

MORPHOLOGY AND DISTRIBUTION PATTERNS OF THE WHALEFISHES OF THE FAMILY RONDELETIIDAE *

JOHN R. PAXTON

The Australian Museum, Sydney, Australia

ABSTRACT

Midwater fishes of the family Rondeletiidæ are known from relatively few individuals taken in the Indian, Atlantic and Pacific Oceans. Two species have been described, but these have been confused in some previous works. *Rondeletia bicolor* can be distinguished from *R. loricata* by the presence of a greater number of vertical rows of lateral line pores, a bony sphenotic hook over the orbit, and the lack of expanded frontals, supratemporals and cleithra. Although other meristic characters overlap, the mean frequencies of dorsal and anal fin rays, vertebrae, and gill rakers are different in the two species.

The osteology of *R. bicolor* was described by Parr (1929). The skeleton of *R. loricata* is basically similar to that of its congener, but differences in the following elements are apparent: lateral ethmoids, frontals, sphenotics, supraoccipitals, hyomandibulars, symplectics, quadrates, epipleural rib origins, caudal skeletons, and pectoral girdles. As in *R. bicolor*, the skeleton of *R. loricata* is characterized by large amounts of cartilage.

Although the number of specimens examined was small, less than 20 of each species, certain trends in distributional patterns are indicated. The center of vertical distribution for each species is apparently below 1000 metres, although individuals of each have been taken as shallow as 350-400 metres. Due to the paucity of data, no estimation of vertical distribution is possible. The vast majority of captures have been of solitary individuals. *R. bicolor* is apparently restricted to the western North Atlantic Ocean and Caribbean Sea west of 60°W; the limited range is not characteristic of previously studied midwater fishes from the area. *R. loricata* appears to be cosmopolitan in distribution made in transitional areas near water mass boundaries. However, the Atlantic and Indian Ocean collections show no correlation with either water masses or areas of productivity. In the Indian Ocean *R. loricata* has been taken by the International Indian Ocean Expedition in both Indian Central and Indian Equatorial waters. Previous captures referable to this species include localities off the southeast coasts of both Indian and South Africa.

INTRODUCTION

THE family Rondeletiidæ is one of the lesser known fish families inhabiting the oceanic midwaters. Representatives of this family have previously been recorded from the Indian Ocean by Rofen (1959) and Grindley and Penrith (1963). The fishes are small and scaleless, with large mouths, moderate-sized eyes, reduced musculature and ossification, and an orange-brown colouration. Two species are known which have been confused in some of the previous literature.

In 1895, Goode and Bean described *Rondeletia bicolor* from the western North Atlantic as the sole representative of the family Rondeletiidæ. Parr (1928) reported on additional specimens from the Caribbean Sea and the species has since been recorded from the South Atlantic and Indian Oceans (Rofen, 1959), off South

* Presented at the 'Symposium on Indian Ocean and Adjacent Seas — Their Origin, Science and Resources' held by the Marine Biological Association of India at Cochin from January 12 to 18, 1971

Africa (Grindley and Penrith 1965), and from the Eastern Pacific Ocean (Ebeling, 1962). Abe and Hotta (1963) described *Rondeletia loricata* as the second known species of the family from the waters off Japan. They suggested that the specimens described by Rofen (1959) were representatives of *R. loricata*.

Recent collections of rondeletiids by the University of Southern California in the north and south Pacific Oceans indicated that the species from Japan is indeed widespread. The present paper characterizes the two species of *Rondeletia*, based upon an examination of 29 specimens, including both type specimens and those described by Parr (1928). Distribution patterns for both species are presented. The osteology of *R. loricata* is compared with that of *R. bicolor* as described by Parr (1929).

Thanks are offered to the following individuals who generously allowed the examination of specimens under their care: Tokiharu Abe, Tokyo University (ZITU); Ernest Lachner, U. S. National Museum (USNM); Robert Lavenberg, Los Angeles County Museum of Natural History (LACM); Giles Mead and Myvanwy Dick, Harvard University (MCZ); C. Richard Robins and Thomas Devany, Institute of Marine Science, University of Miami (UMML); Richard Rosenblatt, Scripps Institution of Oceanography (SIO); Keith Thomson, Yale University (BOC); and Loren Woods, Chicago Field Museum of Natural History (FMNH). Indian Ocean collections from the *Anton Brunn* were kindly made available by Mead and Daniel Cohen, U. S. Bureau of Commercial Fisheries, Washington, D.C. Michael Penrith of the South African Museum provided information on the South African specimen. Collections of specimens by the University of Southern California were supported by National Science Foundation grants. Virginia Moore and Charles Turner aided with the figures.

MATERIALS AND METHODS

The list of specimens examined includes the following information where available: institution and registration number, ship and station number, latitude and longitude, greatest trawling depth, type of trawl, time of and date of capture, and standard length of specimen in millimeters.

Rondeletia bicolor—USNM 38202 (holotype), *Albatross* 2724, 36°47'N, 73°25'W, 3000 m, large beam trawl, 23 Oct. 1886, (97); BOC 2104, *Pawnee* 11, 23°58'N, 77°26'W, 1400m, 14' ring net, 2 March 1927, (22.5); BOC 2105, *Pawnee* 41, 22°31'N, 74°26'W, 2000m, 14' ring net, 30 March 1927, (20.5, one of two specimens seen); BOC 2106, *Pawnee* 9, 23°55'N, 77°09'W, 1400 m, 14' ring net, 1 March 1927, (26); BOC 2107, *Pawnee* 48, 21°44'N, 72°43', 1400 m, 14' ring net, 6 April 1927, (19); BOC 2108, *Pawnee* 56, 21°20'N, 71°13'W, 1300m, 14' ring net, 13 April 1927, (24-41.5, four or five specimens seen); BOC 2109 *Pawnee* 31, 24°29'N, 75°53'W, 1400 m 14' ring net, 21 March 1927 (19.5); BOC 2110, *Pawnee* 39, 22°43'N, 74°23'W, 1600 m, 14' ring net, 29 March 1927, (22.5, one of two specimens seen); MCZ 35166, *Blake* XX, 16°42'N, 83°01'W, 1675m, bottom trawl, Feb.-May 1880, (51.5); FMNH 66135, *Silver Bay* 3732, 29°58'N, 80°09'W, 350 m, 70' flat trawl, 4 Feb. 1962, (57); UMML 15974; *Toto* 9-4(23°57'-55'N, 77°10'-09'W, 637 m, 1 m plankton net, 22 June 1952, (59.5).

Rondeletia loricata —ZITU 52196 (holotype), Fish Trawler, approx. 38°45'N, 142°15 E, 750m, two boat trawl, Oct. 1962, (102); LACM 9571-5, *Velero IV* 10975, 33°03'-32° 40'N, 120°56'-35'W, 1300m, 10' IKMT, 1730-0122 hrs., 16-17 Feb. 1966, (83)

LACM 7254-33, *Velero IV* 11243, 32°28'-31° 58'N, 120°47'-36'W, 400 m, 10' IKMT, 1710-1901 hrs., 18 Oct. 1966 (94); LACM 10970-1, *Eltanin* 1401, 41°15'-30'S, 179°31'-29°W, 2350 m, 10' IKMT, 0500-0912 hrs., 30 Nov. 1964, (110); LACM 11271-1, *Eltanin* 1761, 40°32'-30'S, 135°29'-37'W, 1350 m, 10' IKMT, 1119-1503 hrs., 7 Aug. 1966, (46.5); SIO H52-404(*Horizon* trawl 13, 1°43'-49'S, 89°52'-90°00'W, 1025 m, 10' IKMT, 1944-0144 hrs., 8-9 Aug. 1952((64.5); SIO H53-356, *Spencer F. Baird*, MWT 8, 35°02'-34°48'N, 145°12'-05'E, 1850 m, 10' IKMT, 1408-2045 hrs., 1 Oct. 1953, (82.5); SIO 56-128, *Horizon*, 11°N, 167°E, 1300 m, 10' IMMT, 1415-2400 hrs., 3 May 1956, (98); SIO 63-560, *Argo* 79, 0°56'-1°25'N, 11°29'-43'W, 2300 m, 10' IKMT, 0250-0745 hrs., 6 July 1963, (89); SIO 66-42, *Alexander Agassiz* MU 66-I-37, 31°05'-24'N, 117-19'-42'W, 1150 m, 2048-0554 hrs., 7-8 April 1966, (92); MCZ 41341, *Atlantis* 1030, 37°47'N, 31°41'W, 800 m, 15' net 2200-1100 hrs., 4-5 Aug. 1931, (42.5); MCZ 41344, *Atlantis* 1043, 37°10'N, 56°30'W, 2000 m, 15' net, 1500-1700 hrs., 17-18 Aug. 1931, (33); MCZ 43336, *Anton Bruun* 6-338B, 2°20'S, 64°54'E, 1650 m, 10' IKMT, 0220-0910 hrs., 29 May 1964, (22.5); MCZ 43330, *Anton Bruun* 6-351D, 31°45'S, 65°08'E, 1786 m, 10' IKMT, 0359-1507 hrs., 29 June 1964, (67); USNM 200524, *Anton Bruun* 3-18, 28°54' S, 60°01'E, 1222 m, 10' IKMT, 2155-0240 hrs., 6-7 Sept. 1963, (70).

In addition, M. J. Penrith (pers. com.) has kindly re-examined the whalefish reported as *R. bicolor* from South Africa (Grindley and Penrith, 1965) and confirmed that it is *R. loricata*. The collection data are Sta. 40, 38°50'S, 33°08'E, 500 m, 10' IKMT, 2230-0050 hrs., 13-14 Nov., 1962, (63). The following two specimens were not seen, but identified by R. Rosenblatt (pers. com.) as *R. loricata*: SIO 63-551, *Argo* 52, 19°13'18°58'S, 13°44'-36'W, 2000 m, 10' IKMT, 2100-0145 hrs. 24-25 June 1963; SIO 63-552, *Argo* 55, 18°58'-30'S, 10°15'W, 2000 m, 10' IKMT, 2137-0240 hrs., 25-26 June 1963.

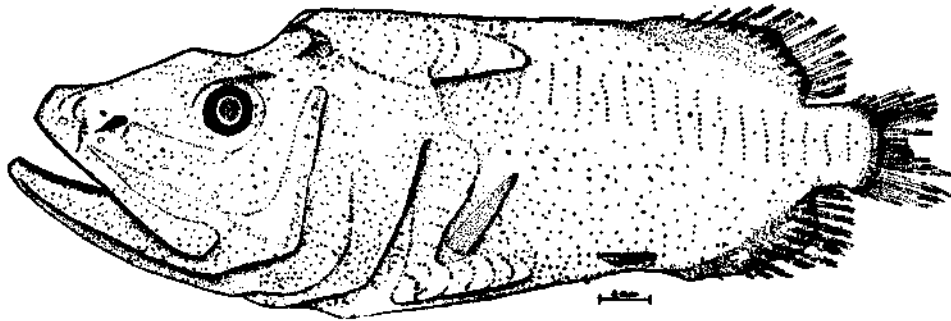


Fig. 1. *Rondelettia loricata*, 83 mm SL, LACM 9571-5.

EXTERNAL CHARACTERISTICS

Rondelettia loricata has been described by Abe and Hotta (1963), but the lateral line system was not described in detail. The lateral line consists of a number of pores arranged in a series of vertical lines on the side of the body between the upper edge of the operculum and the base of the caudal (Fig. 1). The number of pores per vertical row varies from five to seven in the shortest, the anterior-most and posterior-most, rows, and 10 to 16 pores in the longest rows underneath the anterior third of the dorsal fin. One single pore is usually present in each space between the posterior-most rows, and 10 to 16 pores in the longest rows underneath the anterior vertical rows, about in the midline of the body. *R. loricata* has from 14 to 19

vertical rows of lateral line pores. A series of vertical pores is also present in *R. bicolor*, in which the number of vertical rows ranges from 24 to 26. The number of pores in the longest row of *R. bicolor* ranges from 13 to 16. In both species two parallel rows of pores are present on the dorsal profile anterior to the dorsal fin origin; the number of pores per predorsal row ranges from 10 to 16 in *R. bicolor* and 8 to 14 in *R. loricata*. Pores are also scattered on the head and caudal fin of each species. The range of meristics for the two species overlaps in all other characters, although the most frequent values differ in most cases (Table 1).

TABLE-1 Variation in meristic characters for *Rondeletia bicolor* and *R. Loricata*

	D	A	P	V	Vert.	GR	Rows of LL pores
<i>R. bicolor</i>							
Min.	14	13	9	5	26?	6+1+15	24
Min.	15	15	15	6	27	7+1+18	26
Mast. freq.	15	14	10	6	27*	6+1+16+17	24
<i>R. Loricata</i>							
Min.	13	13	9	5	24	4+1+13	14
Max.	16	14	11	5	26	6+1+15	
Mast freq.	14	13	10	5	25	5+1+13-14	

*Only four specimens x-rayed.

The delineation of morphometric differences between the two species is made difficult by two factors. The soft tissue of the body limits the accuracy of any measurement to about one mm; for the small, 20 mm specimens, such inaccuracy in any measurement results in a 5% error when compared with SL. In addition certain features show allometric growth. The length of the premaxillary increases in relation to SL with growth (Fig. 2), while the relative depth of the caudal peduncle appears to decrease with growth (Fig. 3). The only measurement, taken as percent of SL,

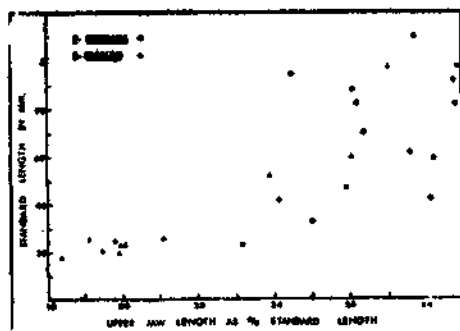


Fig. 2. Variation in upper jaw length with growth for *Rondeletia bicolor* and *R. loricata*.

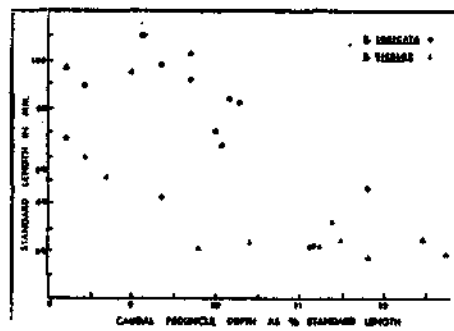


Fig. 3. Variation in caudal peduncle depth with growth for *Rondeletia bicolor* and *R. loricata*.

that did not overlap in the examined sample were snout to ventral origin, *R. bicolor* 51.3-63.1 (ave. 57.6), *R. loricata* 63.3-71.1 (ave 67.4), and snout to anal origin, *R. bicolor* 65.9-74.8 (ave. 70.2), *R. loricata* 77.0-82.4 (ave. 79.0) Abe and Hotta (1963) have pointed out that the length of the jaws and the eye diameter are apparently different in the two species. The data presented (Fig. 2) suggest that premaxillary length cannot be used as a definitive character. The diameter of the eye is also variable, in large part due to the nature and condition of the specimens.

The striking modifications of the skull bones above the orbit are more distinctive characters for the differentiation of the two species. In *R. bicolor* the frontals are relatively slender bones that do not project over the orbit. However, the sphenotics have definite hook-like projections over the posterior portion of the orbit that usually break through the skin. In *R. loricata* the sphenotics lack hooks, but the frontals are large bones which slightly overhang the orbits. The final differences that can be noticed in preserved specimens of the two species are in the pectoral girdle. But the supratemporal and cleithrum of *R. loricata* have large, rounded posterior extensions that the corresponding bones of *R. bicolor* lack (Fig. 5.)

Diagnostic characters of the two species are summarized in the following key :

- 1A. Vertical rows of lateral line pores 24-26; snout -ventral 51.3-63.1% SL; snout-anal 65.8-74.8% SL; bony hook over orbit; no large posterior extensions of supratemporal or cleithrum..... *Rondeletia bicolor* Goode and Bean
- 1B. Vertical rows of lateral line pores 14-19; snout -ventral 63.3-71.1% SL; snout-anal 77.0-81.4% SL; no bony hook over orbit; supratemporal and cleithrum with large posterior extensions..... *Rondeletia loricata* Abe and Hotta

OSTEOLOGY

To facilitate future work on familial affinities, the osteology of *R. loricata*, based upon one 94 mm cleared and stained specimen (LACM 9254-33), is compared with the osteology of *R. bicolor* as described by Parr (1929). The staining technique follows that of Taylor (1967), and the method of dissection is described by Paxton (1971).

The skeleton is poorly ossified and considerable amounts of cartilage are present, particularly in the skull. The ossification of the dermal bones results in a coarsely spongy structure, while the replacement bones of the skull consist of extremely thin laminae of bone overlying cartilage.

Cranium : The large, unossified rostral cartilage lies between the anterior heads of the premaxillae. The ethmoid cartilage is massive, overlying the vomer and parasphenoid almost to the level of the basisphenoid. This main bar of cartilage is somewhat compressed with lateral expansions just above the vomer. Also anteriorly the cartilage extends dorsally in the midline to the nasals, where slight lateral expansions are present. Arising from this region paired cartilagenous bars extend posterolaterally just under the frontals to the level of the pterosphenoids. The ossifications overlying the ethmoid cartilage are complex and distinct bones cannot be distinguished with certainty. The mesethmoid is a complex ossification which covers much of the anterior region of the ethmoid cartilage and is most strongly ossified directly under the nasal. Separate osseous laminae appear to cover the anterior regions of the dorsal cartilagenous bars under the frontals. No ossifications or cartilagenous masses resembling in form or position the lateral ethmoids of *R. bicolor* are present in *R. loricata*. Cartilagenous rods covered by thin ossifications, apparently representing the lateral ethmoids, arise at the anterodorsal corner of the second circumorbital, where they are firmly attached by ligaments, and run posteriorly

to the anterior border of the orbit. Here the rods narrow and turn dorso-medially for a short distance before curving anteriorly and terminating in the connective tissue anterior to the orbit. The presumed lateral ethmoids lie in the dense connective tissue between the anterior circumorbitals, the orbit and the palate, and are not attached in any way to the main ethmoid cartilage.

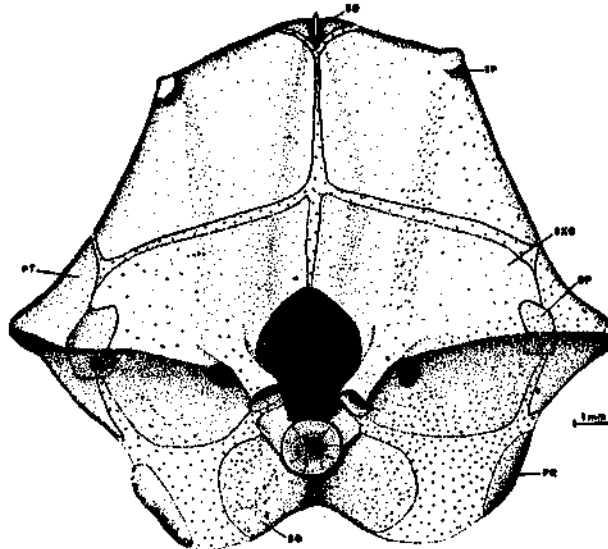


Fig. 4. Occipital region of neurocranium of *Rondeletia loricata*. BO — basioccipital; EP — epiotic; EXO — exoccipital; OP — opisthotic; PR — pootic; SO — supraoccipital.

The frontals are of spongy consistency, without a median crest and slightly separated in the midline; the orbital borders are greatly expanded and appear to be fused supraorbitals. A tiny, incomplete strip of bone arising from the posterior region of the supraorbital expansion presumably covers a portion of the latero-sensory canal; just anterior to this region a foramen pierces the frontal. The sphenotics have a slight ventrolateral projection at the dorsoposterior corner of the orbit, but no orbital hook as in *R. bicolor*. The parietals are small and lateral to the anterior portion of the supraoccipital, as in *R. bicolor*. The supraoccipital does not have as large a median crest as that of *R. bicolor*, nor does it extend as far posteroventrally. The epiotics are somewhat pyramidal in shape as in *R. bicolor*, but are larger and meet in the midline ventral to the supraoccipital (Fig. 4).

The exoccipitals are separated ventrally by the foramen magnum; each exoccipital bears a condyle at the ventrolateral corner of the foramen magnum. The condyles articulate with the two dorsolateral processes of the first vertebra. The posterior face of the cranium is almost vertical and formed by the epiotics and exoccipitals; the trapezius (protractor capulae) originates in this area, but no posttemporal fossae are present. The basioccipital is as in *R. bicolor*, with a single condyle for articulation with the centrum of the first vertebra. The opisthotics are small, but relatively well ossified. The pterotics (squamosals of Parr) are as in *R. bicolor* and have a lateral shelf for articulation with the hyomandibulars. The prootics are similar to those of *R. bicolor* and form most of the auditory bulla encapsulating the otoliths. The two large foramina for branches of the fifth and seventh cranial nerves are separated by a thin strip of bone laterally; three smaller foramina are

present medially between and above the larger openings. A separate, anterior foramen for the oculomotor nerve is not present and is presumably incorporated in the larger anterior foramen. An exit for the palatine nerve was not found in the prootic and is probably present in the space between the prootic and parasphenoid or basisphenoid.

The basisphenoid has paired lateral laminae, triangular in shape, that extend from the parasphenoid to the anterior portion of the prootic. In *R. loricata*, no large space exists between the lateral extensions of the basisphenoid and the parasphenoid. The pterosphenoids (alisphenoids of Parr) extend dorsally and anteriorly from the basisphenoid and prootics to the sphenotics and frontals; the bony canal and foramen described by Parr are present in *R. loricata*, as is a small orbital projection from the anteroventral margin. The pterosphenoids appear to be trough-shaped ossifications surrounding a core of cartilage which is roofed by the frontal. The bony canal mentioned above crosses through the trough of cartilage. Anteriorly the trough widens and the inner layer of bone curves medially. No orbitosphenoid is present. The parasphenoid, a long slender bone underlying the main ethmoidal cartilage anteriorly, sends small, lateral processes to the anterior border of the prootics about the middle of its length and extends posteriorly under the basisphenoid. The first pharyngobranchials are suspended from the parasphenoid at the bases of the processes to the prootics, just ventral to the basisphenoid. The vomer is shaped like that of *R. bicolor*, edentate, and plastered to the ventral side of the ethmoid cartilage.

The nasals are situated as in *R. bicolor*, and partially fused to the anterior borders of the frontals. No antorbitals are present. Five thin and poorly ossified circumorbitals are present that lack of subocular shelf. They are arranged essentially as in *R. bicolor*, but the first becomes more narrow anteriorly.

Mandibular Arch. The upper jaw consists of three bones, maxillary, premaxillary and supramaxillary. The supramaxillary is slender and narrow anteriorly as in *R. bicolor*. The maxillary is widest posteriorly, without any ridges for support of the premaxillary or supramaxillary; the maxillary has a small dorsal process and strong anteroventral process articulating with the premaxillary. Just behind these processes, a short ligament runs to the lateral ethmoid and the palatine articulates with the maxillary. The premaxillary has two anterior processes, but no well developed distal premaxillary process (Greenwood *et al.*, 1966:366), although a narrow shelf extends dorsally above the dentigerous portion. No palatomaxillary ligament is present. The premaxillary narrows considerably posteriorly, not reaching the posterior margin of the maxillary. The premaxillary teeth are villiform, in a band which narrows posteriorly, with the teeth slightly decreasing in size posteriorly.

The lower jaw consists of four bones, the angular, articular, coronomeckelian and dentary. The angular is a small ossification fused to the posterolateral tip of the lower jaw, to which the interopercular ligament joins. The coronomeckelian (unreported in *R. bicolor*) is small, but distinct, approximately thumb tack-shaped and lying on the medial side of the articular slightly behind the posterior margin of the dentary; a muscle or ligament is attached here. The articular is complexly shaped at the posterior end of the jaw with a strong process projecting posteriorly from the middle of the posterior border, for articulation with the quadrate and preopercle. The articular is narrow anteriorly, slightly overlapping the dentary medially. The dentary is the only toothed bone of the lower jaw; the band of villiform teeth

resembles that of *Cetomimus* (Harry, 1952) and narrows posteriorly. The anterolateral tube of the mandibular canal is only a thin strap of bone behind the anterior tip of the dentary; a slight ventral process is present at the anterior tip.

Palatine arch: The ventral tips of the quadrate and preopercle are fused to form a complex articulation with the lower jaw. Although lines of fusion between the preopercle and quadrate are not clear, the preopercle is involved in the articulation of the lower jaw. The quadrate has a thin posterior shelf overlying the ventral half of the symplectic laterally.

The symplectic does not taper to the ventral tip of the quadrate but ends abruptly, with cartilage between the ventral portion of the symplectic and quadrate-preopercular fusion. The symplectic is longer than in *R. bicolor*, projecting dorsally above the quadrate; a distinct bend is present in the middle of the bone, below which it narrows considerably.

The quadrate is triangular in shape with a ventral apex and articular head facing slightly anterior, not directly anterior as in *R. bicolor*. The quadrate-ectopterygoid-palatine relationship is the same as in *R. bicolor*. The metapterygoid is weakly ossified anteriorly and posteriorly articulates in two areas with the hyomandibular at the ventral tip of the hyomandibula and lateral to the orbital plate of the hyomandibula just below the junction of the dorsal and opercular heads. Ventrally the metapterygoid ends just above the dorsal edge of the quadrate, as in *R. bicolor*; the anteroventral portion of the metapterygoid is very weakly ossified. The mesopterygoid (entopterygoid of Parr) is a small, weakly ossified bone immediately anterior to the metapterygoid, with fingerlike anterior projections, as figured for *R. bicolor* (Parr, 1929; Fig. 16). The ectopterygoid is as in *R. bicolor*, thin and curved. The palatine is short, posteriorly overlapping part of the ectopterygoid; two anterior facets—a well developed lateral head and a thin shelf as a ventromedial head—articulate with the maxillary; the postpalatine process behind these heads is weakly ossified. Neither palatines nor pterygoids are dentigerous.

All the opercular bones are thin and poorly ossified. The opercle, subopercle, and preopercle are as figured for *R. bicolor*, but the preopercle completely overlies the hyomandibula. The interopercle is long and narrow with a ligament from its anterior end to the angular.

The hyomandibula is covered by the preopercle; the dorsal head is single and wide, and the opercular head is twice as long as that figured for *R. bicolor*. The main shaft of the hyomandibula is without facets or ridges and the foramen for the hyomandibular nerve is present at the junction of the dorsal and opercular heads. The orbital shelf of the hyomandibula is moderate and medial to the metapterygoid. The interhyal articulates at the cartilagenous juncture of the hyomandibula and symplectic.

Hyoid and Branchial Arches: The ceratohyal possesses a well defined foramen. The anterior eight branchiostegal rays articulate on the hyoid arch, four internally and the posterior four on the external face of the arch (McAllister, 1967: 98). A distinct suture line is evident through the longitudinal axis of the hypohyal. The basihyal is completely cartilagenous. The urohyal is a thin plate under the basi-branchials and connected to the hypohyals by strong ligaments.

Elements of five branchial arches are present. No dentigerous plates overlie the basobranchial (copula) region. A weak suture line is widest between the first

two basibranchials. The fourth basibranchial is cartilagenous and the fifth apparently absent. The first three arches all contain hypo-, cerato-, epi-, and pharyngobranchial elements. The fourth arch lacks an ossified hypobranchia, while the fifth is represented only by a ceratobranchial. Long, slender gill rakers are present on the hypo-, cerato-, and epibranchials of the first three arches, and only on the latter two elements of the fourth arch. The gill rakers decrease in size on each succeeding arch, and decrease in number on the third and fourth arches. A few small patches of teeth are on the medial faces of ceratobranchials two, three and four and on the lateral face of the fifth. Membranes connect the epibranchials of arches three and four, while the posterior end of the fifth ceratobranchial is closely bound to that of the fourth by connective tissue, so the gill openings behind arches three and four are restricted to the ventral halves of the arches. The first epibranchial has a dorso-medial head articulating with the second pharyngobranchial, while the second epibranchial has an articulating head with the third. Epibranchials three and four articulate with each other through heads. Pharyngobranchial one is long and slender and articulates with the prootic. The second pharyngobranchial is much like the first, but with a dorsolateral facet. The third pharyngobranchial is a wide ossification with small median facet. Most of the oral surface is overlain by a large patch of small conical teeth. The fourth pharyngobranchial is represented by a small cartilage between the heads of the third and fourth epibranchial and the third pharyngobranchial. A small patch of conical teeth overlies the area.

Postcranial Axial Skeleton: Ten precaudal and 16 caudal vertebrae are present in the cleared and stained specimen: x-rays of 14 other specimens yielded a range of total vertebrae from 24 to 26, although the first full haemal spine could not be seen clearly and therefore the differentiation of precaudal and caudal could not be determined. All the vertebral centra are fused to the neural arches, which bear spines. The prezygapophyses of vertebrae two through 18 extend anteriorly over the centra of the preceding vertebrae. The first vertebra lacks prezygapophyses or they have become incorporated with the dorsolateral facets for cranial articulation. The prezygapophyses of vertebrae 19 to 25 are weakly developed and do not extend anterior to the centra of their vertebrae. Presumably all but the preural vertebra in *R. bicolor* have anterior extensions (Parr, 1929:Fig. 18). A large single foramen pierces the base of each side of the neural arches of the fifth through twenty-second vertebrae; the foramen is absent or obscure in vertebrae one to four and 23-26. Bilateral, ventral parapophyses are present on all centra behind the third. The third centrum has a parapophysis on one side only. Epipleurals are present on the first through the ninth vertebrae; anteriorly they arise at the base of the neural arch, but move ventrally on more posterior vertebrae. The last epipleural originates at the base of the parapophysis of the ninth vertebrae. The epipleurals never originate at the tips of the parapophyses, in contrast to *R. bicolor* (Parr, 1929:43). Pleural ribs are present only on the precaudal vertebrae which bear parapophyses, beginning on the third vertebra on one side and the fourth on the other, all originating at the tips of the parapophyses.

The first vertebra is shorter than all the following, with greatly expanded anterior dorsolateral facets for articulation with the condyles of the exoccipitals; these facets are slightly smaller than the median anterior face of the first vertebra which articulates with basioccipital.

Seven supraneural ossifications are in the median dorsal plane between the supratemporal and dorsal fin. The first two supraneurals are thin rods which extend from the dorsal midline to just below the tips of the neural spines anterior to those of the first and third vertebrae. The third supraneural is a very small rod immediately

behind the dorsal quarter of the third supraneural and directed diagonally posterior. The fourth and fifth supraneurals are like the first two, thin rods extending between the neural spines of the fourth and fifth and fifth and sixth vertebrae respectively. The sixth element is about a third the length of the fifth, originates immediately behind it and extends slightly posteriorly. The seventh supraneural is about half the length of the longest supraneurals and does not reach the neural spines; it lies between vertebrae seven and eight.

The caudal skeleton of *R. loricata* displays a number of differences with that of *R. bicolor* figured by Parr. In *R. loricata* both the second and third preterminal vertebrae have secondary ossifications widening the neural and haemal spines and the first preterminal vertebra lacks a neural spine, but the neural arch has an expanded crest over which the base of the first epural lies. The anterior portion of the first uroneural extends forward between the base of the first epural and the neural arch of the preterminal vertebra. Three dorsal hypurals articulate with the urostyle and second centrum of the terminal vertebra; the second ventral hypural is not split. In *R. bicolor*, *R. loricata* possesses three equals, two uroneurals, three ventral hypurals and two unfused centra in the terminal vertebra. There are 19 segmented principal, caudal rays, 17 of which are branched. The procurvent rays include two segmented and three unsegmented uppers plus one segmented and four unsegmented lowers. The anteriormost procurvent rays are supported by the expanded neural and haemal spines of the second preterminal vertebra.

The dorsal and anal fin rays are supported by only two radials. The distal radial is largely cartilagenous and extends between the bases of the supported ray. Two small ossifications are present on each distal radial where it articulates at the base of each half ray. The distal ends of the proximal radials are expanded into large, completely cartilagenous heads that articulate with the cartilagenous portions of two distal radials, one immediately opposite and one just posterior to the proximal radial. The large cartilagenous portion of the proximal radial may represent a fused medial radial. While there are 14 dorsal and 13 anal rays (the last of each is split to the base and counted as one), only 13 and 12 series of radials are present respectively for each fin. The last proximal radial of each fin supports the distal radial of both the penultimate and last (double) ray.

Although the first ray of both dorsal and anal fins shows no sign of segmentation, it is a bilateral structure throughout its length. The second ray of each is segmented for the distal fourth of its length and all the following rays are both segmented and branched at their tips.

Pectoral Girdle : Dermal bones of the pectoral girdle are massive when compared to those of *R. bicolor* (Figs. 5 and 6; Parr, 1929:Fig. 17). The post-temporal has a large posterior extension and a weakly developed anterior fork for the post-cranial articulation. A single, thin, horseshoe-shaped extrascapular was found on only one side of the specimen (this small element may have been lost from the other side during preparation).

The supracleithrum is short and wide, without ridges. The cleithrum is large and complex, with a posterior wing off the main ossified rod running dorso-ventrally and a large ventral expansion posteriorly. The anterior portions of both the scapula and coracoid articulate with a medial shelf of the cleithrum. The single postcleithrum has the same shape as that of *R. bicolor*, but both dorsal and ventral extension are bound to the medial sides of the posterior expansions of the cleithrum.

The posterior extension of the posttemporal and the posteroventral extension of the cleithrum both possess what appear to be growth rings. If these rings are annual, the specimen may be between three and five years old.

Both the scapula and coracoid are similar to those figures for *R. bicolor*, with a posterodorsal scapular peg for articulation with the first pectoral ray, a scapular foramen and coracocleithral fenestra. No mesacoracoid is present. Of the four distal radials, the posterior two are thin and poorly ossified. No calcified proximal radials were found. The basal portion of the first pectoral ray is complex; all the pectoral rays are segmented with rays three through eight branched at the tips.

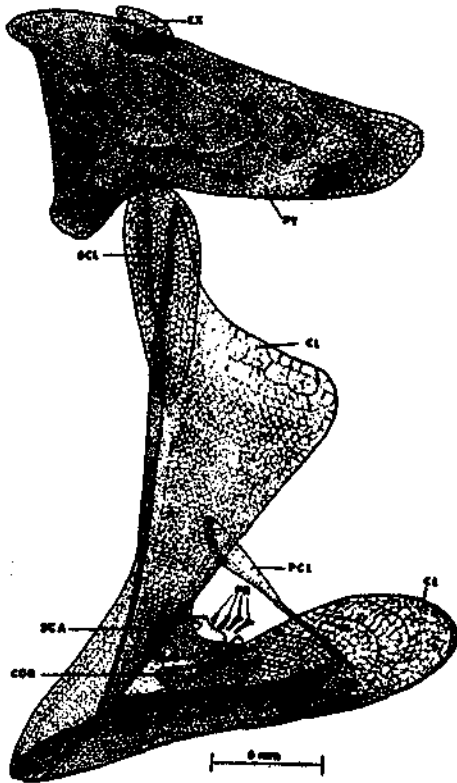


Fig. 5. Left pectoral girdle of *Rondeletia loricata*, lateral view. CL—cleithrum; COR—coracoid; EX—extrascapular; PCL—postcleithrum; PR—proximal radials; PT—posttemporal; SCA—scapula; SCL—supracleithrum.

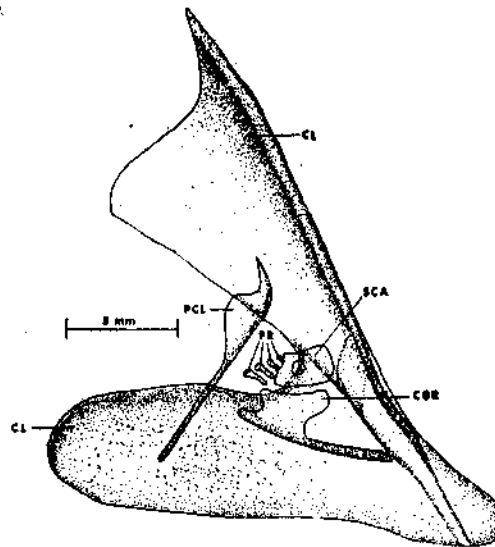


Fig. 6. Left pectoral girdle of *Rondeletia loricata*, medial view. Abbreviations as in Fig. 5.

Pelvic Girdle; The pelvic girdle is much like that figured for *R. bicolor* by Parr, except the anterior limbs are wider and the posterior region of articulation consists of large, bilateral, cartilagenous heads. There is no indication of free radials, either calcified or cartilagenous, although they may be fused to the cartilagenous heads of the girdle itself.

No free pelvic splint is present (Gosline, 1961: 18), but a small enlargement on the outer side of the base of the first pelvic ray may represent a fused splint. The base of the fifth ray is not enlarged and does not support the third or fourth ray. All five rays are segmented and branched at the tips.

A discussion of the familial affinities of the Rondeletiidae will be included in an osteological analysis of the family Barbourisiidae currently under study.

DISTRIBUTION

Horizontal: *Rondeletia bicolor* has been recorded from the western North Atlantic Ocean and the Caribbean Sea by Goode and Bean (1895), Parr (1928) and Harry (1952). This species has also been reported from the eastern North Pacific (Ebeling, 1962), southern Indian Ocean (Grindley and Penrith, 1965) and the eastern South Atlantic and northern Indian Oceans (Rofen, 1959). Abe and Hotta (1963) pointed out that Rofen's specimens were probably *R. loricata*. The fish figured by Rofen (1959: Fig. 4) lacks orbital hooks and has 17 rows of lateral line pores, both diagnostic characters for *R. loricata*. The captures of other specimens of the species from proximate areas to those reported by Rofen (Fig. 7) also suggest that the assumption of Abe and Hotta is well founded.

Penrith (pers. com.) has confirmed that the South African specimen of *Rondeletia* reported by Grindley and Penrith (1965) is also *R. loricata*. The eastern North Pacific records of *R. bicolor* were based on specimens in the S.I.O. collections (Ebeling 1962:138); a re-examination indicates that all of these fish are *R. loricata*.

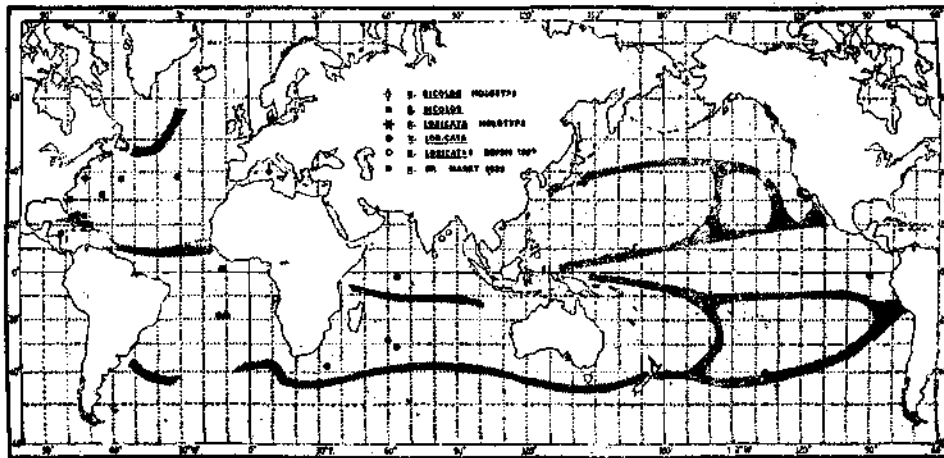


Fig. 7. Distribution of *Rondeletia bicolor* and *R. loricata* plotted against water mass distributions from Ebeling (1962). The specimens reported by Harry (1952) and Rofen (1959) were not examined.

Neither the description nor figure of the Bermuda specimens recorded by Harry (1952:69, Pl. 1) allows a determination of which of the two species is involved. On the basis of other captures, the Bermuda specimens are most likely *R. bicolor*, but *R. loricata* has also been taken in the North Atlantic.

The distribution of *R. bicolor* therefore appears restricted to the western North Atlantic and Caribbean Sea, west of 60°W (Fig. 7). The capture of all of the small specimens (under 45 mm SL) in the Bahamas area suggests this may be the breeding or nursery ground for *R. bicolor*.

The restricted distribution of *R. bicolor* is not typical of other midwater fishes studied from the North Atlantic (Ebeling, 1962; Nafpaktitis, 1968; Backus *et al.*, 1970), although the distributional pattern may be an artifact due to insufficient sample size. Backus *et al.* (1970) recognize 10 pelagic regions in the western and equatorial North Atlantic, based upon the distribution of mesopelagic fishes and physical parameters. The distribution of *R. bicolor* includes most of the Caribbean Sea region and only the western portions of both the Northern and Southern Sargasso Sea regions. All of the 17 species of *Diaphus* mapped as occurring in the North Atlantic west of 69°W also occurred east of 40°W, and most were spread east of 20°W (Nafpaktitis, 1968). The four species of *Melamphaes* that occur in the western North Atlantic are all similarly spread to at least east of 30°E (Ebeling, 1962).

Although all of these fishes have centers of distribution above 1000 m, in contrast to *R. bicolor*, Sverdrup *et al.* (1942) have suggested the influence of the North Equatorial Current may be greater than 3000 m. A more extensive distribution of this bathypelagic species would be expected, unless the Caribbean is the only area with environmental factors able to support a reproductive population, and other North Atlantic captures represent expatriates.

R. loricata has a much wider distribution, occurring in the North and South Atlantic, North and South Pacific and Indian Oceans (Fig. 7). No correlation of distribution with water masses is evident and the sample size is not conducive to extended discussion. Present data suggest the species is cosmopolitan between latitudes 40°N and 45°S. However, almost all of the captures in the Pacific Ocean have been made in areas of transitional waters between major water masses. The specimen taken near the Galapagos Islands is the only one far from water mass boundaries. Ebeling (1962) has summarized considerable information on the environmental factors responsible for distribution patterns. He suggested accumulation or growth of certain pelagic organisms are enhanced by transitional or mixed water and cited the fish *Melamphaes pardus* and the arrow worm *Sagitta minima arinima* as examples. The Pacific populations of *R. loricata* appear to fit this pattern. However, no morphological features could be found to distinguish the Pacific population from those of the Atlantic or Indian Ocean. In the latter areas, no distributional correlation, either with water mass boundaries (Fig. 7) or organic production in the surface waters (Ebeling, 1962: Fig. 72) is evident.

REFERENCES

- ABE, T. AND H. HOTTA 1963. Description of a new deep-sea fish of the genus *Rondeletia* from Japan. *Jap. J. Ichth.*, 10 (2/6):43-48.
- BACKUS, R. H., J. E. CRADDOCK, R. L. HAEDRICH AND D. L. SHORES 1970. The distribution of mesopelagic fishes in the equatorial and western North Atlantic Ocean. *J. Mar. Res.*, 28(2): 179-201.
- EBELING, A. W. 1962. Melamphaeidae I. Systematics and zoogeography of the species in the bathypelagic fish genus *Melamphaes* Günther. *Dana Rep.* 58:1-164.
- GOODE, G. B. AND T. H. BEAN 1895. On Cetomimidae and Rondeletidae, two new families of bathybial fishes from the north eastern Atlantic. *Proc. U. S. Nat. Mus.*, 17(1012):451; 454.
- GREENWOOD, P. H., D. E. ROSEN, S. H. WEITZMAN AND G. S. MYERS 1966. Phyletic studies of teleostean fishes with a provisional classification of living forms. *Bull. Amer. Mus. Nat. Hist.*, 131:339-456.

- GRINDLEY, J. R. AND M. J. PENRITH 1965. Notes on the bathypelagic fauna of the seas around South Africa. *Zool. Africana*, 1(2):275-295.
- HARRY, R. R. 1952. Deep-sea fishes of the Bermuda Oceanographic Expeditions. Families Cetomimidae and Rondeletiidae. *Zoologica (N.Y.)*, 37(1):55-72.
- MCALLISTER, D. E. 1968. The evolution of branchiostegals and associated opercular, gular, and hyoid bones and the classification of teleostome fishes, living and fossil. *Bul. Nat. Mus. Canada*, 221:1-239.
- MEAD, G. W., E. BERTELESEN AND D. M. COHEN 1964. Reproduction among deep-sea fishes. *Deep Sea Res.*, 11:569-596.
- NAFFAKTIS, B. N. 1968. Taxonomy and distribution of the lanternfishes, genera *Lobianchia* and *Diaphus*, in the North Atlantic. *Dana Rept.*, 73:1-131.
- PARR, A. E. 1928. Deepsea fishes of the order Iniomiformes from the waters around the Bahama and Bermuda Islands. *Bull. Bingham Oceanogr. Coll.*, 3(3):1-193.
- . 1929. A contribution to the osteology and classification of the orders Iniomiformes and Zenoberyces. *Occ. Pap. Bingham Oceanogr. Coll.*, 2:1-45.
- PAXTON, J. R. 1971. Osteology and relationships of the lanternfishes (family Myctophidae). *Mem. Los Angeles Co. Mus.* (In Press).
- ROFEN, R. R. 1959. The whale fishes: families Cetomimidae, Barbouriidae and Rondeletiidae (order Cetunculi). *Galathea Rept.*, 1:255-260.
- SVERDRUP, H. U., M. W. JOHNSON AND R. H. FLEMING 1942. *The oceans, their physics, chemistry and general biology*. Prentice-Hall, New Jersey, 1087 pp.
- TAYLOR, W. R. 1967. An enzyme method of clearing and staining small vertebrates. *Proc. U. S. Nat. Mus.*, 122 (3596):1-17.

ADDENDUM

Since the present manuscript was completed and submitted for publication, Dr. Richard Rosenblatt has kindly informed me of the following additional specimens of *Rondeletia loricata* taken by Scripps Institution of Oceanography in the Pacific Ocean: SIO 68-471, *Alexander Agassiz* Styx Exped. VII 35, 19°13'-17'N, 166°40'-27'E, 1000m, 10/IKMT, 1238-1725 hrs., 12 Sept. 1968, (29); SIO 68-476, *Alexander Agassiz* VII 40, 20°0'-21°57'N, 171°40'-172°2'E, 1250m, 10/IKMT, 0640-1300 hrs., 15 Sept. 1968, (30); SIO 68-490, *Alexander Agassiz* VII 54, 29°07'28"47"N, 178°05'14"W, 10/IKMT, 0646-1301 hrs., 22 Sept., 1968 (89); SIO 70-310, *Melville* Antipode Exped. IV 53A, 27°8'-26°49'N, 138°56'-139°6'E, 2000m, 10/IKMT, 1635-2359 hrs., 31 Aug. 1970(33.5); SIO 70-336, *Melville* IV 68A, 18°49'-50'N, 124°22'-123°58'E, 1525m, 10/IKMT, 1125-1855 hrs., 14 Sept. 1970, (24.5); SIO 70-339, *Melville* IV 69A, 19°35'-11'N, 122°57'-58'E, 1450m, 10/IKMT, 1845-0225 hrs., 15-16 Sept. 1970 (56.5); SIO 70-340, *Melville* IV 69D, 19°11'6"-N, 122°57'-28"E, 1599m, 10/IKMT, 0440-1315 hrs., 16 Sept., 1970 (83); SIO 70-345, *Melville* IV 71B, 17°04'-16°40'N, 119°25'23"E, 1550m, 1030-1830 hrs., 18 Sept. 1970 (37). Mr. John Moreland of the Dominion Museum, New Zealand (D.M.) has kindly made available a specimen of *R. loricata* with the following locality data: DM 5569, Tui Exped. 07401, 30 miles from 35°15'S, 176°15'E, 475 fms., 10/IKMT, 1719-2055 hrs., 22 July, 1962 (55). It is apparent that the suggested correlation of *R. loricata* with water mass boundaries in the Pacific was due to sampling error.

In addition Rosenblatt and Robert Johnson of Scripps have identified a specimen of *R. bicolor* from the eastern Pacific with the following data: SIO 69-345, Piquero Exped., 25°58'-38'S, 108°51'-44'W, 2000m, 10/IKMT, 4-5 April, 1969 (83). According to meristic data and a sketch kindly forwarded by Johnson, the Galapagos specimen does not appreciably differ from the north Atlantic population. On the basis of one extra Atlantic specimen it is difficult to predict what the total distribution pattern may be. Considering the number of trawls taken in the eastern Pacific by various institutions, the capture is surprising and indicative of the need for continued collecting.