

## OBSERVATIONS ON SOME TASMANIAN FISHES: PART XXXI — REVIEW OF GNATHANACANTHIDAE

by the late E.O.G. Scott

(with four tables, four text-figures and three plates)

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GNATHANACANTHIDAE. The sole representative of this family, *Gnathanacanthus goetzei* Bleeker, 1855, specified in the last century as the type of three different genera by Dutch, English and Australian ichthyologists, with type locality Tasmania (twice), Victoria, and endemic to southern Australian waters, is here made the subject of detailed investigation based on 15 individuals. Fin spines and rays are specified by rectified exponential equations. Differential growth with age is recognized; consistent negative correlation of the lengths of fin spines and rays with overall length of fish occurs. Features not previously reported include: presence of a subrectangular fleshy intermandibular pad, not matched in other families of the suborder Scorpaenoidei; disposition of dermal papillae, known to be irregular on the head and body, in parallel rows on the fins; and intrusion beneath the upper margin of operculum of a slip of papillate integument.

**Key Words:** Tasmania, fish, Gnathanacanthidae.

### INTRODUCTION

This paper follows the general plan of others in the series. Linear dimensions are given throughout in millimetres or as thousandths of standard length. The symbols *Ls*, *Lt*, *TLs* and *TLt* denote standard length, total length, thousandths of standard length and thousandths of total length, respectively. Registration numbers are those of the Queen Victoria Museum and Art Gallery, Launceston. Certain other conventions are noted in earlier contributions.

### FAMILY GNATHANACANTHIDAE

In current Australian literature the remarkable fish *Gnathanacanthus goetzei* Bleeker, 1855, of which the River Derwent is the type locality, is accepted as the only species of its genus, which in turn is the sole representative of its family, the Gnathanacanthidae, proposed in 1891 by Gill for its accommodation. Its status at specific, at generic and at familial levels has involved considerable debate and no little confusion, particularly in respect of the higher taxa; the question of species being, with a single exception, restricted to that of type-species and hence to that extent coextensive with that of genus.

In 1855 with the unique holotype of a new species before him Bleeker defined *Gnathanacanthus* as follows: "Caput corpusque compressa.

Spinae capite nullae. Cristae occipitales sejunctae ossa interspinosa amplectentes. Dentes maxillis parvi pluriseriali; vomerini palatinique nulli. Pinnae dorsalis et analis caudali sejunctae, dorsalis vertice insipiens, in parte spinosa profunde incisa. Radium pinnis omnibus simplicibus, liberi nulli, ventrali 1/5. Spinae anales 3. Membrana branchiostega radiis 7." He noted that the new genus is related to the genera *Agriopus* Cuvier, *Blepsias* Cuvier, *Peropus* Lay, Benn. [*sic*; later in text *Peropeas*], *Taeniopus* Cuvier and *Sthenopus* Richardson (genera referred by Gunther (1880) to Scorpaenidae and Cottidae), and discussed some similarities and differences, features of the new genus cited including the unarmed head, the division of the dorsal and its disjunction from the caudal, the absence of vomerine and palatine teeth, and the number of branchiostegal rays. Bleeker originally referred *Gnathanacanthus*, in terms of the taxonomic framework of the time, to the Cataphracti; subsequently, as noted by Gill (1891), in several papers he referred it to the Scorpaenidae. Of two papers devoted to that group, the first, entitled "Generum familial Scorpaenoideorum conspectus analyticus" (1876a), is stated in a footnote on the first page to be an extract from the more comprehensive *Memoir* (1876b): the diagnosis of *Gnathanacanthus* remains consistent with the original version cited above, but appears in a condensed form, given in French in the *Memoir*, in Latin in the extract. These papers are relevant to Bleeker's assessment of the status of his

**TABLE 1**  
**Comparative Morphological Features**

Some comparative morphological features characterizing Tasmanian species of the six families of the suborder Scorpaenoidei (order Scorpaeniformes).

Scaleless, not enclosed wholly or partly in bony scutes	+	+ <sup>1</sup>	—	—	+	+
Skin with numerous small papillae; velvety	+	—	—	—	+	—
Pelvice absent	—	—	—	—	—	+
Pelvic present, with fewer than 5 rays	—	—	—	—	+	—
Pelvics attached to body by sheet of tissue	+	—	—	—	—	—
Anal spines	3	3	3	0	0-1	0
Dorsal attached by membrane to caudal	—	—	—	—	—	+
Dorsal with well elevated crest on head	—	—	—	—	+	—
Dorsal origin over or in advance of eye	+	—	—	—	+	+
Number of dorsal spines relative to dorsal rays	<	>	>2 <sup>x</sup>	<	<	>
Dorsal spines and rays, anal rays wholly enclosed in membrane	+	—	—	—	—	+ <sup>2</sup>
Lower pectoral rays separate, digitiform	—	—	—	+	—	—
Lower pectoral rays branched	—	— <sup>3</sup>	+	—	—	—
Bony stay across cheek, usually with conspicuous spines	—	+	—	—	—	—
Pillow-like flap in front of isthmus	+	—	—	—	—	—
Subparallel lines of villi on parts of fins	+	—	—	—	—	—
Small intrusion of integument beneath upper operculum	+	—	—	—	—	—

1 One Tasmanian species, *Gymnapistes marmoratus* (Cuvier, 1829) scaleless.

2 Tasmanian species, *Aetapcus maculosus* (Gunther, 1861), *A. armatus* (Johnston, 1891).

3 One Tasmanian species only, *Gymnapistes marmoratus* (Cuvier, 1829).

genus in that they provide his interpretation of the definitive features of genera to which in the 1855 paper it is noted as being allied. In the section on Pisces in the *Zoological Record* for 1876, reviewing the second of these papers it was mistakenly stated the genus *Gnathanacanthus*, with type *G. goetzi* [sic], had not yet been described. Gunther, in ignorance of Bleeker's work, established the new genus and species, *Holoxenus cutaneus*. Concerning the status of this, "one of the most singular fishes of the Tasmanian fauna", he remarked: "At first glance the observer is inclined to refer it to the Scorpaenidae or Pediculati; but there is no bony stay for the praeperculum, which is not armed, and the forelimb is not pediculated. Its nearest allies are evidently the Cirrhitidae, although in this family it stands isolated on account of its divided dorsal, small eye, slender pectoral rays, and almost scaleless [= scaleless] body. Placed at the end of that family, it forms a passage to the Scorpaenidae." The specific description gives A.9; but the generic diagnosis correctly notes "three anal spines". In the same year Bleeker realized the identity of Gunther's fish and his own. *Holoxenus* is the only genus of the three established for the reception of the present fish that has been provided with a species other than the type-species. Johnston (1883), after calling

attention to differences in fin formulae between those of a fish before him and Gunther's specification, commented: "Should it prove to be a distinct species I propose for it the name *Holoxenus Guntheri*": by universal consent Johnston's proposal has lapsed.

The third generic name advanced, one unknown to Johnston, was *Beridia* Castelnau (1878), with type-species *B. flava*, founded on a specimen from Portland Bay, Victoria: the account includes some errors (e.g., two anal spines, a branched ray in the pectoral). Of its affinities Castelnau commented: "This new genus belongs to the *Triglidae*, and its spinous dorsal being rather less in length than the soft [the plate depicts the two fins as wholly separate without the small interposed elements], ought probably to be placed in the group *Cottina*, but the general form is very different from all the other fishes of *Triglidae*, and is more like some sorts of Gobiidae."

In the first comprehensive catalogue of Australian fishes Macleay (1881a: 438, species 138) listed Gunther's species under Scorpaenidae (without notice of Bleeker's fish), also Castelnau's (1881b: 592, species 227); subsequently in the supplement (1884: 19, species 299) noticing Johnston's suggested *H. guntheri* [sic] among the

Scorpaenidae. (In his table of synonymy Gill (1891: 703) gives two page numbers for each of two entries for Macleay: the second number is the species number.)

After having included in a brief summary of the progress of Vertebrate Zoology in 1878 a simple statement that *Beridia* "is the same as *Gnathanacanthidae*, long before described by Bleeker", Gill (1879: 458) later (1891) devoted a whole paper to a valuable review of the nomenclatural problems associated with the present fish; the second binomen, *goetzei*, is there unjustifiably emended to *goetzi*, the name of the collector of the holotype, after whom the species was named, being W.J. Goetze.

As pointed out by Gill, Bleeker's and Castelnau's plates show characters quite different from those manifest in any scorpaenids or cirritids. "The eyes are near the proximal ends of the preopercular bones, the proscapular bones are very much inclined backwards, and must consequently connect with the posterotemporals at decided angles, the pectorals are comparatively narrow and consequently the actinosts and coracid elements must be modified, and the ventrals are subbrachial." Dismissing the suggestion from Bleeker of the presence of the normal cataphract structure in the form of a bony stay from the third suborbital across the cheek, he formally recognized for the first time the appropriateness of an independent, new family, the *Gnathanacanthidae*, which may be most nearly related to the congiopodids or agriopodids and the pataecids (Gill 1891: 704); suggesting in the next paragraph that these four "may even constitute a separate superfamily."

It is to be noted Bleeker himself had included *Agriopus* Cuvier, 1829, a synonym of *Congiopodus* Perry, 1811 (emended forms proposed in 1872 by Gunther, *Conchopodus* and *Coniopodus*) as one of the genera to which his novelty was related, more closely indeed than to some other genera noted by him. By early writers (Gunther 1880, Boulenger 1910) Cuvier's genus is accommodated in the very large early Scorpaenidae, with upwards of 250 species. Two members of the small family Congiopodidae (Agriopodidae), the sole family of the suborder Congiopodoidei, occur in Australia, both reported from South Australia, one also from Western Australia (and New Zealand, which has two other species). They resemble the present fish and the pataecids in being small (Australian species 0.16-0.24 m), wholly scaleless, with the forehead not greatly oblique (though, as a characteristic feature, the mouth is much produced, suggesting the vernacular name Pigfishes) and with the pala-

tines edentulous. The pectoral, ventral and anal resemble those of *Gnathanacanthus* in size and disposition, while the dorsal, like that of the pataecids, is continuous, with spines almost twice as numerous as rays.

In Tasmania this fish has been referred to the Triglidae ("includes Scorpaenidae and Cottidae, erected into independent families in recent works" Johnston 1883), Scorpaenidae (Johnston 1891; two species of *Holoxenus* listed), Pataecidae (Lord 1923, 1927), and *Gnathanacanthidae* (Lord & Scott 1924, Scott 1974b, Edgar *et al.* 1982, Last *et al.* 1983). Family rankings are not noted in a paper on Tasmanian fishes by Ogilby (1897) that includes a good description of *Gnathanacanthus goetzei*.

Deciding against the convention, virtually now universally recognized locally, of the recognition of a monotypic family *Gnathanacanthidae*, Greenwood *et al.* (1966) subsume it in Pataecidae. Examples of *Gnathanacanthus* are quite without resemblance to their figure for Pataecidae, depicting a member of that family *sensu stricto*. These authors treated the suborder Scorpaenoidei (order Scorpaeniformes) as comprising five families, Scorpaenidae (Sclerogenidae in part, including Tetrarogidae), Triglidae (Sclerogenidae in part, including Peristediidae, Peristediontidae), Caracanthidae, Aploactinidae (Aploactidae), including Bathyaploactinidae, Synancejidae (Synancejidae) and Pataecidae (including *Gnathanacanthidae*). All five occur in Australia and all save Caracanthidae are represented in our waters. All possess features indicative of some relationship with the *Gnathanacanthidae*. With this family treated as distinct from Pataecidae, *s.s.*, the subjoined tabulation sets out for ready comparison some of the more obvious external features of the five groups found in Tasmania (table 1).

#### Genus *Gnathanacanthus* Bleeker, 1855

- Gnathanacanthus* Bleeker, 1855: 20. Type-species, *Gnathanacanthus goetzei* Bleeker.  
*Gnathanacanthus* Bleeker, 1855: 31 (legend to plate).  
*Errore pro Gnathanacanthus*.  
*Holoxenus* Gunther, 18766: 393. Type-species, *Holoxenus cutaneus* Gunther.  
*Beridia* Castelnau, 1878: 229. Type-species, *Beridia flava* Castelnau.  
*Baridia* Castlenau, 1878: legend to plate. *Errore pro Beridia*.  
*Gnathanacanthus* Gill, 1879: 458, and 1891: 701.  
*Gnathanacanthus* (*Holoxenus*) Boulenger, 1910: 695.  
*Errore pro Gnathanacanthus*.

*Gnathanacanthus goetzei* Bleeker, 1855

## (Plates 1-3, text-figures 1-4)

- Gnathanacanthus goetzei* Bleeker, 1855: 21, unnumbered plate, fig.1. Type locality: Tasmania ["Hobarttown in ostiis fluminis Derwent"].
- Gnathanacanthus goetzei* Bleeker, 1855: 31 (legend to fig.1 of unnumbered plate). *Errore pro Gnathanacanthus goetzei*.
- Holoxenus cutaneus* Gunther, 1876: 393. Type locality: Tasmania.
- Gnathanacanthus goetzei* Bleeker, 1876a,b.
- Beridia flava* Castelnau, 1878: 229, pl.2. Type locality: Portland Bay, Victoria.
- Baridia flava* Castelnau, 1878: legend to pl.2. *Errore pro Beridia flava*.
- Holoxenus guntheri* [sic] Johnston, 1883: 115. Type locality: Tasmania.
- Gnathanacanthus goetzei*: Ogilby, 1897: 82; Waite, 1921: 171, fig.280, and 1923: 197, unnumbered fig. (after Bleeker), and 1924: 484, pl.31; Lord & Scott, 1924: 13 (species ascribed to Black), p.86, pl. facing p.86; Whitley, 1948: 30, and 1964: 57 (species 2219); Scott, T.D., 1962: 164, unnumbered fig. facing p.164; Thomson, 1971: 130, pl.11; Scott, T.D., Glover & Southcott, 1974: 185, 358 (venom), unnumbered fig., p.185; Scott, E.O.G., 1974b: 189; Edgar, 1981: 72; Edgar, Last & Wells, 1982: 58, color pl.43; Last, Scott & Talbot, 1983: 329, 526 (venom), fig.28.17.
- Gnathanacanthus goetzi*: O'Shaughnessy, 1876: 15; Gill, 1891: 701, unnumbered fig. (after Bleeker); Lord, 1923: 71. *Errore pro goetzei*.
- Gnathanacanthus goetzii*: Gill, 1891: 703. *Errore pro goetzei*.
- Gnathanacanthus goetzei*: Lord, 1927: 15. *Errore pro goetzei*.
- Holoxenus cutaneus*: Macleay, 1881a: 438, and 1884: 19; Johnston, 1891: 31 (p.10, reprint).
- Beridia flava*: Macleay, 1881b: 592.
- Holoxenus guntheri*: Macleay, 1884: 19; Johnston, 1891: 31 (p.10, reprint).

**Material**

Fifteen Tasmanian examples are examined, listed below in order of increasing magnitude of standard length, mm: (a) *Ls* 125 *Lt* 162, off Eddystone Point, 137 m (75 fathoms), 19 June 1978, S. Downe, Q.V.M. Reg. No. 1978/84; (b) *Ls* 155 *Lt* 212, northwest coast, 17 March 1980, anon., 1980/5/45; (c) *Ls* 172 *Lt* 225, Middle Arm, Tamar River, 3 August 1973, S. Mountney, 1974/5/172; (d) *Ls* 190 *Lt* 258, Binalong Bay, 24 April 1973, D.

Wright, 1973/5/94; (e) *Ls* 190 *Lt* 260, Bicheno, 26 February 1959, F.J. White; (f) *Ls* 192 *Lt* 250, Tamar River at mouth, 19 June 1977, J. Head, 1977/5/27; (g) *Ls* 195 *Lt* 256, off east coast, Waterhouse Island, Bass Strait, 26 May 1984, D. Barratt, 1984/5/23; (h) *Ls* 200 *Lt* 265, Greens Beach, 17 January 1980, R.H. Green, 1980/5/3; (i) *Ls* 201 *Lt* 260, Tamar River estuary, 17 September 1973, E. Porter & A.W. Hesketh, 1973/5/109; (j) *Ls* 204 *Lt* 280, off West Point, 15 December 1969, R. Burgess, 1974/5/17; (k) *Ls* 210 *Lt* 275, Eaglehawk Neck, 8 February 1975, P.R. Last, 1975/5/152; (l) *Ls* 213 *Lt* 285 3.2 km (2 miles) south of Little Swan Port, Tamar River, 1 January 1980, M. Gray, 1980/5/1; (m) *Ls* 218 *Lt* 288, off Eddystone Point, 27 December 1972, G. Allen, 1973/5/5; (n) *Ls* 235 *Lt* 315, off east coast, Cape Barren Island, Bass Strait, 2 July 1969, B. Greeno, 1969/5/28; (o) *Ls* 256 *Lt* 320, Ocean Vista, West Burnie, 2 November 1972, C. Jones & P. van der Woude, 1972/5/605. With a single exception these specimens are preserved in the collections of the Queen Victoria Museum and Art Gallery, Launceston, with registration numbers as here noted; specimen (e) from Bicheno is no longer at hand and the only measurements of it available are the 21 items recorded earlier (Scott 1974b: 190).

**Figures**

The account given below involves comparison with published illustrations of this species. It is expedient here to specify those examined. They comprise (a) original figure of the holotype from Tasmania, 199 mm in length (Bleeker 1855, fig.1 on unnumbered single plate), reproduced in the catalogues of South Australian fishes by Waite (1821: 171, fig.280, and 1923: 197, unnumbered fig.); (b) Castelnau's figures of the holotype from Victoria, "about seven and a half inches [0.19 m] long", of his *Beridia flava* (1878, pl.2); (c) figure published by Gill (1891, unnumbered fig.; second binomen rendered *goetzi*), of which Waite (1924: 485) noted it "was copied from that of Bleeker, but the artist, without seeing an example of the fish, straightened out some of the fin rays"; (d) in the same paper by Waite a new representation (pl.31), based on a South Australian example, 262 mm in length; (e) a painting, apparently from life, by Mrs Louisa Anne Meredith, reproduced on Lord & Scott (1924, plate facing p.86); original there noted as being in the Tasmanian Museum, Hobart; (f) a color photograph of a living example in Edgar *et al.* (1982, pl.43).

Waite's (1924) depiction, not wholly satisfactory, has been accepted as the standard figure in



PLATE 1 — *Gnathanacanthus goetzeei* Bleeker, 1855. Specimen 201 mm in standard length, from Tamar River estuary (Q.V.M. 1973/5/109). On preservation the spines and rays of the vertical fins commonly tend to slope backward: in this example

subsequent Australian State catalogues, e.g., Scott (1962, unnumbered on p.165), Scott *et al.* (1974, unnumbered on p.185), Last *et al.* (1983, fig.28.17), the source not acknowledged in the South Australian lists and attributed to the second of these in the Tasmanian work. In offering his figure Waite criticized those of Bleeker and Castelnau, valid points concerning the former being the shortness of the pectoral and ventral fins and the early termination of the lateral line, and concerning the latter the unacceptable sense of rotundity suggested by the shading, the complete separation of the dorsal fins, and the curiously extensive continuation of the membrane behind the dorsal and anal. Of available drawings that giving the most lively impression of the characteristic overall appearance of this fish with its large flaring fins is that of Mrs Meredith. A version of Waite's (1924) figure washed a uniform somewhat orange red has been published by Thompson (1971, pl.32). Plate 1, a photograph of a whole fish 201 mm in standard length, shows, as does a painting by L.A. Meredith reproduced in Lord and Scott (1924), vertical fins more erect than

the fully erect condition attainable in life is more nearly maintained, with total height, including fins, equal to, or more than, half total length. Photo: M.A. Bartkevicius.

is commonly found in preserved material and depicted in illustrations. Notable morphological features, e.g., characteristic "interdorsal" region, slip of papillate integument intruding beneath operculum, arrangement of dermal papillae in files on fin, subrectangular cutaneous intermandibular pad (present in *Gnathanacanthida* but not in representatives of the six other locally occurring families of the Scorpaenoidei, are illustrated in several figures. Some morphological ratios are the subject of graphs.

#### Size

The lengths of their type specimens were noted by Bleeker, Castelnau and Gunther as 199 mm, 190 mm and 254 mm, respectively. The maximum normal size is about 0.3 m, a value accepted by Lord & Scott, Scott *et al.*, Last *et al.* Johnston noted "average total length 10 inches [254 mm]"; while a sample of 5 examples noted by the writer (1974b) showed a standard length range of 190-301, or total length of 206-320 mm. Last *et al.* reported a maximum weight of 660 g.

### Distribution

Subsequent to its original recognition in Tasmania this species was successively recorded from Victoria (Castelnau 1878), South Australia (Waite 1923) and Western Australia (Whitley 1948), apparently occurring only in the southern part of the last-mentioned State. It has not been encountered elsewhere, and is thus endemic to the region between latitudes 30° and 45° S, extending along the southern coast of the Australian mainland and reaching Tasmania. It is of interest to note the Pataecidae (in which the Gnathanacanthidae is by some authors subsumed) is also restricted to Australia and is likewise primarily southern Australian in distribution, with only one of the six species recognized in the check-list (McCulloch 1929), *Pacaecus fronto* Richardson 1844 (synonym, *P. subocellatus* Gunther, 1872), ranging northwards to New South Wales and Queensland. Two members of this family, treated in the most recent review of the Tasmanian fish fauna (Last *et al.* 1983) as *Aetapcus armatus* (Johnston, 1881) and *A. maculatus* Gunther, 1881, occur, in the former being confined to, our waters.

### Head

#### General

The head is large, though not immoderately so, its length relative to that of fish being much the same as, or a little greater than, that commonly encountered among Tasmanian representatives of the other families of the Scorpaenoidei (most marked difference presented in Aploactinidae, in which it is less than one-third standard length). The "1/32 and 3/35 in longitudine corporis" of Bleeker relates, as is evident from his figure, to total length. Castelnau's "twice and one-third" and Waite's 2.2 in length without caudal are tolerably diagnostic. In our material head length as *TLs* is 359-460 ( $\pm 405.6 \pm 6.80$ ). The ratio of its depth to depth at hind end of trunk, approximately unity, is greater than that among the other related forms, except the Pataecidae where it is close to twice. The overall angle of entrance as estimated from figures is in general round about 80°-90°, being, at some 65°, unduly small in Castelnau's plate. In our material it is 90°-100°, smaller individuals showing some tendency towards the higher value. In specimens in which the apex is at the level of the margin of the operculum the formal angle of run is about 45°; however, in view of the approximation to equality in depth at this point and at the level of the vent, the effective angle of run is perhaps more appropriately determined measuring back from the latter point; it is then found to be near 60°.

The posterior border formed by the free margins of the branchiostegal membrane below and the operculum above is striking by virtue of its close approximation to rectilinearity from its lower extreme at the ventral contour of the fish to its upper termination located above the level of the full eye structure by a distance of from one to three times the diameter of pupil (tip shown noticeably too low by Castelnau). This straight-line course contrasts strongly with the convexity, either in the lower half or throughout the whole extent of the hind margin, in related forms. From the highest point on the posterior border the fleshy border extends briefly forward, for a distance equal to from twice to thrice a pupil diameter, in one of three main forms: (a) a simple flap with its border overall straight or very gently concave, obscurely or obviously minutely crenulate, its general course varying from an angle of about 45° to the anteroposterior axis of the fish to subparallel with the virtually horizontal dorsal profile above; (b) running obliquely down and back in its anterior portion with resultant formation there of a well-marked process, bluntly rounded, slightly broadening basally, its greatest width about two-thirds its length, the latter subequal to the pupil diameter, the border beyond this process extending forward and upward in the same crenulate linear course as that taken by the entire superior margin in the first form; (c) found in two or three individuals a structure similar to that of (b) but differing in the development at its anterior termination of a second much smaller process, the presence of which is indicated in Castelnau's plate. In that figure two long slender spines are shown running back to the bases of the processes (the text, however, noting opercles "ended by two smooth points"): no such external spines are depicted by Waite, but a strong zigzag-shaped marking in Bleeker in the relevant region may be related to them, while their general location in Castelnau is marked by two lines of shading. In our specimens there are two very slender acute subdermal spines placed as in Castelnau's figure, extending back only to the origins of the processes where these occur, their presence obscurely indicated in some individuals by slight ridges: Ogilby reported "two concealed spines", while Last *et al.* (1983: 329) observed "2 large spines on opercle, often concealed by skin."

In specimens in which the action is not inhibited by undue rigidity of the concealed spines, the fleshy border of the opercle can be carried (even, superficially, delicately rolled) forward to the level of the point of attachment, thus exposing an elongate inverted triangular region, reaching

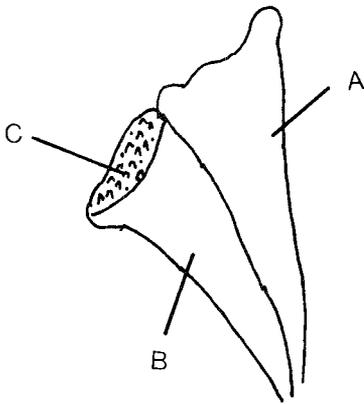


FIG. 1 — *Gnathanacanthus goetzeei* Bleeker, 1855. Inner surface of drawn-back operculum. A, exposing smooth membrane-invested cranium, B, into which intrudes a slip of papillate integument, C.

down to the pectoral base, normally hidden; the hind side of this being constituted by a low rounded ridge running parallel to the border of the operculum in its normal position. This ridge is presumably indicative of the presence of the coracoid, this bone, linear down to immediately above pectoral base, thus forming "the frame or 'sill' against which the opercular and branchiostegal doors shut in closing the branchial cavity" (Owen 1866: 126); here, in agreement with the opercular form, with a straight instead of the more usual curved margin. While the greater part of this, representing the underlying cranium invested by glistening membrane, is firm and uniformly smooth, the uppermost portion presents a small subrectangular or subtriangular area (widest behind), extending horizontally for its whole length, vertically for a distance somewhat less, and being delimited above by a distinct upwardly convex fleshy rim that is continuous anteriorly with the fleshy upper margin of the operculum. This specialized region, soft to the touch, is covered throughout by the minute, closely set papillae that invest almost the entire outer surface of the fish and clearly represents an intruding element of the general integument (fig. 1).

No such invasion of the area normally covered by the operculum by an extension of the ordinary external tissue of the flank has been observed in any of the related forms examined.

In his generic diagnosis Bleeker (1885) noted occipital ridges but made no further reference to these features in his description of the holotype. In other accounts only that of Waite (1921) mentions

cephalic ridges, "marked preorbital subdorsal and opercular ridges". In many specimens they are by no means strongly evident, in some practically untraceable, the degree of visual development probably being associated at least partly with mode and history of preservation. In an example left untreated for several days and then placed in alcohol (Q.V.M. No. 1984/5/23) ridges are visible as described below. Beginning below the anterior nostril, midway between it and upper lip, a narrow ridge curves back to approach the ocular capsule at 7-8 o'clock (left side viewed); it continues upward, coming in its upper half to constitute the raised orbital rim, traceable round to about 5 o'clock. In front of this and just in advance of its origin a much broader and more conspicuous ridge, after briefly bordering the front of the posterior nostril, ascends obliquely, constituting the frontal profile here, to just below the base of the first dorsal spine, whence it continues, now much sharper and somewhat more elevated, in a slightly irregular upwardly convex arc to vertically below the fourth dorsal spine, its distance from the orbit through most of its length subequal to that from the dorsal profile. Originating immediately below the middle of the lower lip, a moderately developed ridge, in the form of a reversed L, defines the preopercular border to the level of the middle of the eye. The most conspicuous elevation extends almost linearly from middle of the hind border of the orbit to the base of the upper flap of the operculum. From near its origin one ridge proceeds obliquely down and back to meet the opercular border, itself showing some tendency to elevation, and near the middle of its length develops a short spur linking it with the subopercular ridge; a second, less pronounced, runs back about horizontally to the opercular border. From near the hind end of the ridge overarching the eye (Waite, "subdorsal") a slender ridge curves up and back more than halfway to the dorsal profile. In the generality of the specimens of our sample only two two or three best developed ridges are evident, and these may in some cases be traced only with difficulty.

It is not practicable to determine through the thick integument the disposition of the bones of the head in the suborbital and immediate postorbital region. However, examination of specimen (g), in which the skin, in the course of preservation, has behaved in a fashion markedly different from that found in all other examples, becoming thin and rigid, would appear to substantiate the account given by Bleeker in a papers published more than 20 years after the original description of his species and cited by Gill (1891: 702)) who rejected Bleeker's

interpretation, and dismissed the association with the Cataphracti, commenting (p.704) "Notwithstanding Bleeker's remarks, I must regard it as doubtful whether the normal cataphract structure is manifest, that is, whether the *third* suborbital is developed as a stay." In thus dismissing association with the Cataphracti, he was led to to establish his own new family Gnathanacanthidae.

#### Eye, Nares

As is commonly the case in scaleless fish, the periphery of the eye is rather ill-defined. The exposed ocular structure proper, as preserved, is quite small, circular, occasionally longitudinally somewhat elliptical, its diameter about twice that of the circular pupil; this is surrounded by a strongly elevated ring of minutely papillate tissue, the width of the annulus less than the diameter of the pupil, its external diameter about twice that of the included structure; this raised annulus is set in a depressed annulus of subequal width and usually well defined, commonly but not invariably being bounded externally by a distinctly raised rim; further, this whole complex is usually set in a quite ill-defined region of general slight concavity. As thousandths of standard length the diameter of the exposed eye proper is 26-42 ( $\bar{x}$  32.9  $\pm$  1.13) with a high coefficient of variation ( $V$ ), 13.3. Corresponding values measured to the outer margin of the circumscribing fleshy rim are 48-72 ( $\bar{x}$  64.1  $\pm$  1.61),  $V$  9.7. Bleeker recorded diameter of the eye about 6 in head length, Ogilby  $4\frac{3}{8}$ - $4\frac{5}{6}$ , Waite 9.5 (Gunther "small", no value given by Castelnau). With use of mean values for our 15 specimens of standard length and of the two specifications of eye diameter, the ratios are 6.32, 12.32: it is evident the boundaries of the eye are subject to some differences of interpretation. The location of the eye, noted by Bleeker as well away from the forehead, is such that the distance from the middle of the pupil to the dorsal profile at insertion of the first dorsal spine, which is located vertically above it, is subequal to that from the same point to the anterior nostril, a little less than that to the nearest point on the supramaxilla, and about two-thirds that to the middle of the upper lip. The strongly convex interorbital distance is small, only about one and one-fifth times the diameter of the fleshy ocular capsule; as *TLs* 66-94 ( $\bar{x}$  77.3  $\pm$  2.11). Ogilby reported it as smaller than (1  $\frac{3}{4}$  to 1  $\frac{3}{5}$  in) the diameter of the eye.

The posterior nostril lies level with the middle or the upper one-third of the fleshy ocular capsule (this variation being associated with differences in forehead angle), its shortest distance from it modally two-thirds the capsule diameter. Neither Bleeker's

"naribus posterioribus simplicibus" nor Waite's specification, "a simple pore" is applicable to our material, in which it is in the form of a short tube, the circular or slightly elliptical free border of which is constituted by some 15-20 digitiform processes, either very closely set or contiguous basally, extending as contiguous half-columns down the side of the tube to its base; the height of the tube is some one-third, or more, of its basal diameter. The anterior nostril lies downwards and forwards from the posterior, its distance from which is rather less than that of the latter from the eye-capsule and about half its distance from the upper lip. As preserved, its appearance varies, either being much like a smaller version of the posterior nostril, but with the crenulations less developed and restricted to the hinder half of the margin, or having the form of a short column surmounted by a clump of closely packed small spheres or short broad obtuse processes; no orifice is evident (cf. perhaps, Waite's "small skinny flap"; Bleeker's "leviter tabulatis"). The anterior internarial distance is not greatly less than the interorbital distance, but slightly exceeds the posterior internarial.

#### Dentition

The dentition is extremely insignificant, and escaped mention by Castelnau and Ogilby. No teeth occur on the palatines, the vomer or the tongue. Moreover those present in the upper and lower jaws (in his diagnosis of *Beridia* Castelnau incorrectly wrote "none at the lower jaw") are minute, and arranged in an arc, with the width anteriorly subequal to the pupil diameter, decreasing regularly backward to close to the angle of the jaw. Closely set, they present the general appearance of a flat pavement, with in front up to half a dozen rows, smooth to the eye and to the touch of a finger; but exploration with a needlepoint encounters some discrete elevations. Castelnau (in his generic diagnosis) and Waite described the teeth as "granular", Gunther (in generic diagnosis) as "villiform", Johnston "more granular than villiform". The whole apparatus is curiously cryptic. When the mouth is opened no teeth are immediately evident, the situation clearly justifying the generic name *Gnathanacanthus*, boldly rendered by Waite (1921) "spineless jaw". In each jaw a fleshy arc of tissue, similar in form to, and only slightly smaller than, the external lip is set close to, even contiguous with, the lip; like the lip, though to a much less marked extent, it presents a tessellated appearance. When this structure is forced inwards or the lip is drawn forwards and the cleft between them is

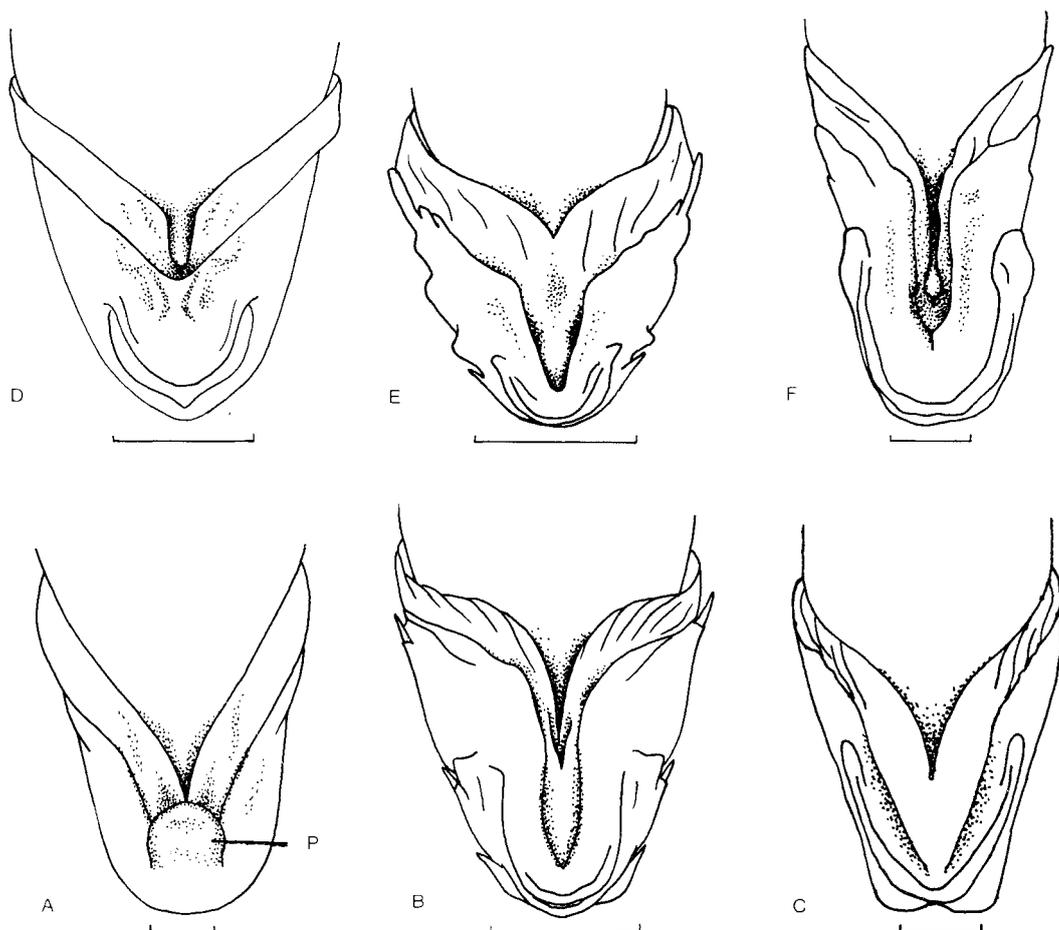


FIG.2— Anterior ventral surface of head, showing presence in Gnathanacanthidae and absence in five other families of the suborder Scorpaenoidei of a subrectangular fleshy intermandibular pad. Bar scale equals 10 mm in each case.

A. *Gnathanacanthidae*, *Gnathanacanthus goetzeei* Bleeker, 1855.  
 B. *Scorpaenidae*, *Gymnapistes marmoratus* (Cuvier, 1829).

C. *Triglidae*, *Chelidonichthys kumu* (Lesson & Garnot, 1826).

D. *Aploactinidae*, *Aploactisoma milesii* (Richardson, 1850).

E. *Synancejidae*, *Glyptauchen panduratus* (Richardson, 1850).

F. *Pataecidae*, s.s., *Aetapcus maculatus* (Gunter, 1861).

widened the teeth appear, exposed on the base of the small ravine. In the upper jaw this fleshy arc develops at the middle of its outer margin a small round knob that is received into a depression on the inside of the upper lip, with which it then becomes continuous. A similar connection is developed in the lower jaw, assuming more or less clearly the nature of a ball-and-socket joint, the main process, however, in this case being developed from the lip instead of the fleshy arc. This small connector at the symphysis effectively separates the tooth-bands of the right and left rami of the jaws.

The edentulous tongue, smooth, pearly white and glistening in preserved specimens, is large, filling the whole mouth, rather massive and with the upper surface strongly convex both laterally and longitudinally. The anterior border is truncate with a variably developed mesial notch. The outline then flares out in a concave arc on either side to the greatest width, behind which the two sides continue rectilinearly with regular progressive decrease in width. From the ends of the anterior mesial notch two parallel ridges extend backward.

#### Snout

The general form of the snout has been described above. Its length ranges from 108 to 160 TLs ( $\bar{x}$  127.4  $\pm$  16.504) equivalent to 2.6-4.0  $\pm$  0.816 in head (Waite 3.5, Gunther "of moderate length"). Ogilby reported length in terms of the eye, "one tenth to one fifth of a diameter of the eye longer than the eye", dimensions that would appear to be unduly small; even for the larger eye value, that of the full capsule, our figures are 1.3-2.7 ( $\bar{x}$  1.96  $\pm$  0.102, with a high value for *V*, 20.1).

#### Branchiostegal Apparatus, adjacent ventral surface

The branchiostegal membrane is indistinguishable in appearance from the general opercle, being minutely papillate like it and the general surface of the fish. As mentioned by Waite, the apparatus is apparently not fully concealable by the opercle. Of published accounts only that of Bleeker recorded the number of branchiostegal rays, 7; of these 5 only are visible externally, clothed inconspicuously throughout their length in the general integument.

On the ventral surface the branchiostegal membranes extend forward to the level of the angle of the rictus, ending close together, briefly in advance of the pointed tip of the isthmus, the margins of which sweep back in deeply concave curves, with the width shortly in advance of the pectoral base equal to, or exceeding, the length. At their anterior ends, level with the hind border of the

supramaxilla, they are continuous with a conspicuous elevated cutaneous pad, somewhat pulpy, rather longer than wide, lying between the free inferior margins of the head here in the form of the mandible, and becoming continuous in front with the interior surface of the chin, about a full eye diameter behind the most advanced point of the latter; the sides of the pad convex, approaching each anteriorly, the hind margin convex, overlapping and concealing junctions of membranes with it.

The curious intermandibular cushion with its suggestion of being pneumatic is without exact counterpart in the Pataecidae as represented by the locally occurring genus *Aetiopus* Scott, 1936. Specimens of *A. maculatus* (Gunther, 1861) show the forward extensions of the branchiostegal arches, instead of terminating near the level of the end of the supramaxilla, continue beyond this halfway to the most advanced point of the lower jaw, terminating well apart, with, in advance of them, a small triangular area, possibly the analogue of the pad in *Gnathanacanthus*, but differing noticeably from it in being very much smaller, not continuous with the arches and, with fish viewed from below, distinctly lower than, instead of overlapping them.

The intermandibular pad of *Gnathanacanthus* is not only absent in the most closely allied family, the Pataecidae, but is not developed in any of the Tasmanian representatives of the remaining local families of the suborder Scorpaenoidei, as is made evident by the illustrations for that family and for *Gymnapistes marmoratus* (Cuvier 1829), Scorpaenidae; *Chelidonichthys kumu* (Lesson & Garnot, 1826), Triglidae; *Glyptauchen panduratus* (Richardson, 1850), Synancejidae; *Aploactisoma milesii* (Richardson, 1850), Aploactinidae provided in fig. 2.

#### Gills, Gill Rakers

The gills, as noted by Gunther and Waite, number four; there being a small slit behind the fourth. The numerous slender cylindrical gill filaments, minutely tuberculate, bluntly pointed, are of much the same length on all arches and throughout the greater part of the extent of each arch. The arrangement of the gill rakers is unusual. With the opercle lifted and the outer arch viewed from behind, the arch is seen to bear a definitive row of 12-13 stout rakers, of which 3-4 are on the upper limb. Waite recorded 4+8 rakers on anterior arch, noting "the first four of the lower limb are paired": in one individual in our material five are so paired, in others the duplication is evident throughout the whole or most of the lower limb, and some

TABLE 2  
*Gnathanacanthus goetzei* Bleeker, 1858

Lengths of fin rays and spines, specified by  $L = bN^k$ , rectified as  $\log L = k \log N + \log b$ ;  $L$  length as permillages of standard length,  $N$  serial number, conventions of enumeration as in Scott (1974a). Example from inshore east of Waterhouse Island, Bass Strait, standard length 195 mm; 17th caudal ray imperfect.

Fin	Set No.	Spine or ray set	Abscissal log set	Parameters		$r$ ( $z$ )	$t$
				Slope ( $k$ )	Intercept ( $\log b$ )		
First dorsal	1	{I-IV}	{1-4}	0.3635	2.2857	0.99374(3.882)	35.499
	2	{IV-X}	{4-10}	-2.4421	3.9649	0.99989(4.903)	152.411
	3	{XI-XIV}	{11-14}	5.1881	-3.5715	0.99875(3.689)	28.282
	4	{X-XIV}	{10-14}	5.7227	-4.1656	0.99988(3.093)	19.032
Second dorsal	5	{1-6}	{1-6 <sup>2</sup> }	0.6093	2.0965	0.99820(3.507)	33.305
	6	{6-9}	{6-9}	-0.4323	1.8922	-0.99728(3.300)	19.148
Anal	7	{1-III}	{1-3}	0.5914	2.0897	0.99996(5.437)	115.007
	8	{1-3}	{8-6}	-0.4631	2.8774	-0.99816(3.495)	16.464
	9	{3-8}	{6-1 <sup>0</sup> }	0.1895	1.9135	0.99918(3.902)	49.463
Pectoral	10	{1-4}	<sup>9</sup> 1-4 <sup>0</sup>	0.3616	2.3541	0.99953(4.180)	46.203
	11	{1-5}	<sup>9</sup> 1-5	0.3413	2.3582	0.99608(3.116)	18.960
	12	{5-14}	{1-10}	0.3835	2.1941	0.99902(3.809)	63.747
Ventral	13	{1-4}	{1-4}	0.1683	2.4174	0.99714(3.274)	18.647
Caudal	14	{1-3}	{1-3}	0.7956	2.1122	0.99862(3.639)	19.018
	15	{3-6}	{3-6}	0.2036	2.3871	0.99995(5.280)	138.802
	16	{8-11}	{3-6}	0.3506	2.3481	0.99401(2.904)	7.204
	17	{11-13}	{1-3}	0.65510	2.2030	0.99970(4.406)	40.946

supernumerary rakers may occur also on the short upper limb. The rakers on the lower limb are set fairly close together, the interval between them subequal to their length; each is in the form of a short cylinder having a rounded top or expanding terminally into mushroom-like aggregation of very numerous minute pointed processes, the rim of the pileus tending in some individuals to extend, especially inferiorly, beyond the supporting column. (Rakers with a similar distal structure occur in the pataacid genus *Aetapcus*, but here the microscopically spinulate dome-like formation constitutes virtually the whole raker, the domes being contiguous.) The members of the auxiliary row may be opposite but are more usually set alternately between those of the primary series; the latter being set about normal to the arch, the former tending to point inward.

#### Lateral Line

The lateral line is not prominent and in some individuals is detected only with difficulty, particularly posteriorly. Bleeker observed "antice tantum conspicua", and his figure depicts it as ending abruptly, after a somewhat sigmoid, chiefly downward course, below the first dorsal ray on the upper

one-fourth of the flank. Illustrations by Castelnau and Waite trace it throughout its full course, with its termination level with the ends of the dorsal and anal membranes, the former author having it running horizontal for two-thirds of its length, then curving down strongly, the latter showing it, as in his description, "leaving the profile below the soft dorsal", terminating "above the middle of the peduncle", level with the vertical fin terminations. Our specimens exhibit considerable variation, its course at times differing somewhat on the two sides of the same individual. The specification provided by Waite, with origin over the opercle close below the dorsal edge, is appropriate to some of our examples, while some have the general course virtually rectilinear, with others showing much more convexity in the anterior section than depicted in any illustration. The end of the line while modally occurring just above the middle of the origin of the caudal peduncle may be located much higher, about five times as distant from the ventral as from the dorsal profile here. Some 12-15 low rounded tubercles are found back to about the level of the vent; the number behind this being difficult to determine, the sum perhaps about the same as in the anterior section. In a few cases the tubercles

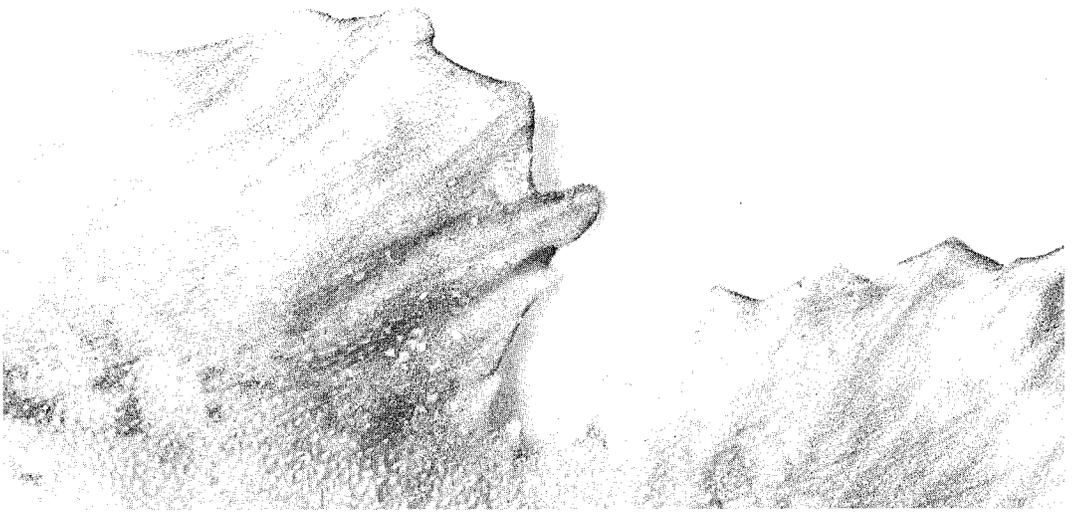


PLATE 2 — *Gnathanacanthus goetzei* Bleeker, 1855. The "Interdorsal" region of the specimen depicted in plate 1, showing the rudimentary of

vestigial spinous elements, wholly invested in membrane, that are a characteristic feature of the species. Photo: M.A. Bartkevicius.

may be connected by a low ridge, with the resultant impression of a continuous line.

#### Fins

In Part XIX of these contributions (1974a) it was noted that in five species, belonging to as many families, a simple relationship, consistent within the species, subsists between the lengths of the fin spines and rays and their sequential distribution along the base of the fin. The size component of the size-position pattern is commonly the logarithm of the length, while the position component is commonly the logarithm of the natural number indicating the sequential relation, in linear series, of the radial item; this natural number series, 1,2,3,... sometimes proceeds from the initial item caudad, sometimes cephalad. Thus  $L = bN^k$  or  $L = bN'^k$ , where  $L$  = length of radial element,  $N$  = the serial number of the ray counting caudad,  $N'$  = the serial number counting cephalad, while  $b$  and  $k$  are constants. Rectification of these exponential relations, yielding  $\log L = k \log N + \log b$  and  $\log L = k \log N' + \log b$ , affords a ready visual comparison between samples of the parameters,  $k$  being represented by the slope of the resultant straight line, and  $\log b$  by its intercept on the ordinate axis. The statistical significance of the line, indicated by the value of  $t$ , can be read directly from the rectified equation, as also can be estimated values of variates it yields. In contributions following Part XIX, published a dozen years ago, numerous instances, relating to a wide range of families, have

been reported in which this logarithmic length-number relation of radial elements has been found to obtain.

In these results, figures in one or more parentheses preceding "on" specify the spines or rays, while the figures following are the natural numbers with which the radial element numbers are associated for graphing: in both cases the logarithmic values of the lengths and the serial numbers are employed. "First" (= total spinous) dorsal, {1-IV}, {IV-X}, {XI-XIV} on {1-4}, {4-10}, {11-14}; second (= rayed) dorsal, {1-4}, {4-9} on {9-6}, {6-1}; anal, {1-III} on {1-3}; and {1-3}, {3-8} on {8-6}, {6-1}; pectoral, {1-5}, {5-14} on {1-5}, {1-10}; ventral {1-4} on {1-4}; caudal, {1-3}, {3-6} on {1-3}, {3-6}; and {8-11}, {11-13} on {3-6}, {1-3}; (7th caudal ray imperfect). Data for an example of *Gnathanacanthus goetzei*, specimen (m) of present material, were reported in Part XX (1974b: 192,193).

The parameters of the rectified equations and indications of their significance and predictive reliability, are set out in table 2. Specimen (g) thus investigated proves to be not at all points typical, and, while the subsistence of a length-number relationship remains, some differences in detail are encountered in other examples; further, it would appear that a descendant section of a fin that may be regarded as constituting a section with a negative slope in an overall graph for a fin may alternatively be treated as a separate graph using inverse numerals and having a positive slope.

### Dorsal Fins

The occurrence of, as it were, a *tertium quid* interspersed between what would normally be recognized as first and second dorsal fins, the elements of which may conceivably be assigned to either of those fins, or to neither of them, constitutes a quite exceptional feature of this fish. While a first-glance assessment might accept the existence of two separate dorsal fins (the first of spines only, the second of spines and soft rays), and of these two only (an assessment explicitly made by Castelnau, with such a situation depicted in his plate), closer inspection shows the termination of the normal first dorsal is followed by several small processes, ranging from short to barely recognizable, those projecting only 1 or 2 mm terminating as fleshy knobs, barely distinguishable at sight from the smaller fleshy villi covering the general surface of the fish, but found to extend rigidly beneath the soft integument and to include concealed spines (plate 2); beyond these minor processes there are several well-developed spines, increasing in length caudad, that are fully incorporated in a common membrane with the 9-10 soft rays of the putative second dorsal.

The dorsal formulae as reported in the literature present a highly unusual (possibly unparalleled) diversity. Attention was called by Johnston to marked differences between his fish counts and those of Gunther, differences that provided the basis for his tentatively proposed name of *Holoxenus guntheri* [sic]. In the classic paper in which the identity of all three genera, *Gnathacanthus*, *Holoxenus* and *Beridia* was first recognized, Gill (1891: 702) provided a table of the radial formulae as presented by the four authors involved, and discussed some discrepancies. Some of the published reports make no typographical distinction between counts of spines and rays and some give counts in words: to facilitate comparison they are here rendered with observance of the conventional use of roman numerals for spines, arabic for rays. Published formulae include: xxi, 11 (Bleeker); viii, 10, in generic diagnosis, or vii, 10, in specific diagnosis and in plate (Castelnau); viii, iii, 10 (Gunther); xii-xiii, 9-10 (Ogilby); viii, v, 10 (Johnston); viii, v, 9 (Waite); vii-viii, iii-v, 10 (Lord & Scott 1924); vii, iii, 10-11 (Scott 1962, and later version of Scott *et al.* 1974); vii-viii, iii-iv, 9-10 (Scott 1974b); x, 10-11 (Last *et al.* 1983). Thus the combination of individual variation in fish and individual variation in observer leads to the formulae being as numerous as the sources cited. In the present sample of 14 individuals the counts are as follows: spines of first dorsal 7 (13 cases), 8 (1);

other spines, small, normally developed, 1, 4 (3 cases), 2, 4 (6), 3, 4 (4), 3, 3 (1); rays 9 (5), 10 (9); total number of elements 22 (3), 23 (10), 24 (1); cf. reported totals of 17-23 (or, disregarding Castelnau's clearly incorrect count, 19-23), with 23 as mode.

The significance of the fin structures occurring along the dorsal profile of this species is problematical; the most obvious interpretation being that they represent an otherwise conventional continuous dorsal fin (such as that in the Pataecidae, Aploactinidae, Synancejidae, some Scorpaenidae; not Triglidae) that has suffered a collapse, or even a local disjunction, near the middle of the spinous section. Such an interpretation receives support from the fact that it is possible in some cases (in view of the irregularity among the small spines, not in all) to treat (table 2) the whole spinous complement as a graphic continuum (even though the line consists of several sharply angled components). Further, the occurrence in what would be a second dorsal of 4-5 well developed spines, is in marked contrast to the pattern of 0, 1 or 2 in most species of fish. However, if such a process has taken place in a wholly continuous pataecid or aploactinid type of fin, it would be necessary to recognize it has been followed by a curious adjustment in the lengths of some spines leading to the establishment of fins comparable in general formation to independent first and second dorsals, with the spines of the descendant edge of the former and those of the ascendant edge of the latter having lengths that in a loglog plot are functions of low natural numbers, a relationship that would not be expected to be characteristic of an unmodified uninterrupted fin of *Aetapcus* or *Aploactisoma*. It is to be noted moreover that a serial number-length pattern of spines is found also in the anal, the two fins as a whole coming close to being a pair. With the interpretation of a modified single, continuous dorsal here suggested, the small structures immediately behind the present first dorsal would be accepted as vestigial: if it were shown they are rudimentary, the whole dorsal complex would appear *sui generis*.

Originating at or very close to the level of the eye the first dorsal extends to about an eye-capsule diameter beyond the operculum (not far enough back in Castelnau), the membrane continuing down and back in a concave arc from tip of last spine, usually becoming more or less obscurely continuous with the low membrane of the first low spine. The membrane as a whole exhibits a moderate degree of emargination; as an individual variation it may be straight between the spines, giving the

fin a rather curious squared-off appearance. The base ranges from 208 to 349 *TLs* units ( $\bar{x}$  294.2  $\pm$  11.26), the coefficient of variation thus being high ( $V$  14.3). The hindmost point of the fin may be level with, or somewhat in advance of or behind, that of the anal, ranging from 10 *TLs* units short of to 64 units past the level of the hypural joint. The spines are rigid, straight or, especially the first, slightly proconvex: in our material none exhibit the degree of curvature depicted by Bleeker and by Waite. They are normally wholly enveloped in thick integument, though when the tip is touched the spine is clearly felt; when exposed it is seen to taper through some distance to a needle-point. A fin margin with an arc of acute projections such as is commonly illustrated (spine points conspicuous in Waite) is purely a post-mortem feature. Scott *et al.* and Last *et al.* note the spines can inflict a painful wound, the former reporting a pricking that caused extreme pain with loss of consciousness, associated with discoloration and swelling of the hand, the swelling being still present two weeks later.

The dorsal spines regularly increase in length from first to third, exceptionally [specimens (d), (g)] to fourth. Lengths of some of these as fractions of another are noted by several writers; however, a precise specification of relative magnitudes is afforded by the relation  $\log L = bN^k$ , where  $N$  is serial number of spines {1-3}, exceptionally {1-4}. The three dorsal spine lengths as reported for the specimen dealt with in Part XIX were absolute, in millimetres. With lengths treated as millesimals of standard length, the rectified equation is  $\log L = 0.4365 \log N + 2.5267$ , giving  $r$  0.99930 ( $z$  3.979),  $t$  26.783; percentage deviation of estimated from measured lengths 0.3-1.0(0.6),  $\bar{x}$  0.68. Table 2 sets out specifications for this and for length-number relations of other fins for specimen (g), *Ls* 195 mm, one of two exceptional individuals with longest spine fourth. Mean lengths of spines {1-3} in our other material are 183.6, 244.8, 275.4 *TLs*: for the best straight line of length-number relation the slope is 0.3740, intercept 2.2671, giving  $r$  0.99617 ( $z$  3.128),  $t$  11.389; percentage deviations 0.8-2.1(1.3),  $\bar{x}$  1.39.

In the calculations for specimen (g) in table 2 the three small spines beyond the seventh spine of the patent first dorsal were treated as part of that fin. In view of the variation of the small spines from 1 to 3, in the consideration of the whole sample spines for the formal dorsal considered have been restricted to the initial seven, the descendant series thus being {4-7}. These four spines decrease regularly caudad, mean lengths (13 specimens) being 233.2, 213.2, 153.6, 91.5. Logarithmic lengths

plotted on logs {1-4} give a straight line significant at better than  $P$  0.01 ( $t$  11.154); slope 0.6914, intercept 1.9710,  $r$  0.99206 ( $z$  2.763); percentage deviations 1.7-6.2(4.6),  $\bar{x}$  3.78.

Not only are the relative lengths of the spines in the individual fish a function, as shown above, of their ordinal position in the fin, but, further, they are found to vary among individuals as a function of overall length. This relation is considered below in a section on differential growth.

The second dorsal, treated as represented by the last four spines (one specimen 3) and the 9 rays (5 cases) or 10 rays (9 cases), originates about over the vent and ends directly above, or marginally before or behind, the end of the anal, being attached to the peduncle by a short membrane, the end point of which is modally near that of the addressed ray; however, marked individual variation occurs and the backward extension may be considerable, though nothing matching the long sweep depicted in Castelneau's plate has been observed. The area of the membrane of the whole fin, shown as less than that of the anal by Bleeker and greater by Castelneau, is modally somewhat less, in several specimens somewhat greater.

The four significant spines have been considered above. The rays are all simple, rather stout basally, either essentially rectilinear or exhibiting a slightly proconvex curve that may become marked in the short terminal section extending beyond the adjacent emarginate membrane, this emargination moderate (height of arc less than, commonly half to two-thirds, base), much the same as in anal, caudal, ventral, greater than that usual in first dorsal and pectoral (somewhat greater than in Waite's figure; scarcely indicated by Bleeker). The hindmost point of the addressed fin approximates the level of the hypural joint, ranging from 2.4 *TLs* units in advance of this to about 60 behind it.

Primarily owing to the presence of some imperfect rays, measurements of the full dorsal series are available only for 7 individuals with 10 rays and 4 for those with 9; in 6, 3 of these lengths increase to fourth ray, in specimen (g), *Ls* 195, the data for which are set out in table 2, exceptionally to sixth. For the 6 individuals with fourth ray longest, rays {1-4} are specified by  $\log L = 0.2039 \log \{1-4\} + 2.4455$ ;  $r$  0.99983 ( $z$  4.864),  $t$  76.616; percentage deviation 0.1-0.2(0.2),  $\bar{x}$  0.02. For rays {5-10} on logs {1-6}, the slope of the best straight line is 0.7364, the intercept 1.9724;  $r$  0.99748 ( $z$  3.443),  $t$  28.128; percentage deviation 0.4-5.0(4.0),  $\bar{x}$  2.8. In an earlier contribution (1974b: 192) rays {5-10} of the specimen here listed as (m) were dissected into two sets, {5-7}, {8-10}, each plotted

on log {1-3}; pooled as for above sets on logs {1-6} they still show a satisfactory correlation of  $r$  0.99714 ( $z$  3.274), yielding  $t$  26.398.

#### Anal Fin

The large anal fin, opposite and subequal in size and similar in general form to the second dorsal, consists of 3 spines and 7-9 rays, modally 8, the 7 being found in one individual only in our material (only 2 spines were reported by Castelnau and by Waite; in his species description Gunther has simply "9", but in the generic diagnosis notes "three anal spines"). They are tolerably stout but normally quite invisible, wholly enclosed in thickish integument. The ranges and means of the lengths are 70-116, 90.16; 106-184, 139.24; 137-216, 176.85. The relative length, TLs, of each is inversely correlated with length of fish (see section on differential growth below).

When the logarithms of the mean spine lengths are plotted against their serial numbers, a very good straight line with  $r$  0.99967 ( $z$  4.359),  $t$  3.801 results; the slope is 0.6147, the intercept 1.9560; estimated lengths differ from measured only by 0.2-0.6(0.4),  $\bar{x}$  0.41%. For the single individuals of Part XX and of table 2 here, the slopes are 0.6153, 0.5806; intercepts 2.2340, 2.0283;  $r$  0.99969, 0.99784 ( $z$  4.400, 3.414),  $t$  40.158, 15.191; percentage deviations 0.4-1.0(0.6),  $\bar{x}$  0.66; 0.9-2.5(1.9),  $\bar{x}$  1.75.

The simple anal rays are similar in character to the dorsal rays and in general subequal in size to them. They modally increase in length to the fourth (two exceptions, one being reported in table 2, only to third). For seven sets of fins with eight rays the logarithmic lengths of {1-4} and of {8-5}, each on logs {1-4} yield highly significant straight lines. Slopes are 0.2138, 0.7104; intercepts 2.3798, 2.0435;  $r$  0.99947, 0.99900 ( $z$  4.118, 3.805),  $t$  43.611, 31.611; percentage deviation of estimated from measured lengths 0.0-0.6(0.4),  $\bar{x}$  0.29, 0.1-2.3(2.1),  $\bar{x}$  1.32.

#### Pectoral Fin

The pectoral fin is large (as pointed out by Waite, shown unduly small by Bleeker), extending when adpressed from the level of the vent to below the first anal ray, modally about to anal origin. When fully expanded it presents a broadly rounded fan, its lateral extent up to four-fifths its longitudinal, subequal to postorbital head, with the degree of emargination of the membrane of the same order as that found in the dorsal fins; the margin is depicted by Bleeker as entire. It originates shortly behind pelvic origin at 349-364 ( $\bar{x}$  390.4  $\pm$  7.560) permillages of standard length. The characteristic ray count is 11; in one specimen (b) 11 in one

fin, 10 in other, in one specimen (d), 12 in both fins, and 14 in (g), ray lengths of all fins of which are recorded in table 2. All rays (like those of the other fins) are simple, Castelnau's "one upper branched ray", figure showing division near middle of length, presumably being a misinterpretation of the fact that the two upper rays are either, as described by Waite for his individual, conjoined at the base or are at least closely apposed there. It has been observed (Scott 1974b: 190) "the partial concealment of the rays by thick membrane may lead to there being the appearance of a single ray bifurcated in its distal two-thirds or so". The rays are wholly enclosed in thick membrane, the tip differing notably from the more or less pointed form found in the vertical fins (including the caudal) in being rounded or distinctly spatulate, the short distal expansion in the latter case often with a minute medial cleft or notch; the whole with at times something of a ruffled effect. The broad fin base, its width subequal to the direct distance of the eye from the upper lip, is set low, its distance from the ventral profile below it one-third its base or a little more.

The pectoral rays modally increase to the fifth, the fourth and sixth often not greatly shorter. From table 2 it is seen that the exceptionally large total of 14 rays in the specimen there dealt with is divisible into two sets, the initial {1-5} and the following {5-14}, with the sets intersecting, such that on a loglog plot on {1-5} and {5-10}, second set with rays counted cephalad ( $N'$ ), yield highly significant straight lines — a significance higher than that for {1-5} being found for {1-4}. To provide data for a specimen with the modal complement of 11 rays, comparable equations have been calculated for comparable sets in specimen (n),  $L_s$  235, the second set here comprising only rays {5-11}, both sets, as before, being intersecting. For {1-5}  $\log L = 0.2383 \log N + 2.3803$ ;  $r$  0.99523 ( $z$  3.012),  $t$  17.665; for {5-11}  $\log L = 0.4395 \log N' + 2.1837$ ;  $r$  0.99828 ( $z$  3.051),  $t$  38.078. Percentage deviations of estimated from measured lengths are 0.7-2.2(1.3),  $\bar{x}$  1.22; 0.4-2.6(2.5),  $\bar{x}$  1.41. Lengths (14 specimens) of first ray are 176 (next lowest 226)-310,  $\bar{x}$  267.8  $\pm$  10.522; of last ray 162-248,  $\bar{x}$  209.1  $\pm$  8.451, of longest ray 285-407,  $\bar{x}$  353.6  $\pm$  8.716, the last measurement, with  $V$  9.2, showing the least variation (cf. 14.7, 14.9). Relative (TLs) ray lengths of individuals show some indication of being inversely correlated with size of fish (see further, below).

#### Ventral Fin

The large ventral, with 1 spine and 5 rays, is inserted at 264-393, ( $\bar{x}$  320.7  $\pm$  8.125) TLs of the

length, the mean value being 1.22 times the mean value for length to pectoral insertion. The fin as depicted by Bleeker is much too small; in Castelnau's plate only four rays are evident, though the text correctly gives five. The fin extends, as reported by Ogilby, from just before the vent to just beyond the origin of the anal, its hindmost point normally being slightly in advance of that of the pectoral. A striking feature of the ventral (reported among early observers only by Gunther, and not mentioned in the recent Tasmanian catalogue by Last *et al.*), without parallel in other members of the suborder Scorpaenoidei (no ventrals in Pataecidae), is the presence of an extension of the fin membrane behind the postaxial ray, joining the fin to the body and extending as a variably developed slip about to the level of the vent and continuing as a ridge, becoming progressively obsolescent, about to the level of the anal origin; the degree of development subject to some individual variation but with the anterior portion always clearly evident. The nature and size of the fin elements have received some notice in the literature. Before these are looked at it seems expedient to set out the data provided by the present material.

For 12 specimens the ranges and means of the lengths of the spine and rays are as follows, the ray taken as the first being that furthest from the spine (nearest to mediolateral line of fish; postaxial), in accordance with the convention proposed in Part XIX (1974a: 238): spine 143-192 ( $\bar{x}$  166.3  $\pm$  6.411), ray 5224-308 ( $\bar{x}$  265.9  $\pm$  10.202), ray 4238-333 ( $\bar{x}$  283.9  $\pm$  10.588), ray 3219-321 ( $\bar{x}$  271.5  $\pm$  9.582), ray 2200-292 ( $\bar{x}$  224.7  $\pm$  11.984), ray 1126-262 ( $\bar{x}$  156.3  $\pm$  13.604), the minimum value being provided in each instance by specimen (k), *Ls* 210. In an excellent account of two specimens, length (apparently total length) 270, 280 mm, part of a Tasmanian collection later destroyed by an accident, Ogilby reported the spine as 1 2/3 to 2 in the length of the longest ray. In good agreement the ratio for 12 specimens is 1.42-1.79 ( $\bar{x}$  1.65  $\pm$  0.035). He stated "the margin of the fin is either rounded or subacuminate owing to the prolongation of the two outer rays". As is seen from the figures above for our material these two rays, though the longest elements of the fin, do not on the average greatly exceed the adjacent ray (in our notation the third), ray 4 may in individual cases be one-seventh longer than ray 3. Waite's statement that the second and third rays are equal to the fourth and fifth is not valid for our material. Waite further noted the stout spine (completely concealed in membrane) "is equal to the second of the anal". In our material the spine of the ventral is larger on the average than the second anal spine

(166.3, 139.2); however the ranges overlap (143-192, 106-184) and in several cases the lengths are close to equality.

It has been reported in these contributions that in a wide range of species it is found that in a loglog plot the lengths of rays {1-4} yield a statistically significant straight line on their serial numbers. Using mean lengths for 12 fish the equation is  $\log L = 0.4562 \log N + 2.2026$ ;  $r$  0.99231 ( $z$  2.773),  $t$  13.767; percentage deviations 2.0-3.7(3.1),  $\bar{x}$  2.84. A notably different slope of 0.1683 is found (table 2) for specimen (g). For the individual noted in Part XX (1974b), specimen (m) of present series, with dimensions (there cited in millimetres) expressed as *TLS*, the equation is  $\log L = 3427 \log N + 2.2224$ ;  $r$  0.99915 ( $z$  3.884),  $t$  34.371; percentage deviations 0.0-1.2(0.7),  $\bar{x}$  0.62.

#### Caudal Fin

The well developed caudal resembles all the other fins in having all the rays simple and wholly enclosed in membrane. In 12 individuals the rays number 12(6), 13(2), 14(4): the number reported by most writers is 12, though Last *et al.* give 10-12. It ranges from barely to moderately convex, never among the present specimens quite reaching the degree of convexity shown in the figure of the type, and differing further in the junction of the distal with the lateral profiles being not obviously continuous. The fin presents two distinct moieties, the innermost rays of which are separated basally by an interval from two to three times as great as that between each of them and the next outward ray. Though the overall hind margin is close to symmetrical, the short outer rays, which are not involved in the main sweep of that border, differ in length, that of the uppermost ranging from 152 to 291 ( $\bar{x}$  234.3  $\pm$  12.62), that of the lowermost from 119 to 292 ( $\bar{x}$  180.8  $\pm$  16.35). Both these dimensions fall well short of that of the longest ray, 349.1  $\pm$  10.33, this length being achieved by one or both of the innermost rays of the moiety. With length to base of caudal (*Ls*) taken as 1 000, total length is 1 250-1 373 ( $\bar{x}$  1 324.3  $\pm$  8.76); the set being compact with *V* 2.6. Ogilby's statement that the fin is subequal to the pectoral is valid for most of our sample, being inapplicable, however, to all the smaller specimens, the smallest individual having its pectoral half as long again as its caudal. His ratios for fin in total length are 3 5/9-3 2/3: our wider range is 2.8-5.0, with mean 4.0  $\pm$  0.140. The fin appears to be noticeably flexuous, the color photograph of a living fish in Edgar *et al.* apparently depicting the lower portion as sweeping in front of the rest.

In the specimen from Bass Strait (g), *Ls* 195, a difference in preservation procedure has led to an end result quite different from that found in the other examples, the thick opaque integument enveloping the rays in this fin having become sufficiently transparent for the transverse septa of the fin rays to become readily visible. These are set exceptionally close together, with, in a ray 1 mm in diameter, 25-30 in 10 mm of its length. Though they are not so evident in rays of the other fins, it is possible to determine a similar approximation obtains here also.

### Integument

The soft velvety skin that suggests the vernacular name of "velvetfish" (sometimes rendered as two words), or, in distinction from the locally occurring aploactinid velvetfish *Aploactisoma milesii* (Richardson, 1850), red velvetfish, envelops the whole fish including the fins, and, as pointed out by Waite, even the branchiostegal membrane and its rays. It is highly pliable and is capable of being gathered up to some extent between the fingers, exhibiting, however, less general looseness than is often encountered in preserved examples of the pataecid *Aetapcus*. It bears everywhere minute closely set soft villi which cover the lips, continuing briefly into the buccal cavity, and extend over the whole of the ocular capsule other than the actual eyeball; as noted above a small patch intrudes beneath the upper angle of the operculum (fig. 1). Upon superficial inspection these all appear to be closely similar; on more careful examination they are found to exhibit some variety of form, the outline most commonly circular, sometimes elliptical, sometimes with an otherwise circular circumference briefly rectilinear, the general form either dome-like or mammiform, at times with a distinct mammillary termination. On the flank of an average-sized fish the larger villi have a basal diameter of a millimetre or a little less but there is marked variation in size, scattered among these being many only half as large or less, while examination with a lens reveals between the bases of the others what may be described as a secondary series with a diameter of about 0.1-0.2 mm. All sizes are distributed irregularly, with a modal number of the larger series on most parts of the fish in the vicinity of 70 cm<sup>2</sup>, this number being double or more on parts of the head, the villi there being smaller than elsewhere and all of one size, there being among them no small secondary elements. Though closely set, in some areas at varying in others at tolerably even distances apart, they are seldom, if ever, contiguous.

Though on the head, trunk and tail the villi are normally scattered irregularly, on the left side of one individual examined (barely on the right) in an area above the middle of the anal base, extending halfway towards the dorsal profile, they form more or less definite subvertical lines. In marked contrast to the usual condition on the body, on the fins they are generally, though not invariably, in definite straight lines, 4-5 such lines running along a pectoral ray, round about 15 on the membrane between adjacent spines of first dorsal (plate 3). These lines may extend the whole distance between the proximal and distal borders, in which case they are subparallel to the spine or ray, or they may become apparent only in the outer half or more of the fin, then running somewhat obliquely upward and backward. At times the intervals between successive villi are elevated, resulting in a continuous ridge surmounted by closely set projections. This linear disposition on the fins is not clearly evident in published figures and appears not to have attracted notice in the literature.

### Coloration

The coloration has been reported by most early authors as being uniform, though of differing hues ("corpore pinnisque fuscente-rubris immaculatis", Bleeker (1855); "entirely of a beautiful orange colour", Castelnau (1878); "head and body scarlet, paler below", with fins mainly similar but darker, Waite (1921); "rich red or reddish purple", Lord & Scott (1924); "reddish, sometimes with slight orange tinge", Scott *et al.* (1974). Departures from uniform coloration are noted by Johnston, "sometimes more or less marbled with yellow"; the only available color photograph, that of Edgar *et al.* (1982), exhibits the pale yellow reticulation stated by Last *et al.* often to be found on the sides. Of the type of his *Holoxenus cutaneus* Gunther wrote, "uniform whitish (in spirits)". This is applicable to all our material save specimen (g), which was left unprocessed for some time before being placed in alcohol: it is largely orange, somewhat dusky in parts, with the anterior portion of the head yellowish; the fins largely greenish, the pectoral somewhat yellowish green, the ventral and pectoral with some deep red, the vertical fins with yellow or orange longitudinal stripes. Coloration of another specimen (present e) examined shortly after capture was reported in detail by Scott (1974b). Castelnau noted of the holotype of his *Beridia flava*, "Having received it in a dry state, I put it in warm water to extend parts of the fins; the water became almost immediately of the same beautiful yellow colour of the fish". The color is

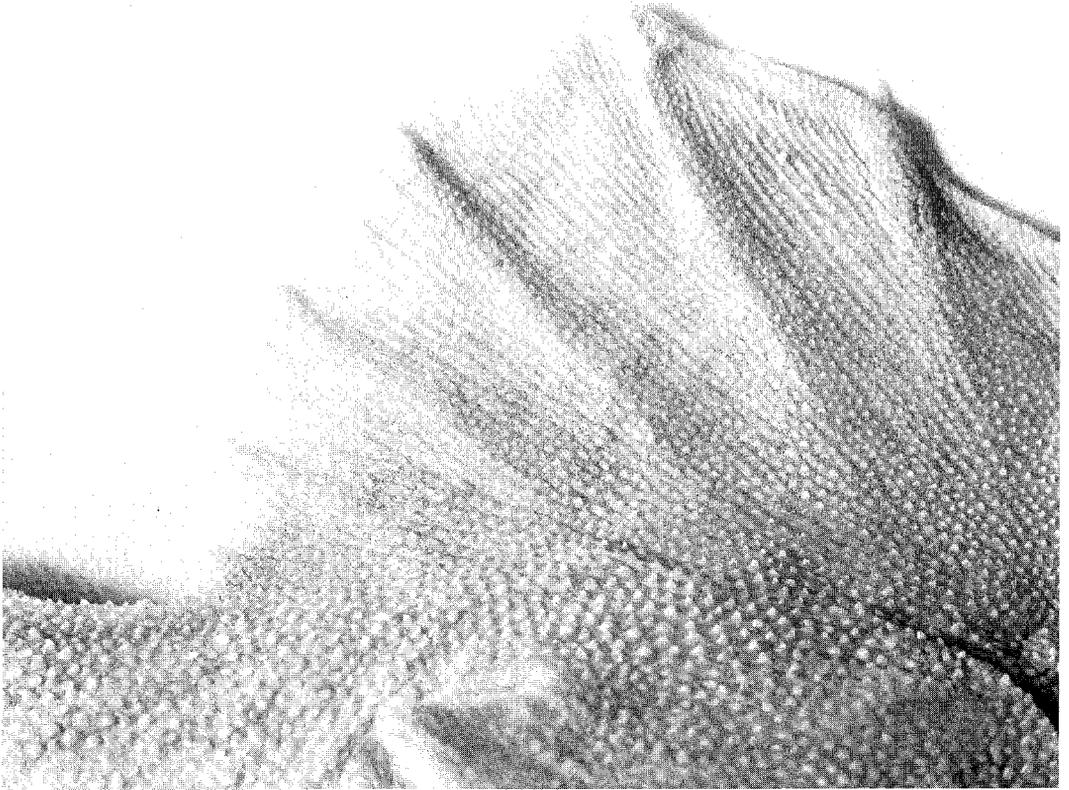


PLATE 3 — *Gnathanacanthus goetzeei* Bleeker, 1855. Part of first dorsal and of head, showing disposition of dermal papillae; arranged in parallel

lines on the former, irregularly dispersed on the latter. Photo: M.A. Bartkevicius.

extracted also by alcohol; if the fish is contained in a white plastic dish the walls take a stain very difficult to remove. Noting the reports on coloration and the evidence that the pigments are soluble, Gill remarked that "discrepancies as to the shade of colour are of little account".

### Relative Growth

#### General

With authors having in general only one of two specimens [Scott (1874b) five] at their disposal, no study of differential growth throughout ontogeny has hitherto been attempted. With 11 of the 15 individuals covering only the restricted standard length range of 172-218 mm, showing the small coefficient of variation of 6.5, the present material is by no means ideally adapted for the investigation of relative growth. Two approaches to the problem are here adopted. In cases in which the correlation of the relevant item with  $L_s$  obtains, the whole sample (or so much of it as is available, allowing for

damaged parts) is used for the determination of statistical significance by calculation of  $t$ . The presence of two small individuals of  $L_s$  125, 155 and of two large individuals of  $L_s$  235, 256, with each set tolerably well distanced from the rest of the series, suggests the comparison of these two pairs, the means of which are here denoted by L and H [low and high]. With this comparison there is considered a further one, the direct comparison of the mean of a subsample LL, consisting of 7 specimens of  $L_s$  125-195, with the mean of subsample HH, consisting of 5 specimens of  $L_s$  200-256. In general it is not appropriate to divide the material into two subsamples with subequal numbers of variates and proceed to the standard test for the difference of small samples (Simpson & Roe 1939): with the subsample made of reasonable size by the inclusion of the two extreme values with the remaining five or six intermediate values the magnitudes of  $d_1^2$  and  $d_2^2$  will tend to lead to a very large denominator, and hence to an unacceptably

low measure of significance. While the subsample procedure here adopted cannot be counted on to provide a formally significant test of difference, nevertheless a marked divergence between L and H, particularly if supported by a discrepancy of like sense between LL and HH, may well point to the more or less probable existence of correlation.

#### Fin Origins and Terminations

When lengths to fin origins and terminations as found in the largest two specimens, *Ls* 235, 256 mm, are plotted against those found in the smallest two, *Ls* 125, 155, two straight lines are formed. One, involving the first and second dorsal and the pectoral and ventral origins, together with the termination of the first dorsal, has a slope of 1.33, intercept -61.49, exhibiting a correlation of  $r$  0.97778 ( $z$  2.244) representing  $t$  13.193 [in the calculation of the equation specimen (a) was paired with (n), (b) with (o)]. Caudad of the first dorsal origin, where the mean value for (a), (b) is 164 and that for (n), (o) 148.5, the lengths to origins and terminations of the fins exceed those to the dorsal (by 10-105,  $\bar{x}$  48.5 *TLs* units); the relative lengths to accepted morphological loci within this domain thus increasing with the length of the fish. To the contrary in the second line with slope less than unity (0.855), the values for the smaller fish are in excess of those for the larger; this line has  $r$  0.99713 ( $z$  3.432);  $t$  28.593. Hence on these findings the anterior portion of the fish increases, while the posterior decreases with age. However, it is to be noted that extrapolation of the second line to include length to head yields the very high correlation of  $r$  0.99887 ( $z$  3.738),  $t$  58.573, with the formally possible consequence that the relative growth of the head stands apart from that of the insertions and terminations of the anterior fins, being linked with those located in the posterior part of the body.

#### Fin Spines and Rays

The lengths of the radial elements of the fins as a function of the length of the fish have been examined for all fins. In each instance the sum of a set of rays is dealt with, this sum being that of all elements of the fin (as with dorsal rays), of the elements of a distinct section of a fin (spines of ascending edge of first dorsal), of a selected ray (largest) or of a selected group of rays (first, last, longest). The striking fact emerges that in every case the value of the correlation coefficient of spine or ray length with standard length is negative. In seven instances the  $t$  value represents formal statistical significance at  $P$  0.05 or better. These are specified in table 3. Other negative correlations

that do not yield such a definitive result by virtue of differences between L and H and between LL and HH suggest probable correlation are noted below, numerals in round brackets noting the number of specimens involved when this falls short of the full complement. For each set there are given  $r$  ( $z$ );  $t$ ; L, H; LL, HH in that sequence. Dorsal spines {4-7} (12): -0.4508 (-0.486); 2.117; 775, 622, 784(6), 658. Dorsal rays {1-10} (7): -0.7305 (-0.875); 2.214; 2774, 2642(1); 2730(3), 2593(4). Anal rays {1-8} (7): -0.4341 (-0.465); 1.077; 2012, 1754(1); 2025(4), 1890(3). Anal rays {first, last longest} (12, omitting (b)): -0.5376 (-0.601); 2016, 756(1), 614(1); 730(6), 668(6). Pelvic {spine, 5 rays} (12): -0.3519 (-0.368); 1.187; 1398, 948(1); 1466(5), 1309(7). Caudal rays {first, last, longest} (13): -0.2542 (-0.260); 0.872; 678, 620; 798(5), 712.

#### Other Correlated Features

Some correlations involving features other than those dealt with above are here noted. Where the magnitude of  $r$  is not sufficient to denote formal significance, as is mostly the case, only the values of L, H, LL, HH are cited, and these only when the discrepancies between L and H and that between LL and HH are of the same sense: dimensions as *TLs*.

Head 418, 378; 411, 401. Trunk in *Ls* 129, 183; 123(6) 173 (rate of increase as measured by slope of best straight line 0.71,  $t$  2.617, better than  $P$  0.05). Snout 158, 114; 131, 123 (in head L 2.65, H 3.32, but LL, HH marginally inconsistent). Interorbital 85.0, 91.5; 76.9, 78.5 (in head 4.98, 4.14; 5.37, 5.18). Ocular capsule in head 6.5, 6.1; 6.5, 6.3. Eyeball in head 12.3, 11.7; 12.9, 12.2. Depth, as represented by sum of depths at front of eye, back of eye, operculum, vent 1454, 1238; 1427, 1376 (rate of decrease as measured by slope of best straight line -1.63;  $t$ , at 2.021, not greatly below  $P$  0.05 value of 2.160). Maximum depth 423, 362; 404, 401 (slope -0.48; 1.782, just better than that for  $P$  0.10). Width, as represented by sum of widths at same points as for depth 696, 573; 657(6), 601 (slope -1.12,  $t$  3.457, better than  $P$  0.01).

Thus there are indications that with increasing size of fish direct dimensions that decrease include head, snout, summed depths at several points, maximum depth, summed width at several points; with increases found in interorbital, trunk. The three ratios examined, ocular capsule in head, eyeball in head, interorbital in head, all show decreases in magnitude.

#### Lengths to Opercular Border, Vent, Hypural Joint

It has been found in these contributions for a number of species that in a loglog plot the lengths of three primary regions of head, head plus trunk,

**TABLE 3**  
***Gnathanacanthus goetzei* Bleeker, 1855**

Relative growth: decrease in length of fin spines and rays (recorded as millesimals of standard length) with increase in length of fish. Data from 15 Tasmanian examples (figure in round brackets notes number of specimens involved if fewer than full complement). For nature and specification of subsamples see text.

Variate	Correlation		<i>t</i>	Regression		Subsample means			
	<i>r</i>	<i>z</i>		Slope	Intercept	L (a), (b)	H (n), (o)	LL (a)-(g)	HH (h)-(o)
A	-0.6678	-0.895	3.095	-1.770	1053.3	613	527	773	652
B	-0.6722	-0.875	3.011	-2.113	993.8	665	467	668(7)	507
C	-0.7640	-1.006	3.926	-1.978	729.0	517(1)	321	462(5)	381
D	-0.8640	-1.154	3.433	-5.4551	3104	2380(1)	1754(1)	2204(3)	1870(3)
E	-0.6655	-0.803	2.957	-0.8904	490.9	661	644	707	668(6)
F	-0.7355	-0.996	3.460	-1.0736	530	756(1)	644	730(6)	668(6)
G	-0.6973	-0.862	3.370	-1.6586	1160	860	730	880(6)	802

Variate A: Dorsal spines {1-3}  
 B: Dorsal spines {last four} (14)  
 C: Anal spines {1-4} (13)  
 D: Anal rays {1-8} (6, omitting (b))  
 E: Anal ray, longest (13)  
 F: Anal ray, longest (12, omitting (b))  
 G: Pectoral rays {first,last,longest} (14)

head plus trunk plus tail are linear on three integers of which the first is 1, second 2, the third a number not exceeding 10, most commonly 3. Here the integer set is {1, 2, 10}. In the present sample no such relation could be looked for as holding for each individual fish, inasmuch as relative head length decreases, while relative trunk length increases. However, plotting the mean values is found to yield a statistically significant straight line ( $t$  16.222), with equation  $\log L = 0.3855 \log N + 2.6186$ , where  $L = \{\text{length of head, length to vent, standard length}\}$  and  $N = \{1, 2, 10\}$ , successive members of the length set being associated with successive members of the numeral set. The percentage variation of the estimated lengths from the given lengths 406.5, 560.3, 1 000 is 1.0-3.1(2.4),  $\bar{x}$  1.81.

#### Depth, Width

##### General

The maximum depth ranges from 340 to 450 *TLs*, with a mean of  $404.0 \pm 7.76$ , representing 2.9-2.2, mean 2.48 in the standard length (Waite, 2.6; Ogilby  $3 \frac{1}{3}$  to  $3 \frac{2}{3}$  in total length). The range and the mean are very similar to those for the length of the head, namely 359-460,  $405.6 \pm 6.80$  (Bleeker, "altitudine capitis  $1 \frac{1}{3}$ ; circiter in ejus

longitudine"; Ogilby, "depth of head below the first dorsal spine  $1 \frac{1}{5}$  to  $1 \frac{1}{4}$ " in head length; Waite depth of body 2.6 in fish length). The mean depth is rather less than the mean pectoral length (last-named notably short in Bleeker's illustration). Largely as the result of genuine individual variation, but perhaps somewhat influenced by the history of preservation, its location may be at the opercular border (5 specimens), at the vent (4), or somewhat in advance of the level of opercular border; however, differences of magnitude among the three locations are in general small. The depth of the caudal peduncle, like its length, is moderate, the minimum depth showing a range of 79-104,  $\bar{x}$   $88.9 \pm 1.64$ . The marked increase in depth at base of caudal rays has already been noted. While measurements of depth recorded in diagnoses and descriptions are customarily confined to overall maximum and minimum and of caudal peduncle, useful supplementary information is provided by measurements made at selected morphological loci. In these contributions data are usually provided for the depth at the level of front of eye, back of eye, opercular margin and vent; this procedure is observed here. Depth at front of eye ranges from about one-fifth to somewhat more than one-third of the standard length, with range 219-360 *TLs*,  $\bar{x}$   $293.5 \pm 9.00$ . In our

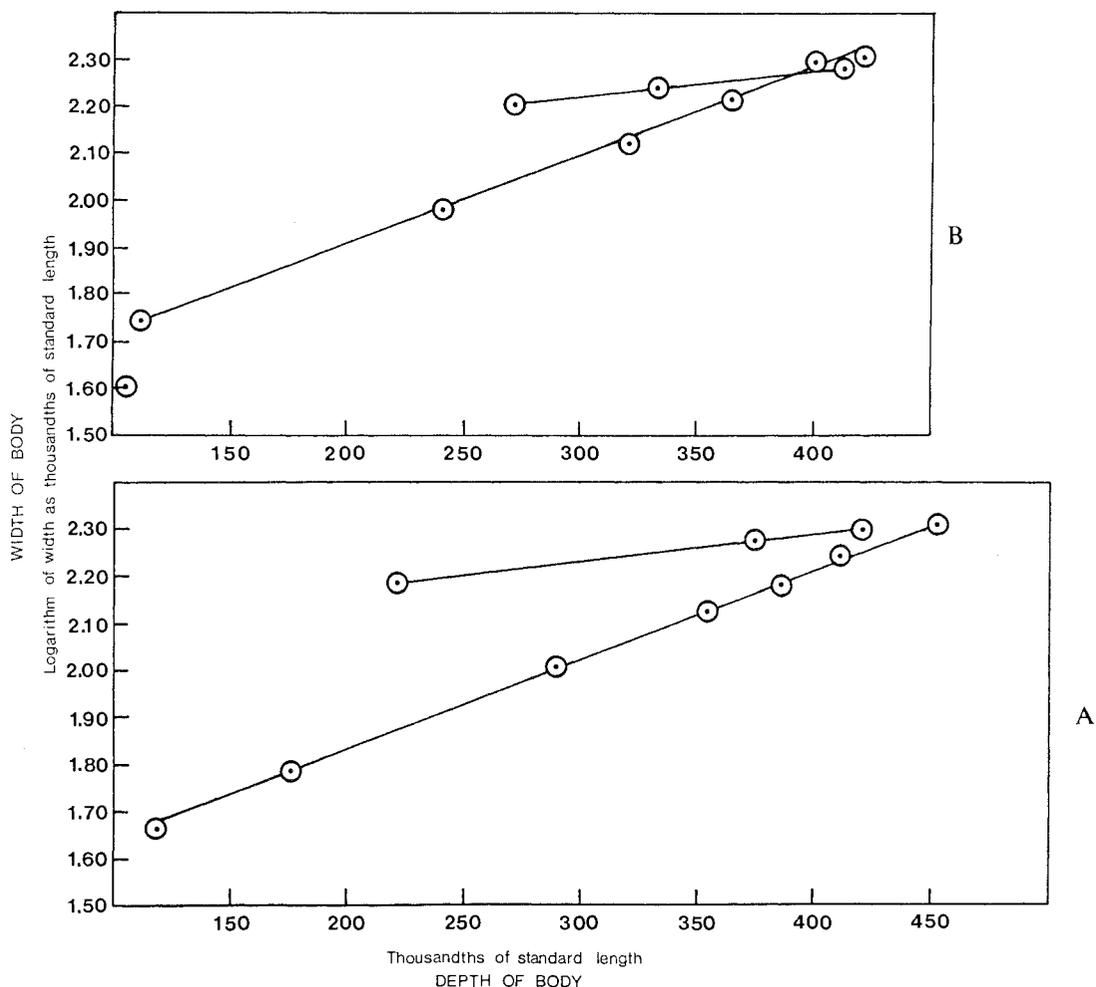


FIG. 3 — *Gnathanacanthus goetzeei* Bleeker, 1855. Depth-width relationship: ten measurements of width taken at equal intervals between most advanced point and level of hypural joint plotted

against ten measurements of depth at the same points. A, specimen 201 mm in standard length; B, specimen 256 mm in standard length.

material it exhibits a distinctly higher coefficient of variation, namely 11.9, compared with 7.7, 7.3, 6.9, 7.4, 7.2 for depths at the other points of measurement proceeding caudad. In proceeding backward through the short distance to the hind border of the eye the mean height increases to 1.2 that of the front of the eye; 311-401,  $\bar{x}$  346.6  $\pm$  6.88. At the opercular border it has increased to 1.4 the first measurement; 336-433,  $\bar{x}$  396.6  $\pm$  7.43, range and mean here differing only slightly from those at vent, 336-419,  $\bar{x}$  382.2  $\pm$  6.84. Variation of relative depth with size of fish has been noted above in the section on relative growth. Both head and body are

notably compressed, a feature noted in all reports. As is commonly the case the compression is associated with a general approximation to flatness; the impression of rotundity given by shading in Castelnau's plate having been criticized by Waite. The width at the front of the eye (121-168,  $\bar{x}$  147.1  $\pm$  3.63) increases slightly at the back of the eye (143-194,  $\bar{x}$  151.8  $\pm$  9.49) and more markedly at the level of the opercular margin (143-216,  $\bar{x}$  182.1  $\pm$  6.03), the last specification being the equivalent of an in-length specification of 7.0-4.6, mean 5.49, and an in-head specification of 2.1-2.5, mean 2.23 (Ogilby  $2\frac{2}{3}$  to  $2\frac{3}{4}$ ). Behind this point it exhibits a

**TABLE 4**  
***Gnathanacanthus goetzei* Bleeker, 1855**

Depth and width measured at ten equidistant points along anteroposterior axis of fish of three specimens, (i), (n), (o), of standard length 201, 235, 256 mm; dimensions as millesimals of standard length. For each of the two decile sets  $D = k \log W$  (for parameters see text).

Specimen	Decile set	Depth		Width		Estimated width		Percentage deviation of estimated from measured width				
		Range	Mean	Range	Mean	Range	Mean	Range	Mean			
(i)	{1-3}	221	374	420	154	190	200	154	189	201	0.1-0.5 (0.4)	0.32
		451	410	385	205	174	154	207	173	155		
	354	285	174	133	103	62	135	99	61			
	118				48		47					
(n)	{1-3}	247	323	366	149	162	170	149	162	170	0.1-0.2 (0.2)	0.16
		374	332	311	128	106	98	126	107	98		
	277	157	85	85	55	43	87	55	42			
	115				47		47					
(o)	{1-3}	272	332	412	160	176	192	161	175	193	0.4-0.8 (0.4)	0.53
	{4-9}	420	400	364	200	180	164	200	184	159	0.1-3.0 (2.5)	1.53
		320	240	112	132	96	56	130	95	56		

progressive decrease, to become at the vent only four-fifths value at the front of the eye (102-159,  $\bar{x}$  118.4  $\pm$  10.87). At the four points mentioned the depth relative to the width increases from first (1.99) to second (2.28), decreases to third (2.18) and increases to fourth (3.23). The relation of depth and width considered throughout the length of the first exhibits a precise and interesting pattern discussed in the immediately following section.

#### Depth-Width Relationship

When 10 measurements of depth and 10 of width were taken at equal intervals between most advanced point of snout and level of hypural joint in specimen (i), *Ls* 201 mm, the and widths were plotted against the corresponding depths (both as millesimals of standard length; the width logarithmic) there resulted the graph shown in fig. 3a. To permit the comparison with graphs for other specimens measurements made in millimetres have in all cases been rendered as millesimals of standard length. It will be seen that there the graph comprises two lines, the upper connecting deciles 1, 2, 3 (from the left to right), the lower connecting deciles 4-10 (from right to left). Extrapolation of the upper line beyond decile 3 comes close to junction with the lower line at 4; indeed, when the rectification noted below is made the line for deciles {1-4} shows statistical significance at  $t$  21.102. While not

invariably demonstrable at formally significant levels, conjunction of the two lines would appear clearly to be the norm.

In specimen (i) the equation for the decile set {1-3} is  $\log W = 0.0005739 D + 2.0613$ ; with  $r$  0.9987 ( $z$  3.670), significant at  $t$  19.610. For the set {10-4} the parameters are 0.001929, 1.4470; with  $r$  0.9994 ( $z$  4.077),  $t$  65.914. If the extrapolation beyond 3 to 4 is made, thus linking the two segments, the parameters for {1-4} become 0.0005530, 2.0668;  $r$  0.9978 ( $z$  3.400),  $t$  21.102.

Apart from an anomaly at times involving deciles 9 and 10, apparently occasioned by the fact that a small pad-like structure, resulting in a brief local increase in width, that may be or (a post-mortem condition?) may not be developed on either side in the region of locally extended depth at the hypural, a similar two-line graph is yielded by other specimens. For specimens (n) and (o), *Ls* 235, 256, the slopes and intercepts for the deciles {1-3} are 0.0004842, 0.0005635 and 2.0551, 2.0527; for the lower line [deciles {9-4} only in (o)] 0.001638, 0.001789 and 1.4844, 1.5509. For (n) the correlation coefficients are  $r$  0.9995 ( $z$  4.195), 0.9996 ( $z$  4.278); for (o) 0.9971 ( $z$  3.274) 0.9993 ( $z$  3.966);  $t$  values are 33.168, 80.609; 19.610, 65.914. In specimen (n), *Ls* 235, plotting of width and depths as millesimals arithmetically yields two upwardly concave arcs as also in (i), in the largest of the three examples

examined, (o), *Ls* 256, the upper arc is upwardly convex — a condition encountered in *Pseudaphritis bursinus* (Cuvier, 1830) and previously illustrated (Scott 1982, fig. 8a). The graph for width and depth of specimen (o) is presented here as figure 3b.

Decile measurements of depth and width for these three individuals are recorded, in two sets for each, in table 4, together with estimates of width as given by the relevant regression equations. To obviate the recording of two (closely similar) values for decile 4 that would result from calculations for both the sets {1-3} and {1-4} only those yielded by the former are noted.

This precise and interesting relation subsisting between width and depth is not here recognized for the first time, a two-arc sublenticular curve having previously been reported (1982: 210, figs 8, 9) for the bovicthyid *Pseudaphritis bursinus* (Cuvier, 1830) and having earlier been encountered in an unpublished study of a scombrid, *Thunnus maccoyii* Castelnau, 1872. As is the case here, the decile sets involved are {1-3}, {10-4}, the arithmetic curve for the former, however, there being upwardly convex instead of upwardly concave. It would seem probable this arithlog formulation of depth-width represents the specification of some profound morphological significance (presumably with hydrodynamic implications) in these fish; and might well be found to be applicable, with appropriate parametric adjustments, conceivably associated with the existence of decile sets other than the present two, to other species as yet unexamined.

### General Form

In the subjoined account recorded dimensions are in general derived from all 15 specimens listed above; in instances in which such is not the case the number of examples involved is noted in round brackets. Except where otherwise indicated linear dimensions are given as thousandths of standard length, *TLs*.

### Lateral Aspect

While the depth is less at the posterior end than at the anterior, the general outline is far removed from the conventional backwardly tapering fish form, being perhaps most appropriately characterized as comprising a subquadrangular trunk, flanked by a subtriangular head and (discounting the caudal peduncle) a subtriangular tail of more or less equal dimensions. The approximation of the dorsal and ventral profiles between the dorsal and anal fins is such that in 11 individuals the depth at the end of the head never exceeds 1.1 that at the end of the trunk, while in one example

these dimensions are equal and in three the posterior depth is greater than (1.1, 1.1, 1.01) the anterior. The resultant "chunkiness" that characterizes the fish is better depicted in Bleeker's plate and in Mrs Meredith's painting (Lord & Scott 1924) than in the illustration by Waite, in which the backwardly downward slope between level of eye and level of beginning of soft-rayed dorsal is noticeably over-emphasized, and in that by Castelnau, which shows an exaggerated elevation of a short section of the profile above the eye, a region actually barely above, or even slightly below, the profile further back close to the level of pectoral insertion. In Mrs Meredith's painting and in the photograph by Edgar *et al.*, the body margins are largely obscured by the outspread fins.

Between the upper lip and the first dorsal spine the profile is subject to considerable individual variation, ranging between a complex sequence comprising an inferior short concave segment, a longer pronouncedly convex one ending near the level of the upper rim of the orbit, a longer less deep concavity and a short terminal convexity before the base of the spine (pattern essentially as in Bleeker's figure), and a simple virtually even concave sweep (seldom, however, as deep as in Waite's figure); some individuals present a continuous line close to linear. The modal overall angle of the forehead ranges from 55°, through a modal value of about 50° to a minimum of close to 40°, this last value characterizing the figures of Bleeker, Castelnau and Waite. Caudad of this the profile extends, as already noted, more or less straight to, or past, the origin of the second dorsal, thereafter continuing rather strongly convexly down to the termination of the fin, about on a horizontal level with the middle of the eye (too low in Waite). The superior border of the caudal peduncle is distinctly concave, ascending noticeably towards the insertion of the uppermost caudal ray.

The inferior profile back to the origin of the ventral fin descends about two-thirds as much as the dorsal profile ascends through the same horizontal distance, being distinguishable, though not trenchantly, into two arcs, the shorter anterior ending near the level of the end of the isthmus, or, by virtue of the downward expansion of the lowest branchiostegal ray, somewhat behind this. The belly is virtually straight (see Bleeker; Waite's figure suggests a concave margin). From the vent, or from the adjacent first anal spine, an even convex sweep extends to anal termination, its level here horizontal with the angle of the gape. The inferior margin of the caudal peduncle is symmetrical with the superior margin, with again a noticeable

curve to meet the relevant caudal ray. The depth at the level of the hypural joint is 1.1-1.5,  $\bar{x}$  1.30  $\pm$  0.032 times (14 specimens) the minimum depth of the peduncle at its middle.

#### Ventral Aspect

The nature of the ventral surface in the region of the isthmus, characterized by the occurrence in Gnathanacanthidae of an intermandibular pad not found in other families of the suborder has already been described and is illustrated in figure 2. From behind the rounded snout and the moderately outwardly sloping outline of the remainder of the head, the ventral surface back to the level of the vent comes close to being rectangular, about twice as long as wide. From the vent caudad the outline tapers strongly, decreasing at the caudal peduncle to about half its initial width, the borders being virtually linear. The head and trunk, particularly the latter, are notably flattened beneath, while in the tail the lateral surfaces descend to become more or less rounded off adjacent to the anal base and on the caudal peduncle. The vent commonly takes the form of a moderate-sized opening, typically circular but at times showing some tendency towards ellipticity, the long axis anteroposterior; provided with a sphincter, its presence indicated externally by a fairly conspicuous ridge. It is located (14 specimens) at 497-606 *TLs* units,  $\bar{x}$  560.4  $\pm$  7.974 behind tip of snout, the interval between it and the insertion of the first anal spine being somewhat variable.

#### Aspect

Viewed strictly from in front, the fish, apart from the fins, is visible back to, or somewhat beyond, the end of the operculum, behind which it narrows to visual extinction. The interorbital region, with some upward extension to the origin of the first dorsal and a downward continuation to just below the upper nostril presents an almost flat platform considerably in advance of the rest of the head nearby, its sides for the most part linear or slightly concave, about the same distance apart throughout most of their extent, but widening slightly to embrace the anterior nostril.

#### Overall Body Form

In terms of the systematic description of body form proposed by Gregory (1928) this species is specified thus: (1) hypsisomatic (strongly), (2) gasterion postapical (exceptionally preapical), (3) apex anterior (exceptionally median), (4) gasterion median, (5) hypsinotic (strongly), (6) bathygastric (strongly), (7) leptopygidial, (8) opisthion preuranic (noticeably). This combination of variable body

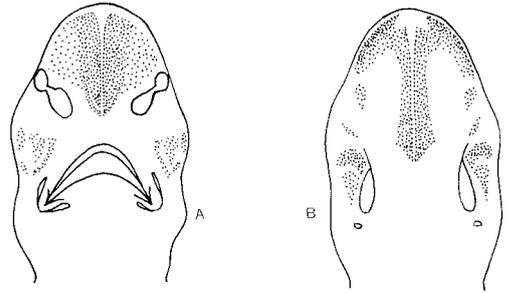


FIG. 4 — *Gnathanacanthus goetzei* Bleeker, 1855. A, lower surfaces of head; B, upper surface, showing disposition of ampullae of Lorenzini.

factors is not exhibited by Tasmanian representatives of the five families of the suborder Scorpaenidae reported from our waters, points of difference including: Scorpaenidae nomopygidial; Triglidae, Aploactinidae and Synancejidae mesonotic, mesogastric; Pataecidae (*s.s.*) dolichogastric.

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