Fishes Killed by the 1950 Eruption of Mauna Loa
II. Brotulidae[1]

William A. Gosline[2]

Deep-water brotulids have not hitherto been recorded from Hawaii, or, for that matter, from the Central Pacific Ocean. The Mauna Loa collections contain five brotulid species belonging to four genera. None of the species can be allocated to known forms with any certainty, and three of them are described as new. One of the genera appears to be new.

Unfortunately, as is true of many deep-water collections, each of the species is represented by a single specimen. This restricts the possible value of the present report in two ways. In the first place, the type and range of variation within these Hawaiian species must remain for the present unknown, and the possibility exists that the specific and generic descriptions are based on aberrant individuals. However, only one of the specimens at hand which has a regenerated tail shows any obvious abnormality. Fortunately, all are adult or subadult and in good condition. The second, and perhaps more serious, restriction lies in the infeasibility of dissecting such specimens. I have indicated elsewhere (in press) the great variability of the internal characters in brotulids. It seems improbable that a sound classification of this family can ignore internal anatomy, yet it has been deemed advisable to forego investigation of most such structures in the specimens at hand.

However, if all specimens had represented the same species, no insight into brotulid variation at the specific and generic level could have been obtained. As it is, a comparison between the Hawaiian specimens has brought to light a few hitherto unused characters which may prove of value in the classification of the family as a whole.

This paper is limited to descriptive taxonomy in its narrow sense, but in the present rudimentary state of knowledge concerning the fishes of the family Brotulidae little else is possible. The best that can be hoped, therefore, is that the rather full descriptions that follow will make the specimens described identifiable to future workers and that these Hawaiian records can hence be incorporated into the groundwork necessary for any sound conclusions concerning brotulid derivation, phylogeny, and distribution.

Before the various species are described, it seems advisable to comment on two morphological characters.

One is the nature of the copulatory organ in the males of many brotulids. Hubbs (1938: 288) states, "The structure of the clasper-like penis will probably prove to be one of the most trenchant characters by which to separate the several genera of Brosmophycinae." Although I do not disagree with Hubbs's statement, I have found the character of the copulatory organ of the available male brotulids difficult to use taxonomically. In the first place, there seem to be no hard parts in this rather complicated organ, and the relative positions of its soft structures seem to depend considerably on the preservation of the specimen. Whether, as stated in the literature, this organ varies from individual to individual is impossible for me to determine, but I am inclined to believe that the observed variations are due to differences of preservation.

---

[1] Contribution No. 42, Hawaii Marine Laboratory.

[2] Department of Zoology and Entomology, University of Hawaii. Manuscript received January 17, 1953.

Second, the organ is difficult to describe or illustrate adequately. In Figure 1, I have drawn the external features of the four Hawaiian species for which I have males with a copulatory organ.

Turner (1946: 92–96) has recently dealt in detail with the male copulatory apparatus of *Dinematichthys*, and I shall follow his terminology. In all the four species I have examined, the anus lies well forward on the midventral line of the copulatory chamber (Fig. 1*a*, *c*) and is well separated from the anal origin by the copulatory apparatus itself. In *Microbrotula*, a shallow-water genus described previously (Gosline, in press), the penis and claspers project posteriorly beyond the walls of the urogenital sinus and may be seen from below or from the side (Fig. 1*a*, *b*). The penis is elongate and bent upward in the specimen at hand so that its tip lies in part between the claspers. The claspers are relatively large.

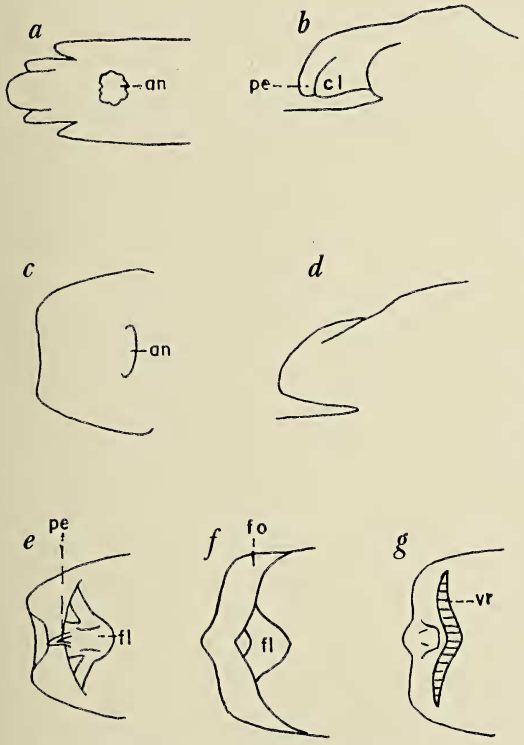

FIG. 1. Male copulatory apparatus of four species of brotulids. *a*, *b*, *Microbrotula rubra*, from below and from the side; *c*, *d*, *e*, *Diplacanthopoma* (sp.?), from below, from the side, and from above; *f*, *Diplacanthopoma* (*rivers-andersoni?*), from above; *g*, *Cataetyx hawaiiensis*, from above. The head is to the right in all figures. Abbreviations: an, anus; cl, clasper; fl, reverted flap covering the urinary opening in *Diplacanthopoma;* fo, superficial fold of skin covering genital structures in *Diplacanthopoma* (*rivers-andersoni?*); pe, penis; and ur, urinary opening.

In *Cataetyx* (Fig. 1*g*) and *Diplacanthopoma* (Fig. 1*c–f*) the copulatory apparatus is bent upward and appressed against the midventral wall of the body in such a way that its outlets cannot be seen from below or from the side. In *Diplacanthopoma rivers-andersoni?* (Fig. 1*f*) much of the area of the urogenital openings is covered by a fold of skin. Such a fold is not now present in the other specimens. In both *Diplacanthopoma* and *Cataetyx* the area of the urogenital openings is divided into two sections. Within the posterior section lies the penis. Whether this organ is exserted (Fig. 1*e*) or retracted (as apparently in *D. rivers-andersoni?*, Fig. 1*f*) seems to depend upon the circumstances at death and the nature of the preservation. The forward section is formed by the large opening of the urinary sinus, and the two sections are divided by a vertical wall which runs transversely. In *Cataetyx* the urinary sinus opens directly to the exterior, but in *Diplacanthopoma* the urinary opening is entirely covered by a reverted flap which extends from the wall separating the two sections. In neither genus are any vertical, clasper-like flaps present.

Though a far more complete knowledge of the variations in the copulatory apparatus with preservation must be gained before this structure, in the brotulids, can be used taxonomically with any confidence, it does seem that the copulatory organs of *Microbrotula* and *Dinematichthys* are of a rather different type from those of *Cataetyx* and *Diplacanthopoma*. The male organs of these last two genera can in turn be separated readily by the presence of a reverted flap covering the urinary opening in *Diplacanthopoma* and the absence of such a flap in *Cataetyx*.

The other character about which some com-

ment seems desirable is the caudal fin structure. I have shown elsewhere (in press) that the caudal fin in brotulids varies at least from a fairly normal percoid type (*Dinematichthys*) to one with a single "hypural" plate to which only four rays are attached (*Brotula* and *Microbrotula*). The species here considered all fall between these two extremes in that there are never less than 10 or more than 12 rays articulating with the last vertebra. These 10 to 12 rays are counted as the caudal rays in the present paper.

The following characters are held in common by all the brotulids treated here and will not be redescribed for each genus and species.

Body completely covered with overlapping, elliptical scales with eccentric axes. No enlarged lateral line scales. Dorsal and anal continuous with caudal. Pectoral fin undivided, with no rays greatly produced. No barbels or crests, but at least a few papillae on top and sides of head. No spines on head except on opercle and (in one species) on preopercle. Mouth subterminal. A flap of skin above opercle connected with the pectoral base. Opening behind fourth gill arch restricted. Three separate pairs of pharyngeals above and one pair below, all with small, granular teeth. Peritoneum black.

Counts and measurements for these five species are given in Table 1 rather than in the specific descriptions. The major differences between the species are summarized in Table 2. Their interrelationships and the recorded distributions of the genera to which they belong are dealt with at the end of the paper.

Genus Diplacanthopoma Günther

Diplacanthopoma Günther, 1887: 115. (Type species: *D. brachysoma* Günther, by monotypy.)

Sarcocara Smith and Radcliffe, in Radcliffe, 1913: 167. (Type species: *Diplacanthopoma* (*Sarcocara*) *brunnea* Smith and Radcliffe, by monotypy.)

Head with large muciferous channels, completely scaleless. Anterior and posterior nostrils well separated, the former opening on the snout rim, the posterior just ahead of eye. Teeth in villiform bands on jaws, vomer, and palatines; the vomerine and palatine bands very narrow. Posterior preopercular border without spines. Opercle with a spine above, ending in a sharply angulated point below. Three developed gill rakers on the first arch. Pelvic fins each of a simple filament that originates below the opercle. Pseudobranchiae represented by a pair of minute filaments or absent. Pyloric caeca absent.

The reasons for placing *Sarcocara* in synonymy are explained by Norman (1939: 79). *Myxocephalus* and *Saccogaster* appear to be closely related to *Diplacanthopoma* and are perhaps not generically distinct.

Most of the seven known species of *Diplacanthopoma*[3] have been inadequately described, probably due in part to the poor condition of the specimens upon which the descriptions were based. Scale count, for example, is given for only one of the seven species and fin counts for only two. The described species have been differentiated from one another (where they have been differentiated at all) by such features as the shape and size of the head, the size of the eye, and the standard length. As a result, it is impossible to tell from existing descriptions (and probably from re-examination of the type specimens) how many of these seven species are valid. Furthermore, all the species have been described from one or a few specimens, so that the nature of the individual variation within species in this genus remains unknown. Until abundant and topotypic material of these species becomes available, there seems no way of determining with any as-

[3] *Diplacanthopoma jordani*, described from near the Galapagos Islands by Garman (1899: 160), is not mentioned in Norman's list of deep-water brotulid species (1939: 84-92), nor can I find other mention of it in the literature. In any event, *D. jordani* is described in hopelessly unrecognizable fashion; no figure, no generic characters, no fin-ray or scale counts, not even the length of the type is given.

TABLE 1

Measurements* and Counts of Hawaiian Deep-Water Brotulids

	Diplacanthopoma (rivers-andersoni?)	*Diplacanthopoma* (sp.?)	*Cataetyx hawaiiensis*	*Volcanus lineatus*	*Pycnocraspedum armatum*
Standard length (in millimeters)	292	135+	222	267	302
Depth at anal origin	124	(262)	168	150	227
Snout to dorsal origin	295	(646)	359	318	195
Snout to pelvic origin	272	(591)	224	207	213
Snout to anal origin	473	75.8[mm.]	487	494	454
Pelvic origin to anal origin	256	(525)	280	293	260
Head to end of opercular flap	261	(579)	283	240	255
Postorbital head length	167	(355)	178	150	154
Length of upper jaw	116	(263)	136	109	143
Snout	61	(142)	70	64	65
Fleshy interorbital	77	(153)	55	33	77
Eye	41	(103)	39	33	44
Distance between ends of free preopercular border	50±	(145±)	75±	75±	95±
Distance between anterior and posterior nostril	24	(66)	49	13	16
Greatest width of premaxillary tooth band	11	(16)	7	10	13
Length of premaxillary tooth band	99	(199)	94	83	122
Greatest width of mandibular tooth band	8	(13)	6	9	10
Length of mandibular tooth band	82	(183)	102	83	97
Greatest width of vomerine tooth band	3	(12)	6	7	10
Length of vomerine tooth band	37	(78)	37	30	35
Greatest width of palatine tooth band	3	(13)	5	10	4
Length of palatine tooth patch	...	(91)	...	48	56
Length of longest pelvic filament	147	(343)	118	151	115+
Length of pectoral fin	130±	(275+)	110+	105	157
Length of caudal fin	58	...	87	82	99
Length of longest dorsal ray	110±	(198)	51	52	85
Greatest height of fleshy membrane on dorsal base	15	(30)	40	...	58
Transverse scale rows	140±	126+	200±	175±	135±
Transverse scale rows ahead of anal origin	47±	48±	50±	72±	40±
Scales above lateral line	11±	11±	17±	16±	20±
Scales below lateral line	27±	34±	34±	35±	47±
Predorsal scales	29	38	48	44	9
Dorsal rays	163±	130+	88±	89±	90±
Anal rays	111±	95+	67±	77±	72±
Caudal rays	10	...	11	12	10
Pectoral rays	26	28	25	26	26
Pelvic filaments	1	1	1	2	2
Developed gill rakers	3	3	3	3	5–6
Branchiostegal rays	8	8	7	8	8

* Measurements, except standard length, are given in thousandths of the standard length. However, for *Diplacanthopoma* (sp.?), which has lost the posterior tip of the body, measurements are given in thousandths of the distance from the snout to the anal fin origin. A + alone indicates that the actual value is at least as great as the figure.

TABLE 2

SUMMARY OF DIFFERENCES BETWEEN FIVE HAWAIIAN DEEP-WATER BROTULIDS

	Diplacanthopoma (*rivers-andersoni?*)	*Diplacanthopoma* (sp.?)	*Cataetyx hawaiiensis*	*Volcanus lineatus*	*Pycnocraspedum armatum*
Standard length in millimeters	292	135+	222	267	302
Head					
Head length in snout–anal distance	1.8	1.7	1.7	2.1	1.8
Eye diameter in fleshy interorbital	1.9	1.5	1.4	1.0	1.8
Distance from eye to posterior nostril in distance between nostrils	2.3	2.6	6.0	0.6	4.4
Position of anterior nostril	on snout rim	on snout rim	on snout rim	behind snout rim	behind snout rim
Structures along snout rim	elongate cavities alternating with narrow fleshy bridges	as in *D. (rivers-andersoni?)*	with large pores	with several small flaps	without pores or flaps
Preopercular spines	absent	absent	absent	absent	present
Opercle	pointed below	pointed below	not pointed below	not pointed below	not pointed below
Head squamation	head totally scaleless	head totally scaleless	scaled except for isthmus, maxillary, lips, and front of snout	about as in *Cataetyx*	completely scaled except for lips
Tooth size	some of teeth slightly enlarged	some of teeth slightly enlarged	some of teeth considerably enlarged	none of teeth enlarged	none of teeth enlarged
Vomerine teeth	in a continuous band	in a continuous band	with a median, toothless interspace	in a continuous band	in a continuous band
Tongue	not reaching vomer	not reaching vomer	protruding between vomerine tooth patches	not reaching vomer	reaching to below vomer
Teeth on branchial arches below	none	patches at base of each third gill arch	none	a short median band; lateral patches at bases of each third gill arch	a long median band; no lateral patches

TABLE 2—Continued

SUMMARY OF DIFFERENCES BETWEEN FIVE HAWAIIAN DEEP-WATER BROTULIDS

	Diplacanthopoma (*rivers-andersoni?*)	*Diplacanthopoma* (sp.?)	*Cataetyx hawaiiensis*	*Volcanus lineatus*	*Pycnocraspedum armatum*
Developed gill rakers	3	3	3	3	5–6
Branchiostegal rays	8	8	7	8	8
Body					
Snout–anal distance in standard length	2.1	...	2.1	2.0	2.2
Lateral line structure	separate papillae	separate papillae	separate papillae	a continuous fleshy tube along surface of body	a continuous fleshy tube along surface of body
Lateral line position	two unconnected lines which between them run the length of the fish	as in *D.* (*rivers-andersoni?*)	as in *Diplacanthopoma* except that there is a rudimentary third line	single, incomplete, terminating about below dorsal origin	single, almost reaching posterior end of body
Pyloric caeca	absent	absent	a single, flap-like appendage	absent	about a dozen finger-like appendages
Fins					
Dorsal origin	slightly behind pectoral bases	slightly behind pectoral bases	slightly behind pectoral bases	well behind pectoral bases	about over preopercular border
Hypural	single, narrow, undivided	...	single, broad, divided	two broad hypurals	single, broad, divided
Scales on vertical fins	absent	absent	absent	present	present
Scales on pectoral rays	absent	present	present	present	present
Spine above pectoral base	absent	present	a small, blunt spine	absent	absent
Ventral filaments	simple	simple	simple	bifid	bifid

surance what names should be applied to the *Diplacanthopoma* specimens at hand.

It would be an easy matter (and one for which the precedent has already been set in *Diplacanthopoma*) to describe the Hawaiian species as new. However, I can see no advantage in doing so at present. It would appear preferable to describe the Hawaiian specimens sufficiently for specific recognition, leaving the names to be applied to them to the time when the genus can be revised on a world-wide basis.

The two specimens in the present collections appear to represent two species. It is true that most of the differences between them could be attributed to discrepancies in preservation, to size, to the regeneration of the tail in one, or to individual variation. There are, however, a few characters that apparently could not be attributed to any of the above categories.

Diplacanthopoma (?rivers-andersoni Alcock)

Tables 1, 2; Figs. 1*f*, 2*a*, 3*a*

?*Diplacanthopoma Rivers-Andersoni* Alcock, 1895: 144 (Arabian Sea); Alcock, 1895?, pl. 17, fig. 1 (from the holotype); Alcock, 1899: 98–100 (on the holotype); Norman, 1939: 91 (species listed).

MATERIAL EXAMINED: 1 male, 292 mm. in standard length, taken off the Mauna Loa lava flow, Hawaii, by Gosline, Hayes, Keen, and Ellis, June 6, 1950.

Body tapering to a rather fine point posteriorly, the 10 caudal rays articulating with a single, undivided hypural and forming a very narrow, pointed tail. Head large, subcylindrical, entirely scaleless. Maxillary reaching about to level of posterior border of eye. Posterior nostril a large hole just ahead of eye, partially covered over in front by a flap of skin. Anterior nostril in a short tube at rim of snout. Large sinuses on head: one under each ramus of lower jaw, a second below preopercle, a third within the fleshy flap above the opercle, all these sinuses inflated in this specimen. Snout rim, from beside premaxillary pedicels to about opposite middle of eye, with an elongate, slit-like cavity, closed over at two points by narrow, fleshy bridges. Free preopercular border somewhat angular below, but without developed spines. Lower points of opercle not penetrating flesh.

Teeth all small but not of equal size, some

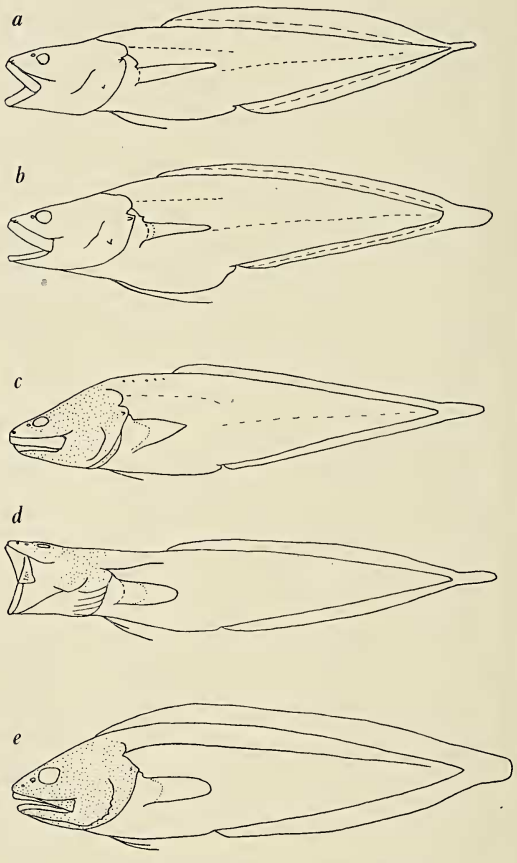

FIG. 2. *a*, *Diplacanthopoma* (*rivers-andersoni*?); *b*, *Diplacanthopoma* (sp.?); *c*, *Cataetyx hawaiiensis; d*, *Volcanus lineatus; e*, *Pycnocraspedum armatum.* Scaled portions of head are indicated by stippling. The limit of the scaly lobe on the pectoral fin base is shown by the dotted line. The limits of the fleshy sheaths along the bases of the dorsal and anal in *Diplacanthopoma* are shown by broken lines. The lateral lines of the body are shown in three ways: the superior, rudimentary line of *Cataetyx* by dots; developed lateral lines consisting of papillae penetrating the scales by dashes; and continuous, fleshy tubes running along the surface of the body by solid lines.

granular, some sharply conical. No teeth on tongue or branchial arches. Lower pharyngeal tooth-patches widely separated. Premaxillary bands separated by a slight interspace at symphysis. Vomerine teeth in a continuous, narrow band. Palatine band very narrow, practically two-rowed. Tongue a short, blunt knob, which does not extend as far forward as the vomer. Slit behind fourth gill arch very small. Pseudobranch represented by a pair of minute filaments on one side, but apparently absent on the other.

Lateral line composed of small papillae that penetrate the scales at intervals; in two sections, the anterior straight and well dorsal on the back to about the level of the anus, the posterior mid-lateral from above the anal origin to the end of the body, becoming less prominent posteriorly.

Dorsal originating nearly an eye diameter behind the pectoral axil, the rays, as in the anal, increasing gradually in length to near the tail. Dorsal and anal with a scaleless basal sheath of skin which covers the greater part of each of the first rays but which decreases in width posteriorly, terminating slightly ahead of the tail.

Pectorals with the rays graduated in such a way as to give the fin a somewhat tapering point above the middle. Base of pectoral fin with a scaleless, lobate sheath which contrasts strongly with the scaled lobe from which the pectoral base projects. Pelvics originating approximately under the lower point of the opercle, each of a simple filament which is apparently composed of two fused rays.

Copulatory lobe present (Fig. 1*f*). Air bladder present.

Body brownish. Head and fins bluish black.

The specimen described above appears to differ from *D. brachysoma* Günther (1887: 115) in a number of minor respects. *D. brachysoma* is said to have the eye equal to the interorbital width; the specimen at hand has the eye considerably less than the interorbital width. (However, the Hawaiian specimen is considerably larger than the type and only specimen of Günther's species.) Also, the dorsal fin of *D. brachysoma* seems to originate farther forward than that of the Hawaiian specimen, and no basal, fleshy sheaths along the dorsal and anal are described or figured for *D. brachysoma*.

D. rivers-andersoni Alcock (1895: 144) is the second species to be described in the genus. Though there are several descrepancies between Alcock's description and plate and the specimen at hand, I can find none that seem to be of certain specific validity. Alcock's plate shows enlarged scales along the front of the lateral line, but, as most of the scales in Alcock's specimen appear to have been lacking, I am not sure that this is not an artist's artifact. The head of the Hawaiian specimen appears to be somewhat larger (but Alcock's specimen was larger), and there is no scaleless membrane figured or described on the base of the pectoral fin of *D. rivers-andersoni*. (As in *D. brachysoma*, no fin-ray or scale counts are given for Alcock's species.)

From *D. brunnea* Smith and Radcliffe (Radcliffe, 1913: 167), the Hawaiian specimen differs distinctly in the more numerous fin rays.

D. raniceps Alcock (1898: 154), *D. alcocki* Goode and Bean (1895: 528), *D. jordani* (1899: 160), and *D. nigripinnis* Gilchrist and von Bonde (1924: 20) are inadequately described species about which little can be said.

Diplacanthopoma (sp.?)

Tables 1, 2; Figs. 1*c–e*, 2*b*, 3*b*

MATERIAL EXAMINED: 1 male, 135 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.*, June 3, 1950.

This specimen has a regenerated tail, and its standard length, lateral line scale count, and dorsal and anal count are consequently all abnormal, i.e., too low. In general, the specimen is in a better state of preservation than that of *D.* (*rivers-andersoni?*), with fewer scales lost, the mucous sinuses on the head and the fleshy sheaths at the bases of the fins less bloated, etc. The fish, however, has died with the gill covers widely flaring and the

isthmus pushed up against the roof of the mouth, giving the head a flattened appearance as compared with *D.* (*rivers-andersoni?*). I believe this apparent difference is due to the manner of preservation and that the head shapes of the two species are actually very similar.

The differences in counts and measurements of the two Hawaiian species of *Diplacanthopoma* are given in Table 1. Among these the most marked discrepancies are the somewhat larger head and eye, the longer ventral filaments, and the more numerous predorsal scales in *D.* (sp.?). However, more significant structural differences are also present. In *D.* (sp.?) the cleithrum just above the pectoral base projects backward as a sharp point which can easily be felt through the skin; in *D.* (*rivers-andersoni?*) there is no such point. In *D.* (sp.?) the basal part of the pectoral fin rays are scaled; in *D.* (*rivers-andersoni?*) there are no scales on the base of the pectoral rays, though a fleshy sheath extends on to the fin. Again, in *D.* (sp.?) there is a patch of teeth at the base of the third gill arch on each side; in *D.* (*rivers-andersoni?*) there are no such patches. Finally, in the latter species the lower pharyngeals appear to be much more widely separated than in *D.* (sp.?). Aside from these differences, the description of *D.* (*rivers-andersoni?*), given above, will apply equally well to *D.* (sp.?).

D. (sp.?) appears to differ from *D. brachysoma* in about the same way that *D.* (*rivers-andersoni?*) does, but I cannot with any certainty distinguish it from any of the other six described species in the genus. Indeed, it is quite possible that this specimen, and not the one I have provisionally called *D. rivers-andersoni*, represents that species.

Genus Cataetyx Günther

Type species: *Cataetyx messieri* Günther (1887: 104), by monotypy.

The genus *Cataetyx* has been interpreted very broadly by Norman (1939: 83) as including those brotulids with the following characters:

Head low, more or less depressed. Opercles and cheeks scaled. Interorbital region and preopercles without spines. Snout and lower jaw without barbels. Vomer and palatines toothed. No canine teeth. Two to five developed gill rakers on the first arch. Body scaled, not very tapering posteriorly. Lateral line present, double, inconspicuous. Caudal united with dorsal and anal, dorsal with more than 90 rays, anal with more than 70. Tips of cleithra firmly united. Pelvics each of a simple filament originating behind eye. Flap-like appendages near pylorus.

Within the genus *Cataetyx* as thus defined, the species *C. messieri*, *C. rubrirostris*, the species described below, and perhaps *C. laticeps* (of which the teeth are said only to be "in viliform bands," Koefoed, 1927: 137) would seem to form a closely related group.[4] These may be differentiated from other species included in the genus by Norman (1939: 90) by having the head scaled to forward of the eyes and some enlarged teeth on the sides of the mandibles and on the vomer and palatines. Whether the genus should be restricted to such species, I do not have the material to determine. Under any circumstances, however, *Pteridium alleni* Byrne does not appear to belong in *Cataetyx*, where it was placed by Norman (*loc. cit.*).

Cataetyx hawaiiensis n. sp.

Tables 1, 2; Figs. 1*g*, 2*c*, 3*c*

Holotype: U. S. N. M. 162715, a male 222 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Gosline, Hayes, Keen, and Ellis, June 6, 1950.

Body tapering to a rounded point posteriorly, covered with nonembedded, overlap-

[4] Another species which may belong in this group but which is impossible to place from the description is *Oculospinus brevis* Koefoed (1927: 138). Koefoed's new genus (*Oculospinus*) and both of his new species have been omitted from Norman's "Synopsis" (1939: 79–92).

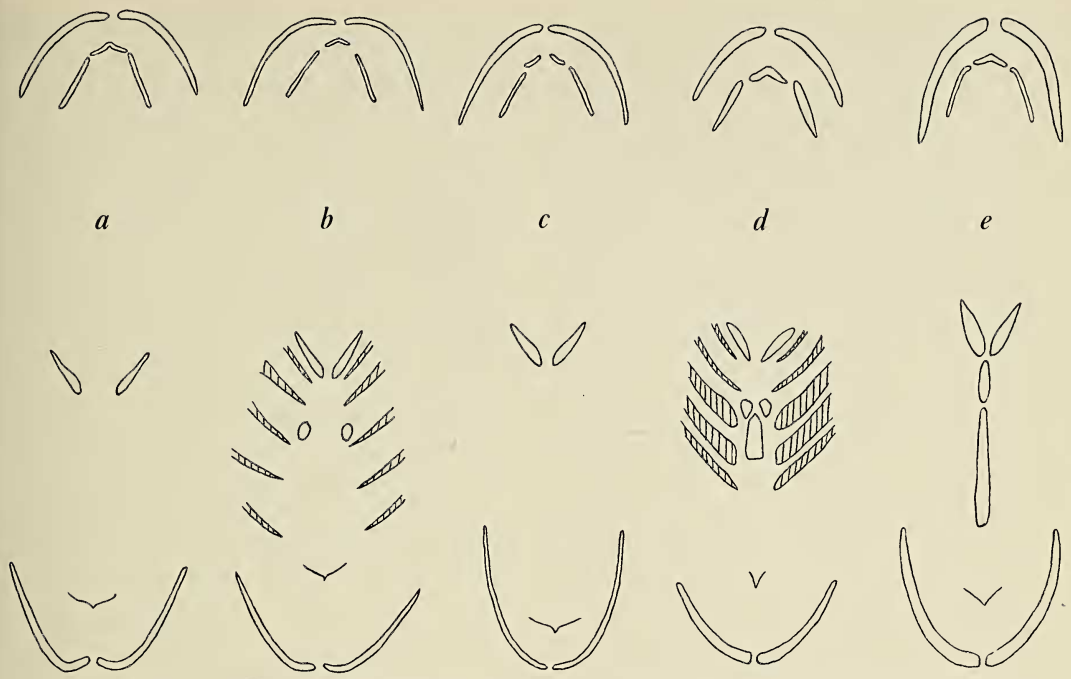

FIG. 3. *a*, *Diplacanthopoma* (*rivers-andersoni*?); *b*, *Diplacanthopoma* (sp.?); *c*, *Cataetyx hawaiiensis; d*, *Volcanus lineatus; e*, *Pycnocraspedum armatum*. Above, tooth bands of upper jaw and roof of mouth; below, tongue and tooth bands of lower jaw and on lower half of gill arches. Upper pharyngeals and spinous gill rakers omitted. The bases of the gill slits are shown (hatched) in two species. Certain differences in the relative position of the parts, e.g., whether or not the gill covers are widely flaring, are undoubtedly caused by differences in preservation.

ping scales. Eleven caudal rays articulating with a single, medianly incised hypural plate.

Head depressed forward, eyes high on snout and directed more superiorly than laterally, covered with scales except for isthmus, lips, maxillaries, and area around rim of snout. No spines on head except for single opercular spine. Maxillary extending about half an eye diameter beyond eye, largely concealed by suborbitals when mouth is closed. Posterior nostril a large hole near front of orbit and slightly below level of middle of eye. Anterior nostril over snout rim. Snout with three enlarged pores on either side in front just above rim; two pores near lower border of suborbitals; a pore on mandibles on either side of isthmus under jaw bone; about three pores along rami of hyoid arch, and one on lower border of preopercle. Free preopercular border more or less rounded, spineless. Opercle not ending in a sharp point below. Flap above opercle covered with minute scales.

Teeth in upper jaw in a villiform band; laterally, teeth increase somewhat in size from outer to inner row. Mandibular rami raised posteriorly, their teeth in long bands. In front the mandibular teeth are in about a half dozen rows, outer three or four small, inner somewhat enlarged. Laterally, teeth in two rows, inner consisting of sharply conical teeth several times as large as those of outer row. Posteriorly, outer row of small teeth drops out leaving only a single row of enlarged teeth, this row continuing well behind premaxillary rows. Vomer with two patches of teeth separated by a median interspace under which the tongue protrudes; each patch consists of about a dozen slightly curved, conical teeth. Palatines with long band of conical teeth less than half the size of those on vomer, with inner rows larger than outer. No teeth on tongue or on bases of the four gill arches.

Lateral line in two sections, with some evidence of a supplementary third section above in front. This uppermost line consists of about six papillae running along either side of nape from behind the occiput to just in front of level of dorsal origin. Upper major lateral line running backward from lobe above opercle, following contour of back and then bending downward posteriorly, ending above origin of about fifth anal ray. Lower lateral line commencing above anal origin and continuing along mid-sides almost or quite to posterior end of body. All three lateral lines apparently composed of papillae that project through the scales.

Vertical fins scaleless, but a lobe of scales projecting on to base of pectoral. Dorsal originating well behind pectoral base, its rays, and also those of anal, all low but highest about middle of fin. Dorsal and anal rays enclosed in skin for most of their length, but this fleshy sheath not forming a prominent band as in *Diplacanthopoma*. Caudal rays projecting well beyond dorsal and anal rays. Pectorals badly frayed, but apparently short and broad. Just above pectoral base a blunt, concealed, backwardly directed point on cleithrum. Pelvics originating under preopercle, reaching less than half way to anus.

A single, short, pointed, pyloric appendage. No pseudobranch.

Head and pectoral base bluish black. Body brownish. Pectoral rays and membranes enclosing bases of dorsal and anal black. Projecting sections of dorsal and anal light.

C. hawaiiensis differs from *C. messieri* Günther in a number of minor respects. The anus is well forward of the middle of the standard length in *C. hawaiiensis* (it is median in *C. messieri*). The head appears to be flatter and broader forward, with the eyes more upwardly directed than in Günther's species. The eyes are also nearer the front of the head, so that the snout plus eye (measured over a horizontal plane for comparison with Günther's plate) is contained about two times in the postorbital head against about 1.6 times in Günther's plate of *C. messieri*. The head length is considerably more than half the distance from snout tip to vent in *C. hawaiiensis*, less than half that distance in *C. messieri*. The dorsal origin lies behind the mid-point between snout and vent in *C. hawaiiensis*, over it in *C. messieri*. Finally, the dorsal and anal of the Hawaiian species seem to differ in being lower, in having fewer rays, and in being scaleless (Günther's plate of *C. messieri* shows scales on the bases of the vertical fins).

Cataetyx hawaiiensis differs from Gilbert's description of *C. rubrirostris* (in Jordan and Evermann, 1898: 2505) in two major features and in dimensions. In *C. hawaiiensis* there is no "short, sharp spine directed backward immediately behind posterior nostril"; instead, the posterior nostril opens out from what appears to be a bony trough just in front of the eye with a single row of scales separating this nostril from the orbit. In *C. rubrirostris* there are said to be "about 135 transverse series" of scales; in *C. hawaiiensis* the scales are more or less regularly arranged, and many of them have been lost from the holotype; nevertheless, four counts made of the transverse series ranged from 190 to 235 scales. In dimensions *C. rubrirostris* would appear to have a larger eye, shorter snout, and narrower interorbital.

In the shape of the head *C. hawaiiensis* resembles *C. laticeps* Koefoed (*loc. cit.*) more than it does *C. messieri*. But *C. laticeps*, like *C. messieri*, is said to have the anus under the middle of the standard length rather than far forward as in *C. hawaiiensis*. In addition, *C. laticeps* is said to have the posterior nostril well in front of the eye and to have nine branchiostegal rays (seven in *C. hawaiiensis*).

Genus VOLCANUS nov.

Type species: *Volcanus lineatus* n. sp.

Body tapering, but with a truncated posterior tip at the end of the two well-developed hypurals. Caudal rays considerably exserted. Lateral line single, incomplete, running along surface of body as a continuous fleshy tube

from flap above opercle about to below dorsal origin. Scales of sides of body with more or less randomly scattered pores, some along mid-sides perhaps representing rudiments of a lower lateral line.

Top of head scaled to in front of eyes; rami of lower jaw, branchiostegal membranes, and maxillary partially scaled; snout in front, lips, lower border of suborbitals, and isthmus completely scaleless. Snout rim bordered by three or four fleshy, leaf-like flaps on either side. Six hair-like lines running backward over scaleless area of snout on each side, forming slight fleshy ridges. No crests or spines on head except for a single, weak opercular spine. Posterior nostril well ahead of eye, about midway between anterior orbital rim and anterior nostril, which exits from a tube well back from snout rim.

Small, granular, pavement-like teeth in short, broad, continuous bands on premaxillaries, mandibles, and vomer. Tongue relatively elongate and pointed but not reaching as far forward as vomer. Two developed gill rakers below and a third at angle of first arch. Pseudobranch reduced to two small filaments on one side and one on the other.

Pelvic fins composed of two filaments each, these divided nearly to their base and originating below the opercle, the outer about half the length of the inner. Pectoral apparently short and rounded, undivided, a scaly basal lobe extending out about two fifths the length of the fin. No sharp point on cleithrum above pectoral base. Dorsal commencing about two thirds of the way out along the depressed pectoral fin. Dorsal, anal, and caudal scaled basally.

Judging from Norman's key (1939: 80–84), *Volcanus* is most closely related to *Luciobrotula* Smith and Radcliffe (Radcliffe, 1913: 170). It differs, however, in lacking a lower opercular spine, in having an incomplete lateral line which is developed as a fleshy tube between and above the scales, and apparently in the peculiar arrangement of flaps and lines on front of snout. Upper part of suborbitals and area between posterior nostril and eye apparently unscaled in *Luciobrotula*, but scaled in *Volcanus*.

Volcanus also bears a superficial resemblance to *Bassogigas* and *Neobythites* but differs at once from these genera in the fewer developed gill rakers and the less complete squamation of the head.

Volcanus is named for Vulcan, the Latin fire god, to whom I am much indebted for sending this fine fish collection.

Volcanus lineatus n. sp.

Tables 1, 2; Figs. 2*d*, 3*d*

HOLOTYPE: U. S. N. M. 162716, a female 267 mm. in standard length, collected by Moore *et al.*, June 3, 1950, off the Mauna Loa lava flow, Hawaii.

The holotype at present has the head thrown back and the gill covers widely flaring. It is more or less impossible to judge the head shape in life. However, the head appears to be relatively small, its length about equal to its distance from the anus. The eyes seem to be on the dorsolateral surface of the head and are separated by a flat interorbital. The posterior nostril is a semicircular hole with the median rim straight. Just posteromedially of this nostril a narrow, linear fleshy ridge commences (resembling a thin barbel attached to the surface of the head for its entire length) which runs back along the upper rim of the orbit. There are four or five scale rows encircling the eye below and in front, except for the area of this ridge. Scaleless area of front of snout with other, similar, longitudinal ridges. Rim of snout with small, overlapping, leaf-like appendages. Maxillary reaching about half an eye diameter beyond eye, with a small patch of about six scales posteriorly. Suborbital rim double for most of its length, with about three inconspicuous pores along its lower edge. Mandibles covered below by a series of assorted scales, fleshy ridges similar to those on front of snout, pores, and pockets with papillae in center. Top of head posteriorly, and to some extent the cheeks, with

fleshy papillae as well as scales. Free preopercular border somewhat angled but without spines. Opercle with a single weak spine above, which does not protrude through the flesh, and no indication of a spine at its lower angle. Teeth uniformly small, granular; the vomerine band of teeth in a widely flaring V of equal width throughout. There is a broad, median patch of teeth between the bases of the second gill arches which extends almost from the bases of the first to the bases of the third. Posterolaterally to this there is a patch of teeth on each side lying on the front surface of the bases of the third gill arches.

Dorsal origin less than a head length behind occiput, the dorsal rays increasing in length to about two thirds of the distance to the tail, then decreasing to the caudal base. Anal rays shorter than dorsal rays and more nearly equal in length throughout the fin. Pelvics originating close to one another and to the symphysis of cleithra, somewhat scaled at base.

The holotype and only specimen has the ovaries somewhat distended and filled with very numerous small eggs. No pyloric appendages.

More or less uniformly brownish on body shading into bluish black on fins, head, and belly.

The trivial name *lineatus* (L.—lined) is given in reference to the linear fleshy ridges on the front of the snout and on the lower jaw.

Genus Pycnocraspedum Alcock

Tables 1, 2; Figs. 2*e*, 3*e*

Type species: *P. squamipinne* Alcock (1889: 386), by monotypy.

Body tapering to a truncate point. Caudal distinguishable from dorsal and anal by closer grouping of last 10 rays, these not much exserted and articulating with a medially incised hypural plate. Lateral line single, straight, continuing almost to posterior end of body, lying in a fleshy tube which extends over surface of, or between, scales for its entire length.

Top of head completely scaled to snout rim. Maxillaries, rami of lower jaw, isthmus, and branchiostegal membranes scaled; only the lips scaleless. Rim of snout forming a smooth, continuous rim unbroken by pores or flaps; a few relatively small pores opening out above rim. Pores on mandible and cheeks inconspicuous; mucous sinuses not apparent. A few fleshy papillae on head, apparently over sensory canals. Opercle with a single sharp point above, the exserted point completely surrounded by scales; apparently, opercle does not form a point below. Small, scaly lobe above opercle.

Posterior nostril opening out into a low, flat collar just ahead of eye; no scale rows between it and eye. Anterior nostril in a tube about halfway between posterior nostril and snout rim.

Uniformly small, granular teeth on premaxillaries, mandibles, vomer, and palatines. Vomerine teeth in a continuous, broadly V-shaped patch under which lie the small, pointed tongue, medianly, and the wings of the hyoid arch, laterally. Three or four developed gill rakers below and another at angle of first arch. Pseudobranch rudimentary.

Dorsal originating over gill cover. Dorsal and anal rays longest just ahead of tail and covered for the greater part of their length with scales. Pectorals fairly long, scaled basally. Pelvic fins each of two filaments which are united basally, separate distally, outer filament about two thirds as long as inner. Pelvic origin below preopercle, considerably behind symphysis of cleithra.

Pycnocraspedum armatum n. sp.

Tables 1, 2; Figs. 2*e*, 3*e*

HOLOTYPE: U. S. N. M. 162717, a female 302 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Hayes and Burke, June 3 and 4, 1950.

The general appearance of this fish is quite *Brotula*-like (except for the absence of barbels) with compressed, scaled head and the vertical fins with high, scaled, but poorly delimited,

fleshy sheaths. Head length greater than its distance from anus. Eyes lateral, with maxillaries reaching almost an eye diameter beyond them. Snout without flaps or ridges, anterior nostril well back from its edge. Preopercle with four sharp points, between which the preopercular border is scalloped.

Basibranchials with an almost continuous, median band of teeth of even width (divided into two sections above bases of third gill arch) running from base of tongue almost to base of lower pharyngeals, which are close together.

About a dozen, finger-like pyloric caeca.

This specimen appears to be a female with small, undeveloped ovaries. The specimen either had spawned recently or it represents the immature form of a rather large species.

Pycnocraspedum armatum differs distinctly from *P. squamipinne*, the only other known species in the genus, in having well-developed, sharp points on the preopercular border. Alcock (1899: 84) says that *P. squamipinne* has "two or three rather indistinct points at the angle of the preoperculum," but only one is shown in his plate (1895?, pl. 21, fig. 1). In addition, the dorsal fin of *P. armatum* originates forward of (rather than behind) the preopercular border, and the pectoral fin reaches about to the anus.

The trivial name *armatum* (L.—armed) is given in reference to the spines on the preopercular border.

INTERRELATIONSHIPS OF HAWAIIAN DEEP-WATER BROTULIDS

In a family as large and varied as the Brotulidae, it is perhaps presumptuous to try to determine interrelationships from the five species at hand. Yet, to fail to do so would seem to be making incomplete use of available material, scanty as it is. The following brief discussion is therefore undertaken, with the full realization that any conclusions reached must remain highly provisional. The bases for these conclusions are summarized in Table 2.

The five brotulids in the lava flow collections would seem to fall into three groups: (1) the two species of *Diplacanthopoma*: (2) *Cataetyx*, and (3) *Volcanus* and *Pycnocraspedum*. Arranged in this way, these brotulids form a series ranging from those with the head completely scaleless (*Diplacanthopoma*) to *Pycnocraspedum* with the head entirely scaled. On this character alone *Volcanus*, with the head partially scaled, would fall with *Cataetyx*, as it would if gill raker count, dorsal fin origin, or preopercular armature were used. However, I feel that *Volcanus* is more closely related to *Pycnocraspedum* because of similarities between these two genera in dentition, the position of the anterior nostril, the lateral line structure, and, to a slight extent, because of the development of a bifid pelvic filament.

In the general classification of the family as erected by Radcliffe (1913) and Norman (1939), *Pycnocraspedum* occupies a somewhat dubious position somewhere between the oviparous forms with a fully scaled head and rather numerous well-developed gill rakers, and the viviparous forms with the head partially scaled or naked and only three developed gill rakers (see Norman, 1939: 89).

Unfortunately, whether *Pycnocraspedum* is oviparous or viviparous remains unknown. The same is true of *Volcanus*, though the numerous small eggs of the holotype of *V. lineatus* bear far more resemblance to the eggs of the oviparous *Brotula* than they do to the few large eggs of the viviparous *Dinematichthys* and *Microbrotula*. Indeed, *Brotula* itself demonstrates that there are oviparous brotulids with the head completely scaled and the developed gill rakers reduced to three.

In view of these points the contingency is presented that between the "oviparous" and "viviparous" groups as drawn up by Norman (1939, key sections C and CC, pp. 80 and 82) there lies an intermediate group of oviparous genera with the head more or less fully scaled and the number of gill rakers more or less reduced. Such a possibility is not pleasant for makers of keys to brotulid genera to con-

template. However, whether or not such an intermediate group is discovered eventually, it seems probable that a more thorough knowledge of the internal and external characters of brotulid genera will make necessary a rather drastic revision of any classification that has hitherto been erected.

GEOGRAPHIC AND BATHYMETRIC RELATIONSHIPS OF HAWAIIAN DEEP-WATER BROTULIDS

The fact that none of the five Hawaiian species of deep-water brotulids can be certainly allocated to hitherto described forms is striking. It could indicate an endemic Central Pacific brotulid fauna. In the light of shallow-water fish distribution—including that of *Brotula multibarbata*, which ranges from South Africa to Hawaii—this seems improbable. Or it might indicate that the Mauna Loa lava flow has brought to the surface wide-ranging brotulids that live in habitats heretofore unsampled. However, in view of the fact that most of the other described brotulids have also been taken only once, it most probably serves merely as a further demonstration of how inadequately brotulids have been collected. If this last is the correct explanation, the inference is that the Brotulidae will eventually prove to be one of the larger fish families.

Turning to genera, *Volcanus* has been hitherto unknown. The distribution of the species presumably related to the Hawaiian species of the other three genera is shown in Table 3. Aside from pointing out the wide extent and variety of these generic distributions, little can be said. *Cataetyx hawaiiensis* suggests affinities with the tropical West American fauna and *Pycnocraspedum armatum* with that of the Indian Ocean, but in the present state of knowledge such suggestions are purely tentative. Perhaps a more curious aspect of the Hawaiian forms is their almost complete lack of affinity with the best known of brotulid faunas—that of the Philippines (Radcliffe, 1913).

TABLE 3
DISTRIBUTION OF SPECIES RELATED TO THE HAWAIIAN DEEP-WATER BROTULIDS

SPECIES	LOCALITY	DEPTH
		Fathoms
Diplacanthopoma brachysoma	Brazil	350
rivers-andersoni	Arabian Sea	947
raniceps	Andaman Sea, Gulf of Aden	405–600
alcocki	Andaman Sea	490
jordani	Galapagos	385
brunnea	Philippines, Arabian Sea	375–1,050
nigripinnis	Natal	700
Cataetyx messieri	Chile	345
rubrirostris	California	205–359
Pycnocraspedum squamipinne	Bay of Bengal, Zanzibar	130–250

Regarding depth distribution, Table 3 indicates *Pycnocraspedum* to be a shallower-water genus than *Cataetyx* or *Diplacanthopoma*. In line with this, the Hawaiian specimen of *Pycnocraspedum* was among the earliest of the fishes collected after the lava flow entered the water. It also maintains a brownish coloration, whereas the others range from gray to blue black.

REFERENCES

ALCOCK, A. W. 1889. On the bathybial fishes of the Bay of Bengal and neighbouring waters obtained during the seasons 1885–1889. *Ann. and Mag. Nat. Hist.* VI, 4: 376–399, 450–461.

——— 1895. On a new species of viviparous fish of the family Ophidiidae. *Ann. and Mag. Nat. Hist.* VI, 16: 144–146.

——— 1895? *Illustrations of the zoology of the royal Indian marine surveying steamer "Investigator."* Fishes. Calcutta. [The plates in this work were issued at various times between 1892 and 1909; those referred to in the text seem to have appeared about 1895.]

——— 1898. A note on the deep-sea fishes, with descriptions of some new genera and species, including another probably vivi-

parous ophidioid. *Ann. and Mag. Nat. Hist.* VII, 2: 136–156.

——— 1899. *A descriptive catalogue of the Indian deep-sea fishes in the Indian Museum.* iii + 211 + viii pp. Indian Museum, Calcutta.

GARMAN, S. 1899. Reports on an exploration off the west coasts of Mexico, Central and South America, and off the Galapagos Islands. The fishes. *Harvard Univ., Mus. Compar. Zool., Mem.* 24: 1–431, 97 pls.

GILCHRIST, J. D. F., and C. VON BONDE. 1924. Deep sea fishes. *Union So. Africa, Rpt., Fisheries and Marine Biol. Surv., Spec. Rpt. VII,* 24 pp. [Not seen.]

GOODE, G. B., and T. H. BEAN. 1895. Oceanic ichthyology. *U. S. Natl. Mus., Spec. Bul.,* xxxv + 26* + 553 pp., and atlas xxiii + 26*, pls. 1–123.

GOSLINE, W. A. In press. The shallow-water fishes of the family Brotulidae from the Hawaiian Islands, with the description of a new genus and notes on brotulid anatomy. *Copeia* 1953 (4).

GÜNTHER, A. 1887. Deep-sea fishes. *Report on the scientific results of the voyage of H.M.S. "Challenger."* Zool. Vol. 22. lxv + 335 pp., 73 pls. Eyre & Spottiswoode, London.

HUBBS, C. L. 1938. Fishes from the caves of Yucatan. *Carnegie Inst. Wash. Pub.* 491: 261–295, pls. 1–4.

JORDAN, D. S., and B. W. EVERMANN. 1898. The fishes of North and Middle America. *U. S. Natl. Mus., Bul.* 47. 3: i–xxiv, 2183–3135.

KOEFOED, E. 1927. Fishes from the sea-bottom. *Report on the scientific results of the "Michael Sars" North Atlantic Deep-Sea Expedition 1910.* Vol. 4, pt. 1. 148 pp., 6 pls. Bergen Museum, Bergen.

NORMAN, J. R. 1939. Fishes. *The John Murray Expedition, 1933–1934, Sci. Rpt.* 7(1): 1–116. British Museum (Nat. Hist.), London.

RADCLIFFE, L. 1913. Descriptions of seven new genera and thirty-one new species of fishes of the families Brotulidae and Carapidae from the Philippine Islands and the Dutch East Indies. *U. S. Natl. Mus., Proc.* 44: 135–176, pls. 7–17.

TURNER, C. L. 1946. Male secondary sexual characters of *Dinematichthys iluocoeteoides. Copeia* 1946: 92–96, pl. 1.