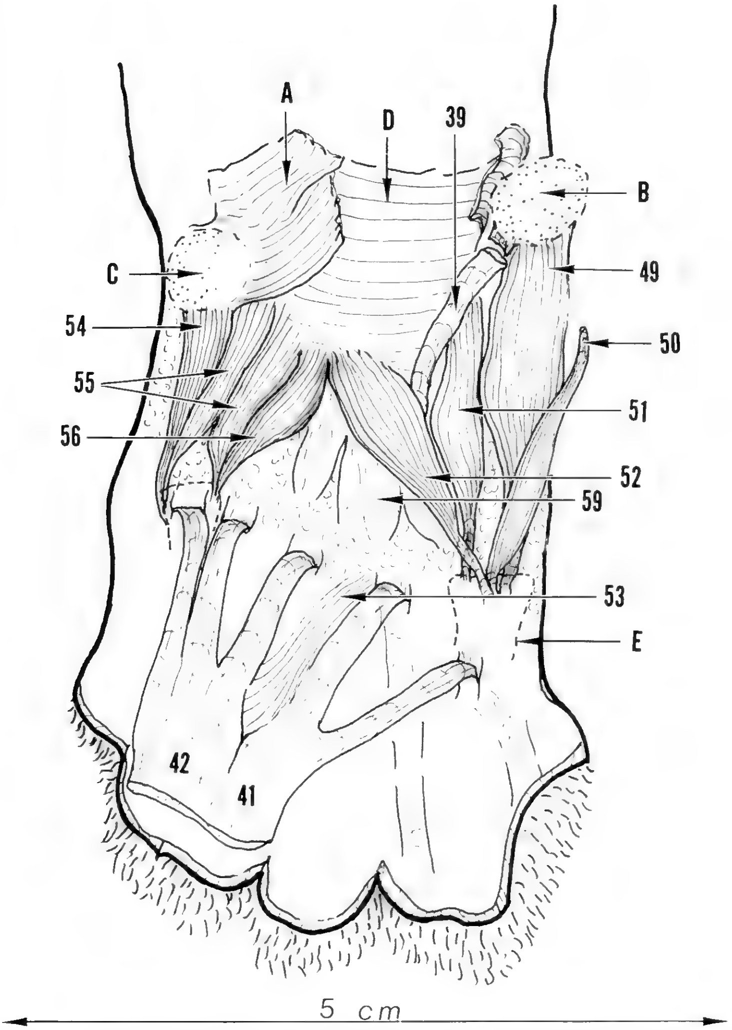

Figure 51. Enlarged palmar view of right hand. The long digital flexor tendons have been reflected distally to show the intrinsic hand muscles grouped about the first and fifth metacarpals. These muscles are termed respectively the thenar and hypothenar muscle groups. The opponens digiti quinti (50) has been detached from its origin and reflected ulnaward. Note absence of an opponens pollicis muscle. The flexor pollicis brevis of digit 1 (55) has two heads designated as radial and ulnar by their position. A heavy fibrous capsule at the wrist joint forms the floor of the carpal tunnel. Key: 39, flexor carpi ulnaris; 41, flexor digitorum profundus (ulnar head); 42, flexor digitorum profundus (humeral head); 49, abductor digiti quinti; 50, opponens digiti quinti; 51, flexor digiti quinti brevis; 52, adductor digiti quinti; 53, lumbricali; 54, abductor pollicis brevis; 55, flexor pollicis brevis; 56, adductor pollicis; 59, interossei; A, transverse carpal ligament—reflected; B, pisiform bone; C, radial sesamoid bone; D, volar capsule of wrist joint; E, proximal phalanx of fifth digit.

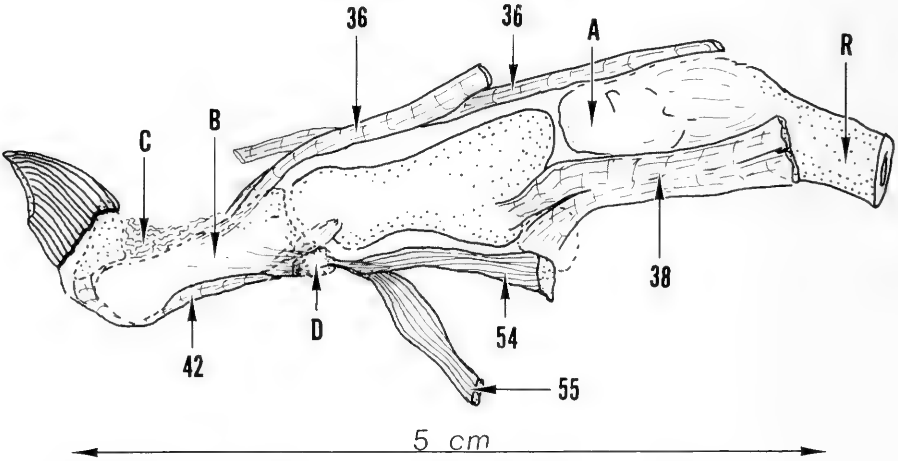

Figure 52. An enlarged radial view of the right first digit to show the relationship of the extensor, extrinsic, and intrinsic muscles. Both pollicis and indicis portions of the extensor pollicis et indicis tendons are shown. The indicis part lies behind the pollicis tendon. Note the more distant extension of the radial fibers of the pollicis tendon at the insertion at the base of the proximal phalanx. Note also the location of elastic tissue (dorsal elastic ligament) which keeps the distal phalanx hyperextended. On voluntary flexion of the distal phalanx, the elastic tissue simply stretches. There is no extensor tendon as such inserting on the distal phalanx at digit 1 nor on the distal phalanges of the remaining digits. Visible in this view is the radial head of the flexor pollicis brevis (55). Key: 36, extensor pollicis et indicis; 38, abductor pollicis longus; 42, flexor digitorum profundus (humeral head); 54, abductor pollicis brevis; 55, flexor pollicis brevis (radial head); A, carpus (multangular); B, proximal phalanx; C, elastic tissue (dorsal elastic ligament); D, sesamoid; R, radius, distal end.

ing on the posterior and lateral aspects at the bicipital tubercle level and terminating in tendinous fibers at the point of maximum bow of the radius. Thus strong mechanical advantage is provided for its action.

Action. This muscle is a strong supinator of the forearm.

38. **Abductor pollicis longus.**

This deep extensor muscle joins the ulna to the thumb.

Origin. This muscle arises from the lateral aspect of the ulna all the way from the articular notch to the end of the bone. The origin is adjacent to and on the radial side of the extensor pollicis et indicis origin. Some fleshy fibers of origin also arise from the proximal interosseus membrane and adjacent opposing surface of the radius. The muscle fibers converge in a triangular configuration to emerge from under the extensor digitorum communis in the distal forearm, where they then pass over the radial carpal extensors toward the radial styloid. The tendon now formed passes in the groove of the radius at the radial styloid level.

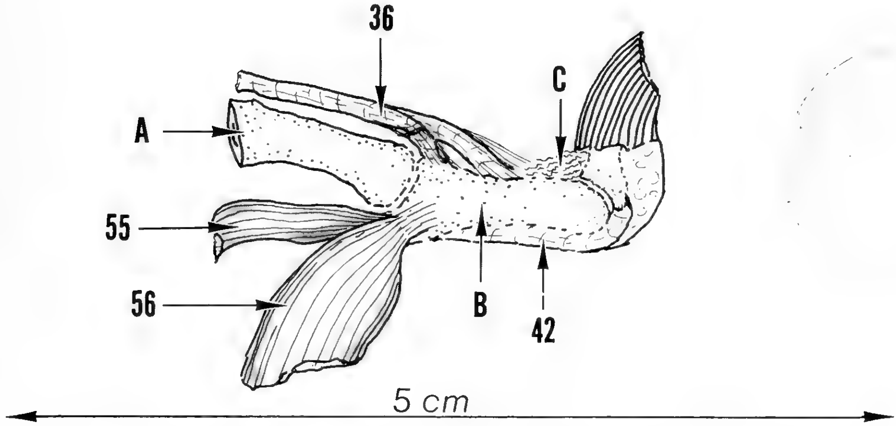

FIGURE 53. Enlarged view of the ulnar side of the right first digit to show the extrinisic and intrinsic muscles on this side. The principal insertion of the extensor pollicis (36) is into bone somewhat to the ulnar side of the midline space of the proximal phalanx. The radial fibers, as noted in figure 52, insert somewhat more distally. Visible in this view is the ulnar head of the flexor pollicis brevis (55). Key: 36, extensor pollicis et indicis (pollicis part); 42, flexor digitorum profundus (humeral head); 55, flexor pollicis brevis (ulnar head); 56, adductor pollicis; A, metacarpal of digit 1; B, proximal phalanx of digit 1; C, elastic tissue (dorsal elastic ligament).

INSERTION. Emerging from the distal compartment of the radius the tendon splits into a lesser one-fourth which inserts volarly into the radial sesamoid, and a greater three-fourths which inserts into a bony tubercle to the radial side of the dorsum of the base of the first metacarpal.

ACTION. By virtue of its insertion this muscle acts to abduct the thumb metacarpal, and also to radiflex the wrist to some degree. Like other extensor musculature it can assist in supination of the forearm.

39. Flexor carpi ulnaris.

This large strong muscle occupies the ulnar side of the volar surface of the forearm and lies adjacent to the palmaris longus muscle. It extends from the elbow area to the hand.

ORIGIN. Arising by muscular tendinous fibers from the medial surface of the lower part of the olecranon crest the origin just overlies the origin of the ulnar head of the flexor profundus digitorum muscles with a few fibers seemingly in common. Other but lesser fleshy fibers arise from the adjacent medial aspect of the olecranon and over the joint capsule in this area, and a few from the humerus along the articular ridge of the medial condyle. The muscle is elongated, fusiform in type, and in its course down the forearm it overlies all but the proximal part of the flexor digitorum profundus (ulnar head). The

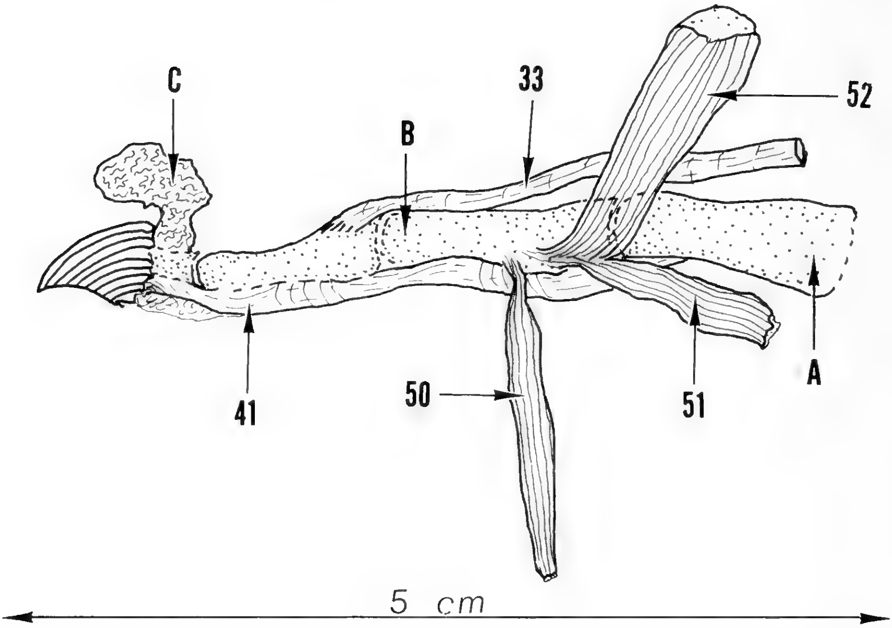

Figure 54. An enlarged radiolateral view of digit 5 to show insertion of extensor digitorum communis (33) at the base of the middle phalanx. The elastic tissue at distal joint level has been reflected from its attachment to the middle phalanx, thus allowing the distal joint to assume a more flexed position. Insertions of the intrinsic musculature on the radial side of digit 5 are shown. Key: 33, extensor digitorum communis; 41, flexor digitorum profundus (ulnar head); 50, opponens digiti quinti; 51, flexor digiti quinti brevis; 52, adductor digiti quinti; A, metacarpal of digit 5; B, proximal phalanx; C, elastic tissue (dorsal elastic ligament).

tendon of insertion begins to appear about halfway down the muscle. The muscle fibers continue as far distally as the pisiform bone.

Insertion. At the carpal level the tendon inserts into and encompasses the pisiform bone but continues to pass deeply into the palm to its final insertion at the volar surface of the base of the fifth metacarpal bone.

Action. This muscle is a strong volar flexor of the wrist and gives ulnaflexion of the wrist as well.

40. **Palmaris longus.**

This is the most prominent muscle on the volar surface of the forearm. It is a large, broad, flat muscle which lies superficially adjacent to the flexor carpi ulnaris and connects the humerus with the hand. A tendinous surface presents on the distal two-thirds of the muscle.

Origin. Arising as the outermost muscle from the distal three-fourths of

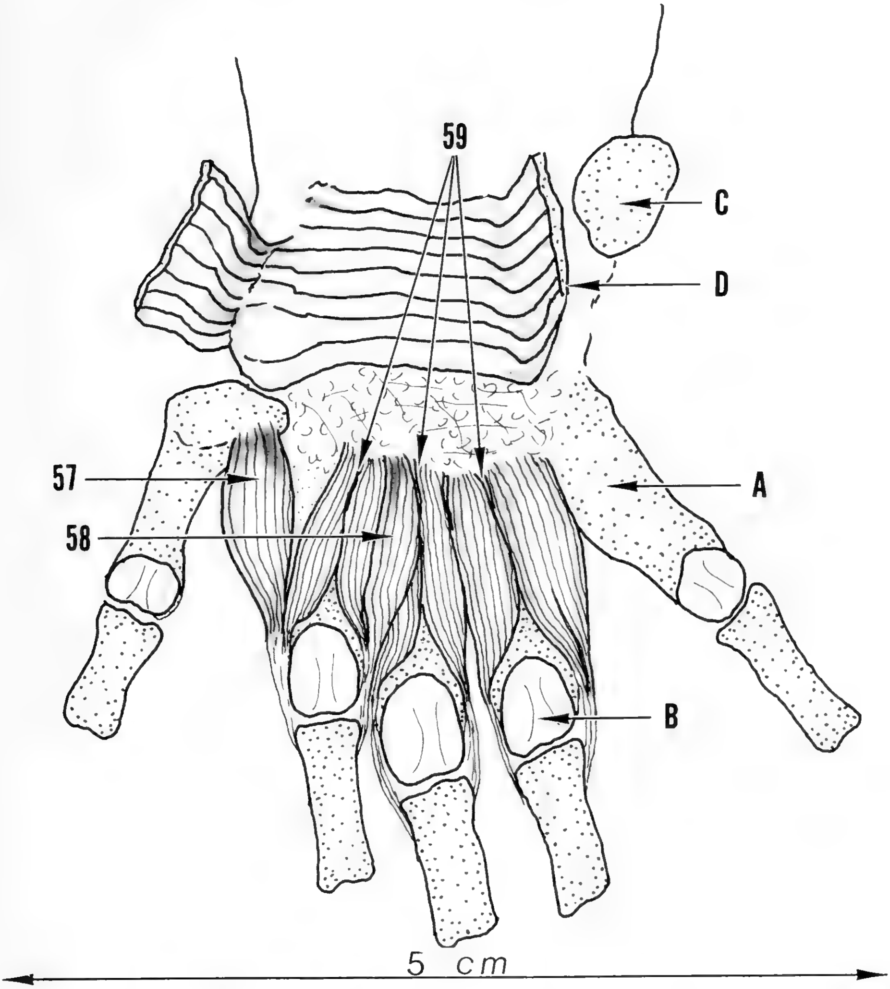

FIGURE 55. An enlarged palmar (volar) view of the right hand with all muscles and tendons removed except for the abductor (57) and adductor (58) digiti secundus and the three interossei (59). The interossei constitute the deepest layer of muscles, as the abductor and adductor digiti secundi lie a bit superficial to them. Key: 57, abductor digiti secundi; 58, adductor digiti secundi; 59, interossei; A, metacarpal, digit 5; B, head of fourth metacarpal; C, pisiform bone; D, transverse carpal ligament—cut and reflected.

the medial epicondyle, the origin overlies the distal one-half of the origin of the pronator teres muscle. Tendinous fibers appear the width of the muscle at the junction of the proximal and middle thirds, and continue distally as a broad tendinous sheath to the wrist. The superficial fibers spread out over the palm forming a dense palmar fascia. Connective tissue fibers from this fascia extend

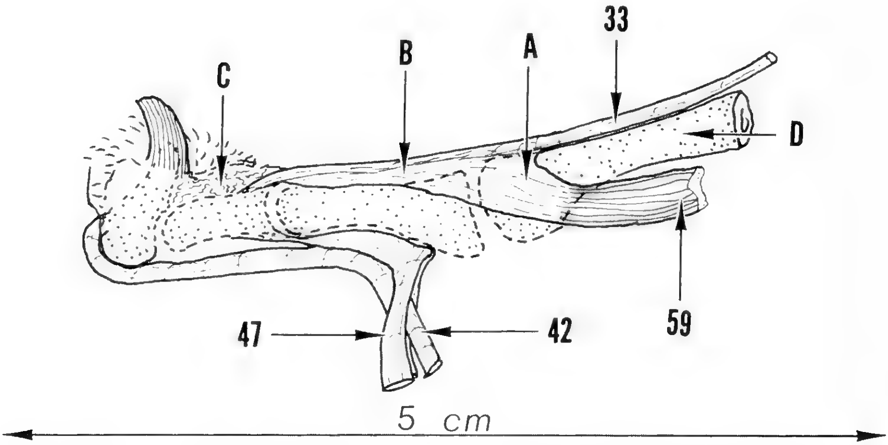

Figure 56. A radiolateral view of digit 4 of the right hand to show the pattern of insertion of all interossei muscles except the one to the radial side of digit 2. Note how the flat interosseus tendon joins the extensor aponeurosis at the extensor hood level overlying the metacarpal phalangeal joint. The anatomical relationship of the long extensor probably allows the interossei to extend the proximal interphalangeal joint when the metacarpal phalangeal joint is in hyperextension. It appears that the hood mechanism probably checks the excursion of the long extensor thus limiting its action on the proximal interphalangeal joint when in the hyperextended position. Key: 33, extensor digitorum communis; 44, flexor digitorum profundus; 47, flexor digitorum sublimis; 59, interosseus; A, extensor hood; B, extensor aponeurosis; C, elastic tissue (dorsal elastic ligament); D, metacarpal of digit 4.

into the pads of the palm and the digits. The dense palmar fascia shows three major fibrous bands extending toward the bases of digits 2, 3, and 4, with lesser concentrations of fibers passing toward the bases of digits 1 and 5. Fibrous extensions of the palmar fascia also pass deeply into the palm forming septum-like structures which attach to the fibrous flexor tendon sheaths on either side of the metacarpal heads. The interval between the metacarpal heads becomes a hiatus through which the volar digital nerves and vessels pass into the digits. When the palmaris longus muscle is divided just above the wrist and the distal portion reflected, the undersurface can be observed. Here it is noted that toward the ulnar side at wrist level muscle fibers continue and separate from the main more superficial tendinous portion. These muscle fibers are now joined by additional muscle fibers arising from the deep transverse carpal ligament. This combined muscle shortly terminates in a small discreet tendon which then promptly splits into two halves which enter the fibrous flexor tendon sheath of digit 5 as a sublimis tendon. At its point of entry, this small tendon is reinforced by main fibers from the palmar fascia. The palmar fascia proper, which spreads over the palm with the concentration of fibers and bands towards the digits 2, 3, and 4, shows these bands attaching to the fibrous flexor sheath and

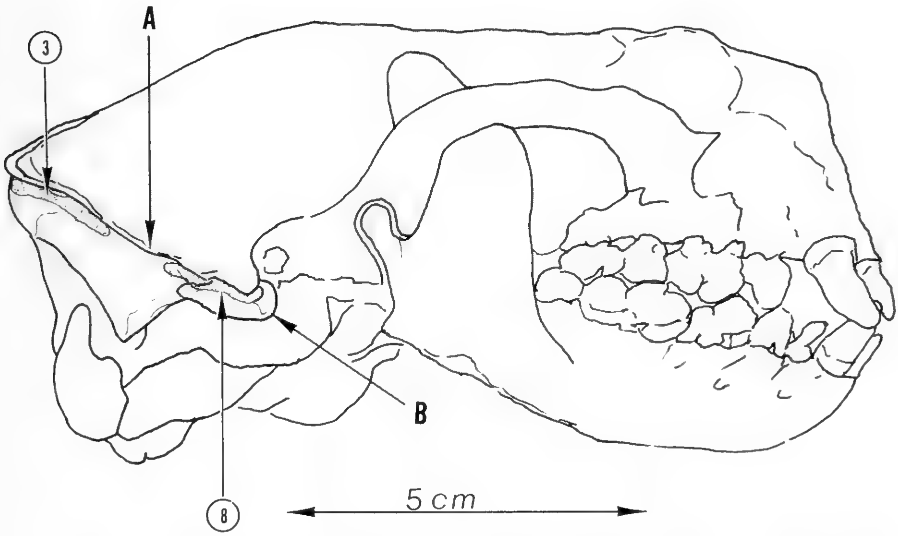

Figure 57. Skull, right lateral view. Key: 3, clavotrapezius (origin); 8, rhomboideus capitis (origin); A, lamboidal crest; B, mastoid process.

entering the sheath to reinforce the respective sublimi tendons to these digits. For the thumb, the lesser fibrous band simply attaches to the fibrous flexor digital sheath as there is no sublimis tendon for this digit.

Insertion. As noted from the description above, the palmaris longus muscle has three functions; namely, cupping of the palm by tensing the palmar fascia, volar flexion of the wrist, and reinforcing the flexor sublimi tendons which flex the proximal interphalangeal joints of digits 2, 3, 4, and 5.

41. Flexor digitorum profundus (ulnar head).

This muscle represents part of the profundus flexor mechanism of the digits. The remaining part is the flexor digitorum profundus, humeral head and central head.

Origin. Musculotendinous fibers arise from the medial olecranon ridge beneath the origin of the flexor carpi ulnaris with additional fleshy fibers of origin continuing distally from the medial surface of the ulna in its upper half tapering along the ulna crest. Tendon fibers begin to appear in the lower half of the muscle but muscle fibers continue as far distally as the wrist. Slightly above wrist level, junction occurs with the humeral and central heads with five resulting strong tendons which pass through the carpal tunnel under the deep transverse carpal ligament and then pass one to each digit. It is to be noted that the contribution from the ulnar head makes up the tendons for digits 4 and 5.

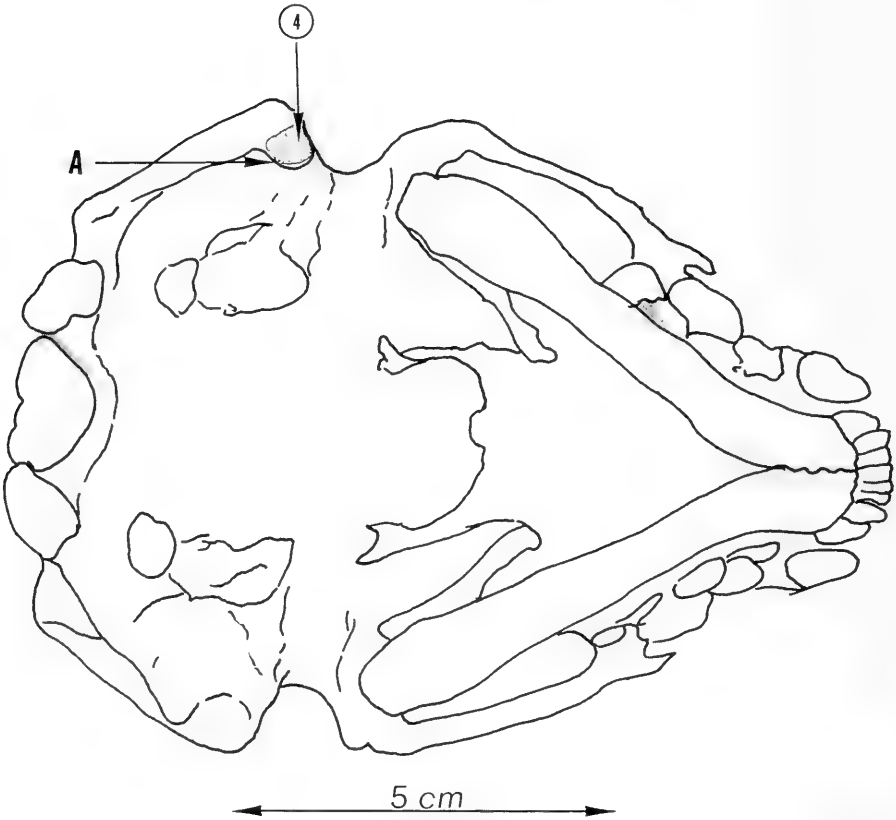

FIGURE 58. Skull, volar view. Key: 4, cleidomastoideus (origin); A, mastoid process.

INSERTION. Flexor profundus tendons of digits 4 and 5 enter the fibrous flexor tendon sheath of the metacarpal-head level passing through a split of the flexor sublimis tendon in the proximal phalanx area, the tendon continues distally in its sheath to its insertion on the volar surface of the base of the terminal or distal phalanx.

ACTION. The profundus tendon flexes the terminal finger joint and all proximal finger joints as well.

42. Flexor digitorum profundus (humeral head).

This is a strong centrally placed forearm muscle connecting the humerus with the digits. It is part of the profundus flexor mechanism.

ORIGIN. Tendinous and muscular fibers arise from the medial humeral epicondyle under the distal one-half of the origin of the palmaris longus muscle and just distal to the origin of the flexor carpi radialis muscle. In the forearm,

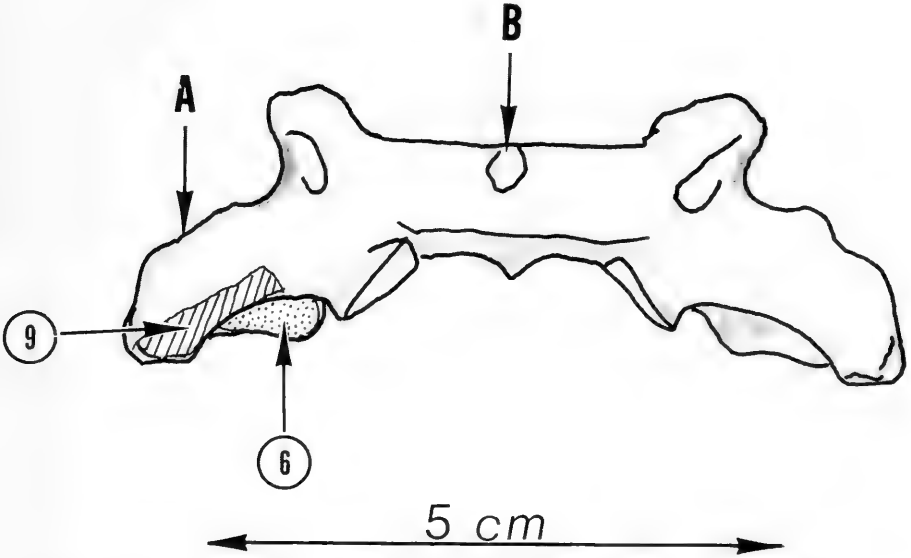

Figure 59. Atlas, volar view. Key: 6, omotrachleon (origin); 9, rhomboideus profundus (origin); A, transverse process; B, anterior tubercle.

the muscle lies between the flexor digitorum profundus (ulnar head) and the flexor carpi radialis. Insertional tendon begins to develop about halfway to the wrist and, at wrist level, junction with the ulnar and central heads occurs and the five resulting tendons pass through the carpal tunnel and on to the digits. The humeral head contributes to the tendons of digits 1, 2, and 3.

Insertion. The profundus tendons of digits 2 and 3 insert as described for those of digits 4 and 5. For the thumb, a similar fibrous flexor tendon sheath is present but there is no sublimis tendon and only two phalanges. Insertion is into the base of the terminal phalanx on its volar surface.

Action. The profundus tendon flexes the distal joint of the digits and all proximal digital joints as well.

43. **Flexor carpi radialis.**

This strong muscle with tendinous fibers at each end connects the humerus to the hand.

Origin. The heavy tendinous fibers of origin arise from the medial humeral epicondyle under the proximal one-half of the origin of the palmaris longus muscle and adjacent to the origin of the humeral head of the flexor digitorum profundus muscle. The flexor carpi radialis is fusiform in shape and passes down the volar aspect of the forearm under the palmaris longus muscle and adjacent to the humeral head of the flexor digitorum profundus. At wrist level, a heavy

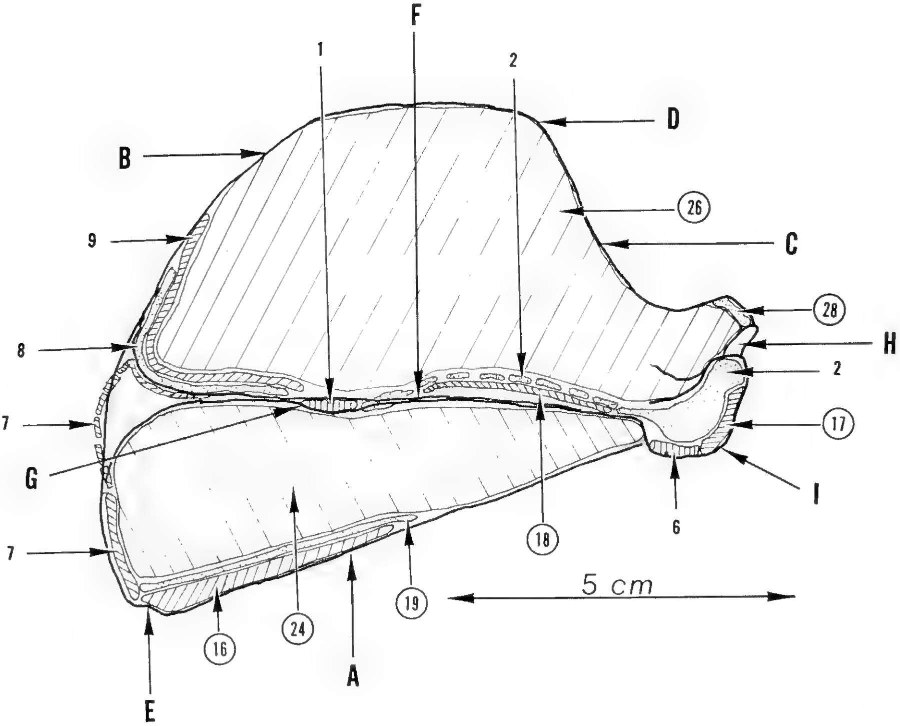

FIGURE 60. Right scapula, lateral surface. Key: 16, teres major (origin); 17, acromiodeltoideus (origin); 18, spinodeltoideus (origin); 19, dorsoepitrochlearis (origin); 24, infraspinatus (origin); 26, supraspinatus (origin); 28, biceps brachii (origin); 1, spinotrapezius (insertion); 2, acromiotrapezius (insertion); 6, omotrachleon (insertion); 7, rhomboideus major (insertion); 8, rhomboideus capitis (insertion); 9, rhomboideus profundus (insertion); A, axillary border of scapula; B, vertebral border of scapula; C, superior border of scapula; D, superior angle of scapula; E, inferior angle of scapula; F, spine of scapula; G, tuberosity of scapular spine; H, glenoid surface; I, acromion process.

tendon forms which passes to the ulnar side of the radial sesamoid and dips deeply into the palm.

INSERTION. This tendon inserts on the volar surface of the base of metacarpal 2.

ACTION. Strong palmar flexion of the wrist results from a pull on this tendon.

44. Pronator teres.

This is a strong thick muscle passing from the medial side of the distal humerus to the radius.

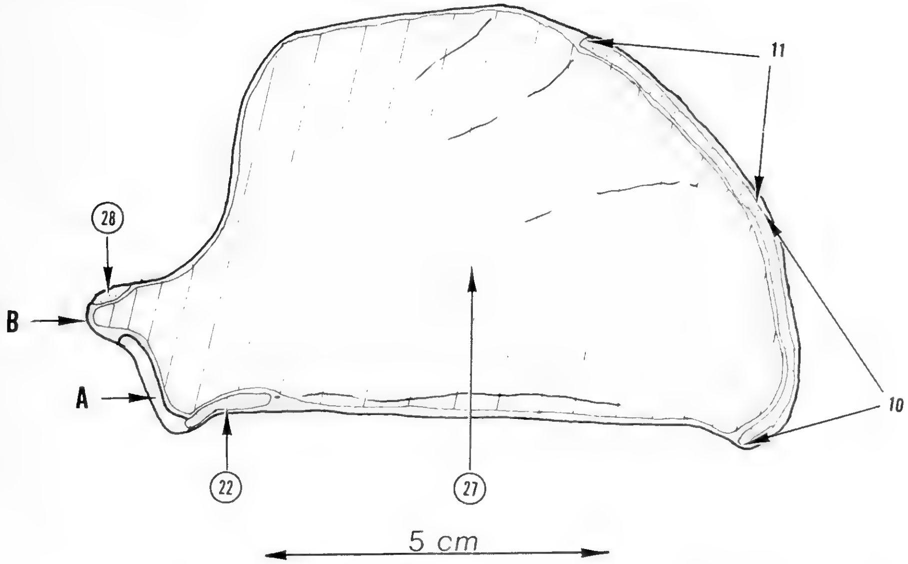

Figure 61. Right scapula, medial surface. Key: 22, triceps brachii caput medialis (origin); 27, subscapularis (origin); 28, biceps brachii (origin); 10, serratus magnus (insertion); 11, levator anguli scapulae (insertion); A, glenoid; B, supraglenoid tubercle.

Origin. This muscle is the most proximal of those arising from the medial humeral epicondyle, but the distal one-half of the origin underlies the origin of the flexor carpi radialis. Arising mostly by tendinous fibers, this muscle diagonally crosses the upper forearm and spreads out as it approaches the radius.

Insertion. Starting along the radial margin of the ridge of the radius, the insertion continues distally the full length of the bone. Tendinous fibers make up the insertion for the most part, with a heavy concentration of fibers at the maximum bow of the radius where the insertion comes in close relationship to the insertion of the supinator muscle. Tendinous fibers continue in lesser concentration along the distal radius to the volar aspect of the radial styloid where they lie adjacent to the insertion of the brachioradialis muscle.

Action. As an antagonist to supination, this muscle is a strong pronator of the forearm.

45. Flexor digitorum profundus (central head).

The deepest of the flexor profundus group, this muscle is roughly Y-shaped and arises in the upper forearm to join with the ulnar and humeral heads of the flexor digitorum profundus to give flexor action to the digits.

Origin. There are three areas of origin of this muscle. The ulnar portion arises as fleshy fibers from the anteromedial surface of the upper two-thirds

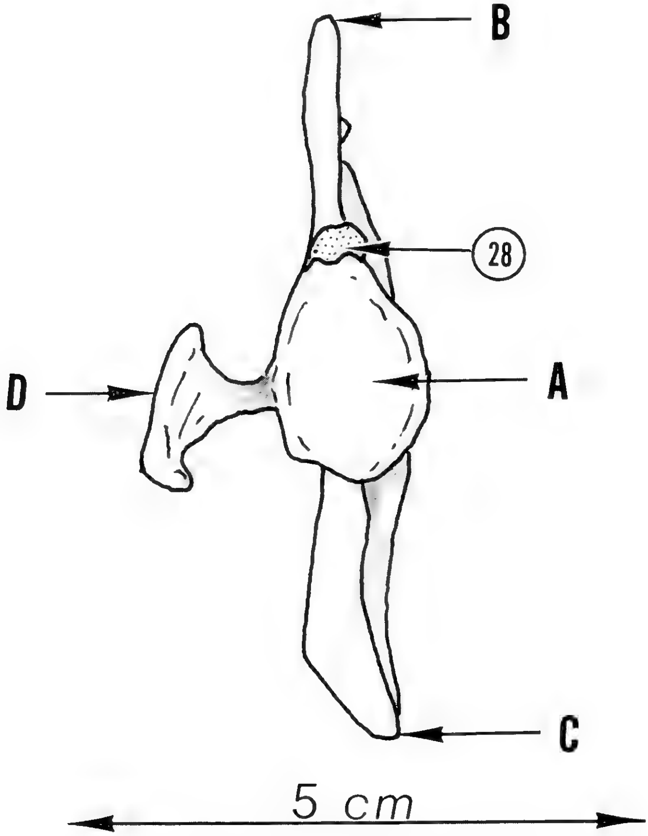

Figure 62. Right scapula, glenoid view. Key: 28, biceps brachii (origin); A, glenoid; B, superior angle of scapula; C, inferior angle of scapula; D, acromion process.

of the ulna. The origin starts near the articular lip of the ulna and adjacent and lateral to the tendons of insertion of the brachialis and pectoantebrachialis muscles. The radial portion arises from the anteromedial surface of the upper two-thirds of the radius, starting near the articular rim at the neck of the radius and just lateral to the bicipital tubercle. The interosseus portion arises from the volar surface of the interosseus membrane between the radius and the ulna, at the upper margin of the membrane. The muscle thus formed is flat and underlies the other profundi musculature which it joins from the underside at the level where the tendons begin to form. Distally, the flexor profundus musculature overlies the pronator quadratus muscle.

Insertion. The muscle fibers join into the flexor digitorum profundus (central and ulnar heads) which contributes to the tendons formed and therefore has a common insertion with them.

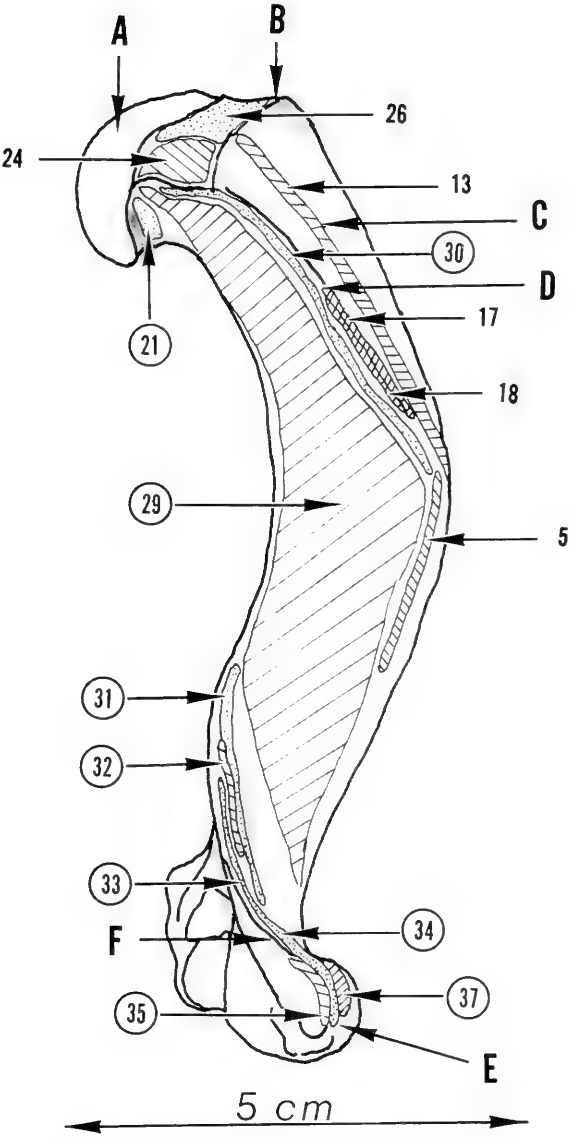

Figure 63. Right humerus, posterior view. Key: 21, triceps brachii caput lateralis (origin); 29, brachialis (origin); 30, brachioradialis (origin); 31, extensor carpi radialis longus (origin); 32, extensor carpi radialis brevis (origin); 33, extensor digitorum communis (origin); 34, extensor digitorum lateralis (origin); 35, extensor carpi ulnaris (origin); 37, supinator (origin); 5, clavobrachialis (insertion); 13, pectoralis major (insertion); 17, acromiodeltoideus (insertion); 18, spinodeltoideus (insertion); 24, infraspinatus (insertion); 26, supraspinatus (insertion); A, head of humerus; B, greater tuberosity; C, pectoral ridge; D, deltoid ridge; E, lateral epicondyle; F, lateral epicondylar ridge.

46. **Pronator quadratus.**

This muscle is flat and thin with fibers running transversely. It lies in the distal forearm connecting the radius and ulna.

ORIGIN. Fleshy and tendinous fibers arise from the distal one-third of the medial surface of the ulna. From its origin, the muscle fibers pass directly transversely to the radius maintaining full width of the muscle.

INSERTION. Fleshy and tendinous fibers insert into the distal one-fourth of the volar surface of the radius adjacent to the lower part of the insertion of the pronator teres muscle.

ACTION. Pronation of the forearm is accomplished by this muscle.

47 and 48. **Flexor digitorum sublimis.**

There are four small flexor sublimi tendons, one each for digits 2, 3, 4, and 5. Digit 1 is without a sublimis tendon. The flexor sublimis of digit 5 has been previously described under the palmaris longus muscle.

ORIGIN. The flexor sublimis tendons for digits 2, 3, and 4, arise from the volar surface of the flexor digitorum profundus complex just proximal to the wrist. The sublimis for digit 4 comes from the ulnar head, those for digits 2 and 3 from the humeral head. Because of their origin and position in the hand, they have been grouped as (47) flexor digitorum sublimis (radial) for digits 2 and 3, and (48) flexor digitorum sublimis (ulnaris) for digits 4 and 5.

INSERTION. The sublimis tendons of digits 2, 3, 4, and 5 enter the digital fibrous flexor tendon sheaths superficially to the profundus flexor tendons. At this point, each is strongly reinforced by palmar fascia fibers to form a wide flat tendon overlying and completely covering the profundus tendon. After a short distance within the sheaths, the sublimis tendons abruptly split longitudinally and curve around on either side of the profundus to rejoin into a thin but broad tendon which hugs the proximal phalanx forming the back wall of the flexor sheaths. The sublimi tendons continue distally across the proximal interphalangeal joint to a broad insertion on the volar lip of the proximal end of the middle phalanx.

ACTION. The sublimi tendons act to flex the proximal interphalangeal joints of digits 2, 3, 4, and 5. In view of their origin, those of digits 2, 3, and 4 must function in relation to the profundus flexor tendons. For digit 5, the anatomy would allow for some independent flexion of the proximal interphalangeal joint. The broad spread of the sublimis tendons at metacarpal-phalangeal joint level could also serve as a pulley mechanism for the profundi tendons.

THE INTRINSIC MUSCLES OF THE HAND

A group of small muscles within the hand proper have been termed intrinsic hand muscles. In view of their size, these muscles are not strong but they serve a most important function in balancing the action of the long forearm flexor and extensor musculature. These muscles, also, can provide the fine skill motion of the digits. This latter function can hardly be recognized in the sea otter as the digits are in the state of syndactyly and the thumb is unopposable.

For descriptive purposes, these intrinsic muscles can be grouped as follows. Those about the first ray are called the thenar intrinsic muscles. Those about the fifth ray are called the hypothenar intrinsic muscles. The remaining small muscles consist of the interossei, one each for the second, third, and fourth digits, and two accessory intrinsic muscles for digit 2.

Also, the lumbrical muscle is generally considered an intrinsic muscle, although its origin is from the flexor digitorum profundus group of tendons.

The Hypothenar Group of Intrinsic Hand Muscles

49. **Abductor digiti quinti.**

This is a rather large coarse muscle forming the ulnar border of the hand.

Origin. Fleshy fibers arise from a triangular area on the distal surface of the pisiform bone. The muscle becomes spindle-shaped passing distally.

Insertion. The insertion is through a sesamoid bone into the ulnar volar aspect of the base of the proximal phalanx.

Action. This muscle flexes the metacarpal phalangeal joint of digit 5 and would also serve to abduct the extended digit within its anatomical limits.

50. **Opponens digiti quinti.**

This is a superficial slender fusiform muscle of the hypothenar group.

Origin. Fleshy and tendinous fibers arise from the ulnar side of the deep carpal ligament to form the thin muscle which first overrides the long flexors of the fifth digit, then passes more deeply into the palm on a slightly oblique course to overlie the adductor and flexor digiti quinti. At the metacarpal phalangeal joint level a small thin tendon forms.

Insertion. The insertion is into the volar aspect of the base of the proximal phalanx of digit 5 just to the ulnar side of the tendinous insertion of the adductor digiti quinti.

Action. The position of this muscle would provide slight opposition action to the fifth ray if such were possible. The muscle probably serves to assist in independent flexion of the metacarpal-phalangeal joint.

51. **Flexor digiti quinti brevis.**

This muscle is small and deep in the palm, being in the general plane of the interossei muscles of the adjacent digits.

Origin. This muscle arises from the fibrous capsule of the wrist joint to the ulnar side of the flexor carpi ulnaris tendon. A fusiform muscle is formed which passes directly to the radial side of digit 5 where a small tendon forms.

INSERTION. This small tendon inserts into the base of the proximal phalanx and on the radial side dorsal to the insertion of the adductor and opponens muscles.

ACTION. Flexion of the metacarpal-phalangeal joint of the fifth digit is accomplished by this muscle and also some degree of adduction.

52. Adductor digiti quinti.

This flat triangular muscle is the next most superficial of the hypothenar group.

ORIGIN. Fleshy fibers arise over a broad area of the volar fibrous wrist-joint capsule adjacent to and on the ulnar side of the origin of the adductor pollicis and extend ulnaward to the margin of the flexor carpi ulnaris tendon. The muscle from its origin triangulates distally and obliquely toward the base of the proximal phalanx of the fifth digit.

INSERTION. A short tendon arises which inserts into the base of the proximal phalanx on the ulnar side just radial to the opponens digiti quinti and overlying the insertion of the flexor digiti quinti brevis.

ACTION. The action of this muscle is to adduct the fifth digit and also to assist in flexion of the metacarpal-phalangeal joint.

THE LUMBRICAL MUSCLE

53. Lumbricali.

This small intrinsic hand muscle differs from the other by virtue of its origin.

ORIGIN. Arising from the opposed surfaces of the profundus flexor tendons of digits 3 and 4 in the proximal palm, the fleshy fibers form a short slim muscle which traverses the palm partly by a very thin tendon which passes to the radial side of digit 4.

INSERTION. This small tendon inserts into the radial side of the proximal phalanx of digit 4 just distal to the joint surface. The tendon fibers terminate into the periosteum and bone rather than entering into the extensor aponeurosis.

ACTION. Owing to its site of insertion, the muscle gives radiolateral motion of the metacarpal-phalangeal joint and also flexion of this joint.

NOTES. The number of lumbrical muscles is variable. In another specimen three lumbrical muscles were noted.

THE THENAR INTRINSIC MUSCLES

54. Abductor pollicis brevis.

This is a small fusiform muscle on the radial side of digit 1.

ORIGIN. Fleshy fibers arise, half from the radial sesamoid and half from the adjacent deep carpal ligament to form a small muscle which passes along the radial side of the metacarpal adjacent to the radial portion of the flexor pollicis brevis.

Insertion. This small muscle terminates distally in a tendon which joins with the tendon of the radial part of the flexor pollicis brevis to insert in the radial volar side of the base of the proximal phalanx through a sesamoid bone.

Action. The principle action is flexion of the metacarpal-phalangeal joint of digit 1. A minor degree of abduction is probably also obtained.

55. **Flexor pollicis brevis.**

This muscle, which divides near its insertion, is the deepest of the thenar group.

Origin. Fleshy fibers arise from the volar fibrous wrist joint capsule between the origin of the adductor pollicis and the abductor pollicis brevis. The muscle then passes distally overlying the proximal area of the metacarpal of digit 1. The muscle then divides into radial and ulnar halves. The terminal tendon of each half inserts into the base of the proximal phalanx, the radial half through the sesamoid with a tendon of the short abductor, the ulnar half with the tendon of the adductor pollicis.

Action. Both halves serve as flexors of the metacarpal-phalangeal joint of digit 1.

56. **Adductor pollicis.**

This muscle is the largest of the thenar group.

Origin. Fleshy fibers arise from the volar fibrous capsule of the wrist joint between the origin of the flexor pollicis brevis on the radial side and the adductor digiti quinti on the ulnar side. The origin of this muscle overlies the origin of the deeper intrinsic muscles of the second digit. The muscle thus formed courses obliquely radiusward across the palm to the ulnar side of the proximal phalanx of digit 1.

Insertion. The short flat tendon which forms overrides but joins with the tendon of the ulnar part of the flexor pollicis brevis to insert on the ulnar volar lateral aspect of the proximal phalanx of digit 1.

Action. This muscle will adduct and flex the metacarpal-phalangeal joint of digit 1.

The Accessory Intrinsic Muscles of Digit 2

57. **Abductor digiti secundi.**

This muscle is a short, somewhat thick, muscle which overlies the interossei musculature.

Origin. Fleshy fibers arise from the volar surface of the base of metacarpal

1. The muscle then passes slightly obliquely across the thumb web to the radial side of the base of the proximal phalanx of digit 2.

Insertion. Tendinous fibers developing at this level have a dual insertion. The more superficial fibers form a sheetlike aponeurosis which passes dorsally into the extensor hood and dorsal extensor aponeurosis. The deeper fibers join with the tendon at the radial part of the interosseus muscle for this digit and insert through a sesamoid bone into the base of the radial side of the proximal phalanx.

Action. The more superficial fibers which join with the extensor aponeurosis act to extend the proximal interphalangeal joint and to flex the metacarpal-phalangeal joint. The deeper fibers serve to radialflex the metacarpal-phalangeal joint.

58. **Adductor digiti secundi.**

This slender fusiform muscle lies in the same plane with the abductor digiti secundi and also overlies the deeper interossei muscles.

Origin. Fleshy fibers arise from a small area of fibrous capsule at the base of metacarpal 3 slightly proximal and to the ulnar side of the origin of the interosseus of digit 2. The muscle then passes slightly obliquely and distally to the ulnar side of digit 2 where a short tendon develops.

Insertion. At the metacarpal-phalangeal joint level the tendon passes close to the volar plate and sesamoid bone and volar to the tendon of the ulnar half of the interosseus muscle of this digit. The insertion is into the base of the proximal phalanx on the ulnar side.

Action. This muscle would adduct digit 2 at the metacarpal-phalangeal joint level and also assist in flexion of this joint.

The Interossei Muscles

59. **Interossei.**

These muscles, three in number, are the deepest intrinsic muscles of the hand. They are short and thick and somewhat fusiform in shape. Each muscle divides about halfway from its origin into radial and ulnar halves which then pass to the respective sides of each digit at metacarpal-phalangeal joint level.

Origin. All interossei muscles arise as fleshy fibers from the volar aspect of the fibrous capsule at the base of the metacarpals. Interosseus 2 between metacarpals 2 and 3, interosseus 3 at the base of metacarpal 3, and interosseus 4 at the base of metacarpal 4. The ulnar half of interosseus 4 is the largest of the interossei divisions and shows a slight tendency toward further division in its distal one-third.

Insertion. With the exception of the radial half of interosseus 2, all interossei form flattened tendons passing close to the volar plate at metacarpal-

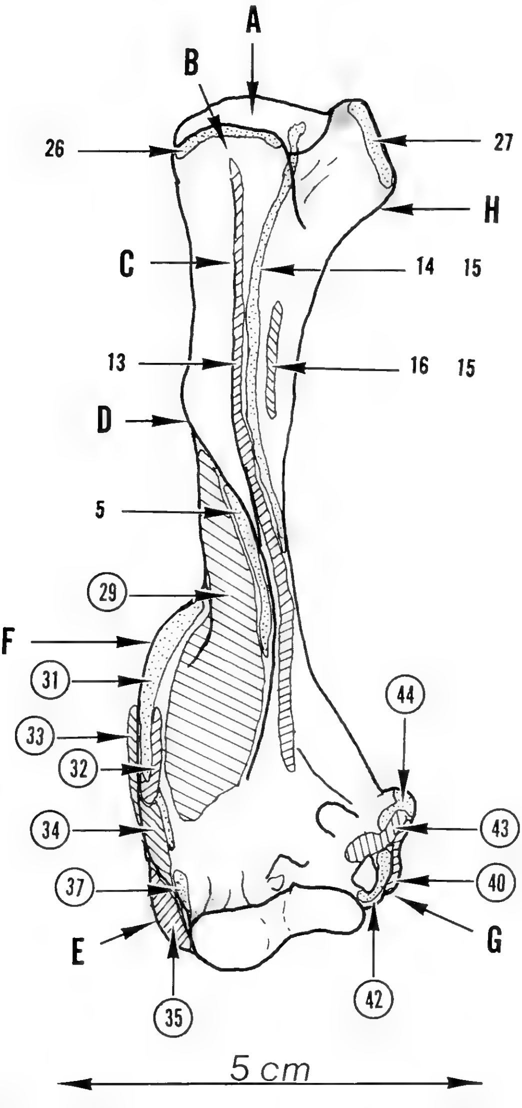

Figure 64. Right humerus, lateral view. Key: 29, brachialis (origin); 31, extensor carpi radialis longus (origin); 32, extensor carpi radialis brevis (origin); 33, extensor digitorum communis (origin); 34, extensor digitorum lateralis (origin); 35, extensor carpi ulnaris (origin); 37, supinator (origin); 40, palmaris longus (origin); 42, flexor digitorum profundus (humeral head—origin); 43, flexor carpi radialis (origin); 44, pronator teres (origin); 5, clavobrachialis (insertion); 13, pectoralis major (insertion); 14, pectoralis minor (insertion); 15, latissimus dorsi (insertion); 16, teres major (insertion); 26, supraspinatus (insertion); 27, subscapularis (insertion); A, head of humerus; B, greater tuberosity; C, pectoral ridge; D, deltoid ridge; E, lateral epicondyle; F, lateral epicondylar ridge; G, medial epicondyle; H, lesser tuberosity.

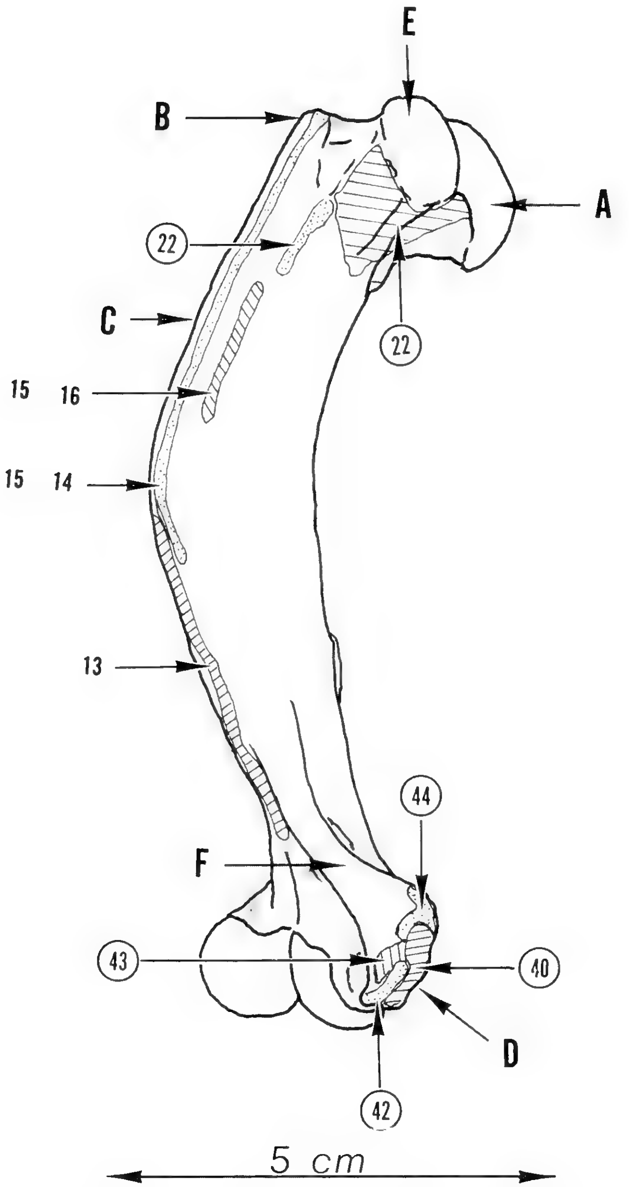

FIGURE 65. Right humerus, anterior view. Key: 22, triceps brachii caput medialis (two of three sites of origin); 40, palmaris longus (origin); 42, flexor digitorum profundus (humeral head—origin); 43, flexor carpi radialis (origin); 44, pronator teres (origin); 13, pectoralis major (insertion); 14, pectoralis minor (insertion); 15, latissimus dorsi (insertion); 16, teres major (insertion); A, head of humerus; B, greater tuberosity; C, pectoral ridge; D, medial epicondyle; E, lesser tuberosity; F, medial epicondylar ridge.

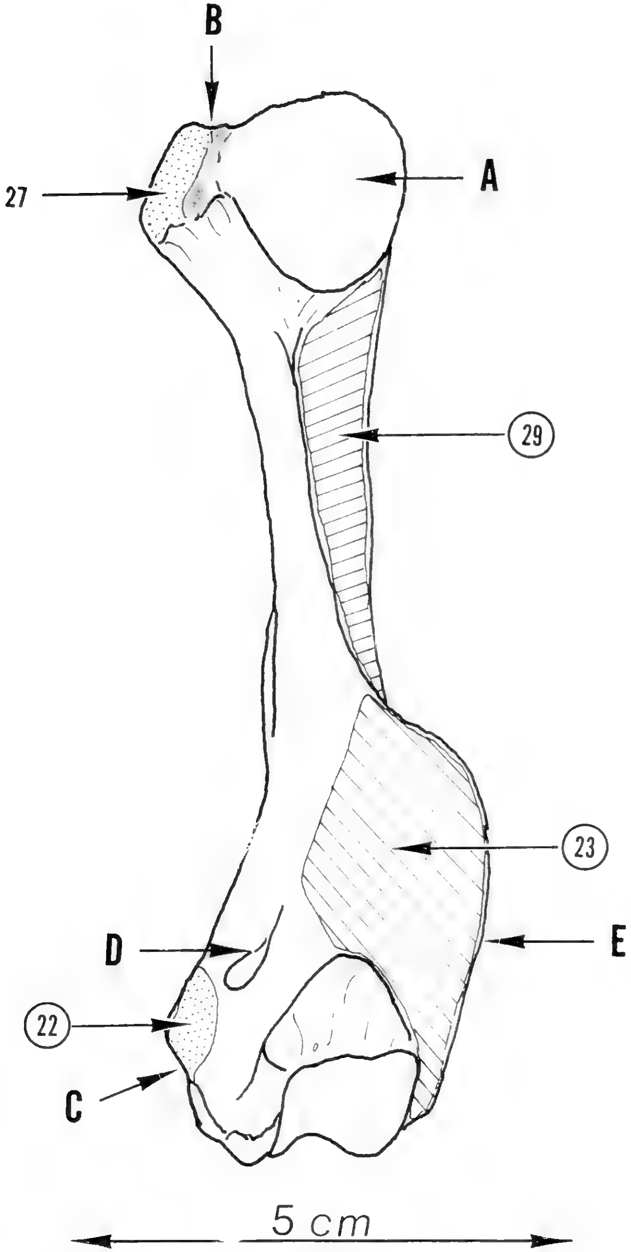

Figure 66. Right humerus, medial view. Key: 22, triceps brachii caput medialis (origin); 23, anconeus externus (origin); 29, brachialis (origin); 27, subscapularis (insertion); A, head of humerus; B, lesser tuberosity; C, medial epicondyle; D, medial epicondylar foramen; E, lateral epicondylar ridge.

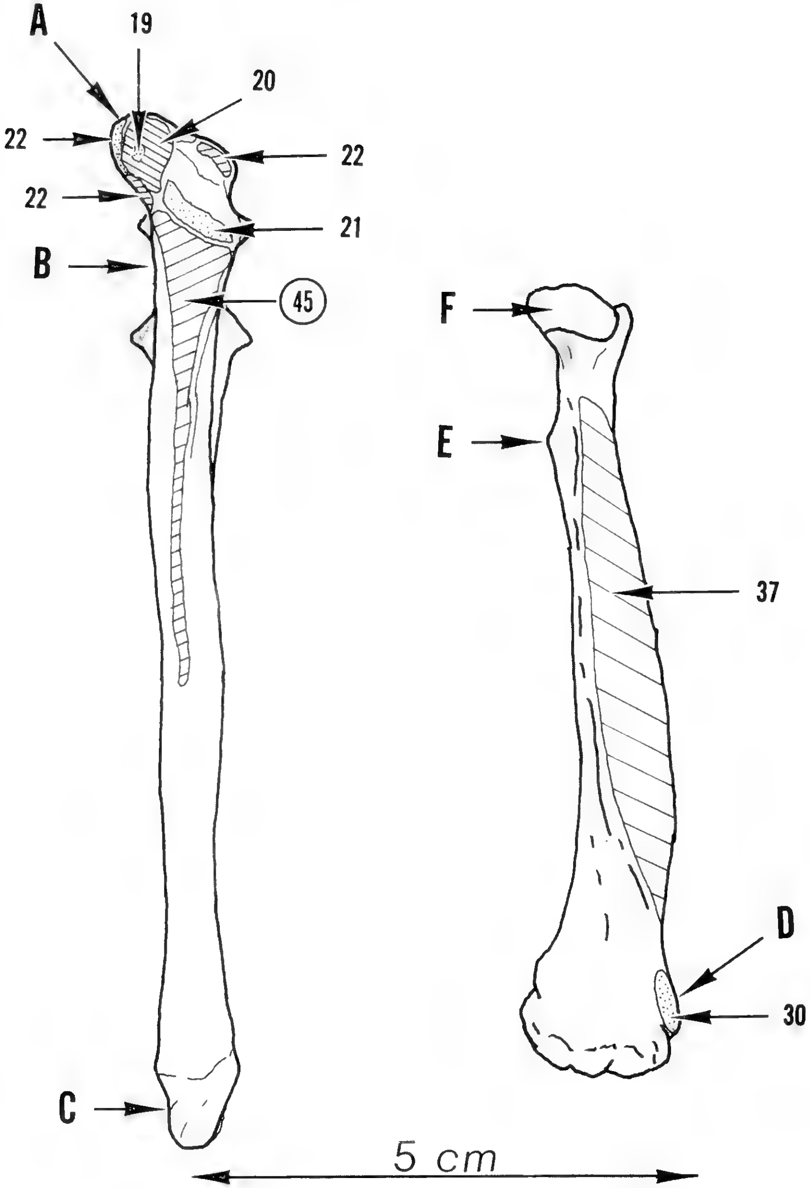

FIGURE 67. Right ulna and radius, posterior view. Key: 45, flexor digitorum profundus (humeral head—origin); 19, dorsoepitrochlearis (insertion); 20, triceps brachii caput longus (insertion); 21, triceps brachii caput lateralis (insertion); 22, triceps brachii caput medialis (insertion); 30, brachioradialis (insertion); 37, supinator (insertion); A, olecranon process of ulna; B, semilunar notch; C, styloid process; D, radial styloid; E, biceps tubercle of radius; F, head of radius.

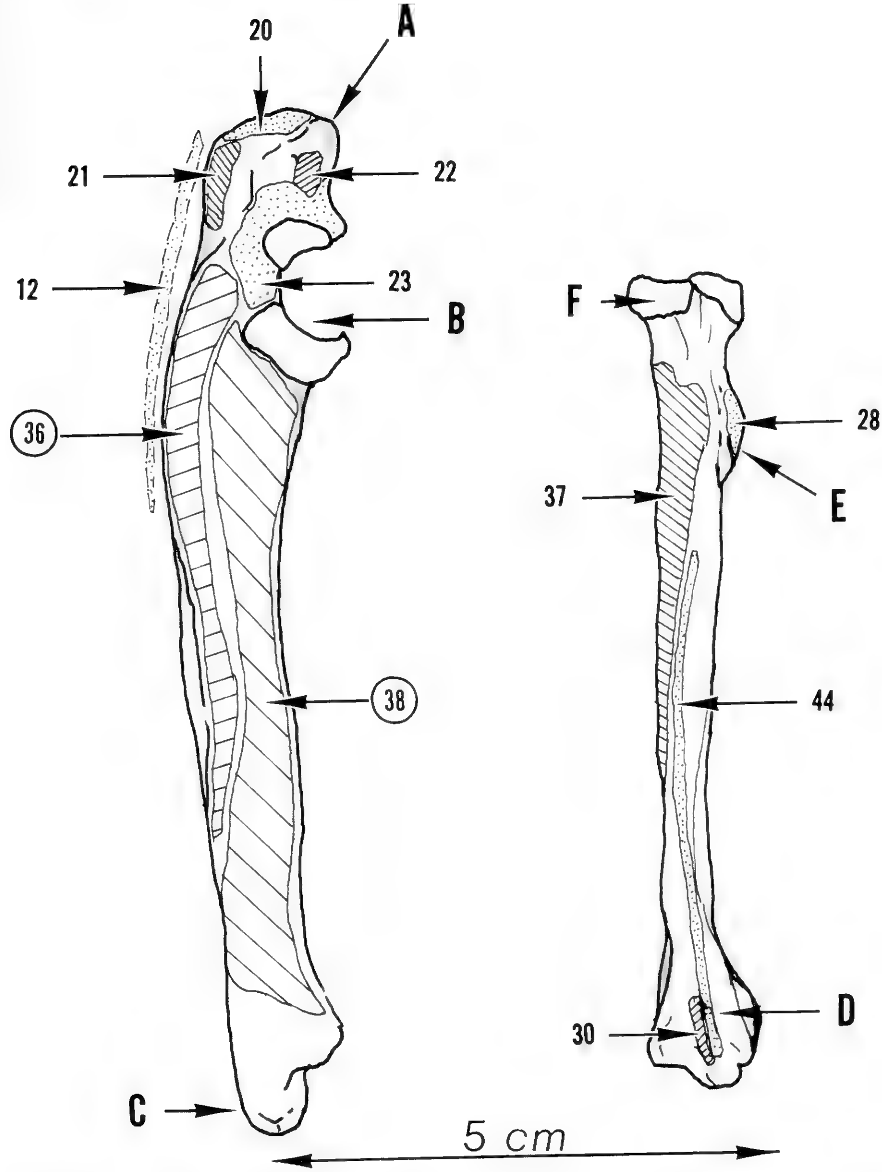

FIGURE 68. Right ulna and radius, lateral view. Key: 36, extensor pollicis et indicis longus (origin); 38, abductor pollicis longus (origin); 12, pectoantebrachialis (into fascia—insertion); 20, triceps brachii caput longus (insertion); 21, triceps brachii caput lateralis (insertion); 22, triceps brachii caput medialis (insertion); 23, anconeus externus (insertion); 28, biceps brachii (insertion); 30, brachioradialis (insertion); 37, supinator (insertion); 44, pronator teres (insertion); A, olecranon process, ulna; B, semilunar notch; C, styloid process, ulna; D, styloid process, radius; E, bicipital tuberosity; F, head of radius.

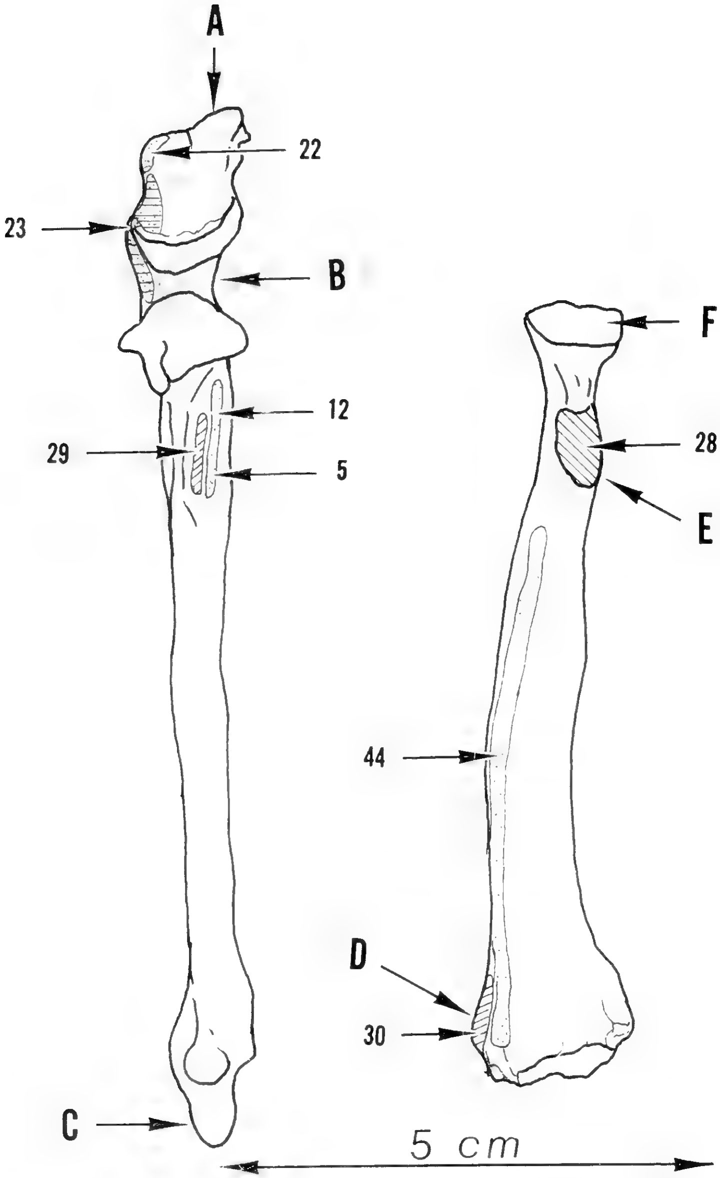

FIGURE 69. Right ulna and radius, anterior view. Key: 5, clavobrachialis (insertion); 12, pectoantebrachialis (insertion); 22, triceps brachii caput medialis (insertion); 23, anconeus externus (insertion); 28, biceps brachii (insertion); 29, brachialis (insertion); 30, brachioradialis (insertion); 44, pronator teres (insertion); A, olecranon process, ulna; B, semilunar notch; C, styloid process, ulna; D, styloid process, radius; E, bicipital tuberosity; F, head of radius.

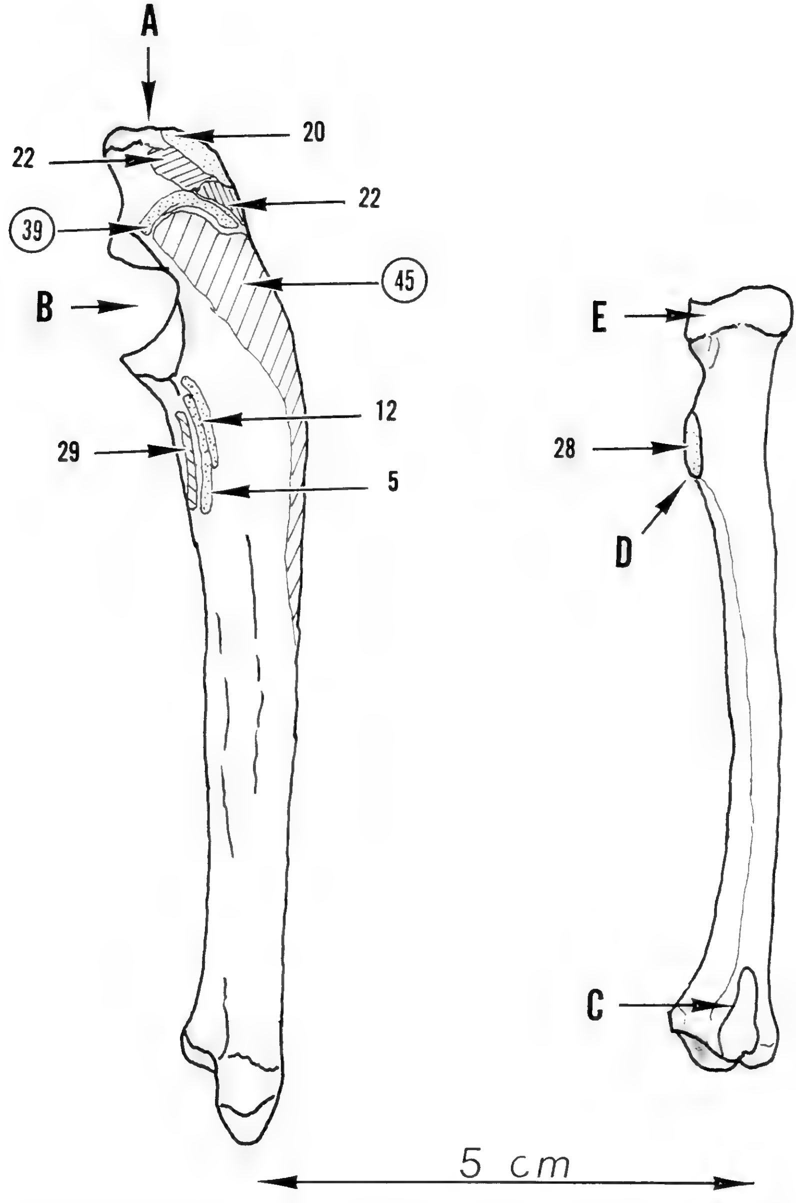

Figure 70. Right ulna and radius, medial view. Key: 39, flexor carpi ulnaris (origin); 45, flexor digitorum profundus (central head—origin); 5, clavobrachialis (insertion); 12, pectoantebrachialis (insertion); 20, triceps brachii caput longus (insertion); 22, triceps brachii caput medialis (insertion); 28, biceps brachii (insertion); 29, brachialis (insertion); A, olecranon process, ulna; B, semilunar notch, ulna; C, articular surface for ulna; D, bicipital tubercle, radius; E, radial head.

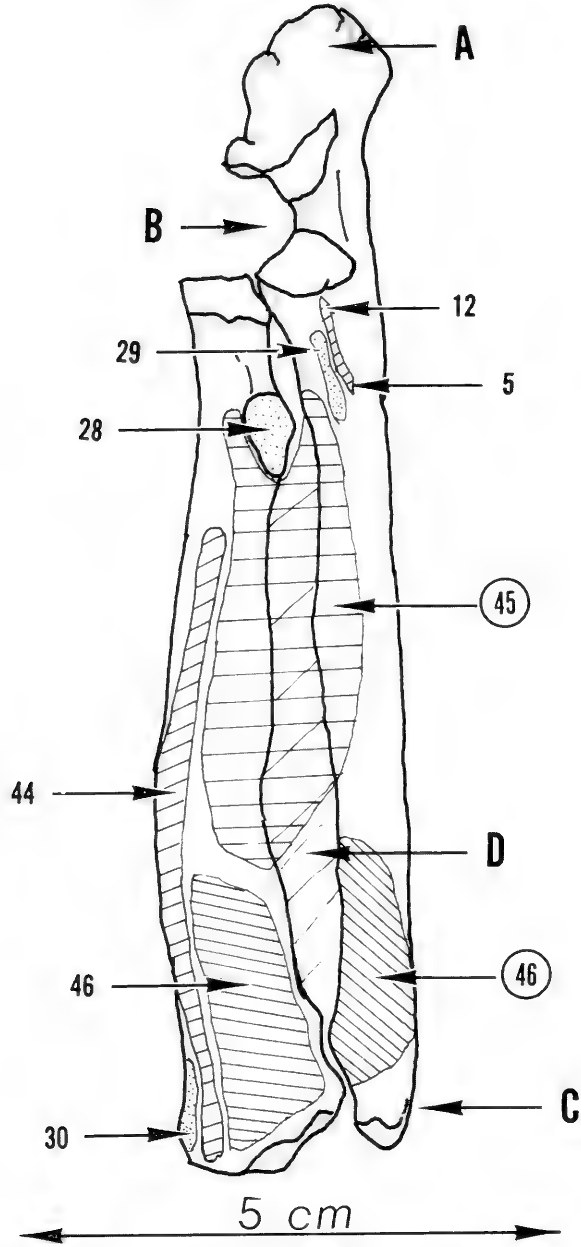

Figure 71. Right ulna and radius, articulated, anterior view. Key: 45, flexor digitorum profundus (central head—origin); 46, pronator quadratus (origin); 5, clavobrachialis (insertion); 12, pectoantebrachialis (insertion); 28, biceps brachii (insertion); 29, brachialis (insertion); 30, brachioradialis (insertion); 44, pronator teres (insertion); 46, pronator quadratus (insertion); A, olecranon process, ulna; B, semilunar notch, ulna; C, styloid process, ulna; D, interosseus membrane.

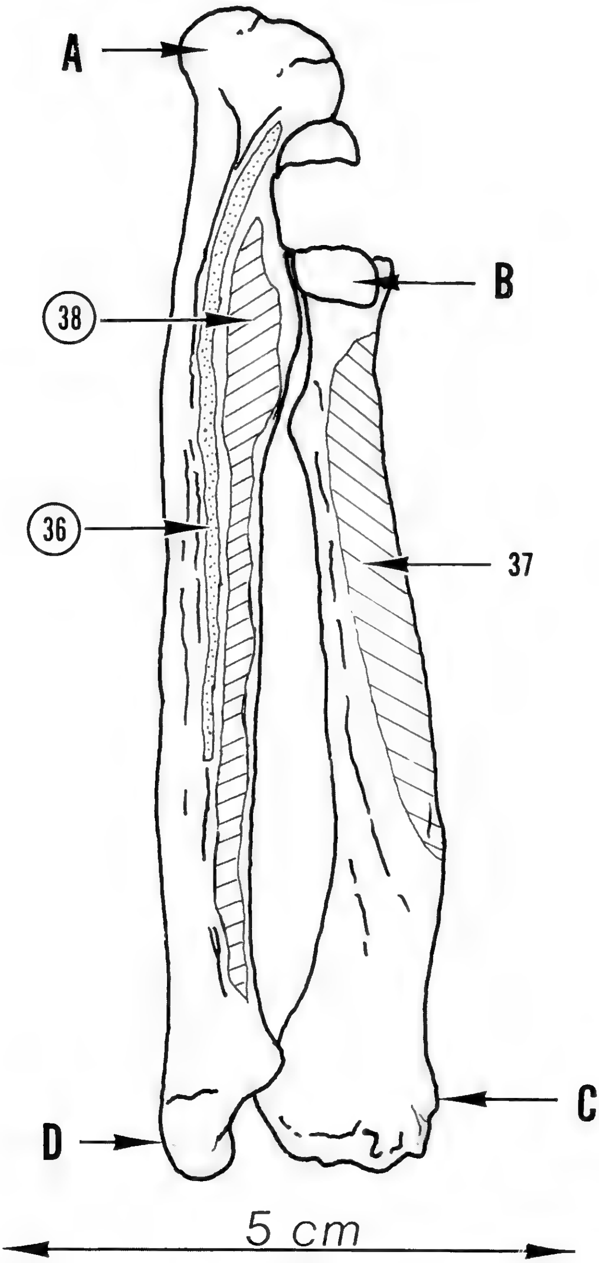

Figure 72. Right ulna and radius, articulated, posterior view. Key: 36, extensor pollicis et indicis longus (origin); 38, abductor pollicis longus (origin); 37, supinator (insertion); A, olecranon process, ulna; B, head of radius; C, styloid process, radius; D, styloid process, ulna.

phalangeal joint level and then, as aponeurotic sheets, join into the extensor hood and extensor aponeurosis of each digit forming the lateral band of the extensor aponeurosis. At the proximal interphalangeal joint level, these lateral bands and extensor aponeuroses terminate into the central extensor tendon to insert into the dorsum at the base of the middle phalanx. The extensor tendon structures do not continue to the terminal phalanx as might be expected. The tendon of the radial half of the interosseus 2 joins with the tendon of the abductor digiti secundi to insert through a sesamoid into the base of the proximal phalanx as previously described.

Action. The interossei tendons joining into the extensor aponeurosis serve to balance the action between the long extensor and flexors of these digits. Acting alone, they would impart lateral motion to the extended digits or serve to flex independently the metacarpal-phalangeal joints. With the metacarpal-phalangeal joints in hyperextension, they would also act to extend the proximal interphalangeal joints. In this way, the balancing effect prevents deformity from action of the long extensors and flexor tendons alone.

Muscle Origins and Insertions

In viewing the origin and insertion of the muscles as shown in the skeletal figures, some confusion may arise owing to the bowing and torsion of the long bones, particularly the humerus. The views as described of each plate are based on the proximal ends of the bones. For example, a posterior view of the proximal end of the humerus gives, as a result of torsion of this bone, a lateral view of the distal end.

Each muscle retains its individual number and, therefore, to distinguish between origin and insertion a circled number means the area of origin and an uncircled number means the area of insertion.

The bones of the forefoot are not shown, as tendon insertions only are present and these areas of insertion are shown quite adequately on the muscle plates.

Summary

The gross muscular anatomy of the forelimb of the sea otter has been presented. For the hand the intrinsic and extrinsic musculature is sufficient to provide for dexterity, but such is extremely limited by reason of the anatomical restrictions imposed by the integument and soft parts.

The forefoot, obviously designed for terrestrial use, has become, by virtue of bimanual use, a highly skilled appendage for other purposes.

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The State of California Deparment of Fish and Game was most cooperative in providing the specimen for anatomical study. The California Academy of Sciences provided the invaluable aid of a disarticulated sea otter skeleton.

The Anatomical Studies of the California River Otter, by Edna M. Fisher, proved to be an excellent guide during the dissection, and her unpublished notes on the sea otter anatomy, which were made available through the courtesy of Mr. Fred Tarasoff, were also of value. Unpublished notes and sketches by Fred Tarasoff were also available and of some assistance.

The dissection and storage of materials took place at the Hopkins Marine Station of Stanford University in Pacific Grove, California, and the personnel of this institution, particularly Dr. I. Abbott, gave encouragement and assistance in every way possible for which I am deeply indebted.

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A NEW HAWAIIAN CHITON, *RHYSSOPLAX LINSLEYI* (MOLLUSCA: AMPHINEURA: CHITONIDAE)

By

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It has always puzzled conchologists that the Hawaiian Islands, which are so rich in marine mollusks, are poor in species of chitons. Only four Hawaiian species are known: *Acanthochitona viridis* (Pease, 1871), *A. armata* (Pease, 1871), *Ischnochiton petaloides* (Gould, 1846), and the new species described below.

This new species has been known for some years but has gone unnamed until this time. The first specimens brought to the attention of the author were collected by Mrs. Harold Gudnason at Puu o Hulu Beach, near Maili, Oahu, Hawaii, in the intertidal waters at low tide (0.0′) on February 26, 1965.

Rhyssoplax linsleyi Burghardt, new species.
(Figures 1–3.)

Diagnosis. The surface of the valves, while appearing smooth to the naked eye, looks pitted when viewed under low magnification. Under high magnification however, it is clear that the surface is indeed smooth, the 'pitted' appearance being caused by a color pattern composed of marks shaped like small starbursts.

In addition to the pattern of 'pit marks,' the anterior valve has a series of between 26 and 36 (holotype has 36) shallow grooves which are weak and difficult to see unless viewed under side light. The interior of the valve has a series of 8 slits on the outer edge of the insertion plate. This edge is also finely pectinated, a feature typical of the family Chitonidae.

Intermediate valves have the lateral areas defined but not sharply raised.

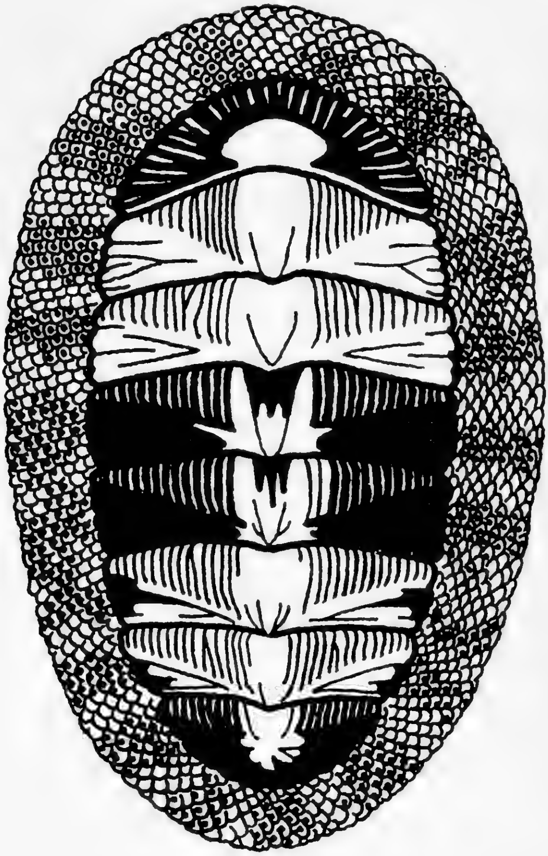

FIGURE 1. Holotype of *Rhyssoplax linsleyi.* Length 13.3 mm., width 8.4 mm., height 2.5 mm.; Puu o Hulu Beach, Oahu, Hawaii.

They possess the same radiating series of bifurcating grooves as does the anterior valve. Generally, these grooves are three in number (as in the holotype), but can be single on young specimens. The central areas of these valves are cut longitudinally with from 10 to 15 (13 in holotype) sharp lines. Both lateral and central areas have the 'pitted' color pattern. The dorsal ridge is smooth and shiny with the valves beaked. The jugal area is also smooth but shows the 'pit marks.' The outer margins of the insertion plates are pectinated and have a single slit.

The posterior valve appears smooth behind the slightly anterior mucro but also has the unique 'pitted' color pattern. This area has a series of from 23 to 32 (26 in holotype) shallow radial grooves similar to those of the

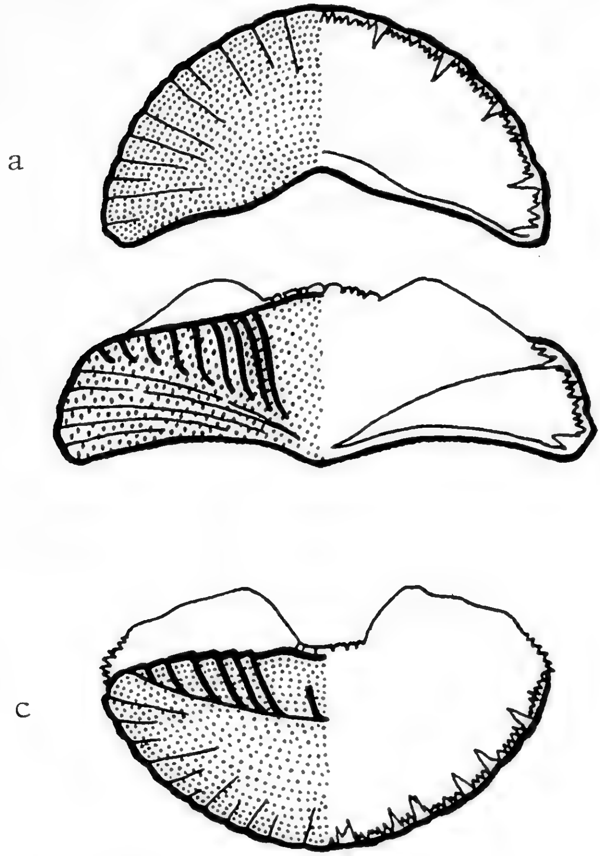

Figure 2. *Rhyssoplax linsleyi*: (a) anterior valve, (b) median valve, and (c) posterior valve. Shown are both the dorsal surface (left) and interior surface (right) of the valves.

anterior valve. The interior of this valve shows the same series of slits—here numbering 12—and pectinations as does the anterior valve.

Description. *Rhyssoplax linsleyi* is a small chiton, averaging 9.6 mm. in length (mean obtained from 116 specimens). It is fairly broad, with an average ratio of width to body length of 3:5. The valves are moderately arched, the average height being in a ratio of 1:5 to the body length.

The color of the valves is quite variable, ranging from a clean grey-white to a mottled black and white (holotype) or green and white. A few specimens in our sample were solid in color, either red or white, but such coloration appears to be rare. The color pattern occurs on both lateral and central areas. The interior of the valves is white with a slight bluish tint.

The girdle is of medium width and is covered with the fairly large, smooth

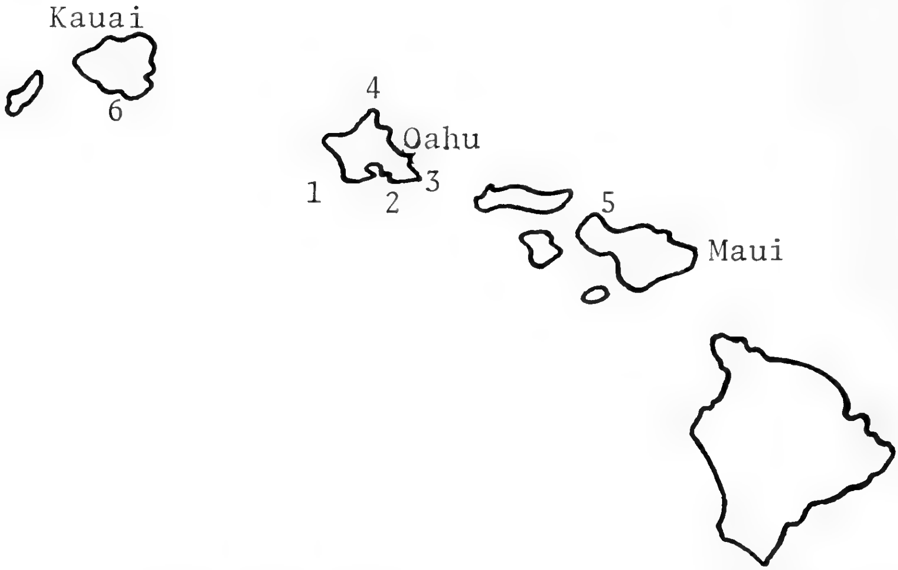

FIGURE 3. Map of Hawaiian Islands showing the collecting sites of ***Rhyssoplax linsleyi*** on the islands of Oahu, Maui, and Kauai: (1) Puu o Hulu (type locality), (2) Ala Moana, (3) Wainanalo, (4) Kuhuku Point, (5) Honolua, and (6) Poipu Beach.

scales typical of Chitonidae. This girdle is cream with green bands except on the solid colored specimens, where the girdle matches the valves in color.

No radular studies were made.

TYPE LOCALITY. The type series was collected at Puu o Hulu Beach, near Maili, Oahu, Hawaii, on 26 February 1965, by Mrs. Harold Gudnason.

TYPE MATERIAL. *Holotype.* An adult specimen preserved in alcohol is deposited in the California Academy of Sciences Department of Invertebrate Zoology Type Series, no. 567. Measurements are 13.3 mm. in length. 8.4 mm. in width, 2.5 mm. in height.

Paratypes. Twenty-four paratypes collected with the holotype have been deposited in the mollusk type collections of the following museums and private collectors: Academy of Natural Sciences of Philadelphia, two specimens, ANSP 330098; Bernice P. Bishop Museum, two specimens, BPBM 206931; California Academy of Sciences, two specimens, CAS Geology 53956 (rearticulated), CASIZ type series no. 594; Los Angeles County Museum of Natural History, two specimens, LACM 1620; Museum of Comparative Zoology, two specimens, MCZ 272531; San Diego Natural History Museum, two specimens, SDSNH 62724, 62725; National Museum of Natural History, two specimens, USNM 735016; Glenn and Laura Burghardt, six specimens; Mrs. Harold Gudnason, four specimens.

Discussion. This chiton has been collected from all sides of Oahu (Maili, Kahuku, Waimonalo, and Ala Moana). It has also been collected by Dr. Antonio Ferreira at Honolua Bay on the northwestern side of Maui, and by Dr. George Ramsay at Poipu Beach on the southern side of Kauai. It is found from the intertidal zone to a depth of 15 feet but not as an emergent species, as it has never been discovered completely exposed by the low tides. Generally, specimens can be found by turning small rocks, exposing the chitons clinging to the undersides.

Measurements of 116 specimens studied are as follows:

	Oahu (82 specimens)		Maui (34 specimens)	
	Range	*Mean*	*Range*	*Mean*
Length	3.5–14.5	8.0 mm.	7.0–21.0	13.4 mm.
Width	2.8– 6.2	4.9 mm.	4.0–12.4	8.2 mm.
Height	0.7– 2.9	1.8 mm.	—	—

According to Smith (1966) and Hyman (1967), many chitons brood their eggs and some even carry their young in the pallial cavity. Upon examining the specimens for this paper, I found that several were carrying eggs. The eggs were found to be slightly less than 0.2 mm. in diameter.

This new species belongs to the family Chitonidae Rafinesque, 1915, genus *Rhyssoplax* Thiele, 1893, the type species being the North African *Chiton affinis* Issel, 1869 (International Committee on Zoological Nomenclature, 1971, p. 18). The approximately 30 species of *Rhyssoplax* have been recorded from Africa, Japan, Australia, New Zealand, and now the distribution includes the Hawaiian Islands. No species of *Rhyssoplax* occurs on the Pacific coast of North America (Burghardt and Burghardt, 1969). Species in this group are sometimes referred to the genus *Anthochiton* Thiele, 1893, but Iredale (1914, p. 40) and Smith (1960, pp. 65–66) have referred *Anthochiton* to the synonymy of *Rhyssoplax* Thiele, 1893, which has been placed on the Official List of Generic Names in Zoology (International Committee on Zoological Nomenclature, 1971, p. 18).

Rhyssoplax linsleyi does not closely resemble any other described species. Its unique 'pitted' pattern, discussed above, distinguishes this species from all other *Rhyssoplax* known to date. Edmonson (1946, p. 118, fig. 546) mentions an undescribed chiton from Kanoehe Bay which undoubtedly belongs to *R. linsleyi*. In the Bishop Museum there are two lots of chitons which were labelled as a new species by Dall (BPBM no. 895.8 and 895.8a), but not published (personal communication, Mrs. H. Gudnason). These also represent *R. linsleyi*.

This new species is named in honor of Mrs. Gudnason's father, Earle G. Linsley, Honorary Associate in Astronomy, Bernice P. Bishop Museum and Planetarium (1957–1962).

The author wishes to express his thanks to Mr. Allyn G. Smith of the California Academy of Sciences for his review and assistance, to Mrs. Harold Gudnason for permission to work on her Oahu specimens, to Dr. Antonio Ferreira for permission to work on his Maui specimens, and to Betsy Harrison and Hilda Manzak for specimens used for this study; and a special thanks to wife, Laura, whose immeasurable help has made this paper possible. The figures were done by Roderick MacPherson.

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NEZUMIA (KURONEZUMIA) BUBONIS, A NEW SUBGENUS AND SPECIES OF GRENADIER (MACROURIDAE: PISCES) FROM HAWAII AND THE WESTERN NORTH ATLANTIC

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INTRODUCTION

In the course of exploratory fishing by the R/V *Oregon* off the Caribbean coast of Colombia in the spring of 1964, a large black grenadier was captured by a trawl fished at a depth of 400 fathoms. The fish resembled *Nezumia atlantica* (Parr, 1946) in its general body shape and dentition, but it differed widely in several meristic and morphometric features and in having a velvetlike texture to its squamation and a peculiarly enlarged scaly swelling anterior to the vent. Additional specimens were subsequently collected both in the Caribbean Sea and in the Gulf of Mexico by the R/V *Pillsbury* and the R/V *Oregon II.* The surprising presence of this species off Hawaii was revealed upon examination of the fishes collected by Paul J. Struhsaker of the National Marine Fisheries Service. An undescribed, closely related species from the South China Sea was examined in June, 1970, in the collections of the Fisheries Research Station, Aberdeen, Hong Kong.

In squamation and in head shape the new species resembles certain species of *Malacocephalus*, and the swelling before the vent appears to be an exaggeration of the slight swelling before the vent in members of that genus; but the dentition, the strong serrations on the second spinous dorsal ray, and several other features are totally in disagreement. In such features as length of upper jaw and number of pyloric caeca, the species approaches certain species of *Ventrifossa*; but in other more important characters, such as the structure of the light organ and the shape of the head, it differs widely from most members of that genus.

The difficulty of allocating the species to a genus has led to further, more extensive study of the generic problems concerning *Malacocephalus* Günther, 1862; *Ventrifossa* Gilbert and Hubbs, 1920; and *Nezumia* Jordan, 1904 (Iwamoto, MS). Publication of that study is being delayed because of the desire to incorporate much additional material. The description given here of the new species of *Nezumia* is being published at this time to make the name available to other workers. I have refrained from describing as new the species from the South China Sea because permanent disposition of the single representative has not been assured. The specimen now is at the Aberdeen Fisheries Research Station, Hong Kong. The new species and its closest congener from the South China Sea share certain characters (as indicated in the diagnosis below) so different from those in other members of the genus *Nezumia* that subgeneric status is designated.

METHODS

Methods for making counts and measurements generally follow procedures outlined by Hubbs and Lagler (1958) and further described for macrourids by Gilbert and Hubbs (1916) and Iwamoto (1970). The rounded snout of the species treated here and the lack of a prominent terminal scute make determination of the anterior tip of the nasal rostrum difficult. For this reason, measurements normally taken from the tip of the nasal rostrum (e.g., snout length, head length) are instead taken from whichever median point on the snout is more anterior. All rays of the pectoral fin are counted, including the short, usually thin, sliver-like uppermost ray and the 1 to 3 small lowermost rays. All gillrakers, including rudimentary ones, along the medial sides of the first and second gill arches are counted.

Institutional abbreviations are as follows: BPBM—Bernice P. Bishop Museum, Honolulu, Hawaii; CAS—California Academy of Sciences, San Francisco, California; FRSA—Fisheries Research Station, Aberdeen, Hong Kong; UMML—University of Miami, Rosenstiel School of Marine and Atmospheric Sciences, Miami, Florida; USNM—Division of Fishes, United States National Museum of Natural History, Washington, D.C.

ACKNOWLEDGMENTS

I thank the persons listed below for their assistance during the preparation of this paper. The following made specimens available for examination: Harvey R. Bullis, National Marine Fisheries Service (NMFS), Miami, Florida; Edward F. Klima, NMFS, Pascagoula, Mississippi; Paul J. Struhsaker, NMFS, Honolulu, Hawaii; William Chan, Fisheries Research Station, Aberdeen, Hong Kong; C. Richard Robins, Rosenstiel School of Marine and Atmospheric Sciences, Miami, Florida. Lillian J. Dempster and William N. Eschmeyer critically reviewed the manuscript.

Nezumia Jordan *in* Jordan and Starks, 1904

Subgenus **Kuronezumia** Iwamoto, new subgenus

DIAGNOSIS. Species of *Nezumia* with light organ peculiarly enlarged into a bulbous, scaly, wartlike structure anterior to anus and between pelvic fin bases (fig. 3); bulbous structure housing a large lens which partly encapsulates luminescent gland that fronts anterior wall of rectum. Light organ closely associated with pelvic girdle, the large lens essentially overriding part of girdle. Anterior dermal window of light organ at bottom of deep fossa and covered by bulbous lens-luminescent-gland mass. Snout almost entirely covered with small uniform scales; only thin margin above upper lips naked. Scales on suborbital region small, uniform, not forming a stout ridge. Body scales small, densely covered with extremely fine erect spinules. Color dark brown to black. Second spinous ray strongly serrated.

REMARKS. The bulbous structure housing the light organ in species of the subgenus *Kuronezumia* is apparently unique in the family, although the structure is vaguely approached by a swelling in the same region in members of *Malacocephalus*. (It appears to be an anteroventral swelling of the scaled area between the periproct and the anterior dermal window and a gross hypertrophy of the condition in *Malacocephalus*, where the area is slightly raised and the anterior dermal window sits in a relatively deep fossa, with the posterior wall of the depression steep, but not overlapping.) The species of the new subgenus have a darker overall coloration than almost every other member of *Nezumia* and resemble *Trachonurus* in that regard. Members of the subgenus are probably the largest of the genus, with *N. (Kuronezumia) bubonis* attaining a length of over 630 mm. The largest specimen of *N. atlantica* (another large species of *Nezumia*) I have measured is 450 mm. in total length.

ETYMOLOGY. The name is derived from the Japanese, *kuroi*, black or dark, and *nezumi*, rat, and is to be treated as feminine in gender.

Nezumia bubonis Iwamoto, new species.

(Figures 1–3.)

COUNTS. First dorsal rays II, 10–12; pectoral fin rays 23–26; pelvic fin rays 11–12 (one specimen with 9 in one fin, another specimen with 13 in one fin). Gillrakers on first arch 1–2 + 7–9 (usually 2 + 8); rakers on second arch 1–2 + 7–9. Scales below origin of first dorsal fin 14 to about 20, below origin of second dorsal fin 12–14; lateral line scales counted from the anteriormost scale posteriorly over distance equal to predorsal length 47–61. Abdominal vertebrae 13.

MORPHOMETRY. Head length of 10 specimens examined 30 to 125 mm.; total length 140 + to 630 mm. The following measurements are in percent of head length: snout length 26–32; ventral length of snout 13–18; orbit diameter 23–31; interorbital width 23–26; postorbital length 44–51; distance orbit to

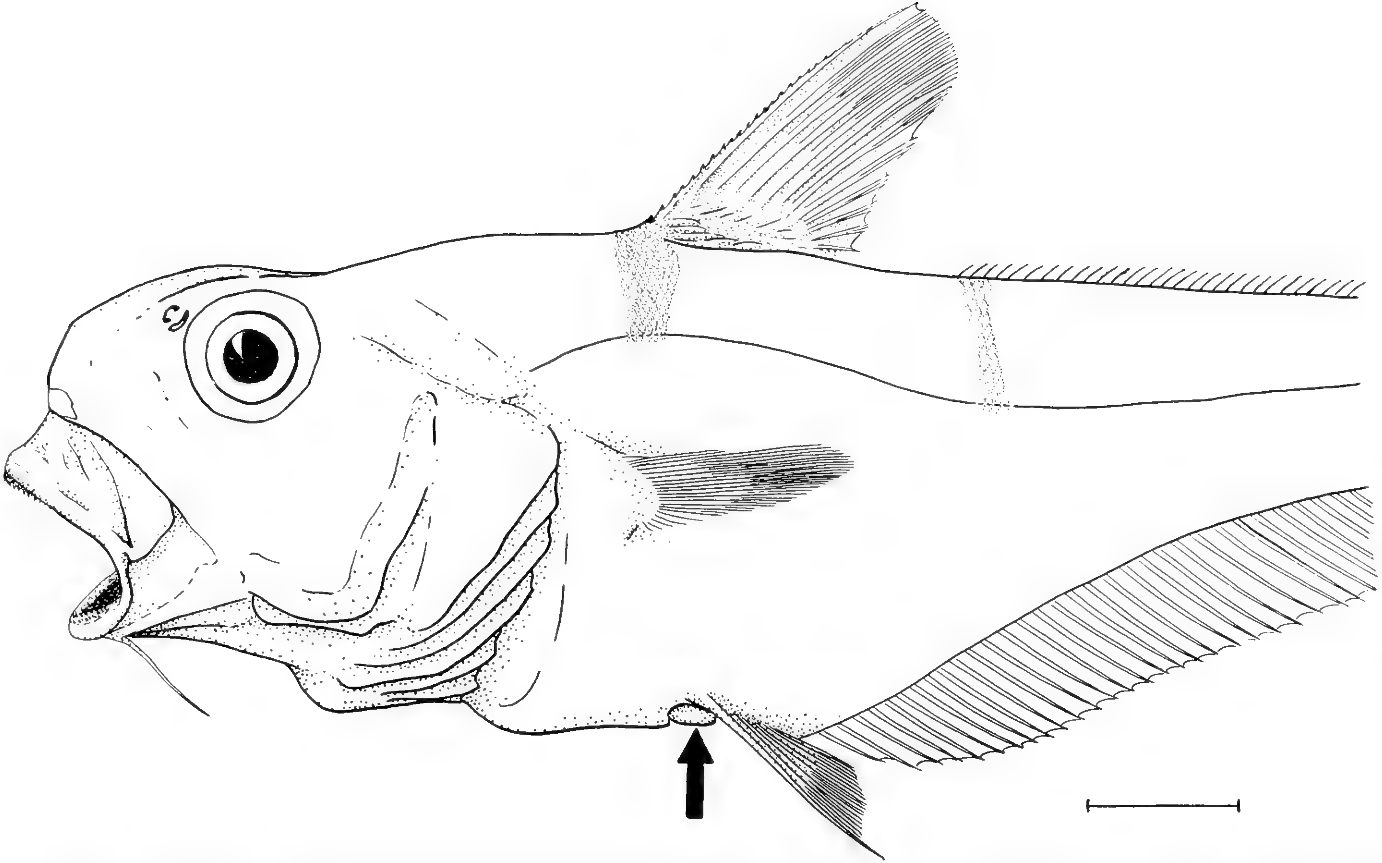

Figure 1. Holotype of *Nezumia* (*Kuronezumia*) *bubonis* Iwamoto, CAS no. 27872, 85.5 mm. head length, Gulf of Mexico, R/V *Oregon* station 4814. Arrow points to bulbous enlargement of light organ. Scale represents 25 mm.

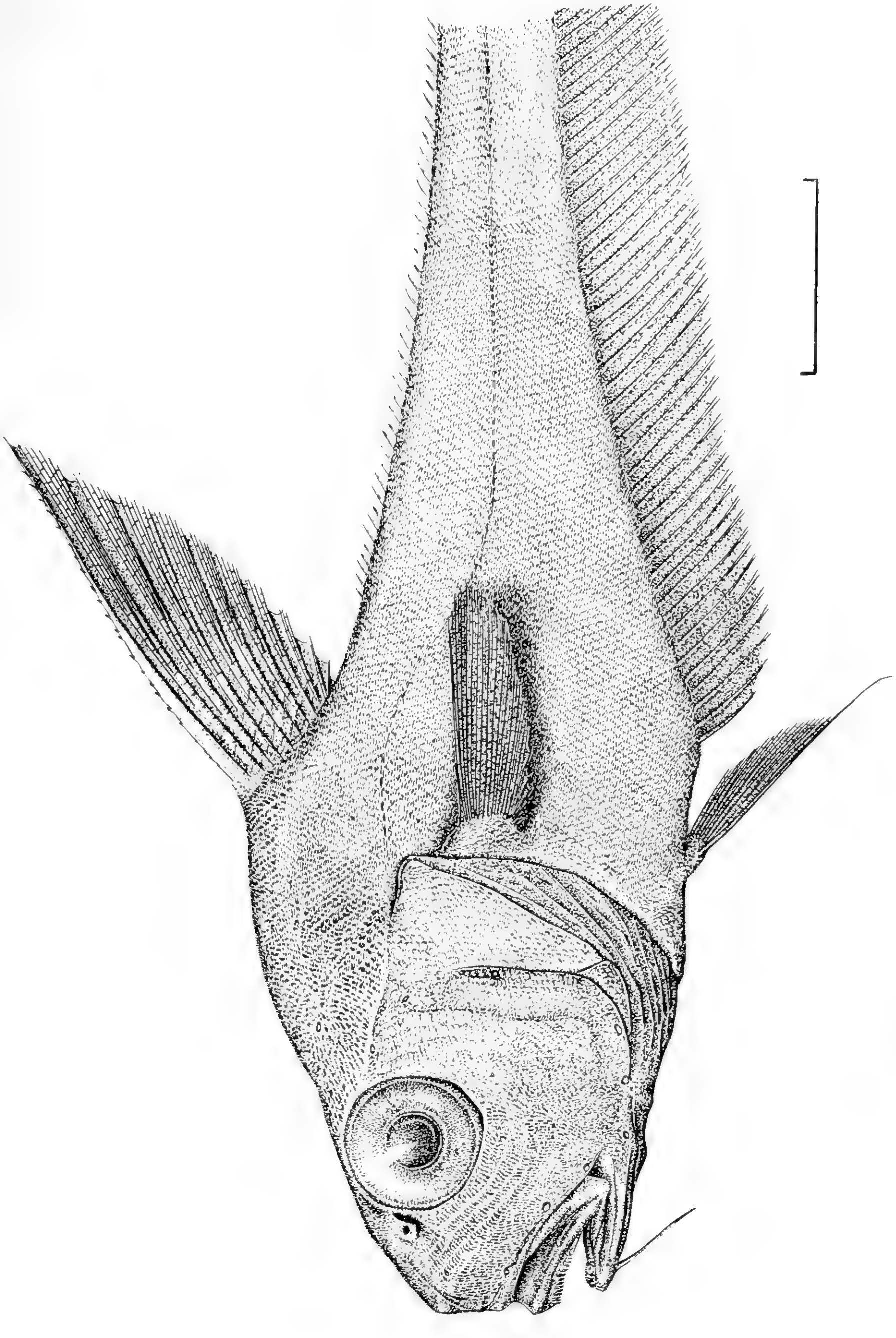

FIGURE 2. Paratype of *Nezumia bubonis*, BPBM uncatalogued, 59 mm. head length, from off Hawaii, R/V *Townsend Cromwell* cruise 40, station 87. Scale represents 25 mm.

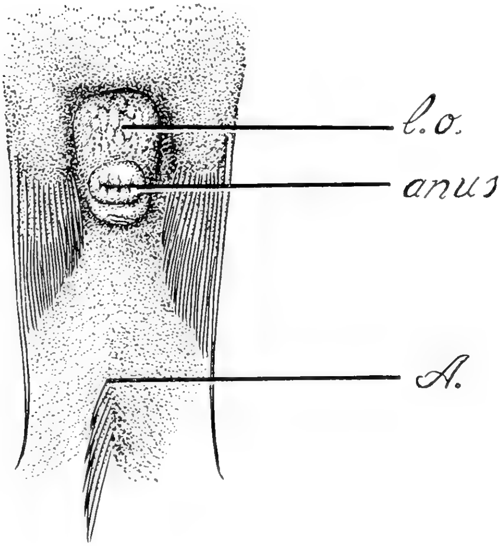

FIGURE 3. Ventral view of abdominal area of *Nezumia bubonis* showing position of bulbous swelling of light organ (l.o.) before anus. A.–origin of anal fin.

angle of preopercle 34–44; suborbital width 17–20; length upper jaw 35–44; greatest body depth 88–109; distance from base of outer pelvic fin to origin of anal fin 23–37 (usually 31–37); distance anus to anal origin 11–22; interspace between first and second dorsal fins 19–34; height first dorsal fin 89–92 (2 specimens); length pectoral fin 49–66; length outer pelvic ray 40–64; length barbel 20–29; length outer gill slit 16–21.

DESCRIPTION. Body deep, its greatest depth just anterior to first dorsal fin; trunk short, distance isthmus to anal origin about one-half length of head; body tapering rapidly behind trunk into long straplike tail. Head about one-fifth total length, laterally compressed, sides almost flat with no prominent projections or ridges; interorbital space slightly convex, proportionately widest in largest specimens; suborbital area broad, flat, evenly and completely scaled, without a coarsely scaled ridge. Mouth almost terminal; posterior end of maxillary lying under anterior half of orbits. Snout broadly rounded in profile, without a well-marked tip, generally not projecting beyond upper jaws. Orbits elliptic, proportionately largest in smallest specimens, usually longer in vertical than in horizontal diameter; upper margins not entering dorsal profile. Gill membranes united just behind vertical through posterior margin of orbits, attached to isthmus with a moderately narrow posterior free fold.

Fin positions best seen in illustration of 59-mm.-head-length paratype from Hawaii (fig. 2). Severe dorsal flexure distorts normal positions of fins of holotype. First dorsal fin complete in only two paratypes from Hawaii, measuring

89 and 92 percent of head length; spinous second ray strongly serrated along leading edge and slightly produced. Pelvic fins finely but densely scaled along exposed bases; outer ray slightly prolonged beyond other rays.

Head and body generally evenly and completely scaled. Exposed posterior and posteroventral margins of interoperculum scaled. Gular and branchiostegal membranes generally naked, although a few small patches of deeply embedded scales occasionally found at bases of branchiostegal rays; in one specimen, a few scales found at extreme tips of fourth and fifth branchiostegal rays. A narrow margin of scaleless skin along snout just above upper lip.

Scales on body and head very small and strongly adherent. Long, fine, slender spinules densely cover scales on body; spinules on nape scales almost erect, those on other parts of body reclined at about a 30-degree angle from vertical. Scales on head tend to have somewhat more stubby and conical spinules generally arranged in 3–7 radiating rows. No stout modified scales present on snout or suborbital region.

Pyloric caeca of two specimens moderately long (about 35 percent head length), unbranched, 35 and 39 in number. Gas glands of swim bladder two, kidney-shaped in outline although almost round in cross section; retia two, long and thin, about 16 mm. long in 113-mm.-head-length specimen.

Dentition consists of broad villiform bands of small teeth in both jaws with a slightly enlarged, evenly spaced outer series in upper jaw.

General color swarthy to dark brown with ventral surfaces of head, gill covers, and abdomen black to brownish black. Lips, gular and branchiostegal membranes, barbel, margins of orbits, periproct, and scaleless ventral margin of snout black. Buccal membranes light gray to dark gray. Gill cavity linings generally blackish towards outer and upper margins and paler ventrally and deeper within the cavity. Peritoneal membrane pallid with numerous black specks. All fins black.

COMPARISONS AND RELATIONSHIPS. The closest relative of *Nezumia bubonis* is an undescribed species from the South China Sea. Together they comprise the subgenus *Kuronezumia*. *Nezumia bubonis* differs from the undescribed species in having more pelvic fin rays (normally 11–12 compared with 8), slightly fewer scales below the second dorsal fin (12–14 versus 16) and a narrower interorbital space (23–26 percent of head length compared with 29 percent).

Nezumia darus (Gilbert and Hubbs, 1916) most closely approaches the members of subgenus *Kuronezumia* by its somewhat similar squamation and head physiognomy. The absence of ventral tubercular swellings, the more pronounced terminal snout scute, and the fewer scale rows below the second dorsal fin immediately separate *N. darus* from both *N. bubonis* and its South China Sea counterpart. *Nezumia burragei* (Gilbert, 1905), *N. hebetatus* (Gilbert, 1905), and *N. macronemus* (Smith and Radcliffe *in* Radcliffe, 1912) all fall in a loose group near *N. darus* in their resemblance to the species of subgenus *Kuronezumia*. But, in addition to the subgeneric distinctions, *N. burragei* differs in having a well developed terminal snout scute and a suborbital ridge formed of two rows of stout scutelike scales, and most of the ventral surfaces of the snout and suborbital area naked; *N. hebetatus* differs in having a more pointed snout, extensive naked areas on both the upper and lower surfaces of the snout and on the ventral surface of the suborbital region, a narrow suborbital ridge formed of two rows of stout scales, and a posterior margin of the preoperculum that is inclined forward; and *N. macronemus* differs in having a more pointed snout and lanceolate scale spinules.

Distribution. Off the Hawaiian Islands, in the Gulf of Mexico, and in the Caribbean Sea. Capture depths ranged from 732 to 1062 meters.

Etymology. The name comes from the Greek, *bubonis*, a tumor, and is to be treated as a noun in apposition.

Remarks. The peculiar distribution pattern of this species cannot be adequately explained because of the paucity of material and our present general lack of knowledge of dispersal means of macrourid fishes. Probably the species is much more widely distributed and the lack of more locality records is simply a reflection of sketchy collecting efforts.

Specimens examined. Holotype: CAS no. 27872, 86 mm. head length, 480 mm. total length (including a small pseudocaudal), western Gulf of Mexico off Barra San Antonio, Mexico, (24°49′N., 96°27′W.), in 500 fathoms (914 meters), by 40-ft. otter trawl, R/V *Oregon* station 4814, 12 March 1964, bottom temperature 41°F (5°C).

Paratypes (9 specimens from 7 localities): USNM 210592 (2, 53–100 mm. head length, 284–500 mm. total length), off Colombia, R/V *Oregon* station 4902 (9°02′N., 76°31.5′W.), in 400 fathoms (732 meters), by 65-ft. otter trawl, 28 May 1964; UMML uncatalogued (1, 111 mm. H.L., 550 mm. T.L.), off Colombia, R/V *Pillsbury* station 388 (10°16′N., 76°03′W.), in 450–580 fathoms (823–1061 meters), by 40-ft. otter trawl, 15 July 1966; CAS no. 27873 (1, 125 mm. H.L., 630 mm. T.L.), Gulf of Mexico, R/V *Oregon II* station 10955 (21°41′N., 96°55′W.), in 490 fathoms (896 meters), by 150-ft. otter trawl, 3 June 1970; USNM 210593 (1, 113 mm. H.L., 560 mm. T.L.), Gulf of Mexico, R/V *Oregon II* station 11136 (24°27′N., 87°38′W.), in 500 fathoms (914 meters), by 71-ft. otter trawl, 9 August 1970; BPBM uncatalogued (1, 39.6 mm. H.L., 180 + mm. T.L.), Hawaiian Islands, R/V *Townsend Cromwell* cruise 35, station 24 (21°06.5′N., 156°13.5′W.), in 640–686 meters, by 41-ft. otter trawl, 5 April 1968; CAS no. 27874 (2, 30–56 mm. H.L., 140 + –246 mm. T.L.), Hawaiian Islands, R/V *Townsend Cromwell* cruise 40, station 86 (21°06.8′N., 156°13.7′W.), in 631–705 meters, by 41-ft. otter trawl, 23 November 1968; BPBM uncatalogued (1, 59 mm. H.L., 247 mm. T.L.), Hawaiian Islands, R/V

Townsend Cromwell cruise 40, station 87 (21°04.6′N., 156°10.6′W.), in 623–667 meters, by 41-ft. otter trawl, 23 November 1968.

Nezumia species.

COUNTS. First dorsal fin rays II,10; pectoral fin rays 24; pelvic fin rays 8. Gillrakers on first arch 2 + 8; on second arch 2 + 7. Scales below origin of first dorsal fin 17–18; below origin of second dorsal fin 16; lateral line scales counted from the anteriormost scale for a distance equal to the predorsal length 50.

MORPHOMETRY. The following are in percent of head length: snout length 30; orbit diameter 25; interorbital width 29; postorbital length 48; distance orbit to angle of preopercle 41; suborbital width 18; length upper jaw 41; greatest body depth 100; interspace between first and second dorsal fins 21; height of first dorsal fin 93; length pectoral fin 63; length outer pelvic ray 55; length barbel 22; length outer gill slit 20.

DIAGNOSIS. A species of *Nezumia* of the subgenus *Kuronezumia* with 8 pelvic fin rays. Scales very small, finely spinulated, 16 rows below origin of second dorsal fin. Pectoral fin rays 24. Interorbital width 29 percent of head length.

REMARKS. The species agrees with the description previously given of *Nezumia bubonis* so closely that it would be redundant to repeat the same characters. A comparison of the differences between the two species of the subgenus is given in the description of *N. bubonis*.

DISTRIBUTION. South China Sea.

SPECIMEN EXAMINED. FRSA uncatalogued, (50 mm. H.L.), from the South China Sea.

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REVISED DIATOM STRATIGRAPHY OF THE EXPERIMENTAL MOHOLE DRILLING, GUADALUPE SITE

By

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ABSTRACT: Thirty-four diatom-bearing samples were obtained from cores recovered at the Experimental Mohole Drilling (EMD), Guadalupe Site. A planktonic-diatom stratigraphy is defined through correlation of ranges of key species of the EMD with a continuously cored section off California (DSDP, leg 18, Site 173). The Pliocene-Miocene boundary (defined as the base of the Gilbert Reversed Paleomagnetic Epoch) occurs between samples EMD-8-10-44/45 cm. and EMD-8-10-100/101 cm. The Middle Miocene to Late Miocene boundary (defined as occurring within Geomagnetic Epoch 11) occurs between samples EMD-8-15-100/101 cm. and EMD-8-15-200/201 cm. The youngest investigated sediment (EMD-8-9-5/6 cm.) correlates with North Pacific Diatom Zone 10 of Middle Pliocene age (upper part of the Gilbert Magnetic Epoch); the oldest investigated sediment (EMD-7-2-0/17 cm.) correlates with North Pacific Diatom Zone 24, with NN 6 Standard Nannoplankton Zone, and with the *Dictyocha octacantha* Silicoflagellate Zone. The sedimentation rate for the interval from 80 to 95 meters below the sea floor is about 7 meters/million years; it increases abruptly over the interval from 95 to 115 meters below the sea floor to approximately 30 m./m.y. and decreases again to approximately 7 m./m.y. for the interval from 115 to 135 meters below the sea floor. One new genus and ten new species of diatoms are described, and five new combinations of names are proposed.

List of new taxonomic entries and new combinations:

a. New genus.

Cussia

b. New species.

Biddulphia moholensis	CAS 54409
Coscinodiscus moholensis	CAS 54410
Cussia lancettula	CAS 54411
Cussia moholensis	CAS 54413
Nitzschia burcklia	CAS 54415
Nitzschia kanayensis	CAS 54417
Nitzschia moholensis	CAS 54419
Nitzschia riedelia	CAS 54420
Nitzschia seiboldia	CAS 54422
Rouxia moholensis	CAS 54424

c. New combinations.

Cussia mediopunctata
Cussia mediopunctata var. *matraensis*
Cussia paleacea
Cussia praepaleacea
Cussia tatsunokuchiensis

Acknowledgments

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Introduction

This study is a revision of the planktonic diatoms contained in 34 samples from cores recovered during the Experimental Mohole Drilling near Guadalupe Island off Baja California (Riedel *et al.*, 1961). Age correlative samples from cores (Lamont-Doherty Geological Observatory) and from a drill hole of the Deep Sea Drilling Project, leg 18, Site 173 near Cape Mendocino, California were also used in this study (chart 1, table 1).

Previous zonations of the Experimental Mohole Drilling cores have been made on Foraminifera (Parker, 1964; Bandy and Ingle, 1970), on calcareous nannoplankton (Martini and Bramlette, 1963; Martini, 1971), on silicoflagellates (Martini, 1972), and on diatoms (Kanaya, 1971).

After publication of the Neogene diatom zonation of the East-Equatorial Pacific (Burckle, 1972) and the completion of a Neogene diatom zonation of the

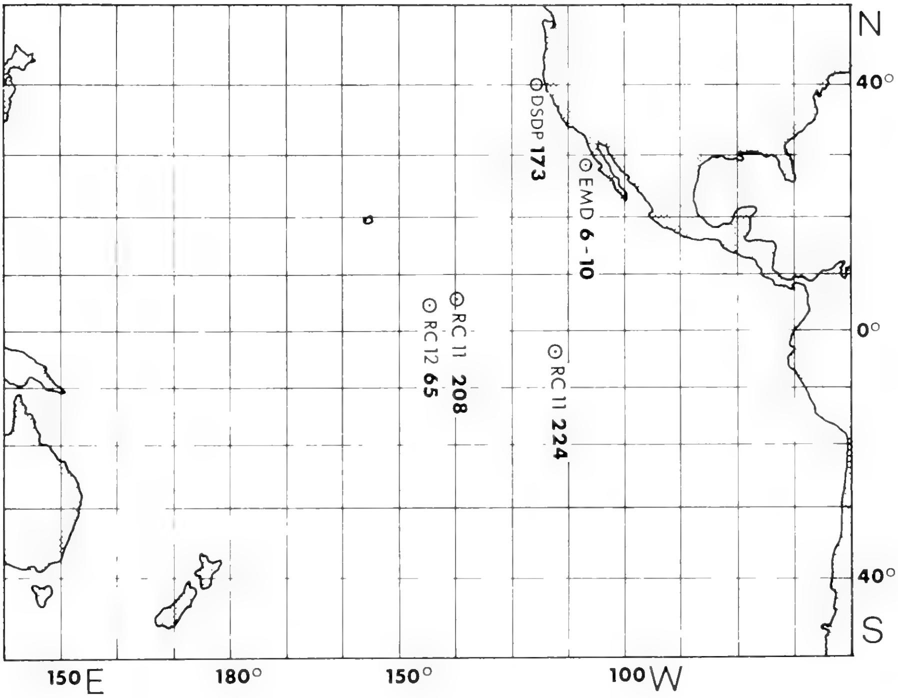


Chart 1. Index map showing localities of investigated cores. DSDP 173: Deep Sea Drilling Project, leg 18, Site 173; EMD: Experimental Mohole Drilling, Guadalupe Site; RC-65, 208, 224: Robert Conrad cores (Lamont Doherty Geological Observatory).

Table 1. *List of cores used in this study, with references to published descriptions. IRDSDP—Initial reports of the Deep Sea Drilling Project; LDGO—Lamont Doherty Geological Observatory; SIO—Scripps Institution of Oceanography.*

Core No.	Inst.	Latitude	Longitude	Water Depth (m.)	Author
RC-12-65	LDGO	04° 39′ N	144° 58′ W	4868	Burckle 1972
RC-11-208	LDGO	05° 21′ N	139° 58′ W	4920	Burckle 1972
RC-11-224	LDGO	03° 32′ S	122° 05.5′ W	4319	Burckle 1972
EMD-6,8,7,10	SIO	28° 59′ N	117° 30′ W	3566	Riedel *et al.* 1961 Parker 1964 Martini 1971 Kanaya 1971
DSDP-173	SIO-DSDP	39° 57.7′ N	125° 27.12′ W	2927	IRDSDP 1973

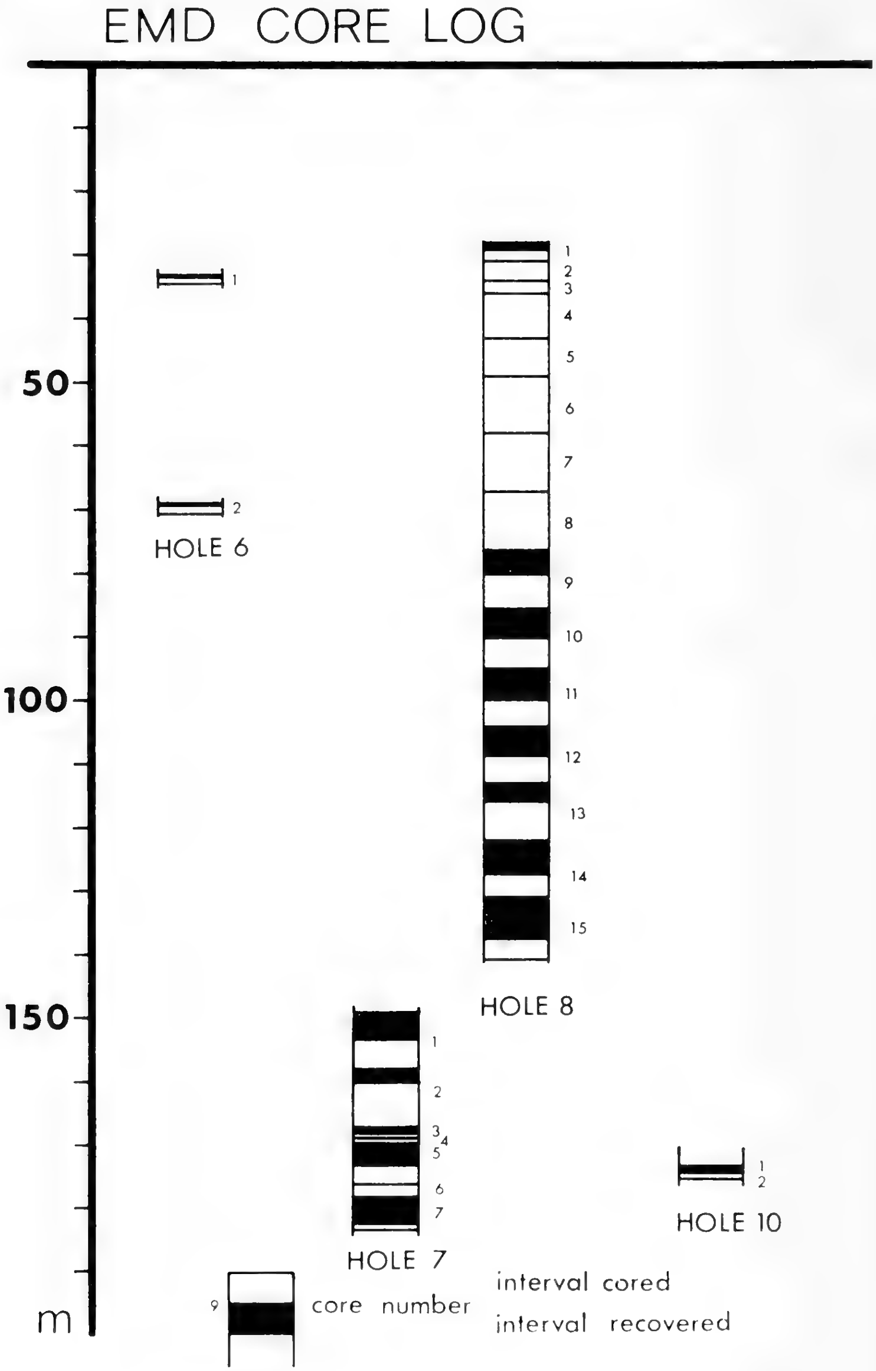


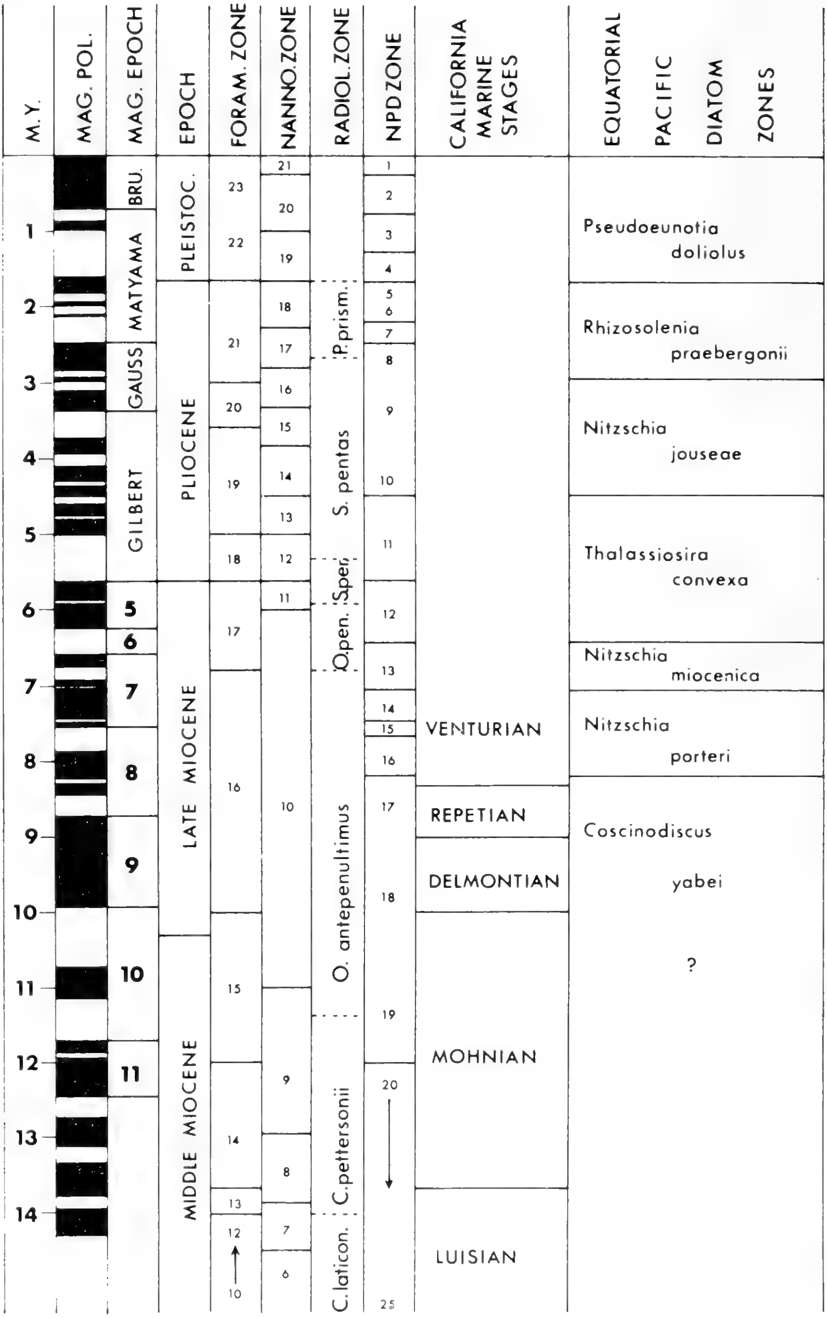
Chart 2. Core log, Experimental Mohole Drilling, Guadalupe Site. Black intervals: interval recovered.

Table 2. *Sample data for cores from the Experimental Mohole Drilling, Guadalupe Site. Sedimentological data from Riedel* et al. *(1961).*

Hole	Core	Sampled interval in cm.	Sedimentological observations (Riedel *et al.*, 1961)
6	2	30/ 31	greenish gray, clayey siliceous-calcareous ooze
8	9	5/ 6	pale olive, siliceous-calcareous ooze
		140/141	pale olive, calcareous-siliceous ooze
		193/194	pale olive, calcareous-siliceous ooze
		240/241	pale olive, calcareous-siliceous ooze
		290/291	olive-gray, siliceous-calcareous ooze
8	10	44/ 45	dusky yellow-green, silty siliceous ooze
		100/101	dusky yellow-green, siliceous ooze
		200/201	dusky yellow-green, siliceous ooze
		300/301	dusky yellow-green, siliceous ooze
		400/401	dusky yellow-green, siliceous ooze
8	11	30/ 31	yellowish gray, siliceous ooze
		90/ 91	grayish green, siliceous-calcareous ooze
		200/201	greenish gray, siliceous ooze
		300/301	greenish gray, siliceous ooze
		390/391	light olive-gray, calcareous-siliceous ooze
8	12	94/ 95	pale olive, calcareous-siliceous ooze
		203/204	grayish yellow-green, siliceous-calcareous ooze
8	13	30/ 31	dark greenish-gray, siliceous ooze
		100/101	dusky yellow green, siliceous ooze
		200/201	dusky yellow green, siliceous ooze
		262/265	dusky yellow green, siliceous ooze
8	14	10/ 11	dark greenish gray, siliceous ooze
		100/101	dark greenish gray, siliceous ooze
		400/401	dark greenish gray, siliceous ooze
8	15	35/ 36	dusky yellow green, siliceous-calcareous ooze
		93/ 95	pale olive, calcareous-siliceous ooze
		100/101	light greenish gray, calcareous siliceous ooze
		200/201	light greenish gray, calcareous siliceous ooze
		300/301	light greenish gray, calcareous siliceous ooze
		504/505	pale olive, calcareous-siliceous ooze
7	1	5/ 6	yellowish gray, calcareous-siliceous ooze
		41/ 42	greenish gray, siliceous ooze
7	2	0/ 17	greenish gray, siliceous ooze
10	1	30/ 43	greenish gray, calcareous ooze

North Pacific based principally on a continuously cored stratigraphic hole off California (Deep Sea Drilling Project, leg 18, Site 173, Schrader, 1973a) it was possible to prepare a revised diatom stratigraphy of the EMD which differs from that of Kanaya (1971).

NEOGENE CORRELATION



Methods

Samples from Lamont-Doherty Geological Observatory were taken by L. H. Burckle; samples of the EMD were taken by T. Walsh, and samples from DSDP Site 173 were made by the author.

Treatment of the diatom material and slide preparation followed the standardized methods of Schrader (MS.). Slides were mounted with Aroclor 4465 and key species were marked with a diamond microscopical specimen marker. All important species were photographed through a Leitz Orthoplan, Apo Oil 92 ×, 1.4 n.A. and 10 × Periplan ocular. Holotypes, paratypes, and some other duplicates are deposited at the Department of Geology, California Academy of Sciences. Other illustrated specimens are in the author's collection. Additional samples have been deposited at the Bundesanstalt für Bodenforschung, Hannover (L. Benda), and at the Friedrich Hustedt Arbeitsplatz für Diatomeenkunde, Bremerhaven (R. Simonsen).

Epochs and Age Boundaries

The Upper-Middle Miocene boundary is placed within Geomagnetic Epoch 11 following Burckle (1972). This boundary is shifted by Berggren (1972) to the upper part of Geomagnetic Epoch 10 (see chart 3).

The Miocene-Pliocene boundary is placed at the top of Geomagnetic Epoch 5 (bottom of the Reversed Gilbert Magnetic Epoch) (Burckle, 1972).

Other boundaries are defined by the range of species in the Equatorial Pacific (Burckle, 1972) and the North Pacific (Schrader, 1973a).

Most of the Equatorial and North Pacific Zones are defined by evolutionary events and morphotypic ranges of species (for definition of terms see Riedel and Sanfilippo, 1971).

Stratigraphic Distribution of Diatoms

The distribution of important planktonic diatom taxa is indicated in table 3. A great effort has been made to recognize and define reworked taxa. Ranges are plotted by symbols representing abundance and type of occurrence (allochthonous or autochthonous). Abundance and preservation was generally good

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Chart 3. Correlation of the North Pacific Diatom Zonation (Schrader, 1973a) with Californian Marine Stages (Berggren, 1972; Bandy and Ingle, 1970), the Equatorial Pacific Diatom Zonation (Burckle, 1972), the Radiolarian Zonation (Riedel and Sanfilippo, 1971; Moore, 1971; after Berggren, 1972), the Standard Calcareous Nannoplankton Zonation (Martini, 1971; Bramlette and Wilcoxon, 1967; Baumann and Roth, 1969; Martini and Worsley, 1970), the Planktonic Foraminiferal Zones (Blow, 1969; after Berggren, 1972), the Paleomagnetic Stratigraphy (Burckle, 1972; Abdel-Monem *et al.,* 1971), and the Radiometric Time Scale (Cox, 1969; Abdel-Monem *et al.,* 1971).

TABLE 3. *List of planktonic diatom species recovered from core samples of the Experimental Mohole Drilling, Guadalupe Site. Diatom species are tabulated using the following abbreviations: — not present; R—rare (only a few specimens per slide); F—frequent (more than 10 specimens per slide); C—common (more than 50 specimens per slide); A—abundant (mass occurrence of species); X—reworked older species.*

Total abundance of diatoms in each sample is tabulated as: A—abundant; C—common; R—rare.

Preservation of diatoms is tabulated as: G—good; M—moderate (etched and many broken frustules).

Experimental Mohole Drilling Guadalupe Site DIATOMS - = not present R = rare F = frequent C = Common A = abundant X = reworked	Actinocyclus okhotensis	" ehrenbergii	" ellipticus	" " var.moronensis	" cubitus	Asterolampra marylandica	Bruniopsis mirabilis	Cladogramma dubium	Coscinodiscus endoi	" lewisianus	" marginatus	" nodulifer	Cussia paleacea	" praepaleacea	Coscinodiscus temperei	" vetustissimus	" " var.javanicus	" symbolophorus	" antiquum	" yabei	Denticula dimorpha	" hustedtii	" hyalina var. hustedtii	" lauta	" nicobarica	" punctata var. hustedtii	Correlation with North Pacific Diatom Zonation, SCHRADER, JADDP leg. 18	Correlation with the Equatorial Pacific Diatom Zonation BURCKLE (1972)
EM - 6 - 2 - 30/ 31	R	R	R	-	-	-	-	R	R	-	R	R	-	-	-	R	-	-	-	-	-	F	-	X	X	-	10	Nitzschia jouseae Partial Range Zone
EM - 10 - 1 - 30/ 43	-	-	-	-	-	-	-	-	-	-	F	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	?	
EM - 8 - 9 - 5/ 6	R	R	R	-	-	R	R	R	-	-	F	-	-	-	R	R	-	R	-	-	-	-	A	-	-	-	10	
EM - 8 - 9 - 140/141	-	-	R	-	-	-	R	-	R	-	F	R	-	-	R	F	-	-	-	-	-	-	F	-	-	X		
EM - 8 - 9 - 193/194	-	R	-	-	-	R	R	R	R	-	R	R	-	-	R	R	-	R	-	-	-	-	A	-	-	-		
EM - 8 - 9 - 240/241	-	R	R	-	-	R	R	R	R	X	R	R	-	X	R	R	-	R	-	-	-	R	R	X	-	-		
EM - 8 - 9 - 290/291	-	R	R	-	-	-	R	R	R	-	R	-	X	X	R	R	-	R	-	X	-	R	R	X	-	X	11	Thalassiosira convexa Partial Range Zone
EM - 8 - 10 - 44/ 45	-	-	R	-	-	-	R	R	R	-	R	R	X	X	R	R	-	R	-	X	X	A	F	X	-	-		
EM - 8 - 10 - 100/101	-	R	R	-	-	R	R	-	-	-	F	-	X	-	R	R	-	-	-	X	-	C	F	X	-	-	12	
EM - 8 - 10 - 200/201	-	R	R	-	-	-	R	R	R	-	C	-	X	-	R	R	-	-	-	-	-	C	F	-	-	-		
EM - 8 - 10 - 300/301	-	R	R	-	-	-	R	-	-	-	R	R	X	-	R	R	-	R	-	-	X	-	-	-	-	-		Nitzschia miocenica Partial Range Zone
EM - 8 - 10 - 400/401	-	R	R	-	-	-	R	R	R	-	C	-	X	-	R	R	-	R	-	-	-	-	-	-	-	-	13	
EM - 8 - 11 - 30/ 31	-	R	R	-	-	R	R	R	R	-	C	-	-	-	R	R	-	R	-	-	-	C	R	R	-	-		
EM - 8 - 11 - 90/ 91	-	R	R	-	-	-	R	-	-	-	C	-	-	-	-	R	-	R	-	-	-	F	R	R	-	-		
EM - 8 - 11 - 200/201	-	R	R	-	-	-	R	-	-	-	C	R	-	-	-	R	-	R	-	X	-	F	-	R	-	-		
EM - 8 - 11 - 300/301	-	R	R	-	-	R	R	R	R	-	R	R	-	-	-	R	-	R	-	-	R	F	-	R	X	-	14	
EM - 8 - 11 - 390/391	-	R	R	-	-	R	R	-	-	-	C	R	-	-	R	R	-	R	-	X	R	C	-	R	-	-		
EM - 8 - 12 - 94/ 95	-	R	R	-	-	R	R	-	-	-	C	-	-	-	-	R	-	R	-	-	-	C	-	R	-	-		Nitzschia porteri Partial Range Zone
EM - 8 - 12 - 203/204	-	R	R	-	-	R	R	-	-	-	F	-	X	R	R	R	-	R	-	-	R	C	-	R	-	-	15	
EM - 8 - 13 - 30/ 31	-	R	R	-	-	R	R	-	-	-	C	-	-	R	-	R	-	R	-	-	-	C	-	C	-	-		
EM - 8 - 13 - 100/101	-	R	R	-	-	-	R	-	-	-	R	-	-	-	-	R	-	R	-	-	R	C	-	R	-	R	16	
EM - 8 - 13 -262/265	-	R	-	-	-	-	R	-	-	-	F	-	-	-	-	R	-	R	-	R	-	C	-	R	-	F	17	Coscinodiscus yabei Partial Range Zone
EM - 8 - 14 - 10/ 11	-	-	-	-	-	-	R	R	R	X	R	-	R	R	-	R	-	R	-	R	-	C	-	R	-	R		
EM - 8 - 14 - 100/101	-	-	-	-	-	-	R	-	-	X	R	-	R	R	-	R	-	-	-	R	R	C	-	C	-	R	18	
EM - 8 - 14 - 400/401	-	-	-	-	-	-	R	-	-	-	R	-	R	R	-	R	-	-	-	R	R	A	-	F	-	R		
EM - 8 - 15 - 35/ 36	-	R	R	-	-	-	F	-	-	-	F	-	R	R	-	R	-	-	-	R	-	C	-	R	-	F	19	
EM - 8 - 15 - 93/ 95	-	R	R	-	-	-	R	-	-	X	F	-	R	R	-	R	-	-	-	R	-	F	-	R	-	R		
EM - 8 - 15 - 100/101	-	R	R	-	R	R	R	R	R	-	F	-	R	R	-	R	-	-	-	R	-	C	-	R	R	F		
EM - 8 - 15 - 200/201	-	R	R	-	R	-	R	-	-	-	F	-	R	R	-	F	R	R	R	R	-	C	-	R	R	R	20	
EM - 8 - 15 - 300/301	-	F	R	R	R	R	R	-	-	-	F	R	R	R	-	R	R	-	R	R	-	C	-	R	R	R		
EM - 8 - 15 - 504/505	-	R	R	R	-	R	R	-	-	R	F	R	R	R	-	R	R	-	-	R	-	C	-	R	R	R	21	
EM - 7 - 1 - 5/ 6	-	-	-	R	-	-	R	R	R	F	F	-	R	R	-	R	-	R	-	R	-	C	-	-	F	-	22	
EM - 7 - 1 - 41/ 42	-	-	R	-	-	R	R	-	-	F	F	-	-	-	-	R	-	-	-	-	-	C	-	R	F	-	23	
															-	R	-	-	-	-	-	-	-	-	R	-	24	

TABLE 3. *Continued.*

- = not present
R = rare
F = frequent
C = Common
A = abundant
X = reworked

Experimental Mohole Drilling Guadalupe Site DIATOMS	Ethmodiscus rex	Hemiaulus c.f. polymorphus	Hemidiscus cuneiformis	" simplicissimus	Lithodesmium californicum	" minusculum	Mediaria splendida	Macrora ste.la (non diatomaceae)	Nitzschia cylindrica	" jouseae	" praereinholdii	" seiboldia	" riedelia	" burcklia	" californica	Rhaphoneis angularis	" angustata	" sacchalinensis	" margaritalimbata	Rhizosolenia barboi	" hebetata var.	" miocenica	" praealata	" praebarboi	" styliformis	Correlation with North Pacific Diatom Zonation, SCHRADER, JRDDP leg. 18	Correlation with the Equatorial Pacific Diatom Zonation BURCKLE (1972)
EM - 6 - 2 - 30/ 31	R	R	-	R	R	-	-	-	-	-	R	-	-	-	-	R	-	-	-	R	R	X	R	-	R	10	Nitzschia jouseae Partial Range Zone
EM - 10 - 1 - 30/ 43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	?	
EM - 8 - 9 - 5/ 6	R	R	R	-	-	R	-	-	-	R	R	-	-	-	-	-	-	-	-	F	-	-	R	-	R	10	
EM - 8 - 9 - 140/141	-	-	R	R	R	R	-	-	-	-	R	-	-	-	R	-	-	R	-	R	-	-	R	-	R		
EM - 8 - 9 - 193/194	-	R	R	R	-	R	-	-	R	R	R	-	X	R	-	-	-	-	-	R	-	-	-	-	R		
EM - 8 - 9 - 240/241	R	R	R	R	R	R	-	-	-	R	R	-	X	R	R	-	-	-	-	R	R	X	R	-	R		
EM - 8 - 9 - 290/291	R	R	R	R	R	R	-	-	R	-	R	-	-	-	R	-	-	-	-	-	-	X	-	X	R	11	Thalassiosira convexa Partial Range Zone
EM - 8 - 10 - 44/ 45	R	R	R	R	R	-	-	-	R	-	R	-	X	-	-	-	R	-	-	F	-	X	R	-	R		
EM - 8 - 10 - 100/101	R	R	R	R	R	-	-	-	R	-	R	-	-	R	R	-	R	-	-	C	R	X	R	X	R	12	
EM - 8 - 10 - 200/201	-	R	R	R	R	R	-	-	R	-	R	-	-	-	R	-	R	-	-	R	-	-	-	-	R		
EM - 8 - 10 - 300/301	R	R	R	R	R	R	-	-	-	-	R	-	-	-	R	-	-	-	-	R	-	-	-	X	R	13	Nitzschia miocenica Partial Range Zone
EM - 8 - 10 - 400/401	R	R	R	R	R	R	-	-	-	-	-	-	-	-	-	-	R	-	-	C	R	-	-	-	R		
EM - 8 - 11 - 30/ 31	R	R	R	R	R	-	-	-	-	-	R	-	-	R	R	-	-	-	-	R	R	R	-	-	R		
EM - 8 - 11 - 90/ 91	R	R	R	R	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	F	R	R	-	-	R		
EM - 8 - 11 - 200/201	-	R	-	R	R	R	-	-	-	-	-	-	-	-	-	-	R	-	-	C	-	R	-	-	R	14	
EM - 8 - 11 - 300, 301	R	R	-	R	R	R	-	-	-	-	R	-	X	-	-	R	-	-	-	R	R	-	R	-	R		
EM - 8 - 11 - 390/391	R	R	-	R	R	-	-	-	-	-	R	-	-	-	-	R	R	-	-	R	-	-	R	-	R		
EM - 8 - 12 - 94/ 95	R	R	-	R	R	-	-	-	-	-	R	-	-	R	-	-	R	-	R	R	-	-	-	-	R		
EM - 8 - 12 - 203/204	R	R	-	R	R	-	-	-	-	-	R	R	-	R	-	-	R	-	R	F	R	R	-	R	R	15	Nitzschia porteri Partial Range Zone
EM - 8 - 13 - 30/ 31	R	R	-	-	R	-	R	-	-	-	R	R	-	-	-	-	-	-	-	R	-	-	-	R	R		
EM - 8 - 13 - 100/101	R	-	-	-	-	-	R	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	-	R	-	16	
EM - 8 - 13 -262/265	R	-	-	-	-	-	R	-	-	-	-	R	-	R	-	-	-	-	-	-	R	R	-	R	R	17	Coscinodiscus yabei Partial Range Zone
EM - 8 - 14 - 10/ 11	R	-	-	-	-	-	R	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	-	R	-	18	
EM - 8 - 14 - 100/101	R	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	-	R	R		
EM - 8 - 14 - 400/401	R	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	R	-	-	R	R		
EM - 8 - 15 - 35/ 36	R	R	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	F	R	19	
EM - 8 - 15 - 93/ 95	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	R	R		
EM - 8 - 15 - 100/101	-	R	-	-	-	-	R	-	-	-	-	R	R	-	-	-	R	-	-	-	-	R	-	R	R		
EM - 8 - 15 - 200, 201	-	R	-	-	-	-	R	R	-	-	-	R	R	-	-	-	R	-	-	-	R	-	-	R	R	20	
EM - 8 - 15 - 300, 301	-	R	-	-	-	-	R	R	-	-	-	R	R	-	-	-	R	-	-	-	R	R	-	R	R		
EM - 8 - 15 - 504, 505	-	R	-	-	-	-	R	-	-	-	-	R	R	-	-	-	R	-	R	-	R	R	-	F	-	21	
EM - 7 - 1 - 5/ 6	-	-	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	-	R	22	
EM - 7 - 1 - 41/ 42	-	-	-	-	-	-	R	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	R	-	23	
EM - 7 - 2 - 0/ 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	24	

TABLE 3. *Continued.*

Experimental
Mohole Drilling
Guadalupe Site

DIATOMS

- – = not present
- R = rare
- F = frequent
- C = Common
- A = abundant
- X = reworked

Sample	Rouxia californica	" c.f. diploneides	Stephanopyxis turris	Synedra jouseana	Thalassionema nitzschioides	" claviformis	Thalassiosira convexa	" decipiens	" excentrica	" antiqua	" spec. A	" nativa	" praeconvexa	" oestrupii	" usatchevii	Thalassiothrix longissima	Triceratium condecorum	" cinnamomeum	Craspedodiscus coscinodiscus	Actinocyclus ingens	Abundance	Preservation	Sponge Spicules	Silt	Correlation with North Pacific Diatom Zonation, SCHRADER, JRDDP leg. 18	Correlation with the Equatorial Pacific Diatom Zonation BURCKLE (1972)
EM - 6 - 2 - 30/ 31	R	–	R	X	A	–	R	R	R	R	–	R	–	R	–	C	–	–	–	R	A	G	–	R	10	Nitzschia jouseae Partial Range Zone
EM - 10 - 1 - 30/ 43	–	–	R	–	C	–	–	–	–	–	–	–	–	–	–	C	–	–	–	–	R	G	–	–	?	
EM - 8 - 9 - 5/ 6	–	–	R	X	A	–	–	R	–	R	–	–	–	R	–	A	–	–	–	R	A	G	–	–	10	
EM - 8 - 9 - 140/141	R	–	R	X	A	–	–	R	R	–	–	R	–	–	–	A	–	R	–	C	A	G	–	–		
EM - 8 - 9 - 193/194	R	X	R	–	A	–	R	–	–	–	–	C	–	–	–	C	–	R	–	R	A	G	C	F		
EM - 8 - 9 - 240/241	R	X	R	X	A	–	R	R	R	–	–	R	–	–	R	C	–	–	–	R	A	G	R	F		
EM - 8 - 9 - 290/291	R	X	R	X	C	–	R	–	R	–	–	F	–	–	R	C	–	R	–	R	A	G	F	F	11	Thalassiosira convexa Partial Range Zone
EM - 8 - 10 - 44/ 45	C	–	R	–	C	–	R	R	–	–	–	R	–	–	R	A	R	R	–	R	A	G	–	–		
EM - 8 - 10 - 100/101	C	–	R	–	C	–	–	–	–	–	–	R	–	–	–	C	R	R	–	R	A	G	–	–	12	
EM - 8 - 10 - 200/201	R	–	R	–	C	–	–	–	R	–	–	–	–	–	–	C	–	–	–	R	C	G	C	F		
EM - 8 - 10 - 300/301	F	–	R	–	C	–	–	–	–	–	–	–	–	–	–	F	–	–	–	R	A	G	–	–	13	Nitzschia miocenica Partial Range Zone
EM - 8 - 10 - 400/401	–	–	R	–	C	–	–	–	–	–	–	–	–	–	–	C	–	–	–	R	A	G	–	–		
EM - 8 - 11 - 30/ 31	–	–	R	–	C	–	–	R	R	–	–	–	–	–	–	A	–	–	–	F	A	G	C	F		
EM - 8 - 11 - 90/ 91	–	–	R	–	C	–	–	R	R	–	–	R	–	–	–	A	R	R	–	F	A	G	R	C	14	
EM - 8 - 11 - 200/201	–	–	R	R	C	R	–	–	–	–	–	R	–	–	–	A	–	R	–	R	A	G	R	R		
EM - 8 - 11 - 300,301	–	R	R	R	C	R	–	–	R	–	–	R	–	–	–	C	–	R	–	R	A	G	–	–		
EM - 8 - 11 - 390,391	R	R	R	R	C	R	–	–	R	–	–	R	–	–	–	F	–	R	–	R	A	G	F	C		
EM - 8 - 12 - 94/ 95	–	–	R	R	C	–	–	–	–	–	–	R	–	–	?	A	–	R	–	F	A	G	–	–	15	Nitzschia porteri Partial Range Zone
EM - 8 - 12 - 203/204	–	–	R	R	C	R	–	–	R	–	–	–	–	–	–	C	–	R	–	R	A	G	R	R		
EM - 8 - 13 - 30/ 31	–	–	R	R	R	R	–	–	–	–	R	–	–	–	–	A	–	–	–	R	A	M	C	C	16	
EM - 8 - 13 - 100,101	–	–	R	–	C	–	–	–	–	–	–	–	–	–	–	A	–	–	–	R	A	M	C	C		
EM - 8 - 13 -262/265	–	–	R	–	C	R	–	–	–	–	R	–	–	–	–	C	–	–	–	F	A	G	C	C	17	Coscinodiscus yabei Partial Range Zone
EM - 8 - 14 - 10/ 11	–	–	R	R	C	R	–	–	–	–	–	–	–	–	–	A	–	–	–	R	A	G	–	–	18	
EM - 8 - 14 - 100/101	–	–	R	R	C	R	–	–	–	–	–	–	–	–	–	A	–	–	–	R	A	G	–	–		
EM - 8 - 14 - 400/401	–	–	R	–	R	F	–	–	–	–	–	–	–	–	–	A	–	–	R	F	A	G	–	–		
EM - 8 - 15 - 35/ 36	–	–	R	–	C	R	–	–	–	–	–	–	–	–	–	A	–	R	F	F	A	G	–	–	19	
EM - 8 - 15 - 93/ 95	–	R	R	R	C	–	–	–	–	–	–	–	–	–	–	C	–	–	F	R	A	G	–	–		
EM - 8 - 15 - 100/101	–	R	R	R	C	–	–	–	–	–	–	–	–	–	–	F	–	R	R	R	A	G	–	–		
EM - 8 - 15 - 200/201	–	–	R	R	A	–	–	–	–	–	–	–	–	–	–	C	–	–	R	F	A	G	–	–	20	
EM - 8 - 15 - 300/301	–	–	R	F	R	–	–	–	–	–	–	–	–	–	–	A	–	R	R	F	A	G	–	–		
EM - 8 - 15 - 504/505	–	–	R	R	C	–	–	–	–	–	–	–	–	–	–	A	–	–	R	F	A	G	–	–	21	
EM - 7 - 1 - 5/ 6	–	–	R	–	C	–	–	–	–	–	–	–	–	–	–	A	–	–	R	C	A	G	–	–	22	
EM - 7 - 1 - 41/ 42	–	–	R	F	C	–	–	–	–	–	–	–	–	–	–	A	–	–	R	C	A	G	–	–	23	
EM - 7 - 2 - 0/ 17	–	–	R	R	C	–	–	–	–	–	–	–	–	–	–	A	–	–	R	C	C	M	R	F	24	

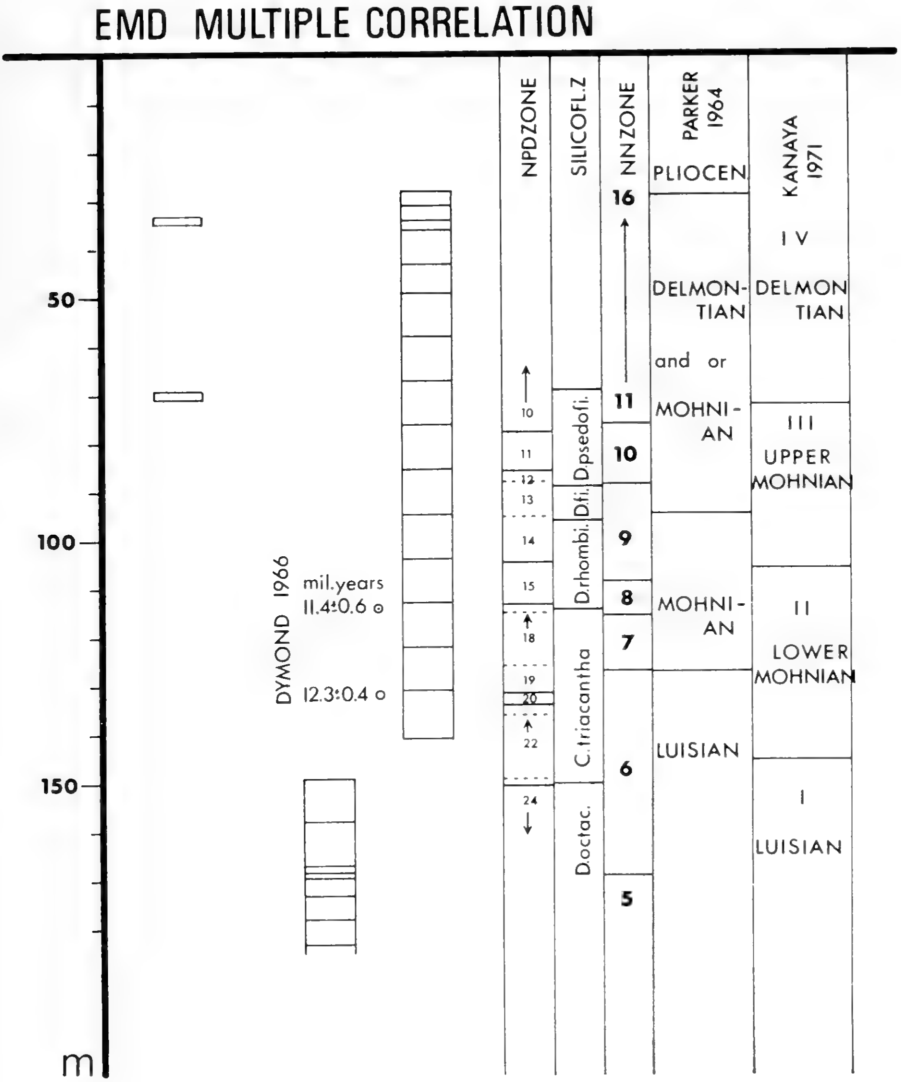


Chart 4. Multiple microplankton correlation of the Experimental Mohole Drilling, Guadalupe Site, with North Pacific Diatom Zonation (Schrader, 1973a), Silicoflagellate Zonation (Martini, 1972), Standard Calcareous Nannoplankton Zonation (Martini, 1971), and Californian Marine Stages (Parker, 1964; Kanaya, 1971). Potassium-Argon dates from Dymond (1966).

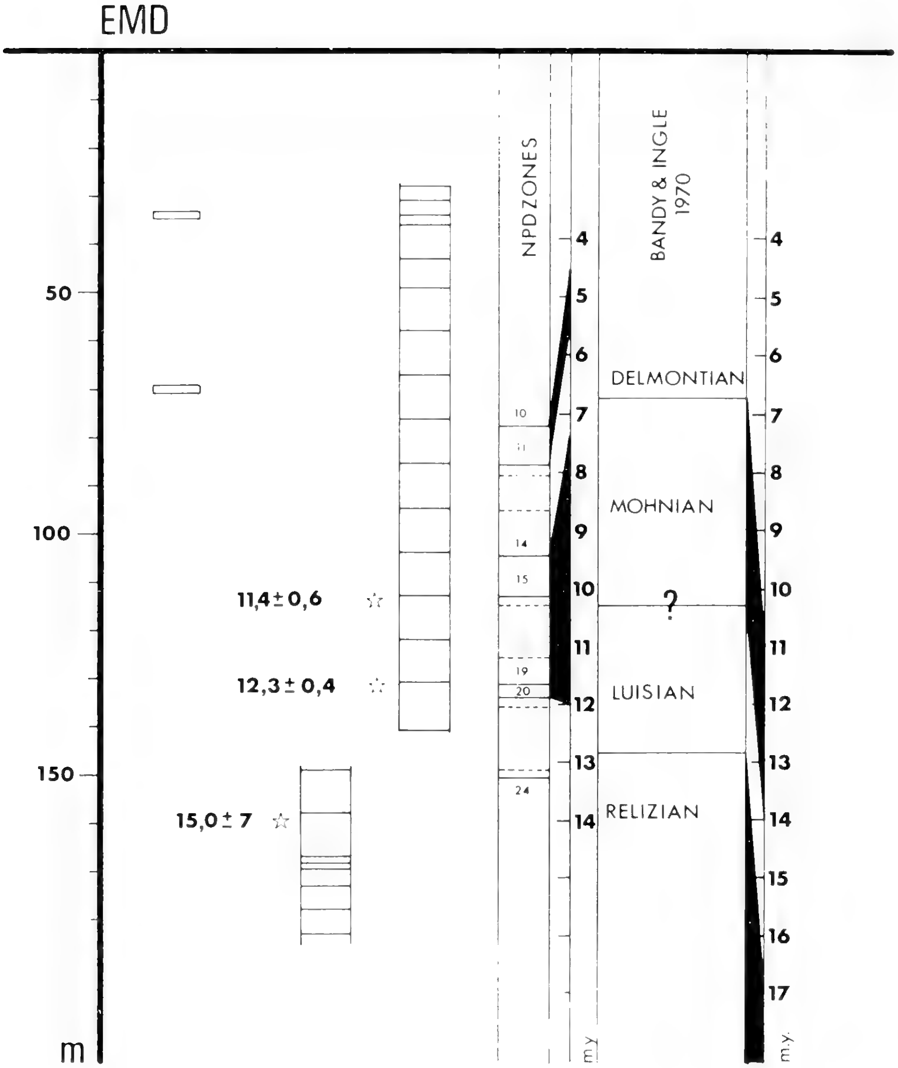


Chart 5. Correlation of the diatom zonation of the Experimental Mohole Drilling, Guadalupe Site, with the North Pacific Diatom Zonation (Schrader, 1973a) and with Californian Marine Foraminiferal Stages (Bandy and Ingle, 1970). Absolute time scale for the North Pacific Diatom Zonation from Schrader (1973a) and chart 4; dates for the Californian Marine Stages from Bandy and Ingle (1970). Potassium-Argon dates from Dymond (1966) and Krueger (1964).

except for sample EMD-10-1-30/43 cm. Additional symbols indicate the occurrences of sponge spicules and silt-size mineral components. The abundance of spicules and silt grain correlates directly with the amount of reworked shallow material including older fossil diatoms (EMD-8-9-193/194 cm.; EMD-8-9-240/241 cm.; EMD-8-9-290/291 cm.).

Fifteen biostratigraphic units of the North Pacific Diatom Zonation and five biostratigraphic units of the East-Equatorial Diatom Zonation can be differentiated on the basis of ranges of planktonic diatom species (table 3).

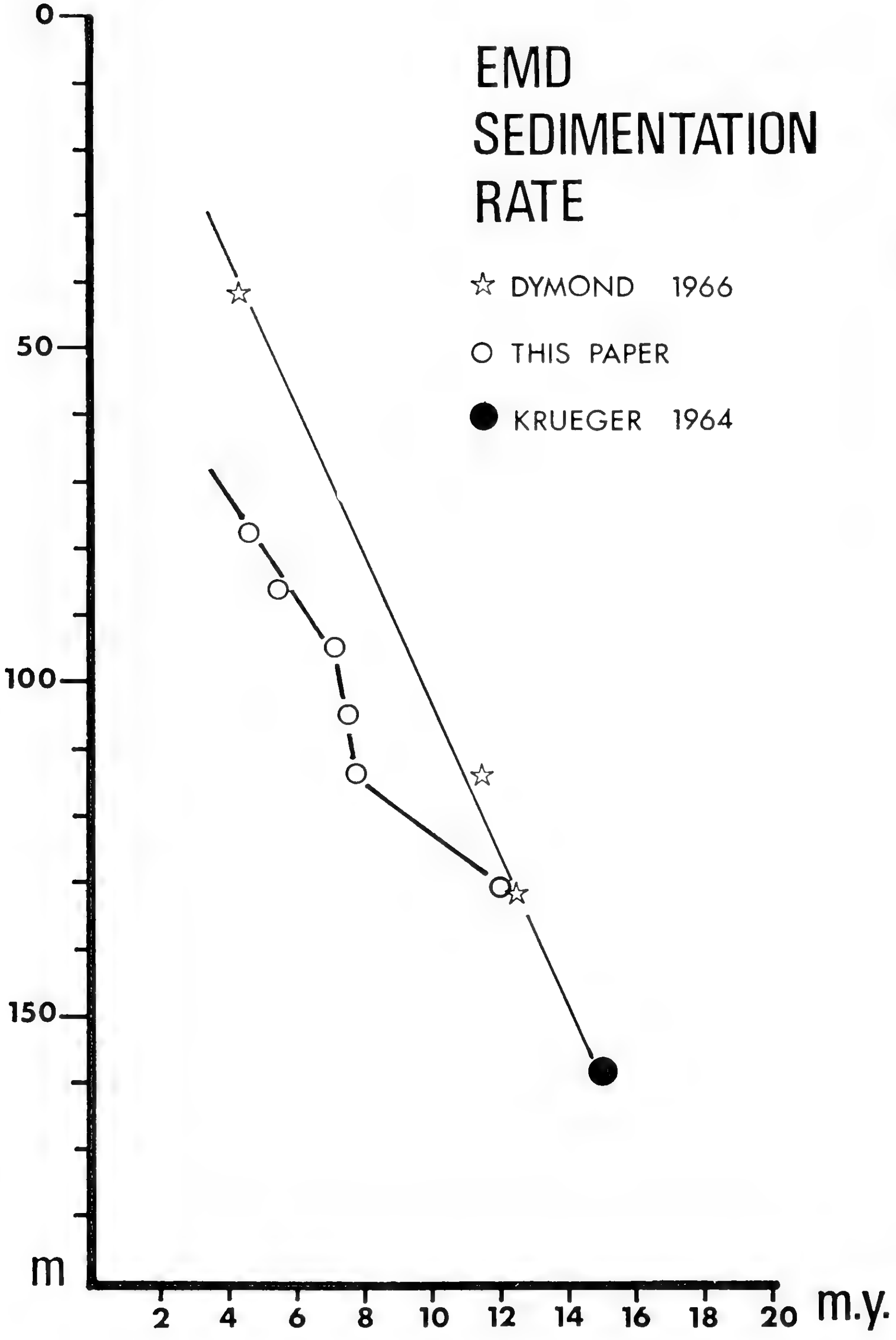
Only cold and temperate water species are present in this Middle Miocene to Pliocene interval. Comparable cool-water biofacies are present at DSDP leg 18, Site 173.

Biostratigraphic zonation of the EMD core.

1.) *North Pacific Diatom Zone 10.* The unit includes samples EMD-6-2-30/31, and EMD-8-9-5/6 to EMD-8-9-240/241 cm. This unit is characterized by the presence of *Coscinodiscus temperei, Denticula hyalina* var. *hustedtii, Lithodesmium minusculum, Nitzschia cylindrica, N. jouseae, N. praereinholdii, Rhizosolenia barboi, Thalassiosira convexa,* and *T. nativa.* The zone is correlative with the lower part of the *Nitzschia jouseae* Partial Range Zone (Burckle, 1972). Youngest investigated material of EMD is of Early Pliocene age (~ 4.2 m.y.). The top of the North Pacific Diatom Zone 10 was not found and should lie higher in the section. Sample EMD-6-2-30/31 is tentatively equivalent to EMD-8-9-140/141 cm.

2.) *North Pacific Diatom Zone 11.* The unit includes samples from EMD-8-9-290/291 to EMD-8-10-44/45 cm. It is characterized by the occurrence of *Thalassiosira usatchevii, T. convexa, Lithodesmium californicum, L. minusculum, Denticula hustedtii,* and *D. hyalina* var. *hustedtii.* This unit is correlative with the upper part of the *Thalassiosira convexa* Partial Range Zone of Burckle (1972) and is of Lower Pliocene age (~ 4.5–5.5 m.y.).

3.) *North Pacific Diatom Zones 12–14.* These three zones could not be subdivided in the EMD core and subdivisions on table 3 are tentative. The unit includes samples from EMD-8-10-100/101 to EMD-8-12-94/95 cm. It is characterized by the occurrence of *Coscinodiscus temperei, Denticula dimorpha* (lower part of the unit), *D. lauta, Lithodesmium minusculum, L. californicum, Nitzschia praereinholdii, Rhizosolenia barboi, R. miocenica* (lower part of the unit), *Rouxia californica, Synedra jouseana* (lower part of the unit), *Thalassionema claviformis* (lower part of the unit), and *T. nativa.* This unit is correlative with the interval from the lower part of the *Thalassiosira convexa* Partial Range Zone to the *Nitzschia miocenica* Partial Range Zone of Burckle (1972) and is of upper Late Miocene age (~ 5.5 m.y. to 7.6 m.y., top of Geomagnetic Epoch 5 to base of Geomagnetic Epoch 7).


EMD
SEDIMENTATION
RATE
☆ DYMOND 1966
○ THIS PAPER
● KRUEGER 1964
0
50
100
150
m
2
4
6
8
10
12
14
16
18
20
m.y.

4.) *North Pacific Diatom Zone 15.* The unit includes samples from EMD-8-12-203/204 to EMD-8-13-30/31 cm. It is characterized by the occurrence of *Cussia praepaleacea, Denticula dimorpha, D. hustedtii, D. lauta, Nitzschia praereinholdii, N. burcklia, Rhizosolenia barboi, R. miocenica, R. praebarboi, Synedra jouseana, Thalassionema claviformis,* and *T.* species A. (Burckle, 1972). This unit is correlative with the upper part of the *Nitzschia porteri* Partial Range Zone of Burckle (1972) and is of upper Late Miocene age (upper part of Geomagnetic Epoch 8; ~ 7.8 m.y.).

5.) *North Pacific Diatom Zone 16.* This unit was only present in sample EMD-8-13-100/101 cm. It differs from North Pacific Diatom Zone 15 in the lack of *Nitzschia praereinholdii* and of *Cussia paleacea,* and in the consistent presence of *Rhizosolenia praebarboi.* This zone is correlative with the lower part of the *Nitzschia porteri* Partial Range Zone of Burckle (1972) and is of middle Late Miocene age (~ 8.2 m.y.–middle part of Geomagnetic Epoch 8).

6.) *North Pacific Diatom Zones 17–19.* These zones could not be divided and subdivisions on table 3 are tentative. The unit includes samples EMD-8-13-262/265 to EMD-8-15-100/101 cm. It is characterized by the occurrence of *Bruniopsis mirabilis, Cussia paleacea, C. praepaleacea, Coscinodiscus yabei, Denticula dimorpha* (upper part of the unit), *D. hustedtii, D. lauta, D. punctata* var. *hustedtii, Mediaria splendida, Nitzschia burcklia* (upper part of the unit), *N. riedelia* (lower part of the unit), *Rhizosolenia miocenica, R. praebarboi, Synedra jouseana,* and *Craspedodiscus coscinodiscus* (lower part of the unit). This unit is correlative with the *Coscinodiscus yabei* Partial Range Zone of Burckle (1972), the base of which has not been defined. It ranges from the middle part of Geomagnetic Epoch 8 to the middle part of Geomagnetic Epoch 11 (~ 8.3 m.y. to 12 m.y.). The base of this unit represents the Late-Middle Miocene boundary as defined by Burckle (1972), but note should be made of the different boundary chosen by Berggren (1972) (chart 3).

7.) *North Pacific Diatom Zone 20.* The unit includes samples from EMD-8-15-200/201 to EMD-8-15-300/301 cm. It is characterized by the occurrence of *Actinocyclus cubitus, Cussia paleacea, C. praepaleacea, Coscinodiscus vetustissimus* var. *javanicus, C. antiquum, C. yabei, Denticula hustedtii, D. lauta, D. nicobarica, D. punctata* var. *hustedtii, Mediaria splendida, Macrora stella, Nitzschia* species 2 (Schrader), *N. riedelia, Rhizosolenia praebarboi, Synedra jouseana,* and *Craspedodiscus coscinodiscus.* This unit has not been correlated to paleomagnetic stratigraphy, but it does correlate with NN 6 of the Standard Calcareous Nannoplankton Zonation (Martini, 1971), and with the *Corbisema triacantha* Zone of the Silicoflagellate Zonation (Martini, 1972). This Zone is of

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CHART 6. Sedimentation rate of the core samples from the Experimental Mohole Drilling, Guadalupe Site, as determined by Potassium-Argon dates (Dymond, 1966) and by diatom zonation. Note change of sedimentation rate at 95 meters below the sea floor.

upper Middle Miocene age. Dymond (1966) determined the absolute age of sample EMD-8-15-86 cm. as 12.3 ± 0.4 m.y. according to the Potassium-Argon dating method. This age correlates well with the top of Zone 20 of the North Pacific Diatom Zonation which has an approximate age of 12 m.y.

8.) *North Pacific Diatom Zones 21–23.* These zones could not be divided precisely and the subdivisions on table 3 are tentative. The unit includes samples from EMD-8-15-504/505 cm. to EMD-7-2-41/42 cm. It is characterized by the occurrence of *Actinocyclus ellipticus* var. *moronensis*, *Coscinodiscus lewisianus*, *Cussia paleacea*, *C. praepaleacea*, *Coscinodiscus yabei*, *Denticula hustedtii*, *D. lauta*, *D. nicobarica*, *Mediaria splendida*, *Nitzschia riedelia*, *N.* species 2 (Schrader), and *Rhizosolenia praebarboi.* The unit has not been correlated to paleomagnetic stratigraphy, but it is correlative with NN 6 of the Standard Nannoplankton Zonation (Martini, 1971), and is of Middle Miocene age.

9.) *North Pacific Diatom Zone 24.* This unit was found at EMD-7-2-0/17 cm. and is distinguished from the upper unit by the absence of *Bruniopsis mirabilis*, *Denticula hustedtii*, *Mediaria splendida*, *Nitzschia riedelia*, and other species. The unit has not been correlated to paleomagnetic stratigraphy, but it is correlative with NN 6 of the Standard Nannoplankton Zonation (Martini, 1971) and with the *Dictyocha octacantha* Silicoflagellate Zone of Martini (1972). It is of Middle Miocene age.

SPECIES FOUND IN EXPERIMENTAL MOHOLE DRILLING SAMPLES

Genera are arranged alphabetically in the list, and species are arranged alphabetically within each genus.

Species and varieties have been identified following descriptions of Hustedt (1930, 1959), Sheshukova-Poretzkaya (1967), Schrader (1973a), and Hanna (1926, 1930, 1932).

Descriptions and discussions are given for species not adequately treated in the literature.

Species which could not be positively assigned to a known species are numbered (if only one or two individuals were found) or described as new and illustrated.

Holotypes and paratypes will be deposited in the California Academy of Sciences diatom collection.

Genus **Actinocyclus** Ehrenberg

Actinocyclus cubitus Hanna and Grant.

DESCRIPTION. Hanna and Grant, 1926, p. 118, pl. 11, fig. 3.

Actinocyclus ehrenbergi Ralfs.

DESCRIPTION. Hustedt, 1930, pp. 525–532, numerous figures.

REMARKS. No subdivisions of this species have been made.

Table 4. *List of samples and corresponding Department of Geology catalog numbers, California Academy of Sciences, San Francisco. A split of the cleaned fraction of each sample is stored at the California Academy of Sciences.*

Sample Number	CAS Number
EMD-6-2-30/31	54427
EMD-10-1-30/43	54428
EMD-8-9-5/6	54429
EMD-8-9-140/141	54430
EMD-8-9-193/194	54431
EMD-8-9-240/241	54432
EMD-8-9-290/291	54433
EMD-8-10-44/45	54434
EMD-8-10-100/101	54435
EMD-8-10-200/201	54436
EMD-8-10-300/301	54437
EMD-8-10-400/401	54438
EMD-8-11-30/31	54439
EMD-8-11-90/91	54440
EMD-8-11-200/201	54441
EMD-8-11-300/301	54442
EMD-8-11-390/391	54443
EMD-8-12-94/95	54444
EMD-8-12-203/204	54445
EMD-8-13-30/31	54446
EMD-8-13-100/101	54447
EMD-8-13-262/265	54448
EMD-8-14-10/11	54449
EMD-8-14-100/101	54450
EMD-8-14-400/401	54451
EMD-8-15-35/36	54452
EMD-8-15-93/95	54453
EMD-8-15-100/101	54454
EMD-8-15-200/201	54455
EMD-8-15-300/301	54456
EMD-8-15-504/505	54457
EMD-7-1-5/6	54458
EMD-7-1-41/42	54459
EMD-7-2-0/17	54460

Actinocyclus ellipticus Grunow.

Description. Hustedt, 1930, p. 533, fig. 303.

Actinocyclus ellipticus var. **moronensis** (Deby) Kolbe.

Description. Kolbe, 1954, p. 21, pl. 3, figs. 29–30.

Actinocyclus ingens Rattray.

Description. Kanaya, 1971, p. 554, numerous figures.

Actinocyclus okhotensis Jouse.

Description. Koizumi, 1968, p. 208, pl. 32, figs. 7–10; Donahue, 1970, p. 135, pl. 2, figs. 2–5.

Genus **Asterolampra** Ehrenberg

Asterolampra grevillei (Wallich) Greville.

Description. Hustedt, 1930, pp. 489–491, fig. 274.

Asterolampra marylandica Ehrenberg.

Description. Hustedt, 1930, pp. 485–487, fig. 271.

Genus **Biddulphia** Gray

Biddulphia moholensis Schrader, new species.

Description. Valve lanceolate-rhombic with produced bluntly rounded apices, 60 μ long, 16 μ in the middle part, 4 μ wide at the apices. Valve with radially arranged rows of punctae, 15 in 10 μ; punctae in quincunx. Middle part slightly lifted from the valve surface with three spines and without any central area. Valves with stronger solitary spines on both sides of the median apical line near the valve mantle and with two to three solitary spines at both apices near the valve mantle.

Discussion. No similar species was found mentioned in the literature. This species was placed within the genus *Biddulphia* because of the shape of the valve and the arrangement of the spines.

Holotype. Figure 4: 3–4, from EMD-8-9-290/291 cm. California Academy of Sciences, Department of Geology no. 54409 (diatom collection).

Derivation of name. This species is named 'moholensis' in memory of the Experimental Mohole Drilling.

Occurrence. Found only in the Neogene section off Baja California, in a sample in North Pacific Diatom Zone 11.

Genus **Bruniopsis** (Tempere) Karsten

Bruniopsis mirabilis (Brun) Karsten.

Description. Kolbe, 1954, p. 24, pl. 4, fig. 44; Kanaya, 1971, p. 555.

Genus **Cladogramma** Ehrenberg

Cladogramma dubium Lohmann.

Description. Lohmann, 1948, p. 168, pl. 9, fig. 5; Sheshukova-Poretzkaya, 1967, p. 192, pl. 24, fig. 6, pl. 29, fig. 4.

Genus **Coscinodiscus** Ehrenberg

Coscinodiscus antiquus (Grunow) Rattray.

DESCRIPTION. Grunow, 1884, p. 84, pl. 4 (D), fig. 24.

Coscinodiscus moholensis Schrader, new species.

DESCRIPTION. Valve circular, 38 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae on the concave plication are round, on the convex plication they are polygonal, radially arranged in a complete meshwork over the valve surface. Areolae 6–7 in 10 μ, of about the same size all over the valve. Areolae forming fascicles. Margin clearly defined with a secondary plication forming triangulate uplifted areas 5 μ wide. On top of each of these areas is one elongated areola. Margin well defined and separated from the valve structure by a small hyaline area. Margin 1–2 μ wide, chambered, radially striated.

DISCUSSION. This species differs from all other species of the *Coscinodiscus plicatus* group in the formation of the triangulate uplifted marginal areas. No reference to such a form was found in the literature.

DERIVATION OF NAME. Dedicated to the memory of the Experimental Mohole Drilling.

HOLOTYPE. Figure 3: 3–5 from EMD-8-13-100/101 cm. California Academy of Sciences, Department of Geology no. 54410 (diatom collection).

OCCURRENCE. Found in the Neogene Section off Baja California, from a sample in North Pacific Diatom Zone 16.

Coscinodiscus endoi Kanaya.

(Figure 3: 11–12.)

DESCRIPTION. Kanaya, 1959, pp. 76–77, pl. 3, figs. 8–11; Koizumi, 1968, p. 211, pl. 32, figs. 21–22.

Coscinodiscus lewisianus Greville.

DESCRIPTION. Kanaya, 1971, p. 555, pl. 40.5, figs. 4–6.

Coscinodiscus marginatus Ehrenberg.

DESCRIPTION. Hustedt, 1930, pp. 416–418, fig. 223.

DISCUSSION. No attempt has been made here to subdivide *C. marginatus* and *C. marginatus* var. *fossilis* Jouse.

Coscinodiscus nodulifer A. Schmidt.

DESCRIPTION. Hustedt, 1930, pp. 426–427, fig. 229.

Coscinodiscus plicatus Grunow.

DESCRIPTION. Grunow, 1884, p. 86, pl. 3, figs. 10, 27; Kolbe, 1954, pp. 34–35 (no illustration); Schrader, 1973a, p. 703, pl. 6, fig. 23.

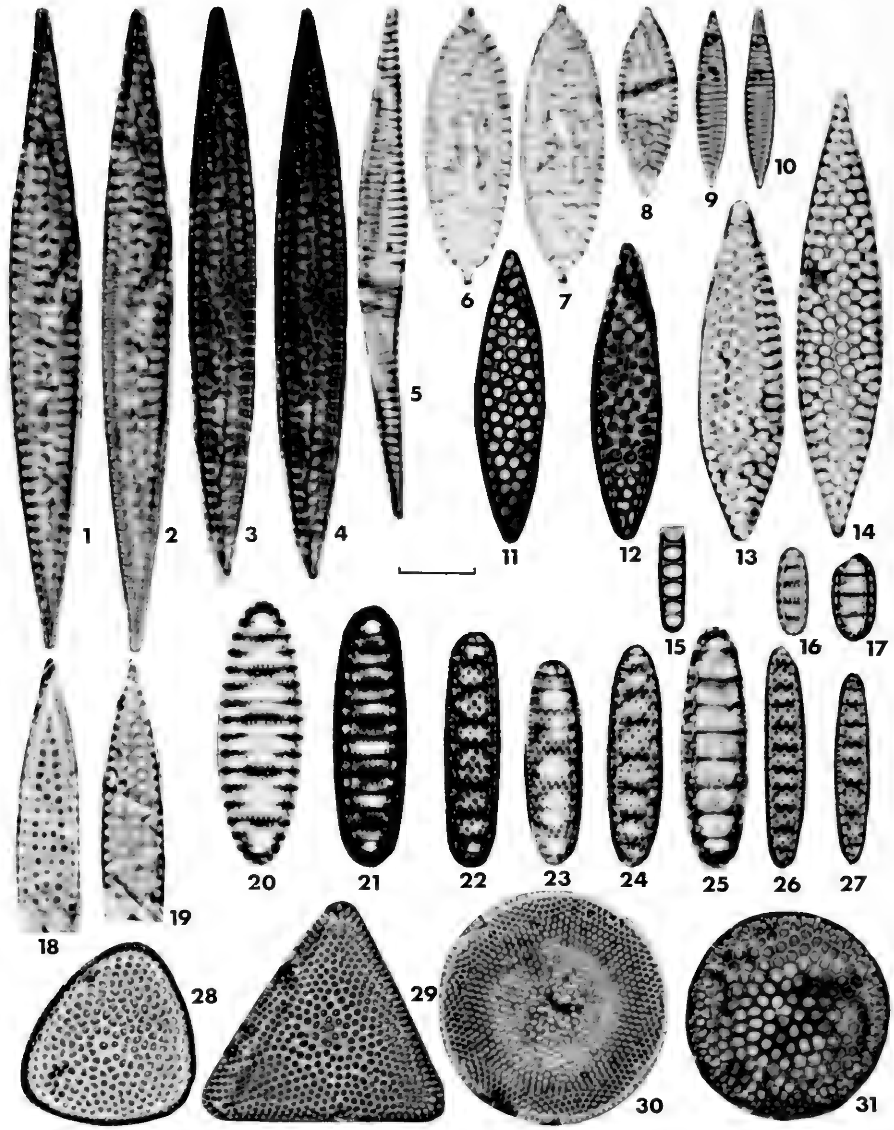

Figure 1. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-10-100/101 cm. *Cussia moholensis* Schrader, new species; 2. EMD-8-10-100/101 cm. *C. moholensis*, California Academy of Sciences, Department of Geology no. 54414; 3. EMD-8-9-290/291 cm., *C. moholensis* (type); 4. EMD-8-9-290/291 cm., *C. moholensis*, California Academy of Sciences, Department of Geology no. 54413; 5. EMD-8-15-100/101 cm., *C. lancettula* Schrader, new species, California Academy of Sciences, Department of Geology no. 54112; 6. EMD-8-11-300/301 cm., *C. tatsunokuchiensis* (Koizumi), new combination; 7. EMD-8-11-300/301 cm., *C. tatsunokuchiensis*; 8. EMD-7-1-5/6 cm., *C. praepaleacea* (Schrader), new combination; 9. EMD-8-15-100/101 cm., *C. lancettula* (type); 10. EMD-8-

Coscinodiscus symbolophorus Grunow.

(Figure 1: 30.)

DESCRIPTION. Hustedt, 1930, pp. 396–398, fig. 208 (as *Coscinodiscus stellaris* var. *symbolophora* (Grunow) Jörgensen); Schrader, 1973a, p. 703, pl. 22, figs. 8–9.

Coscinodiscus temperei Brun.

(Figure 2: 29–33.)

DESCRIPTION. Kanaya, 1959, p. 84, pl. 4, fig. 8.

DISCUSSION. See Schrader, 1973a, p. 704.

Coscinodiscus vetustissimus Pantocsek.

DESCRIPTION. Hustedt, 1930, p. 412, fig. 220.

Coscinodiscus vetustissimus var. **javanicus** Reinhold.

DESCRIPTION. Reinhold, 1937, p. 102, pl. 8, figs. 7–8; Kanaya, 1971, p. 555, pl. 40.2, fig. 1.

Coscinodiscus yabei Kanaya.

(Figure 3: 6–8.)

DESCRIPTION. Kanaya, 1959, pp. 86–87, pl. 5, figs. 5–9; Schrader, 1973a, p. 704, pl. 6, figs. 1–6.

Coscinodiscus species 1 Schrader.

DESCRIPTION. Valve circular, 24 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae round, arranged in radial rows forming a complete network over the entire valve. Areolae 8 in 10 μ and of the same size all over the valve surface. Secondary spiral structure of areolae well developed, interrupted by the axis of the plica-

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15-100/101 cm., *C. lancettula*, California Academy of Sciences, Department of Geology no. 54411; 11. EMD-8-15-93/94 cm., *C. paleacea* (Grunow), new combination; 12. EMD-8-15-93/94 cm., *C. paleacea*; 13. EMD-8-15-504/505 cm., *C. paleacea*; 14. EMD-8-15-504/505 cm., *C. paleacea*; 15. EMD-8-9-240/241 cm., *Denticula dimorpha* Schrader; 16. EMD-8-15-504/505 cm., *D. lauta* Bailey; 17. EMD-8-9-516 cm., *D. lauta*; 18. EMD-8-10-100/101 cm., *Cussia* species 1 Schrader; 19. EMD-8-10-100/101 cm., *Cussia* species 1 Schrader; 20. EMD-8-9-140/141 cm., *Denticula hustedtii* Simonsen and Kanaya; 21. EMD-8-9-140/141 cm., *D. hustedtii*; 22. EMD-8-15-93/94 cm., *D. punctata* var. *hustedtii* Schrader; 23. EMD-8-15-504/505 cm., *D. punctata* var. *hustedtii*; 24. EMD-8-9-140/141 cm., *D. punctata* var. *hustedtii*; 25. EMD-7-2-0/17 cm., *D. hyalina* Schrader; 26. EMD-7-2-0/17 cm., *D. nicobarica* Grunow; 27. EMD-7-1-5/6 cm., *D. nicobarica*; 28. EMD-8-15-300/301 cm., *Triceratium antiquum* Pantocsek; 29. EMD-8-15-35/36 cm., *T. cinnamomeum* Greville; 30. EMD-8-15-200/201 cm., *Coscinodiscus symbolophorus* Grunow; 31. EMD-8-11-30/31 cm., *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko.

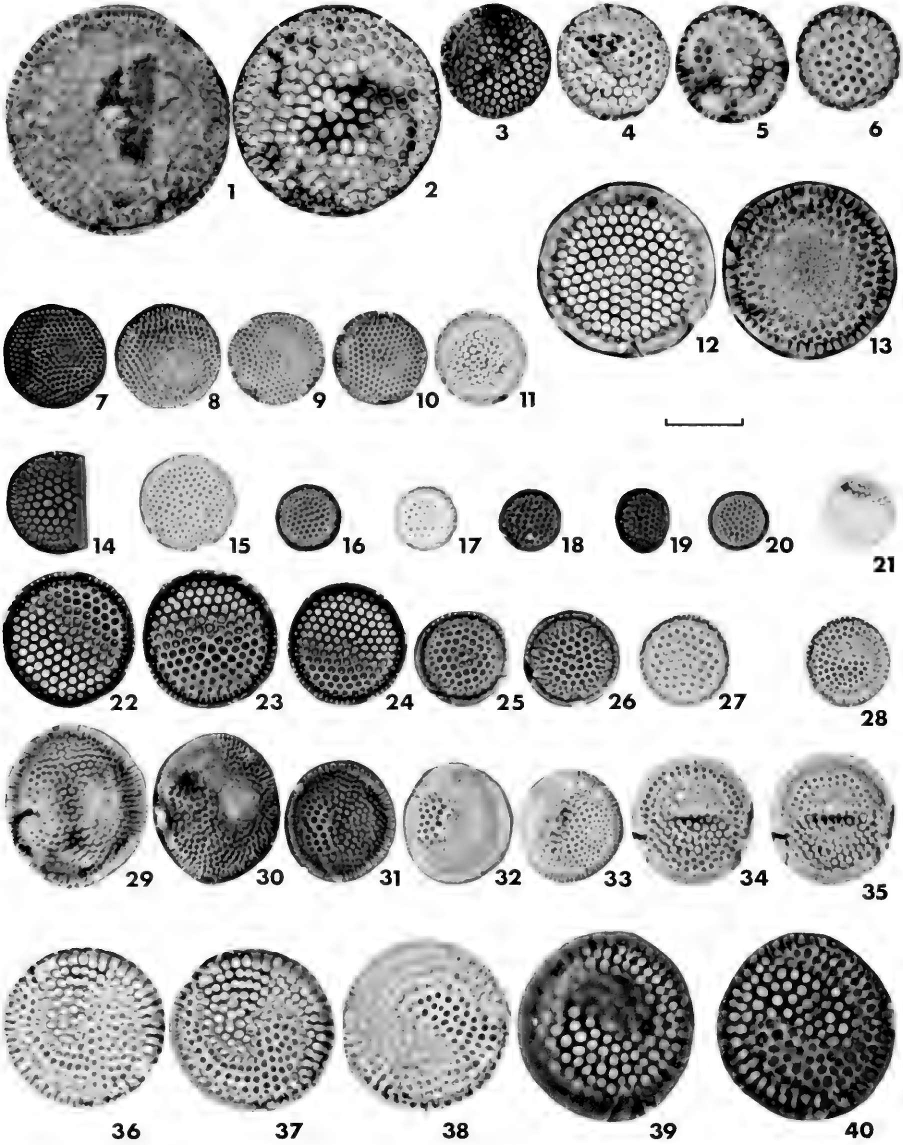

Figure 2. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-11-30/31 cm., *Thalassiosira oestruppi* (Ostenfeld) Proshkina-Lavrenko; 2. EMD-8-11-30/31 cm., *T. oestruppi*; 3. RC-12-65-1915/1917.5 cm., *T.* species A. Burckle; 4. EMD-8-13-30/31 cm., *T.* species A. Burckle; 5. EMD-8-9-140/141 cm., *T. convexa* Mukhina; 6. EMD-8-9-240/241 cm., *T. convexa* Mukhina; 7. RC-12-65-1105/1107.5 cm., *T. praeconvexa* Burckle; 8. RC-12-65-1105/1107.5 cm., *T. praeconvexa*; 9. EMD-8-10-44/45 cm., *T. praeconvexa*; 10. EMD-8-10-44/45 cm., *T. praeconvexa*; 11. EMD-8-9-240/241 cm., *T. nativa* Sheshukova-Poretzkaya; 12. EMD-8-9-140/141 cm., *T. nativa*; 13. EMD-8-9-

tion. Margin clearly defined, not separated from the meshwork, 2–2.5 μ wide, radially striated.

Discussion. This species differs from *C. yabei* Kanaya in the round areolae, and in the striated valve margin. It is close to *Coscinodiscus flexuosus* Brun but differs in the nonseparated valve margin, and the nonchambered margin (see Schrader, 1973a, p. 702). Only one specimen was observed.

Figured specimen. Figure 4: 13–14 from EMD-8-9-290/291 cm., a sample from North Pacific Diatom Zone 11.

Coscinodiscus species 2 Schrader.

Description. Valve circular, 15–16 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae round on the concave plication, polygonal on the convex plication, arranged in radial rows, forming a complete network over the entire valve. Areolae decreasing in size slightly towards the margin, approximately 11 in 10 μ. Secondary spiral structure of the areolae well developed. Margin clearly defined, not separated from the meshwork, 2 μ wide, radially striated, 16 in 10 μ, margin not chambered.

Discussion. This species is close to the above mentioned species but differs in the finer structure and the more finely striated margin. No similar species have been found in the literature. Only one specimen was observed.

Figured specimen. Figure 2: 34–35 from EMD-8-9-193/194 cm., a sample belonging to North Pacific Diatom Zone 10.

Coscinodiscus species 3 Schrader.

Description. Valve circular, 21–22 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae round on the concave plication, polygonal on the convex plication; areolae decreasing in size slightly towards the margin, 10 in 10 μ, arranged in radial rows, forming a complete network over the entire valve. Secondary radial rows present

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140/141 cm., *T. nativa*; 14. EMD-8-9-193/194 cm., *T. nativa*; 15. EMD-8-9-240/241 cm., *T. nativa*; 16. EMD-8-9-5/6 cm., *T. nativa*; 17. EMD-8-11-300/301 cm., *T. nativa*; 18. EMD-8-9-193/194 cm., *T. nativa*; 19. EMD-8-9-193/194 cm., *T. nativa*; 20. EMD-8-9-193/194 cm., *T. nativa*; 21. EMD-8-11-390/391 cm., *T. nativa*; 22. EMD-8-9-390/391 cm., *T.* species 2 Schrader; 23. EMD-8-9-390/391 cm., *T.* species 2; 24. EMD-8-9-390/391 cm., *T.* species 2; 25. EMD-8-9-5/6 cm., *T. nativa* Sheshukova-Poretzkaya; 26. EMD-8-9-5/6 cm., *T. nativa*; 27. EMD-8-9-193/194 cm., *T.* species 2 Schrader; 28. EMD-8-15-504/505 cm., *T.* species 2; 29. EMD-8-9-5/6 cm., *Coscinodiscus temperei* Brun; 30. EMD-8-9-5/6 cm., *C. temperei*; 31. EMD-8-9-5/6 cm., *C. temperei*; 32. EMD-8-10-44/45 cm., *C. temperei*; 33. EMD-8-10-44/45 cm., *C. temperei*; 34. EMD-8-9-193/194 cm., *C.* species 2 Schrader; 35. EMD-8-9-193/194 cm., *C.* species 2; 36. EMD-7-2-0/17 cm., *C.* species 3 Schrader; 37. EMD-7-2-0/17 cm., *C.* species 3; 38. EMD-7-2-0/17 cm., *C.* species 3; 39. EMD-8-9-290/291 cm., *C. yabei* Kanaya; 40. EMD-8-9-290/291 cm., *C. yabei.*

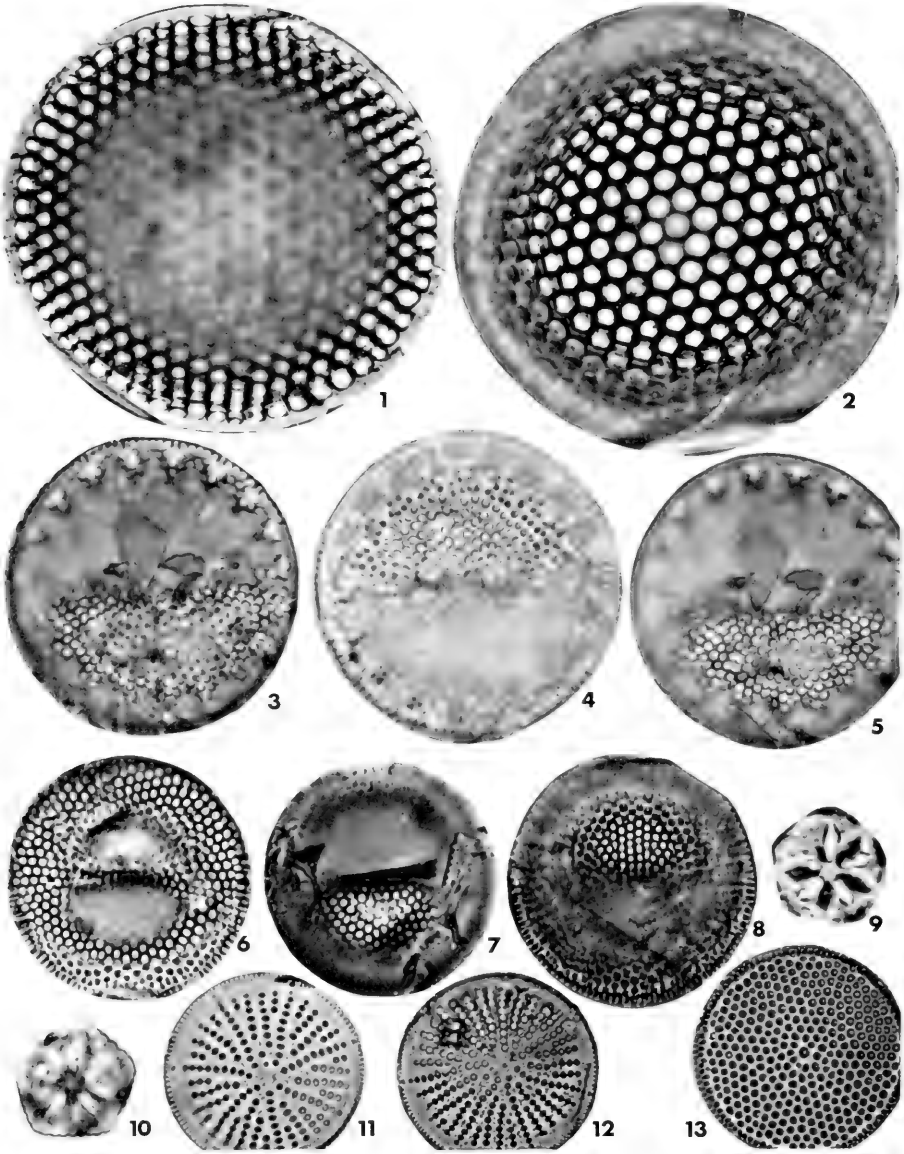

Figure 3. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-12-94/95 cm., *Thalassiosira usatchevii* Jouse; 2. EMD-8-12-94/95 cm., *T. usatchevii;* 3. EMD-8-13-100/101 cm., *Coscinodiscus moholensis* Schrader, new species; 4. EMD-8-13-100/101 cm., *C. moholensis*; 5. EMD-8-13-100/101 cm., *C. moholensis*; California Academy of Sciences, Department of Geology no. 54410; 6. RC-12-65-2142.5/2145 cm., *Coscinodiscus yabei* Kanaya; 7. RC-12-65-2142.5/2145 cm., *C. yabei*; 8. RC-12-65-2142.5/2145 cm., *C. yabei*; 9. EMD-7-1-5/6 cm., *Liostephania* species 1 Schrader; 10. EMD-7-1-5/6 cm., *L.* species 1; 11. EMD-8-9-140/141 cm., *Coscinodiscus endoi* Kanaya; 12. EMD-8-9-140/141 cm., *C. endoi*; 13. EMD-8-15-504/505 cm., *C. vetustissimus* Pantocsek.

with an interstitial mesh. Secondary spiral structure of the areolae well developed. Margin clearly defined, not separated from the meshwork, radially striated 12 in 10 μ. Margin chambered with two areolae between each chamber.

Discussion. This species is close to *Coscinodiscus flexuosus* Brun but differs in the absence of a hyaline area between the valve structure and the marginal structure. Final taxonomic decision can only be made if more individuals are found. Only one specimen was observed.

Figured specimen. Figure 2: 36–38 from EMD-7-2-0/17 cm., a sample from North Pacific Diatom Zone 24.

Genus **Craspedodiscus** Ehrenberg

Craspedodiscus coscinodiscus Ehrenberg.

Description. Kolbe, 1954, p. 36, pl. 1, fig. 4; Kanaya, 1971, p. 555, pl. 40.4, figs. 1–3.

Genus **Cussia** Schrader, new genus

Coscinodiscus e.p. Rattray, 1890, p. 597, fig. 149.
Stoschia (?) e.p. Grunow *in* Van Heurck, 1883, pl. 128, fig. 6.
Coscinodiscus e.p. Schrader, 1973a. (*C. paleaceus*, *C. praepaleaceus*).
Rhaphoneis e.p. Hajos, 1968, p. 143, pl. XLI, figs. 16–27.
Rhaphoneis e.p. Koizumi, 1972, p. 349, pl. 42, figs. 3–4.

Description. Cells solitary, free. Valves elliptical-lanceolate with a symmetrical and/or asymmetrical transapical axis, flat. Valve surface usually either with round areolae or with transapical costae forming a pennate-like surface ornamentation with a zigzag apical costa forming a pseudoraphe-like morphological band; in between the costae are hyaline intercostal membranes. Valve center not furnished with a central area. Spines or apiculi absent. Valve margin usually narrow with a coarse striation.

Type species. *Stoschia* (?) *paleacea* Grunow *in* Van Heurck, 1883, pl. 128, fig. 6.

Distribution. Widely distributed in Neogene marine sediments (Mediterranean Sea and Pacific, Atlantic, and Indian oceans).

Discussion. *Stoschia* Janisch was not validly published by Janisch, but the description was distributed to diatomists privately by the author (Janisch, C.: The diatoms of the "Gazelle" Expedition, 17 plates with manuscript index, no date). Rattray, 1890, p. 548, combined *Stoschia* with *Coscinodiscus* and combined the species *Stoschia admirabilis* Janisch (circa 1888) with *Coscinodiscus reniformis* Castracane (1886, p. 160, pl. 12, fig. 12). Grunow (1883 *in* Van Heurck) established the species *Stoschia paleacea*; this species was newly combined by Rattray (1890, p. 597, fig. 149) and named *Coscinodiscus paleaceus* (Grunow) Rattray. As soon as the evolution of the genus under discussion was clarified, the taxonomic position of some other species could be detected which have been described under *Rhaphoneis* by Hajos (1968) and Koizumi (1972).

Derivation of name. Dedicated to the scientific vessel *Cuss I*, which drilled the Experimental Mohole Drilling.

Cussia lancettula Schrader, new species.

Description. Valves elliptical-lanceolate with acute rounded ends. 24–70 μ long, 4–7 μ wide. Transapical axis symmetrical. Valve surface flat with transapical costae, 10–12 in 10 μ, slightly curved near the apices. Transapical costae not divided in the middle part, divided and in decussate arrangement towards the apices, connected in the middle by an apical zigzag line which simulates a pseudoraphe. Intercostal membranes homogenous even in oblique light. Margin not separated from the valve structure.

Discussion. This species differs from *Cussia praepaleacea* in that the margin is not separated, and the transapical structure is simple.

Derivation of name. From the Latin word 'lancea' meaning 'lance.'

Holotype. Figure 1: 9–10 from EMD-8-15-100/101 cm., a sample from North Pacific Diatom Zone 19. California Academy of Sciences, Department of Geology no. 54411 (diatom collection).

Paratype. Figure 1: 5. California Academy of Sciences, Department of Geology no. 54412 (diatom collection).

Cussia mediopunctata (Hajos), new combination.

Raphoneis mediopunctata Hajos, 1968, p. 143, pl. XLI, figs. 16–27.

Discussion. The illustrations of Hajos verify this new combination. The girdle view is most characteristic, as are the other mentioned morphological features. Unfortunately the micrographs do not show clearly if as stated "in der Längsmittellinie der Schalen zieht sich eine Punktreihe." This species is close to *Cussia moholensis* but differs in the presence of round areolae.

Cussia mediopunctata var. **matraensis** (Hajos), new combination.

Raphoneis mediopunctata var. *matraensis* Hajos, 1968, p. 144, pl. XLII, figs. 1–5.

Cussia moholensis Schrader, new species.

Description. Valves elliptical-lanceolate with acute apices, 76–85 μ long, 9–10 μ wide. Transapical axis symmetrical. Valve surface flat with marginal transapical costae 7 in 10 μ and extending 2–3 μ into the valve surface. In between the marginal transapical costae are round areolae. Valve surface with scattered, sometimes transapically orientated costae, which form a pseudoraphe-like medium apical zigzag line. Intercostal membranes homogenous even in oblique light.

Discussion. This species differs from *Cussia lancettula* in having scattered medium costae and wider valves.

Derivation of name. Dedicated to the memory of the Experimental Mohole Drilling.

Holotype. Figure 1: 3–4 from EMD-8-9-290/291 cm., a sample from North Pacific Diatom Zone 11. California Academy of Sciences, Department of Geology no. 54413 (diatom collection).

Paratype. Figure 1: 1–2. California Academy of Sciences, Department of Geology no. 54414 (diatom collection).

Cussia paleacea (Grunow), new combination.

(Figure 1: 11–14.)

Stoschia paleacea Grunow *in* Van Heurck, 1883, pl. 128, fig. 6.
Coscinodiscus paleaceus (Grunow) Rattray, 1890, p. 597, fig. 149.
Coscinodiscus paleaceus (Grunow) Rattray, *in* Schrader, 1973a, p. 703, pl. 3, figs. 10–12.

Description. Kolbe, 1954, p. 34, pl. 3, fig. 32.

Cussia praepaleacea (Schrader), new combination.

(Figure 1: 8.)

Coscinodiscus praepaleaceus Schrader, 1973a, p. 703, pl. 3, figs. 1–9.

Description. Schrader, 1973a, p. 703, pl. 3, figs. 1–9.

Cussia tatsunokuchiensis (Koizumi), new combination.

(Figure 1: 6–7.)

Raphoneis tatsunokuchiensis Koizumi, 1972, p. 349, pl. 42, figs. 3–4.

Description. Koizumi, 1972, p. 349, pl. 42, figs. 3–4.

Cussia species 1 Schrader.

Discussion. Only two fragments were found with coarsely punctated transapical lines, 7 in 10 μ, the punctae forming straight-apical lines. Middle structure separated from the marginal line of punctae by a hyaline area parallel to the margin. No mention of similar species has been found in the literature.

Figured specimen. Figure 1: 18–19.

Genus **Denticula** Kützing

Denticula dimorpha Schrader.

(Figure 1: 15.)

Description. Schrader, 1973a, p. 704, pl. 1, fig. 42.

Denticula hustedtii Simonsen and Kanaya.

(Figure 1: 20–21.)

Description. Simonsen and Kanaya, 1961, p. 501, pl. 1, figs. 19–25, pl. 2, figs. 36–47.

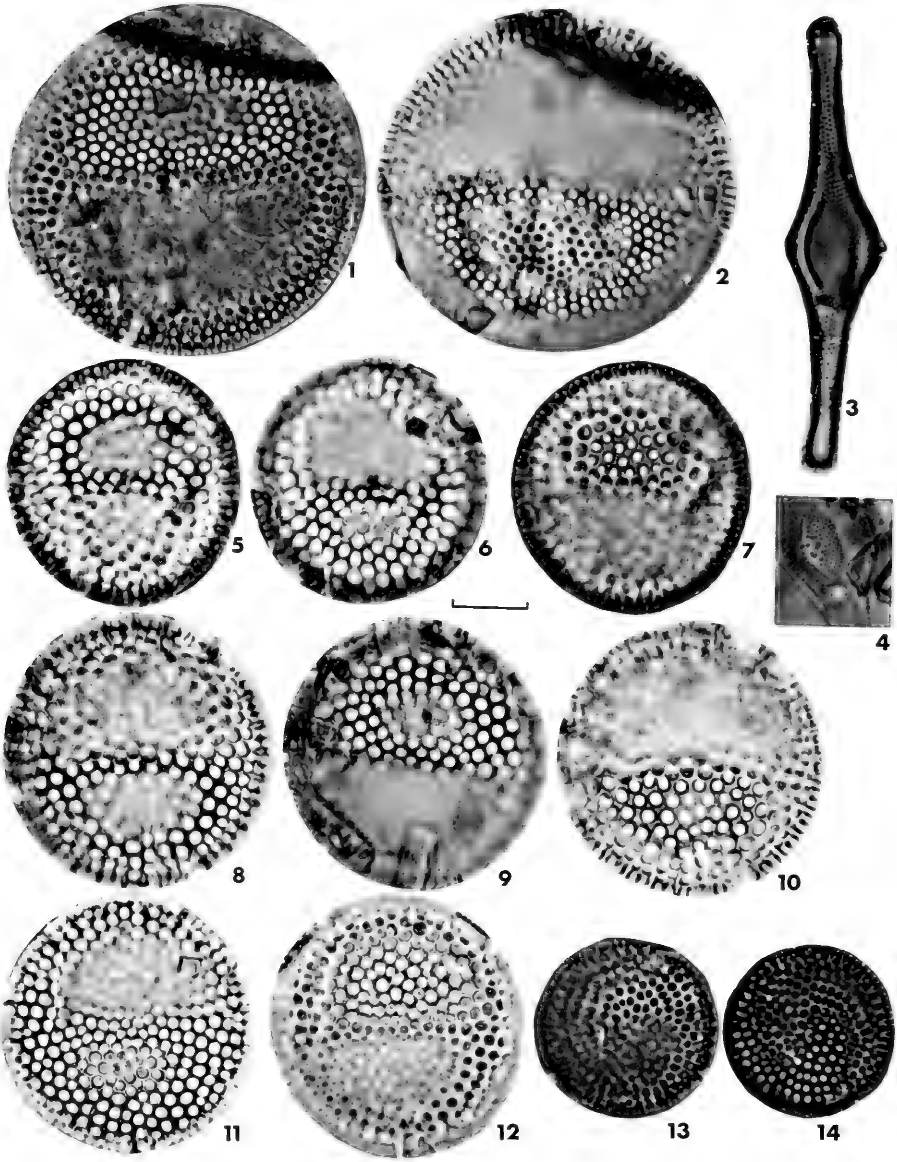

FIGURE 4. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-9-290/291 cm., *Coscinodiscus plicatus* Grun; 2. EMD-8-9-290/291 cm., *C. plicatus*; 3. EMD-8-9-290/291 cm., *Biddulphia moholensis* Schrader, new species; 4. EMD-8-9-290/291 cm., *B. moholensis*, California Academy of Sciences, Department of Geology no. 54409; 5. EMD-8-10-100/101 cm., *Coscinodiscus yabei* Kanaya; 6. EMD-8-10-100/101 cm., *C. yabei*; 7. EMD-8-10-100/101 cm., *C. yabei*; 8. EMD-8-10-100/101 cm., *C. yabei*; 9. EMD-8-10-100/101 cm., *C. yabei*; 10. EMD-8-10-100/101 cm., *C. yabei*; 11. EMD-8-10-300/301 cm., *C. plicatus* Grunow; 12. EMD-8-10-300/301 cm., *C. plicatus*; 13. EMD-8-9-290/291 cm., *C.* species 1 Schrader; 14. EMD-8-9-290/291 cm., *C.* species 1.

Denticula hyalina Schrader.
(Figure 1: 25.)

DESCRIPTION. Schrader, 1973a, pp. 704–705, pl. 1, figs. 12–20, 22.

Denticula hyalina var. **hustedtii** Schrader.

DESCRIPTION. Schrader, 1973b, p. 418, pl. 1, fig. 9.

Denticula lauta Bailey.
(Figure 1: 16–17.)

DESCRIPTION. Simonsen and Kanaya, 1961, pp. 500–501, pl. 1, figs. 1–8.

Denticula nicobarica Grunow.
(Figure 1: 26–27.)

DESCRIPTION. Simonsen and Kanaya, 1961, p. 503, pl. 1, figs. 11–13.

Denticula punctata Schrader.

DESCRIPTION. Schrader, 1973a, p. 705, pl. 1, figs. 27–28, 25–26.

Denticula punctata var. **hustedtii** Schrader.
(Figure 1: 22–24.)

DESCRIPTION. Schrader, 1973a, p. 705, pl. 1, figs. 23–24.

Genus **Ethmodiscus** Castracane

Ethmodiscus rex (Rattray) Hendey.

DESCRIPTION. Hendey, 1953, pp. 51–57, pl. 1, figs. 1–6, pl. 2, figs. 1–3.

Genus **Hemiaulus** Ehrenberg

Hemiaulus cf. **H. polymorphus** Grunow.

DESCRIPTION. Hustedt, 1930, pp. 880–881, figs. 525–526.

DISCUSSION. The specimens which are tentatively identified here as *Hemiaulus polymorphus* differ from the original description in the lack of pseudoseptae.

Genus **Hemidiscus** Wallich

Hemidiscus cuneiformis Wallich.

DESCRIPTION. Hustedt, 1930, pp. 904–907, fig. 542.

Hemidiscus simplicissimus Hanna and Grant.

DESCRIPTION. Hanna and Grant, 1926, p. 147, pl. 16, fig. 13; Schrader, 1973a, p. 706, pl. 24, figs. 12–13.

Genus **Liostephania** Ehrenberg

Liostephania species 1 Schrader.

DISCUSSION. Flat silicified disks belonging to this genus were found occasionally with a moderately well preserved diatom association. Hanna and Brigger (1970) pointed out that these disks are silicified remains of inner chambers of either *Asterolampra* or *Asteromphalus*.

FIGURED SPECIMEN. Figure 3: 9–10.

Genus **Lithodesmium** Ehrenberg

Lithodesmium californicum Grunow.

DESCRIPTION. Schrader, 1973a, p. 706, pl. 12, figs. 11, 20.

Lithodesmium minusculum Grunow.

DESCRIPTION. Schrader, 1973a, p. 706, pl. 12, fig. 7.

Genus **Macrora** Hanna (not a diatom genus, taxonomic position uncertain)

Macrora stella (Azpeitia) Hanna.

DESCRIPTION. Hanna, 1932, p. 196, pl. 12, fig. 7.

Genus **Mediaria** Sheshukova-Poretzkaya

Mediaria splendida Sheshukova-Poretzkaya.

DESCRIPTION. Sheshukova-Poretzkaya, 1967, p. 306, pl. 47, fig. 14, pl. 48, fig. 8.

Genus **Melosira** Agardh

Melosira sulcata (Ehrenberg) Kützing.

DESCRIPTION. Hustedt, 1930, pp. 276–278, figs. 118–120.

Genus **Nitzschia** Hassal

Nitzschia californica Schrader.

DESCRIPTION. Schrader, 1973a, p. 707, pl. 26, fig. 6; pl. 5, fig. 15.

Nitzschia cylindrica Burckle.

(Figure 5: 23–30.)

DESCRIPTION. Burckle, 1972, pp. 239–240, pl. 2, figs. 1–6.

Nitzschia burcklia Schrader, new species.

DESCRIPTION. Valve elliptical with slightly convex margins and broadly rounded apices. 30–33 μ long, 5 μ wide. Transapical costae 11–12 in 10 μ. In between the middle two costae one 'secondary' costa is inserted which is small and derives at the central nodule. Intercostal membranes hyaline, even in oblique light. Transapical costae and intercostal membranes straight in transapical direction, reaching the well developed apical field. Apical field with 2–3 apical costae. Keel well developed, keel punctae 11 in 10 μ. Central nodule present, raphe marginal.

Discussion. This species differs from the allied species *N. riedelia, N. rolandii, N. kanayensis* in the presence of the 'secondary transapical costae' in the middle of the valves.

Derivation of name. Dedicated to Dr. Lloyd Burckle of Lamont-Doherty Geological Observatory, New York.

Holotype. Figure 6: 29 from EMD-8-9-240/241 cm., a sample from North Pacific Diatom Zone 10. California Academy of Sciences, Department of Geology no. 54415 (diatom collection).

Paratype. Figure 6: 30. California Academy of Sciences, Department of Geology no. 54416 (diatom collection).

Nitzschia cf. **N. heteropolica** Schrader.

(Figure 5: 42.)

Description. Schrader, 1973a, p. 707, pl. 26, figs. 1–2.

Discussion. Only one fragment was found in the EMD samples and thus a positive identification could not be made.

Nitzschia invisa Schrader.

(Figure 6: 31.)

Description. Schrader, 1973a, p. 707, pl. 26, fig. 5.

Nitzschia jouseae Burckle.

Description. Burckle, 1972, p. 240, pl. 2, figs. 17–21.

Nitzschia kanayensis Schrader, new species.

Description. Valves elliptical with slightly convex margins, 18–25 μ long, 4–4.5 μ wide, apices broadly rounded. Transapical costae 13–16 in 10 μ, straight transapical in the middle part of the valve, slightly convex towards the apices. Apical field well developed with 2–3 apical costae. Intercostal membranes hyaline even in oblique light. Raphe marginal, keel indistinct; keel punctae hardly visible, about 17 in 10 μ (compare fig. 6: 28).

Discussion. This species is close to *Nitzschia rolandii* and *N. riedelia* but differs in the finer structure and the apical fields.

Derivation of name. Dedicated to Dr. Taro Kanaya.

Holotype. Figure 6: 23 from EMD-8-15-200/201 cm., a sample from North

Pacific Diatom Zone 20. California Academy of Sciences, Department of Geology no. 54417 (diatom collection).

Paratypes. Figure 6: 25, 28. California Academy of Sciences, Department of Geology nos. 54418, 54426 (diatom collection).

Occurrence. Found only in the Neogene section off Baja California and at DSDP Site 173.

Nitzschia miocenica Burckle.

(Figure 5: 17–22.)

Description. Burckle, 1972, pp. 240–241, pl. 2, figs. 10–15.

Nitzschia moholensis Schrader, new species.

Description. Valves elliptical with convex margins and slightly capitate apices. Apices heteromorph. 26 μ long, 5 μ wide in the middle. Transapical costae 10 in 10 μ, straight in transapical direction in the middle of the valves, slightly curved towards the apices. Intercostal membranes with two rows of punctae (20 in 10 μ), punctae in decussate arrangement 10 in 10 μ. Raphe marginal, central nodule absent, keel indistinct; keel punctae about 10 in 10 μ.

Discussion. No similar species has been found mentioned in the literature.

Derivation of name. Dedicated to the memory of the Experimental Mohole Drilling.

Holotype. Figure 6: 10–11 from EMD-8-11-300/301 cm., a sample from North Pacific Diatom Zone 14. California Academy of Sciences, Department of Geology no. 54419 (diatom collection).

Occurrence. Found only in the Neogene section of Baja California.

Nitzschia porteri Burckle non Frenguelli.

(Figure 5: 31–32.)

Description. Burckle, 1972, no description, pl. 2, fig. 16.

Discussion. Frenguelli, 1949, p. 116, pl. 1, fig. 33–34 described a species with "elongato-ovalibus" valves and "striis transversis delicatis, 12–13 in 10 μ." Burckle's figured specimen has elliptical valves with parallel margins and distinct transapical intercostal membranes with one row of punctae and transapical costae which form a slight angle with the transapical direction. I have not yet changed the name because of lack of the original Frenguelli material from Tiltil y Mejillones.

Nitzschia praereinholdii Schrader.

(Figure 6: 1–9, 13–15.)

Description. Schrader, 1973a, p. 708, pl. 5, figs. 24–25, 20, 23, 26.

Nitzschia cf. **N. praereinholdii** Schrader.

(Figure 6: 16–19.)

Description. Schrader, 1973a, p. 708, pl. 5, figs. 20, 23–26.

Discussion. Specimens (from EMD-8-9-240/241 cm.) have been placed doubtfully in *N. praereinholdii* because they possess bent raphe bars near the apices similar to *Nitzschia marina* Grunow.

Nitzschia riedelia Schrader, new species.

Description. Valves elliptical with slightly convex margins and broadly rounded apices, 22–30 μ long, 5–6 μ wide in the middle of the valves. Transapical costae straight in transapical direction in the middle part of the valve, curved near the apices, 11–13 in 10 μ in the middle becoming closer near the apices, approximately 15 in 10 μ. Intercostal membranes hyaline even in oblique light. Apical field not developed. Raphe marginal, central nodule absent, keel distinct, about 15 keel-punctae in 10 μ.

Discussion. This species is close to *N. burcklia* but differs in the absence of apical fields and a central nodule. It is close to *N. rolandii* but differs in having finer transapical costae, no central nodule, and hyaline intercostal membranes noticeable even in oblique light.

Derivation of name. Dedicated to W. R. Riedel of Scripps Institution of Oceanography, La Jolla.

Holotype. Figure 6: 21 from EMD-8-15-504/505 cm., a sample from North Pacific Diatom Zone 21. California Academy of Sciences, Department of Geology no. 54420 (diatom collection).

Paratype. Figure 6: 20. California Academy of Sciences, Department of Geology no. 54421 (diatom collection).

Occurrence. Found in North Pacific sediments of Middle Miocene age.

Nitzschia rolandii Schrader.

Description. Schrader, 1973a, p. 708, pl. 5, fig. 31, pl. 26, figs. 3–5.

Nitzschia seiboldia Schrader, new species.

Description. Valves elliptical with slightly convex margins, and broadly rounded apices. 28–45 μ long, 5–6 μ wide in the middle of the valves. Transapical costae straight in transapical direction in the middle of the valve and becoming curved towards the apices, 12 in 10 μ. Intercostal membranes punctated, with two rows of fine punctae neighboured to the transapical costae. Punctae in decussate arrangement, approximately 20–25 in 10 μ. Raphe marginal, keel distinct with about 11 keel punctae in 10 μ, central nodule absent. Apices dimorph, one apex with downwards curved transapical costae, the other with curved transapical costae, apical field absent.

Discussion. This species is close to *Nitzschia* species 2 Schrader (Schrader, 1973a, p. 708, pl. 5, figs. 16–18); no other similar species has been found in the literature. Specimens from the EMD generally are broken, and some are twisted

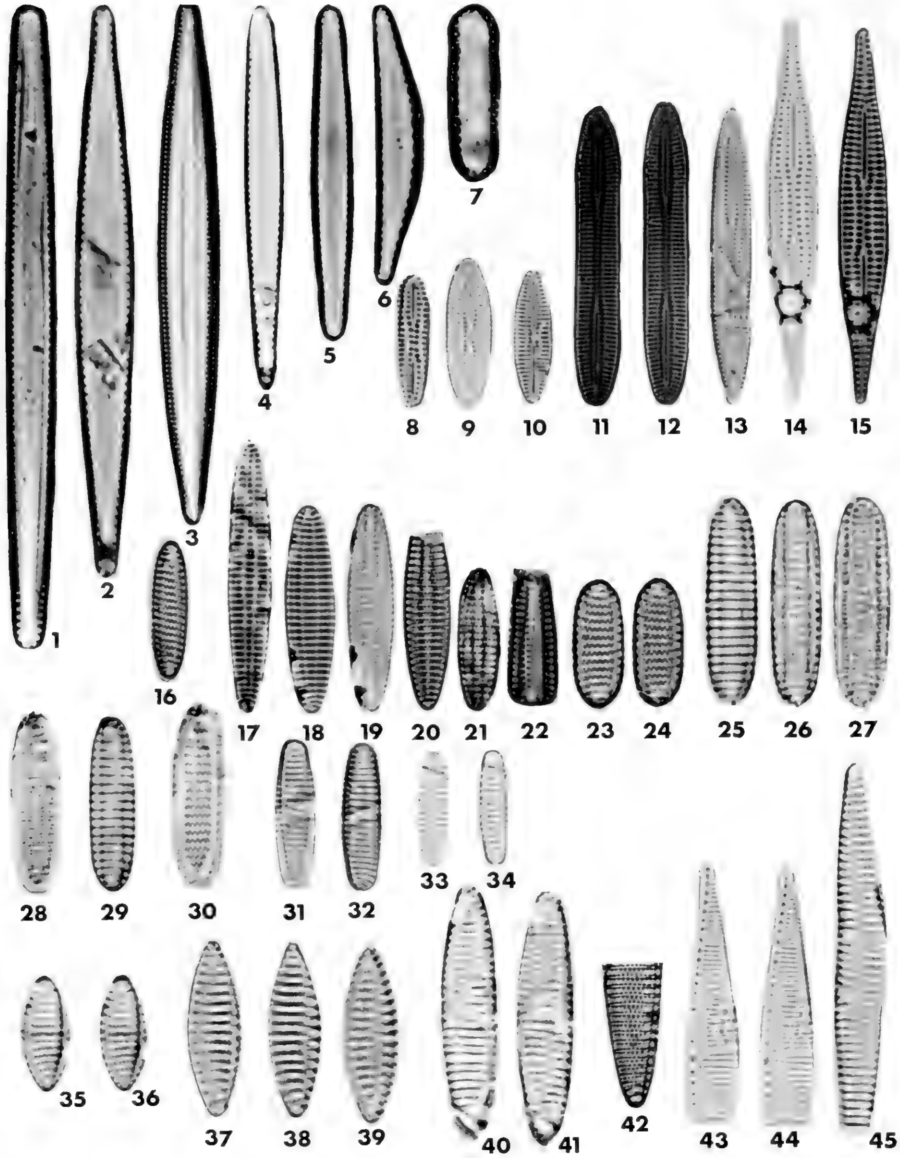

FIGURE 5. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-9-193/194 cm., *Thalassionema nitzschioides* Grunow; 2. EMD-8-9-240/241 cm., *T. nitzschioides*; 3. EMD-8-15-300/301 cm., *Synedra jouseana* Sheshukova-Poretzkaya; 4. EMD-8-15-504/505 cm., *Thalassionema nitzschioides* Grunow; 5. EMD-8-15-504/505 cm., *T. nitzschioides*; 6. EMD-8-15-504/505 cm., *T. nitzschioides*, aberrant specimens; 7. EMD-8-9-240/241 cm., *T. hirosakiensis* (Kanaya) Schrader; 8. EMD-8-15-200/201 cm., *Rouxia naviculoides* Schrader; 9. EMD-8-9-240/241 cm., *R. moholensis* Schrader, new species; 10. EMD-8-11-30/31 cm., *R.* cf. *R. naviculoides* Schrader; 11. EMD-8-9-240/241 cm.,

in apical direction (the author found numerous individuals in samples from San Felipe CAS no. 39904 (Hanna in Hertlein, 1968)).

Derivation of name. Dedicated to Prof. E. Seibold, who encouraged the author during many years with advice and help.

Holotype. Figure 5: 40–41 from EMD-8-15-300/301 cm., a sample from North Pacific Diatom Zone 21. California Academy of Sciences, Department of Geology no. 54422 (diatom collection).

Paratype. Figure 5: 45. California Academy of Sciences, Department of Geology no. 54423 (diatom collection).

Nitzschia species.

The following *Nitzschia* species are treated informally and assigned numbers, because they were found only once, or found only as fragments. The corrected taxonomic assignments will require additional or better preserved specimens.

Nitzschia species 3 Schrader.

Discussion. Valve linear-elliptical, 15 μ long, 4 μ wide. 13 transapical costae in 10 μ. This species is close to *Nitzschia porteri* Burckle non Frenguelli, but differs in the smaller size, in the heteropol apical fields, and in the finer structure of the intercostal membranes.

Figured specimen. Figure 5: 33–34.

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R. moholensis Schrader, new species (type); 12. EMD-8-9-240/241 cm., *R. moholensis*, California Academy of Sciences, Department of Geology no. 54424; 13. EMD-8-9-240/241 cm., *R.* species 1 Schrader; 14. EMD-8-9-193/194 cm., *R. californica* M. Peragallo; 15. EMD-8-9-193/194 cm., *R. californica*; 16. RC-12-65-1915/1917.5 cm., *Nitzschia porteri* Burckle non Frenguelli; 17. RC-12-65-1105/1107.5 cm., *N. miocenica* Burckle; 18. RC-12-65-1105/1107.5 cm., *N. miocenica*; 19. RC-12-65-1105/1107.5 cm., *N. miocenica*; 20. RC-12-65-1105/1107.5 cm., *N. miocenica*; 21. RC-12-65-1105/1107.5 cm., *N. miocenica*; 22. RC-12-65-1105/1107.5 cm., *N. miocenica* (girdle view); 23. EMD-8-9-193/194 cm., *N. cylindrica* Burckle; 24. EMD-8-9-193/194 cm., *N. cylindrica*; 25. EMD-8-10-100/101 cm., *N. cylindrica*; 26. EMD-8-10-100/101 cm., *N. cylindrica*; 27. EMD-8-10-100/101 cm., *Nitzschia cylindrica* Burckle; 28. EMD-8-10-100/101 cm., *N. cylindrica*; 29. EMD-8-10-100/101 cm., *N. cylindrica*; 30. EMD-8-10-100/101 cm., *N. cylindrica*; 31. EMD-8-10-44/45 cm., *N. porteri* Burckle non Frenguelli; 32. EMD-8-10-44/45 cm., *N. porteri*; 33. EMD-8-10-44/45 cm., *N.* species 3 Schrader; 34. EMD-8-10-44/45 cm., *N.* species 3; 35. EMD-8-15-100/101 cm., *N.* species 7 Schrader; 36. EMD-8-15-100/101 cm., *N.* species 7; 37. EMD-8-15-200/201 cm., *N.* species 8 Schrader; 38. EMD-8-15-200/201 cm., *N.* species 8; 39. EMD-8-15-200/201 cm., *N.* species 8; 40. EMD-8-15-300/301 cm., *N. seiboldia* Schrader, new species (type); 41. EMD-8-15-300/301 cm., *N. seiboldia* (type), California Academy of Sciences, Department of Geology no. 54422; 42. EMD-8-15-200/201 cm., *Nitzschia* cf. *N. heteropolica* Schrader; 43. EMD-8-15-504/505 cm., *N.* species 4 Schrader; 44. EMD-8-15-504/505 cm., *N.* species 4; 45. EMD-8-15-300/301 cm., *N. seiboldia* Schrader new species, California Academy of Sciences, Department of Geology no. 54423.

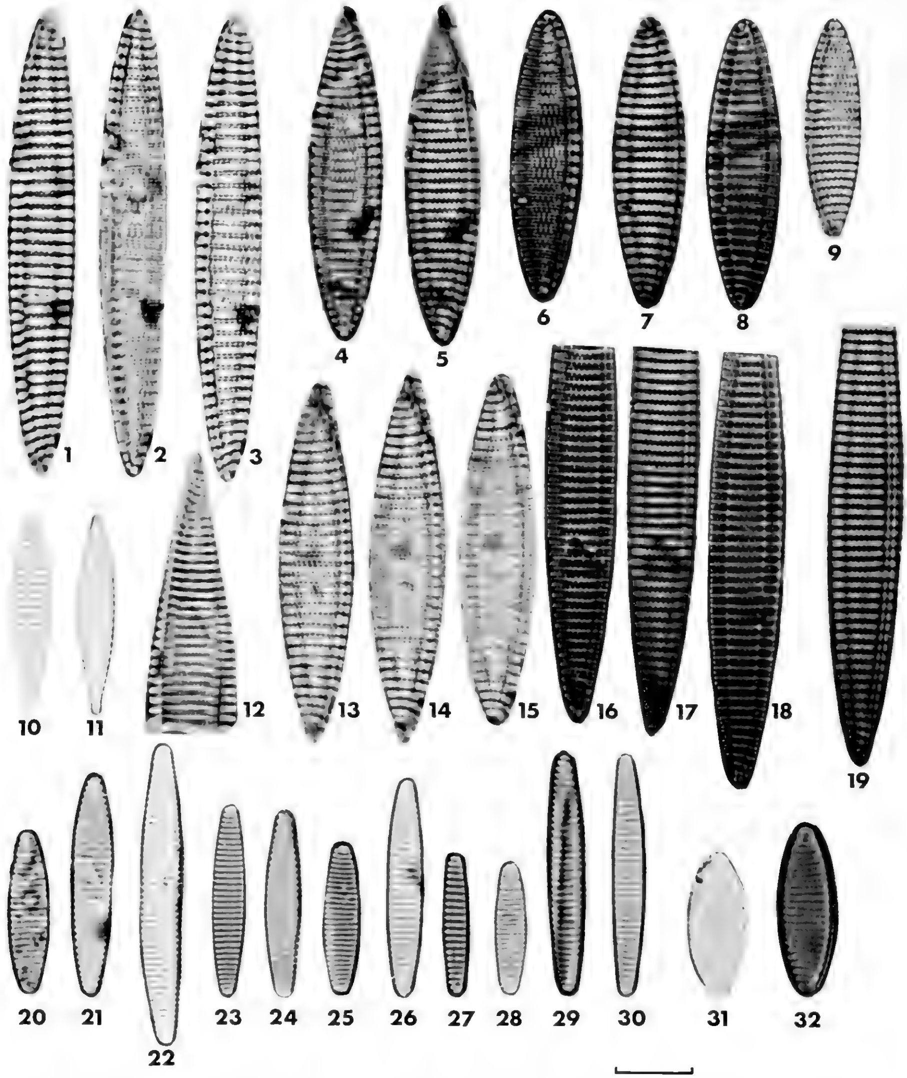

Figure 6. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-11-300/301 cm., *Nitzschia praereinholdii* Schrader; 2. EMD-8-11-300/301 cm., *N. praereinholdii*; 3. EMD-8-11-300/301 cm., *N. praereinholdii*; 4. EMD-8-11-30/31 cm., *N. praereinholdii*; 5. EMD-8-11-30/31 cm., *N. praereinholdii*; 6. EMD-8-9-193/194 cm., *N. praereinholdii*; 7. EMD-8-9-193/194 cm., *N. praereinholdii*; 8. EMD-8-9-193/194 cm., *N. praereinholdii*; 9. EMD-6-2-30/31 cm., *N. praereinholdii*; 10. EMD-8-11-300/301 cm., *N. moholensis* Schrader, new species (type); 11. EMD-8-11-300/301 cm., *N. moholensis* (type), California Academy of Sciences, Department of Geology no. 54419; 12. EMD-8-11-390/391 cm., *N.* species 5 Schrader; 13. EMD-6-2-30/31 cm., *N. praereinholdii* Schrader; 14. EMD-6-2-30/31 cm., *N. praereinholdii*; 15. EMD-6-2-30/31 cm., *N. praereinholdii*;

Nitzschia species 4 Schrader.

DISCUSSION. Only fragments have been found. They display a central nodulus, a marginal well defined keel with 9 keel punctae in 10 μ and 17 transapical costae in 10 μ. Intercostal membranes with one row of punctae. No similar species has been observed in the literature.

FIGURED SPECIMEN. Figure 5: 43–44.

Nitzschia species 5 Schrader.

DISCUSSION. Only one fragment has been found. It has 9 transapical costae in 10 μ, intercostal membranes with double rows of small punctae in decussate arrangement, rows near the transapical costae. This species is close to *Nitzschia reinholdii* Kanaya but differs from the latter in the lanceolate valve, the arrangement of keel punctae, here 9 in 10 μ, and the finer punctated intercostal membranes.

FIGURED SPECIMEN. Figure 6: 12.

Nitzschia species 6 Schrader.

DISCUSSION. Valve elliptical with convex margins, 22 μ long, 8 μ wide, with 12 transapical costae in 10 μ, slightly convex near the apices. Intercostal membranes hyaline even in oblique light, with about 14 keel punctae in 10 μ. This species is close to *Nitzschia invisa* Schrader but differs from it in the coarser arrangement of transapical costae. It is also similar to *Nitzschia porteri* Frenguelli, but owing to the fact that I have not seen a *N. porteri* from Tiltil the correct taxonomic position could not be ascertained. *Nitzschia porteri* possesses 12–13 keel punctae in 10 μ and 12–13 transapical striae in 10 μ.

FIGURED SPECIMEN. Figure 6: 32.

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16. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 17. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 18. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 19. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 20. EMD-7-1-41/42 cm., *N. riedelia* Schrader, new species, California Academy of Sciences, Department of Geology no. 54421; 21. EMD-8-15-504/505 cm., *N. riedelia* (type), California Academy of Sciences, Department of Geology no. 54420; 22. EMD-8-15-504/505 cm., *N. rolandii* Schrader; 23. EMD-8-15-200/201 cm., *N. kanayensis* Schrader, new species (type), California Academy of Sciences, Department of Geology no. 54417; 24. EMD-8-15-93/94 cm., *N. rolandii* Schrader; 25. EMD-8-11-300/301 cm., *N. kanayensis* Schrader, new species, California Academy of Sciences, Department of Geology no. 54418; 26. EMD-8-11-300/301 cm., *N. rolandii* Schrader; 27. EMD-8-10-44/45 cm., *N. rolandii*; 28. EMD-8-9-240/241 cm., *N. kanayensis* Schrader, new species, California Academy of Sciences, Department of Geology no. 54426; 29. EMD-8-9-240/241 cm., *N. burcklia* Schrader, new species (type), California Academy of Sciences, Department of Geology no. 54415; 30. EMD-8-9-240/241 cm., *N. burcklia*, California Academy of Sciences, Department of Geology no. 54416; 31. EMD-8-11-300/301 cm., *N. invisa* Schrader; 32. EMD-8-11-300/301 cm., *N.* species 6 Schrader.

Nitzschia species 7 Schrader.

Discussion. Only one fragment of this small *Nitzschia* species has been observed. It is 15 μ long, 6 μ wide, with 11–12 transapical costae in 10 μ, curved near the apices; intercostal membranes have two rows of punctae with punctae in decussate arrangement. No similar species has been observed in the literature.

Figured specimen. Figure 5: 35–36.

Nitzschia 8 Schrader.

Discussion. Only one specimen has been observed. It is 23 μ long, 7 μ wide, with 9 transapical costae in 10 μ; intercostal membranes finely punctated. Apices heteropol. Transapical costae curved near the apices. Keel distinct, with 9 keel punctae in 10 μ. No similar species has been observed in the literature.

Figured specimen. Figure 5: 37–39.

Genus **Rhaphoneis** Ehrenberg

Rhaphoneis angularis Lohmann.

Description. Lohmann, 1938, pp. 92–93, pl. 22, figs. 6–8.

Rhaphoneis angustata Pantocsek.

Description. Sheshukova-Poretzkaya, 1967, pp. 241–242, pl. 41, fig. 8, pl. 43, fig. 2.

Rhaphoneis margaritalimbata Mertz.

Description. Mertz, 1966, p. 27, pl. 6, figs. 1–3.

Rhaphoneis sacchalinensis Sheshukova-Poretzkaya.

Description. Sheshukova-Poretzkaya, 1967, p. 242, pl. 42, fig. 2.

Genus **Rhizosolenia** Ehrenberg

Rhizosolenia barboi Brun.

Description. Donahue, 1970, p. 136; Schrader, 1973a, p. 709, pl. 24, figs. 4–7.

Rhizosolenia hebetata forma **hiemalis** Gran.

Description. Hustedt, 1930, pp. 590–592, fig. 337.

Rhizosolenia miocenica Schrader.

Description. Schrader, 1973a, p. 709, pl. 10, figs. 2–6, 9–11.

Rhizosolenia praealata Schrader.

Description. Schrader, 1973a, p. 709, pl. 10, fig. 13.

Rhizosolenia praebarboi Schrader.

DESCRIPTION. Schrader, 1973a, pp. 709–710, pl. 24, figs. 1–3.

Rhizosolenia styliformis Brightwell.

DESCRIPTION. Hustedt, 1930, pp. 584–588, figs. 333–335.

Genus **Rouxia** Brun and Héribaud

Rouxia californica M. Peragallo.

DESCRIPTION. Hanna, 1930, pp. 186–188, pl. 14, figs. 6–7.

Rouxia moholensis Schrader, new species.

DESCRIPTION. Valves linear-oblong with parallel margins slightly constricted in the middle. Apices broadly rounded, 35–42 μ long, 6 μ wide in the middle. The two rudimentary raphe bars widely separated and situated near the apices. Transapical striae 18 in 10 μ, transapical in the middle of the valve, becoming radial towards the apices. Transapical striae formed by elliptical pores. No apical lines are present. Axial area narrow, central area thin-elongated. Valves isopol.

DISCUSSION. This species differs from *Rouxia diploneides* in its finer structure and lack of apical lines.

DERIVATION OF NAME. Dedicated in memory of the Experimental Mohole Drilling.

HOLOTYPE. Figure 5: 11–12 from EMD-8-9-240/241 cm., a sample from North Pacific Diatom Zone 10. California Academy of Sciences, Department of Geology no. 54424 (diatom collection).

OCCURRENCE. Found in the Neogene Section off Baja California.

Rouxia naviculoides Schrader.

(Figure 5: 8.)

DESCRIPTION. Schrader, 1973a, p. 710, pl. 3, figs. 27–32.

Rouxia cf. **R. naviculoides** Schrader.

(Figure 5: 10.)

DISCUSSION. Specimens found are tentatively placed in *R. naviculoides*, but they differ from others of that species in the butterflylike arrangement of the central area.

Rouxia species 1 Schrader.

DISCUSSION. Only one specimen of this species was found. It is close to *R. moholensis* but differs in the coarser structure, and in the presence of one apical line near the middle axis.

FIGURED SPECIMEN. Figure 5: 13.

Genus **Stephanopyxis** Ehrenberg

Stephanopyxis turris (Greville and Arnotte) Ralfs.

DESCRIPTION. Hustedt, 1930, pp. 304–307, figs. 140–144.

Genus **Synedra** Ehrenberg

Synedra jouseana Sheshukova-Poretzkaya.

DESCRIPTION. Sheshukova-Poretzkaya, 1967, p. 245; Schrader, 1973a, p. 710, pl. 23, figs. 21–23, 25, 38.

Genus **Thalassionema** Grunow

Thalassionema hirosakiensis (Kanaya) Schrader.
(Figure 5: 7.)

DESCRIPTION. Kanaya, 1959, pp. 104–106, pl. 9, figs. 11–15; Schrader, 1973a, p. 711, pl. 23, figs. 31–33.

Thalassionema claviformis Schrader.

DESCRIPTION. Schrader, 1973a, p. 711, pl. 23, figs. 11, 15.

Thalassionema nitzschioides Grunow.
(Figure 5: 1–2, 4–6.)

DESCRIPTION. Hustedt, 1959, pp. 244–246, fig. 725; Hasle, 1967, p. 111, figs. 5, 27–34, 39–44.

Genus **Thalassiosira** Cleve

Thalassiosira convexa Mukhina.
(Figure 2: 5–6.)

DESCRIPTION. Donahue, 1970, pp. 136–137, pl. 3, figs. a–f.

Thalassiosira decipiens (Grunow) Joergensen.

DESCRIPTION. Hustedt, 1930, pp. 322–323, fig. 158.

Thalassiosira excentrica (Ehrenberg) Cleve.

DESCRIPTION. Sheshukova-Poretzkaya, 1967, pp. 141–142, pl. 14, fig. 4.

Thalassiosira antiqua (Grunow) Cleve.

DESCRIPTION. Sheshukova-Poretzkaya, 1967, pp. 143–144, pl. 14, fig. 3.

Thalassiosira species A Burckle.
(Figure 2: 3–4.)

DESCRIPTION. Burckle, 1972, p. 241, pl. 1, fig. 1.

Thalassiosira nativa Sheshukova-Poretzkaya.
(Figure 2: 11–21, 25–26.)

Description. Sheshukova-Poretzkaya, 1967, p. 145, pl. 14, fig. 7.

Thalassiosira praeconvexa Burckle.
(Figure 2: 7–10.)

Description. Burckle, 1972, pp. 241–242, pl. 2, figs. 7–9.

Thalassiosira oestrupii (Ostenfeld) Proshkina-Lavrenko.
(Figure 1: 31; Figure 2: 1–2.)

Description. Hustedt, 1930, p. 318, fig. 155 as *Coscinosira oestruppii.*

Thalassiosira usatchevii Jouse.
(Figure 3: 1–2.)

Description. Sheshukova-Poretzkaya, 1967, p. 150, pl. 15, fig. 3.

Thalassiosira species 2 Schrader.

Discussion. This species is close to *Thalassiosira nativa* but differs in lacking numerous scattered strutted tubuli in the center. No other similar species were found mentioned in the literature.

Figured specimen. Figure 2: 22–24, 27–28.

Genus **Thalassiothrix** Cleve and Grunow

Thalassiothrix longissima Cleve and Grunow.

Description. Hasle, 1967, p. 114, fig. 20.

Genus **Triceratium** Ehrenberg

Triceratium antiquum Pantocsek.
(Figure 1: 28.)

Description. Pantocsek, 1886, p. 51, pl. 13, fig. 115; Azpeitia, 1911, p. 221, pl. 12, fig. 2.

Triceratium cinnamomeum Greville.
(Figure 1: 29.)

Description. Greville, 1863, p. 232, pl. 9, fig. 12.

Triceratium condecorum Brightwell.

Description. Hanna, 1932, p. 221, pl. 17, figs. 1, 3.

Summary and Conclusions

(1) The North Pacific Diatom Zonation as established from cores obtained during the DSDP leg 18, north of 35° North longitude, provided a basis

for establishing a diatom stratigraphy of core samples from the Experimental Mohole Drilling site off Guadalupe Island, Mexico.

(2) Paleoclimatic oscillations found at the EMD site are comparable to those found at DSDP leg 18, Site 173; no warm period was detected comparable to those found in Lamont Doherty Cores south of 10° longitude.

(3) North Pacific Diatom Zones 20 to 24 are correlative with the lower part of the *Corbisema triacantha* Silicoflagellate Zone and the upper part of the *Dictyocha octacantha* Silicoflagellate Zone of Martini (1972), and with NN 6 Standard Nannoplankton Zone of Martini (1971).

(4) The base of the Late Miocene as defined by Burckle (1972), as occurring within Geomagnetic Epoch 11 of the tropics, and as defined by Bolli (1957) as the *Globorotalia mayeri* Zone below the *Globorotalia menardii* Zone, is correlative with North Pacific Diatom Zone 19, and in the Experimental Mohole Drilling it is between samples EMD-8-15-100/101 cm. and EMD-8-15-200/201 cm. This boundary is correlative (chart 4) with the *Corbisema triacantha* Silicoflagellate Zone (Martini, 1972), with the NN 6 Zone of the Standard Nannoplankton Zone of Martini (1971), with the Luisian stage of California (Parker, 1964; Kanaya, 1971; Bandy and Ingle, 1970). Berggren (1972) placed the Middle to Late Miocene boundary within the upper part of the N 15 Standard Foraminiferal Zone and indicated a radiometric age of 13.5 m.y. for the Luisian-Mohnian boundary, which correlates with the Late to Middle Miocene boundary of Bandy and Ingle (1970). The different correlations are compared in charts 3 and 4.

Dymond (1966) determined a Potassium-Argon date of 12.3 ± 0.4 m.y. for a glass sample from EMD-8-15-89 cm. This date agrees with the correlation of the base of North Pacific Diatom Zone 19 with the paleomagnetic scale, and the correlation of the paleomagnetic scale with the radiometric time scale (Berggren, 1972).

(5) The Pliocene-Late Miocene boundary as defined by Burckle (1972) is at the end of Geomagnetic Epoch 5 at about 5.5 million years B.P. In the Experimental Mohole Drilling this boundary is between samples EMD-8-10-44/45 cm. and EMD-8-10-100/101 cm., and it correlates with the *Dictyocha pseudofibula* Silicoflagellate Zone of Martini (1972), with the NN 10 Standard Nannoplankton Zone of Martini (1971), and with the upper Mohnian Stage of Bandy and Ingle (1970).

(6) The sedimentation rate for the Experimental Mohole Drilling Core in the interval from 80–95 meters below the sea floor, is about 7 meters/million years; for the interval from 95 to 115 meters it is approximately 30 m./m.y., and for the interval from 115 to 135 meters below the sea floor approximately it is again 7 m./m.y. The abrupt increase of sedimentation rate

corresponds with the increase of silt sized minerals and sponge spicules. The sedimentation rate determined by correlation of North Pacific Diatom Zones to paleomagnetic stratigraphy and hence to the radiometric time scale, differs from that obtained by using Dymond's (1966) Potassium-Argon dates (charts 4, 5).

(7) Published correlations of planktonic marine diatoms (Kanaya, 1971), of planktonic foraminiferans (Parker, 1964; Bandy and Ingle, 1970) with the Californian Marine Stages contain discrepancies which could not be resolved in this paper because of a lack of stratotype diatom-bearing material from California [the North Pacific Diatom Zones have not yet been correlated to the Californian Marine Stages].

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INDEX TO VOLUME XXXIX

FOURTH SERIES

New names and principal references in **boldface** type. References to illustrations in *italics*.

ERRATA

Page 33. Line 19 from top: for "*Lissophaira*" read "*Lissosphaira*."
Page 77. Line 3 from bottom of table 1: for "*Mugil cephalis*" read "*Mugil cephalus*."
Page 263. Lines 23 and 24 should appear in reverse order.