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First Hawaiian Record of the Grenadier *Lepidorhynchus denticulatus* (Macrouridae: Gadiformes: Teleostei)

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On August 16, 2003, while night lighting for squid off the northwest coast of Oahu, Mr. Richard Cadaoas caught on hook and line an 18 to 20-inch (about 46–51 cm) squid. In its stomach was a small fish about 20 cm long in excellent condition, having suffered little deterioration from its stay in the squid's stomach. The specimen was taken to Mr. Arnold Suzumoto, Collections Manager for the ichthyological collections of the Bernice P. Bishop Museum, Honolulu. The fish could be readily identified as a grenadier, owing to its long tapered body that ends in a point and lacks a caudal fin, the relative form and positions of the fins, the spinulated body scales, and the general form of the head. The snout in the specimen was narrow and rounded, however, unlike the pointed and often stoutly reinforced snout of most other members of the family (excluding the bathygadids), and none of the ridges on the head were strengthened by stout spiny scutelike scales. The fish did not fit the description of any previously known species from the Hawaiian Islands and was subsequently sent to me, as one of the primary workers on this group of deepsea fishes, for identification.

Even before I had taken it out of the jar, I recognized the fish as a *Lepidorhynchus denticulatus*, a species originally described by Sir John Richardson in 1846 from a dried specimen that "was thrown up on the beach of South Australia, and has lost part of its tail" (Richardson 1846:54). Despite the desiccated state of the type specimen, the original description and illustration more than adequately characterized this distinctive grenadier, which is the sole representative of the genus.

The species was previously known only from the coasts of south and southeastern Australia and off the coasts of New Zealand in depths ranging from less than 100 m to more than 1000 m. It is one of the most common grenadier in these waters and forms a significant part of the by-catch of trawlers fishing at upper-slope depths. So far as known, the species has not been recorded north of latitude 34°S off New Zealand and about 30°S off southeastern Australia. Its distribution is generally confined to subtropical waters. Its occurrence off Hawaii is thus most astounding and prompts the recording of this extraordinary specimen.

Methods

Methods for making counts and measurements follow Iwamoto and Sazonov (1988). Institutional abbreviations follow Leviton et al. (1985).

Description

Lepidorhynchus denticulatus Richardson, 1846

Figs. 1–2

Macrourus vel *Lepidorhynchus denticulatus* Richardson, 1846:1–2, pl. 32, fig. 1–3 (holotype: BMNH 1845.11.31.6; type locality: coast of South Australia).
Coryphaenoides denticulatus: Günther, 1862:396.
Macrurus (*Optonurus*) *denticulatus*: Günther, 1887:147.
Optonurus denticulatus: Gilbert and Hubbs, 1916:144.
Lepidorhynchus denticulatus: Phillipps, 1927:58.

Material examined.— BPBM 39286 (200 mm total length, tail complete; sex indeterminate); Hawaii, Oahu, northwest side about 2 miles (3.2 km) offshore; collected by Richard Cadaoas, 16 August 2004 from stomach of 18–20-inch (46–51 cm) squid caught by hook and line at night. CAS 220920 (6 spec., 240+–456 mm total length); Australia; New South Wales, off Bermagui; 36°46′–41′S, 150°21′E; 285–310 fm [521–567 m]; collected by Ken Graham on F/V "Shelley," by trawl; 15 February 2000.

Counts and measurements.— (Hawaiian specimen first, followed by range of Australian specimens in parentheses.) First dorsal-fin rays II,11 (10–12); pectoral-fin rays i17 and i16 (i15–i18); pelvic fin rays 9 (9); branchiostegal rays 6; gill rakers first arch (outer/inner) 0+11 / 3+13 (0+10–14 / 3–4+13–15 = 17–18), second arch 3+14 / 2+13 (2–3+12–15 = 14–17 / 2–3+12–14 = 14–17); scale rows below origin of first dorsal fin about 8 (about 7–8), below mid-base of first dorsal fin about 5 (5.5), below origin of second dorsal fin about 6 (5–6.5); pyloric caeca 16 (15–25). Head length 31.5 mm (41.7–70.3 mm); the following in mm for Hawaiian specimen followed in parentheses by percent of head length for Hawaiian specimen and then Australian specimens: snout length 7.6 (22%, 20–24%); preoral length 5.1 (16%, 9–13%); internasal width 6.8 (22%, 16–21%); interorbital width 8.8 (28%, 20–25%); orbit diameter 12.6 (40%, 35–39%); suborbital width 2.8 (9%, 8–8%); postorbital length 12.6 (40%, 41–45%); distance orbit to angle of preopercle 11.9 (38%, 39–42%); length upper jaw 15.3 (49%, 47–50%); length barbel 3.1 (10%, 9–15%); length

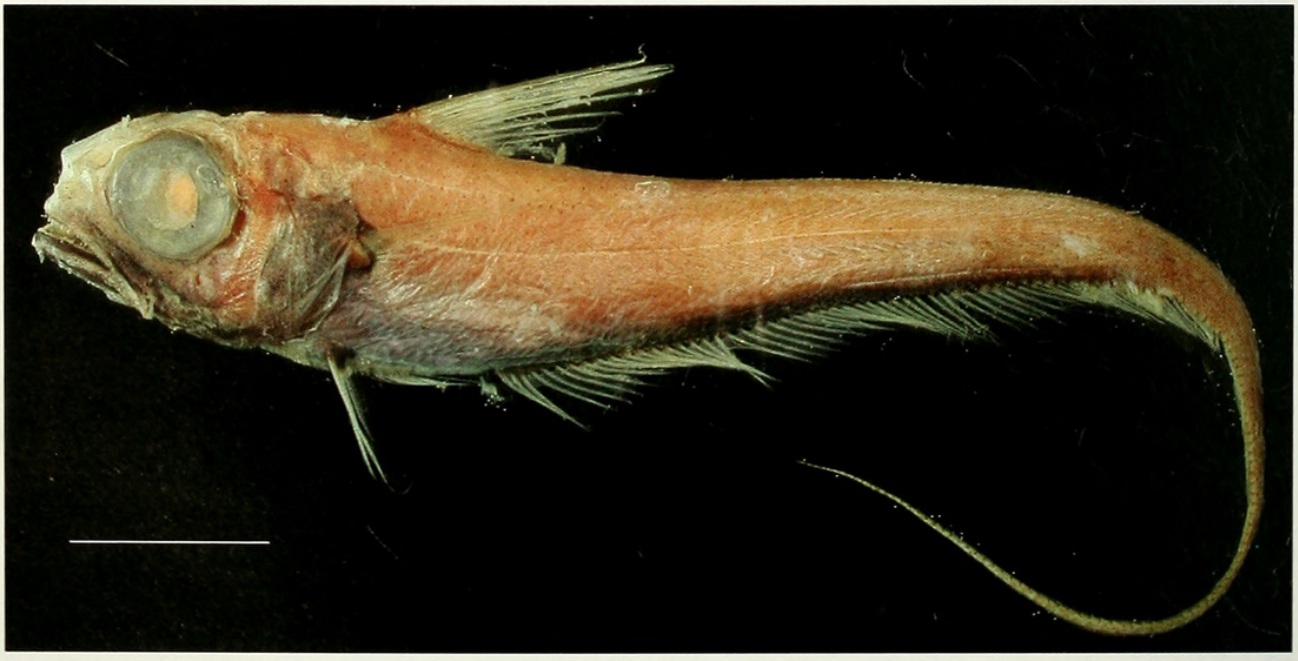

Figure 1. *Lepidorhynchus denticulatus*, BPBM 39286 (31.5 mm head length, 200 mm total length), from off Oahu, Hawaii.

outer gill slit 8.6 (27%, 22–27%); preanal length 47.5 (151%, 158–177%); distance outer pelvic fin to anal-fin origin 17.7 (56%, 53–69%); distance isthmus to anal-fin origin 32 (102%, 108–139%); greatest body depth 24.5 (78%, 79–90%); body depth at anal-fin origin 20.0 (63%, 64–80%); interspace between first and second dorsal fins 23.5 (75%, 74–95%); height first dorsal fin 28.5 (90%, 78+–92); length base of first dorsal fin 11.1 (35%, 34–42%); length pectoral fin 23 (73%, 72–82%); length outer pelvic-fin ray 20.5 (65%, 57–62%).

General description of Hawaiian specimen, with condition in larger Australian specimens in parentheses, if different. Body long and slender, laterally compressed, tapering posteriorly from abdomen into a long tail that ends in a fine point. Width of body across pectoral-fin bases less than half body depth below origin of first dorsal fin; greatest depth about equal to distance from anterior margin of orbit to end of opercle. Head about 6.2 into total length, compressed, its greatest width slightly greater than orbit diameter. Snout rounded and narrow, its tip slightly behind vertical of tip of jaws (slightly forward in larger Australian specimens). Orbits huge, more than postorbital length (slightly less than postorbital), about 2.4 into head length; its dorsal margin entering dorsal profile of head. Mouth large, essentially terminal, unrestricted by lip folds at angle; posterior margin of premaxillary approximately below middle of orbit (below posterior margin of pupil). Suborbital region narrow, shelf and ridge well defined, although this may be partly caused by slightly desiccated state of specimen. Preopercle broadly rounded, its ridges well defined, covering most of interopercle (except anteroventrally and distal tip) and anterior part of subopercle, which ends ventrally in a short tab. Chin barbel short, fine, its length about equal to diameter of posterior nostril. Gular membrane narrowly connected at isthmus far forward under middle of orbit (posterior half of orbit), overlapping and forming a deep fold over branchiostegal membrane. Anus immediately in front of anal-fin origin, separated at most by one or two scale rows. Swimbladder large, elongated, with eight or nine broad, flat retia, each connected to a globular to elongated bean-shaped gas gland (Fig. 2).

Teeth on premaxilla in moderately wide band extending entire length of jaw opening; teeth small and conical or spike-like, except outer series of much larger, widely spaced canines in a single row. Dentary teeth small anteriorly and in one or two irregular series, becoming increasingly larger posteriorly and in a single file. Larger teeth end abruptly and followed at posteri-

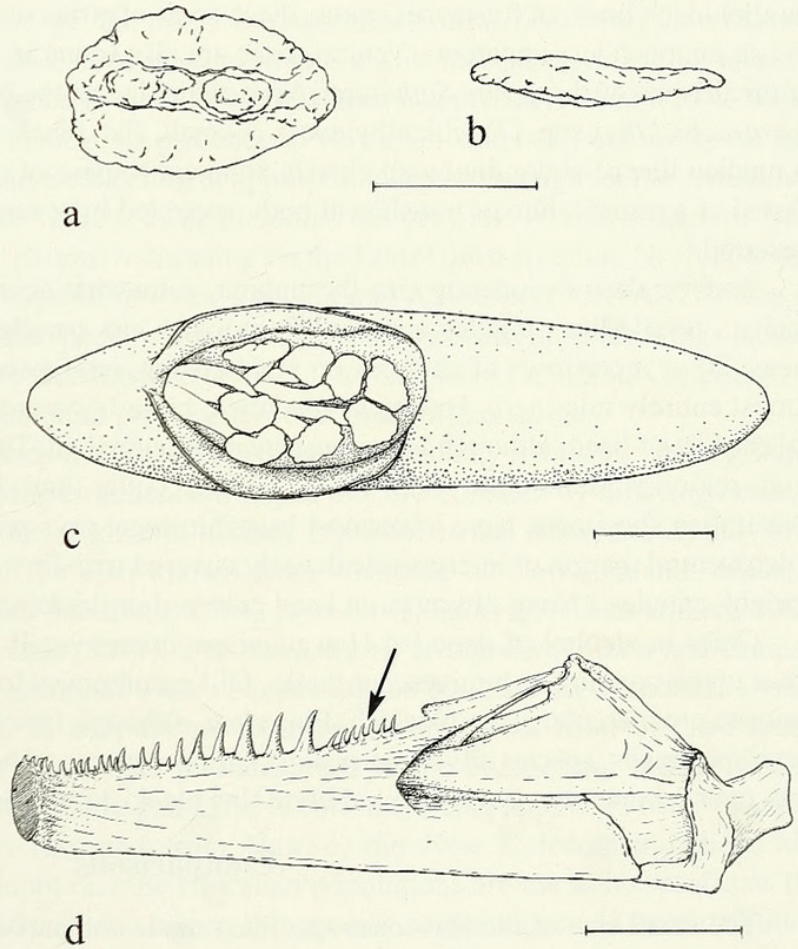

FIGURE 2. *Lepidorhynchus denticulatus*, CAS 202920, 41.7 mm head length, 240+ mm total length. Saggital otolith, (a) mesial and (b) dorsal views; (c) swimbladder, showing retia and gas glands; (d) mesial view of lower jaw showing comblike teeth (arrow).

or angle of jaws by a series of seven (four or five) comb-like teeth, slightly reclined, closely set, and somewhat overlapping at bases. These comblike teeth unlike those seen in any other grenadier. (In much larger Australian specimens, these teeth fewer and mostly embedded in gum tissue.) As with all other macrouroid fishes, no teeth on vomer and palatines.

First dorsal fin high, triangular, with two spinous rays and 11 segmented rays, anteriormost segmented rays appear to be longest. First spinous ray short and splintlike, tightly coalesced with proximal part of long second spinous ray. Distally on second spine a few small thornlike denticles on leading edge (absent in larger Australian specimens). Interspace between first and second dorsal fins wide, much greater than length base of first dorsal fin. Rays of second dorsal fin low and fine to end of tail, although gradually increasing in height posteriorly. Anal fin well developed throughout, its origin slightly behind vertical through posterior edge of first dorsal fin. Upper edge of pectoral fin about at mid-lateral line; fin well developed, relatively long, its length about equal to postrostral length of head, its tip extending to above 10th (4th or 5th) anal ray. Pelvic fins well developed; distal tip of outermost ray filamentous and hairlike, just reaching anal-fin origin.

Luminescent tissue on ventral surfaces of body extensive and consisting of extremely fine transverse parallel black lines, the ventral striae. Luminescent tissue extends from isthmus over abdomen up to and slightly behind pectoral-fin base (as well as lateral surface of fin base), narrowing posteriorly to above anus, gradually tapering above anal fin to approximately 57th (53–57) anal-fin ray. Tissue readily observed in preserved specimens as black areas underlain by extremely fine parallel black lines; in fresh specimens, these areas of striae usually overlain by a silvery reflection and striae much less apparent. (Ventral striae are also found in several unrelated groups such as the cardinalfishes of the genus *Siphamia* [Apogonidae], and the berycoids *Aulotrachichthys* spp. and *Paratrachichthys* spp. [Trachichthyidae]). A small, flat, black, triangular light organ situated within median line of abdominal wall closely adherent to base of rectum. Light organ externally manifested as a round white or translucent body encircled by a narrow black ring continuous with anal surround.

Body scales of moderate size throughout, somewhat deciduous, and fully covered with fine, conical, needle-like spinules arranged in more or less parallel rows. (In larger Australian specimens, 30 or more rows of spinules on scales below interspace between dorsal fins.) Body scales almost entirely missing in Hawaiian specimen, but a few remain on nape and top of head. (Scales cover most of head, although lower surface of snout naked. Tiny scales incompletely cover suborbital region.) Mandibular rami fully scaled. Gular and branchiostegal membranes naked. (Australian specimens have lowermost branchiostegal rays scaled, and in one specimen, exposed anteroventral margin of interopercle densely covered with tiny oval scales, each having a few short, upright spinules.) None of scales on head enlarged or thickened.

Color in alcohol of denuded Hawaiian specimen overall flesh colored with prominent black areas corresponding to luminescent tissue. Gill membranes, lower parts of head, and opercle posterior to preopercular ridge blackish. Fins clear, although first dorsal fin somewhat light dusky. (In fresh specimens, species silvery over most lateral surfaces of head and body, with dorsum gray and area over luminescent tissue black. Pelvic fins blackish; pectoral fins light dusky.)

Comparisons

The small size of the Hawaiian specimen made comparison of the morphometry of head and body structures uncertain. Several proportions of head parts in BPBM 39286 were greater than in the larger Australian specimens: snout length, preoral length, internasal width, interorbital width, orbit diameter, and suborbital width. The postorbital and orbit-to-preopercle measurements were slightly lower, but those were probably related to the relatively larger orbit diameter, which typi-

cally shows allometric growth in grenadiers. That the interorbital and suborbital widths were not narrower is somewhat contrary to what one would expect. The slightly lower values for the preanal length, the distance of isthmus to anal-fin origin, and the greatest body depth are not uncommon in smaller individuals of grenadier species. The weakly and sparsely denticulated distal portion of the spinous dorsal ray is also seen in the smallest Australian specimen and depicted in the original illustration of the holotype. In the larger Australian specimens, these denticulations are lost. All other characters appear exactly the same in Hawaiian and Australian specimens, and despite the small differences in some head proportions, there is little reason to doubt the conspecificity of the two populations at this time. The possibility of there being two species cannot be completely discounted, however, and a more-definitive conclusion can only be made after additional specimens from Hawaii become available.

Discussion

The unusual Hawaiian record of this species leads to speculation as to how this particular individual found its way so far across the Pacific from its normal grounds some 3700 nautical miles and more than 54 degrees of latitude distant. Many species of grenadiers have broad distributions, but those can generally be separated into three categories: (1) abyssal or lower-slope species, such as *Coryphaenoides armatus* (Hector, 1875) and *Cetonurus* spp.; (2) bathypelagic species, such as *Cynomacrurus piriei* Dollo, 1900 and *Odontomacrurus murrayi* Norman, 1939; and (3) species having a long-lived pelagic juvenile stage, the prime example being *Malacocephalus laevis* Lowe, 1843. *Lepidorhynchus denticulatus* does not appear to fit into any of these categories (but its early life history is not known), so its presence in the Hawaiian Islands is a mystery. Were it to be found in intervening areas of the western Pacific, its presence in Hawaiian waters would not be so surprising. Yet, despite relatively extensive collecting at appropriate depths throughout the central and North Pacific, especially by Japanese vessels, *L. denticulatus* has yet to be recorded north of New Zealand and southeastern Australia. Extensive trawling on the Lord Howe Rise and Norfolk Ridge north of New Zealand during the cooperative (New Zealand and Australia) NORFANZ cruise of the R/V *Tangaroa* in 2003 captured the species only once, and that was west of Three Kings Islands off the northern tip of New Zealand's North Island at 34°S. The extensive French survey cruises to New Caledonia and adjacent areas failed to produce any specimen of the species.

Most species of grenadiers are localized in their distributions, usually to basins, island groups, oceanic seamounts and ridges, or along continental margins that are bounded by differing oceanographic or geologic conditions. So far as known, besides *Lepidorhynchus denticulatus*, only five species of grenadiers from Hawaii are also known from Australia or New Zealand: *Malacocephalus laevis, Kuronezumia bubonis* (Iwamoto, 1974), *Hymenocephalus aterrimus* Gilbert, 1905, *Nezumia propinqua* (Gilbert and Cramer, 1897), and *Trachonurus sentipellis* (Gilbert and Cramer, 1897). The last three are found in Australian waters but not off the coasts of New Zealand's main islands. *Malacocephalus laevis* and *K. bubonis* are widespread throughout most of the Pacific, Atlantic and Indian oceans, and *N. propinqua* is widespread in the Pacific and Indian oceans, although there is some question as to whether that name is currently being applied to more than one species. *Trachonurus sentipellis* is recorded from Hawaii, the New Caledonian region, and Australia, but there is again some doubt that the Hawaiian populations are the same species as the austral populations. If the identifications are correct, this species comes closest in its distribution to that of *Lepidorhynchus.*

It has been theorized (Marshall 1965, 1973) that most grenadiers have pelagic eggs that hatch near the bottom; the larval stage is very short before metamorphosis into a pelagic juvenile stage (sometimes called postlarva or prejuvenile) takes place. The young probably spend relatively little

time in the midwaters before descending to the bottom to live a benthopelagic life. A short pelagic early life would ensure that the settled young are over appropriate living depths and are not wafted too far from the narrow continental slopes on which adult populations live. The scarcity of larval grenadiers in collections, despite the group's abundance throughout the world's oceans, adds support to this idea of a short pelagic stage lived close to the bottom. Perhaps there are some species that can tolerate an extended pelagic larval or juvenile stage when wafted far beyond their normal range. The concept of "expatriate" individuals is well known for some fishes, and this may come into play with some unusual range extensions in grenadiers. Whether any of these factors may account for the extraordinary occurrence of *L. dẽnticulatus* in Hawaii is yet to be learned, as the early life history of the species is not known, nor is it known that *L. denticulatus* is actually established in the Hawaiian Islands. It seems unlikely, however, that the captured specimen represents a single stray individual in these waters.

There are few examples of other demersal shelf and upper-slope fishes of southern Australia and New Zealand that have a distribution also in the Hawaiian Islands. Mr. Suzumoto informs me (in litt., Nov. 2004) that the Bishop Museum has "a specimen of *Cheilidonichthys kumu*" caught off Hawaii Island in 1926 and never seen here since." That Bishop Museum sea robin (family Triglidae) was recorded by Pietschmann (1930) and considered of questionable validity by Springer (1982:103). It was said (Gomon et al. 1994:496) to occur off South Africa, southern Australia, and New Zealand, and also in the North Pacific off Japan, Korea, and China; however, recently published books on the Japanese fish fauna (e.g., Masuda et al. 1984; Nakabo 2002) list *C. spinosus* and *C. ischyrus* but not *C. kumu*. Martin F. Gomon (NMV) has informed me (*in litt.*, 12 Dec. 2004) that Peter Last (of CSIRO) "has differentiated several species of *Cheilidonichthys* in Australia, probably none of them also in South Africa, and the Japanese species are probably something else again." Gomon adds that "there are other Hawaiian cognates, like the *Bodianus oxycephalus*-like species. . .with 3 cognates in Japan, southern Pacific and SW Australia, respectively." The morwong *Cheilodactylus vittatus* was thought to have a north-south disjunct distribution: the Hawaiian Islands in the northern hemisphere, the Lord Howe Island and New Caledonia in the southern hemisphere (Springer 1982:33). Burridge (2004), however, has reported that the New Caledonia and Norfolk Island *Cheilodactylus* represents a different species, which he described as *C. francisci*. The mirror dory, *Zenopsis nebulosus*, is a wide-ranging shelf to upper-slope species (62–550 m) found off Australia, New Zealand and Chile in the southern hemisphere, and also in the North Pacific off Japan, Korea, Hawaii and California (Gomon et al. 1994:420–421). Of the three deep-dwelling (100–400 m) Emmelichthyidae in Hawaii, one species also occurs off Japan, Australia and the Philippines (Springer 1982:41). In light of these few examples, it is apparent that many fish species formerly thought to have a broadly disjunct distribution in Hawaii and the southwest Pacific are, in fact, separable into more than one closely related species. Other examples are likely to surface after closer study using tools and knowledge not formerly available. That possibility for *Lepidorhynchus* cannot at this time be discounted.

Springer (1982:117), in his valuable study on Pacific Plate biogeography, found 121 families of shorefishes that are nonmarginally represented on the Pacific Plate. Of these, 15 families (12%) are found only in the Hawaiian Islands, and 10 of the 15 occur there only in deep water. These "Hawaiian exceptions," as so designated by Springer, "denote Indo-Pacific taxa that occur nonmarginally on the Pacific Plate only at the Hawaiian Islands. These taxa usually occur also in Japan and/or the Ruykyu [*sic*; misspelling for Ryukyu] Islands, and many are antitropically distributed in the Indo-West Pacific; some are restricted to north of the tropics and some are moderately deep dwelling." (Springer 1982:135.). *Lepidorhynchus* should be added as an Hawaiian exception, but the underlying cause of its apparent disjunct distribution is unknown.

Central to understanding the vicariant event that produced the current distribution of *Lepidorhynchus*, one should have a firm grasp of its closest relatives. "If one knows the cladistically determined closest relatives (sister groups) of endemic taxa, and the distributions of those relatives, one can narrow the geographic and temporal search for the pertinent vicariant events." (Springer 1982:6). Unfortunately, the sister-group relationships of *Lepidorhynchus* within the Macrouridae are uncertain and a thorough cladistic analysis of macrourid genera has yet to be made. Iwamoto and Sazonov (1988:39), in their tentative phylogeny of macrourines with six branchiostegal rays, included the genera *Cynomacrurus* and *Odontomacrurus* in a clade, with *Lepidorhynchus* as the clade's questionable sister group. *Odontomacrurus murrayi* perhaps comes closest in overall morphology to *Lepidorhynchus*, having a compressed head, large, terminal jaws beset with canines, and a small light organ. That bathypelagic species, however, lacks ventral striae, a developed swimbladder, and a chin barbel, and it has many reductions and differences in its morphology and organ systems that reflect its bathypelagic existence and thereby distance it from *L. denticulatus*. The broad, almost worldwide distribution of *O. murrayi* in tropical to subtropical waters shows a noteworthy hiatus — so far as known, there are no records of its presence on the Pacific Plate except marginally.

Of the grenadiers with seven branchiostegal rays, the luminescence on the body, the rounded snout with little protrusion of the rostrum, and the scale spinulation are most suggestive of *Hymenocephalus,* but the six branchiostegal rays, the eight or nine retia and gas glands, the absence of a light organ lens on the chest, the very different dentition, and the narrowly compressed head in *Lepidohynchus* are among several characters that separate it from members of *Hymenocephalus*. The head shape, especially the narrow snout with little protrusion of the median nasal ridge, is somewhat like that of *Ventrifossa atherodon* (Gilbert and Cramer, 1897) and the scale morphology is quite similar, but members of *Ventrifossa* lack ventral striae, they have seven branchiostegal rays and two retia and gas glands, and there is a small dermal window of the light organ between the pelvic-fin bases that is absent in *Lepidorhynchus*. *Steindachneria argentea* Goode and Bean, 1886, in the monotypic family Steindachneriidae, bears some resemblance to *L. denticulatus* in its ventral striae, large terminal mouth beset with canine-like teeth, and similar retia and gas glands in the swimbladder (see Marshall 1966, fig. 3C), but differs radically in having second dorsal rays well developed and higher than most anal-fin rays, an elevated lobe in the otherwise low anal fin, vomerine teeth, no chin barbel, anus located between pelvic-fin bases and distantly separated from urogenital opening, which is immediately before the anal fin. It is apparent that a more thorough comparative study of the morphology of *Lepidorhynchus denticulatus,* perhaps combined with molecular investigations, will be needed to clarify the phylogenetic position and discover the sister group of this perplexing species.

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