

**A New Indo-West Pacific Species of the Dendronotacean
Nudibranch *Bornella*
(Mollusca : Opisthobranchia)
with Anguilliform Swimming Behavior**

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Abstract—A new species of *Bornella* from the Indo-West Pacific is described. The strictly subtidal, nocturnally active, new species can be differentiated from all other species of *Bornella* by external morphology and coloration, internal anatomy, and by its peculiar anguilliform swimming behavior.

There are presently six valid species of the genus *Bornella* Gray, 1850 (see Bertsch, 1980). An additional seven described species were considered by Odhner (1936) to be synonymous with *B. digitata* Adams and Reeve, 1850, which Bertsch (1980) has shown to be *B. adamsii* Gray, 1850. Recent collecting in the Marshall Islands, west-central Pacific, and several other Indo-West Pacific locations, has yielded an additional species which can easily be distinguished from the others by external morphology, coloration, and behavior.

Family BORNELLIDAE
Genus *Bornella* Gray, 1850

Elongate, slender dendronotacean nudibranchs, with a mostly paired row of dorsolateral processes bearing gills. Rhinophore sheaths tall and papillate around the upper edge. Oral tentacles branching. Buccal mass with scale-like armature, eolid-like jaws, and a long, slender radula composed of a number of rows of teeth. Each row contains a large, usually denticulate median tooth and a number of smooth, sword-like laterals. Reproductive system diaulic, with spines in the ejaculatory duct. Type species: *Bornella adamsii* Gray, 1850.

Bornella anguilla n. sp.
Figs. 1–6

Color illustration: Kuiter (1982 : 37, left column, middle photograph)

HOLOTYPE: Oceanside Ennubuj-Ennylabagan reef, Kwajalein Atoll, Marshall

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Islands; in ledge at night, depth 13 meters, 2 June 1982, 43 × 5 mm; collected by J. Hammon. Undissected specimen with color slide of the living animal, Bernice P. Bishop Museum catalog number 9937.

PARATYPES: Oceanside Ennubuj-Ennylabagan reef, Kwajalein Atoll, Marshall Islands; in ledge at night, 12 m, 21 April 1982, 43 × 5 mm; J. Hammon. Dissected specimen with slide of radula and jaws, Bernice P. Bishop Museum Cat. no. 9938.

Oceanside Ennylabagan Island, Kwajalein Atoll, Marshall Islands; in ledge at night, 13 m, 14 May 1982, 40 × 4 mm; J. Hammon. Dissected specimen with slide of the radula and color slide of the living animal, U.S. National Museum.

ADDITIONAL MARSHALL ISLANDS MATERIAL: An additional 10 or more specimens have been observed at night in ledges and caves on the oceanside of the west reef of Kwajalein Atoll. Also, more than 20 specimens have been found at night on Cement Ship Pinnacle, Enewetak Atoll, in a cave beneath a wrecked ship, at depths of 10–15 m. A single specimen was collected during the day on the same pinnacle, under a large chunk of dead coral in 10 m of water.

FURTHER RECORDS: One specimen has been observed at each of the following locations: Nine Mile Reef, northern coast of Natal, South Africa, on a sertulariid hydroid, 15 m depth, May 1981, collected and photographed by T. Gosliner; near Fremantle, Western Australia, photographed by D. Baker (T. Gosliner, pers. comm.); 300 m south of Old Woman Island, Sunshine Coast, north of Brisbane, Queensland, Australia, on a hydroid, 8–10 m depth, 19 June 1981, photographed by R. J. Spence (R. Willan, pers. comm.); Curacao Channel, off NW tip of Fantome Island, Palm Isles group off Townsville, northern Queensland, Australia, on dead coral rubble beneath a very large plate of dead coral, 6 m depth, 22 March 1982, collected and photographed by R. Willan; Kendrew Island, Dampier Archipelago, Western Australia, 15 m, 13 October 1972 (AMPI no. 176), photographed and collected by N. Coleman (R. Willan, pers. comm.); Lizard Island, Queensland, Australia, photographed by R. Kuitert; several specimens from the Seychelles in the collections of the U.S. National Museum (record courtesy of T. Gosliner).

TYPE LOCALITY: Ledges and caves in surge channels at the upper edge of the steep seaward slope on the west reef of Kwajalein Atoll, Marshall Islands.

DESCRIPTION: The body is soft, elongate, and strongly compressed laterally (Fig. 1). The general color pattern consists of a greenish brown to purplish brown network enclosing variable sized patches which are cream or, less commonly, orange in color. Under magnification, the body can be seen to be covered with soft, subsurface granules, which are typically cream yellow to light tan in color. The darker colored network is formed by purplish brown pigment overlaying, crowding, or coloring the granules in those areas. The orange patches are formed by orange pigment overlaying or crowding the granules in occasional patches. At 12 × magnification, tiny, iridescent, greenish spots can be seen scattered over the body in

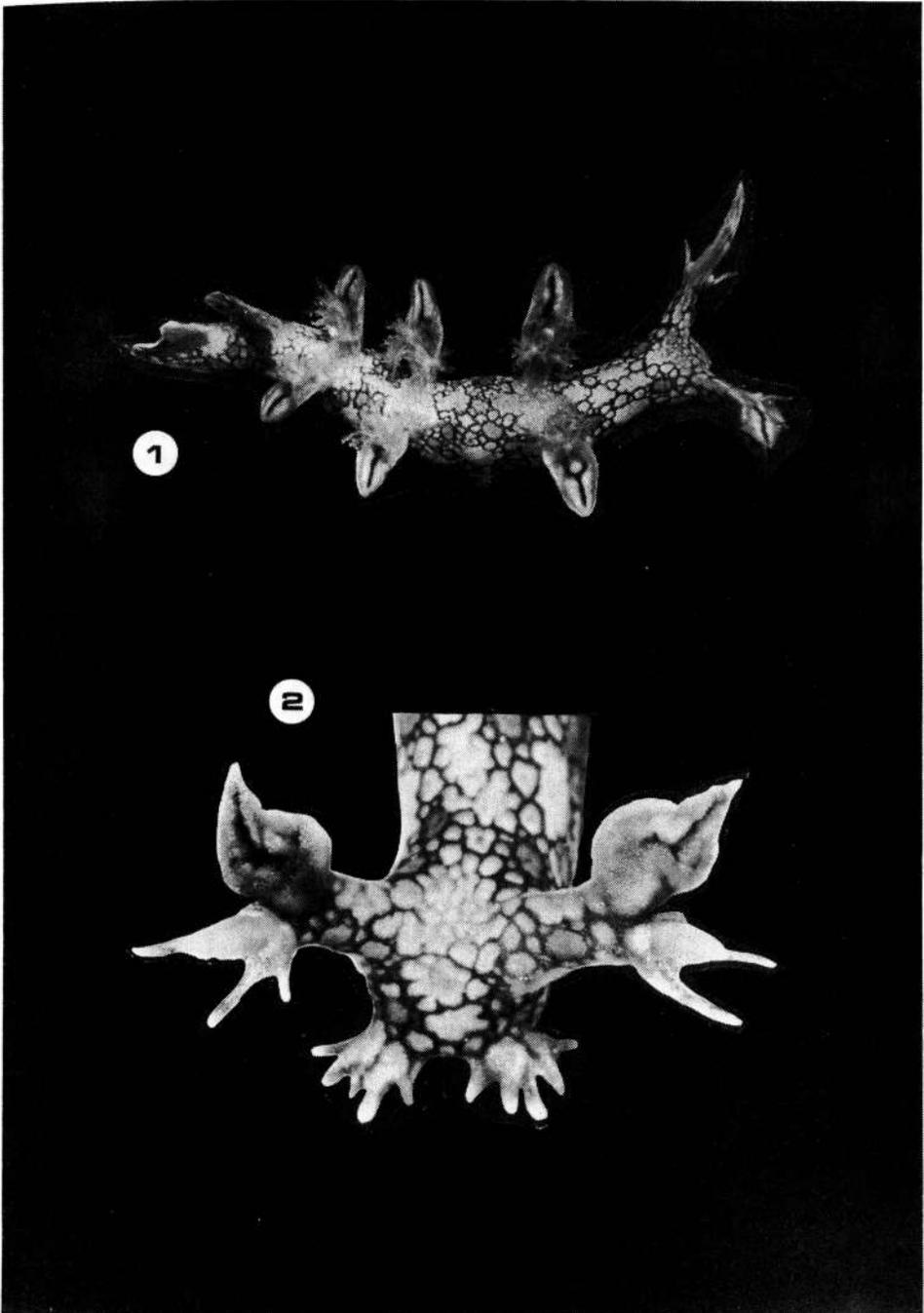


Fig. 1. *Bornella anguilla*, view of entire 47 mm specimen from upper right side.
Fig. 2. *Bornella anguilla*, anterior end of 47 mm individual.

most specimens, and these apparently give the animals their greenish brown tinge. There is some apparently ontogenetic variation in color. The 3 smallest specimens (37 mm in length and smaller) possessed lighter cream colored background granules, a darker purplish brown network, and brighter orange patches, giving these individuals a sort of crisper, more focused appearance.

On either side of the mouth is an oral lobe, which is stout at the base and divided into 5-6 short papillae distally (see Fig. 2, lower part). The stout bases are colored as the body, and the papillae are orange with white tips.

Each rhinophore sheath has a tall, slightly laterally compressed stalk from which the rhinophore protrudes. Surrounding the rhinophore, at the upper edge of the stalk, are 3 small anterior and anterolateral papillae and a taller, posterior, very laterally compressed, sickle-like flap (Fig. 3). The stalks are colored as the body, and the small papillae are orange with white tips. The lower half of the posterior flap on each rhinophore stalk is cream yellow with a faint tinge of purple, usually in wide, faint, vertical bands. Each side of the upper half has a central, vertical, dark purplish brown stripe, bordered on either side by translucent or opaque cream or bright white, then dull to bright orange bands. The rhinophores are light peach in color, and each possesses about 25 lamellae.

Posterior to the rhinophores are 3 pairs of dorsolateral processes, followed by 3 single processes along the middorsal line. The number of processes was consistent in all specimens examined. The paired processes have stout bases, which are translucent gray on the inner surfaces and cream colored with vertical, light purple brown bands on the outer. Each process is topped by a paddle-like flap similar to the flaps.

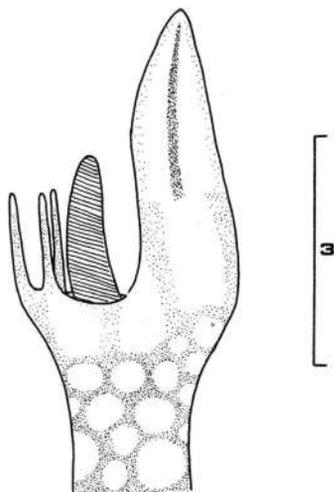


Fig. 3. *Bornella anguilla*, rhinophore process, showing stalk, rhinophore, 3 anterior and anterolateral papillae, and the flattened, slightly curved posterior flap. Scale bar in mm.

on the rhinophore processes, but shorter and straighter. The dorsolateral flaps are colored as the rhinophore flaps, each with a central, vertical, dark purplish brown band, bordered by translucent or opaque white or cream, then dull or bright orange. Frequently, the lower portion of the orange bands curve inward and meet beneath the purplish brown and white. Less commonly, the purplish brown band branches at the top or bottom. There are 3 tripinnate, translucent white gills per dorsolateral process, usually located on the inner surfaces of the paired processes only. In the largest specimens, the bases of the gills are generally irregularly studded with cream colored granules, and the pinnae are splotched with cream white. Occasionally, the pinnae are edged lightly with purplish brown. The 3 posterior, single, dorsal processes are simple, flattened keels resembling fins. In large individuals, a single, somewhat reduced gill is often present on the anterior slope of the most anterior keel. The keels are purplish brown at the base and orange distally, with central smears of dark purplish brown. The brown smears are bordered by white. The most posterior keel is small and located at the tip of the tail, forming more of a tail fin than a typical, pointed tail.

The reproductive opening is edged with orange and located on the right side, approximately midway between the rhinophore sheath and the first dorsolateral process. The anal opening is smaller and less noticeable, and is located on the right side of the dorsum between the first and second pair of dorsolateral processes, closer to the second. The foot bottom is very narrow and cream yellow in color.

The flattened radula of a 44 mm specimen measured 2.1×0.4 mm. The combined radular formula of 8 individuals ranging in length from 24–70 mm was $39-58 \times 13-17.1.13-17$. The median tooth in each row was slightly more broad than tall and possessed about 8 denticles on either side of a strong central cusp (Fig. 4). The denticles increased in size away from the cusp. The blade-like laterals became larger away from the center, up to the 4th or 5th from the outermost. The outermost few teeth decreased slightly in size. One 46 mm individual possessed deformed teeth in the right half row all along the radula; the 3 inner laterals, then the next 4, were each

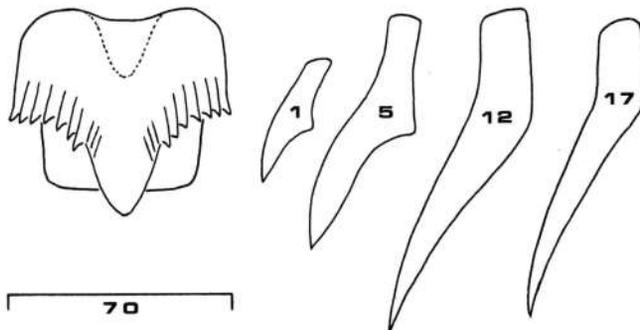


Fig. 4. *Bornella anguilla*, radula, showing median tooth and selected teeth from right half row. Scale bar in μm .

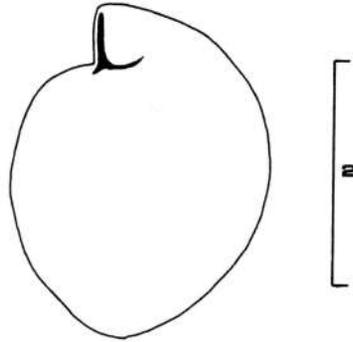


Fig. 5. *Bornella anguilla*, one half of jaw. Scale bar in mm.

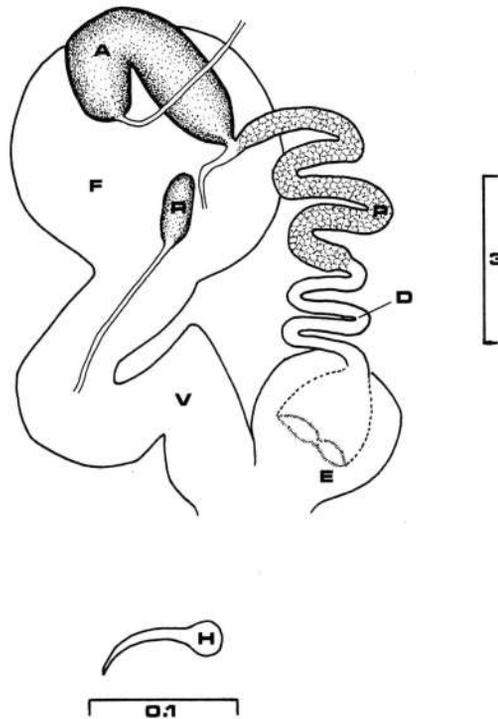


Fig. 6. *Bornella anguilla*, reproductive system. A=ampulla; D=vas deferens; E=ejaculatory duct; F=female gland complex; H=enlarged hook from ejaculatory duct; P=prostate; R=receptaculum seminis; V=vagina. Scale bars in mm.

fused at the base, forming 2 wide, multicusped teeth. The outer laterals in each row appeared normal.

The jaw was roughly oval in shape, without a distinct masticatory process (Fig.

5). The masticatory border was thickened with the edge essentially smooth; in a few specimens, a few very small denticles were visible on the border at $25\times$ magnification. Jaw color was translucent yellowish brown, becoming darker near the inner border. The thickening along the masticatory border was dark brown.

The undissected reproductive system measured 6.0 mm in diameter in a 43 mm specimen. The reproductive system was diaulic, with most of the female portion incorporated into the nidamental gland complex (Fig. 6). The ejaculatory duct was very large and essentially spherical. The penis was edged with a mostly single row (becoming double in places) of approximately 200 purple, chitinous hooks, each measuring $70\text{--}85\ \mu\text{m}$ in length. The ejaculatory duct narrowed to a convoluted vas deferens, which led to a somewhat wider, granular appearing prostate. The prostatic and ampullary ducts joined near the point where they entered the nidamental glands. The brownish ampulla curled over 180° at the distal end, and a narrow duct led back to an orange, tightly packed ovitestis lying along the upper side of the digestive tract. The female opening led into a wide, short, convoluted vagina that terminated in the female gland mass. The receptaculum seminis was at the end of a narrow duct budding from the middle of the vagina.

A 47 mm individual deposited an egg mass on 17 August 1982. The white ova measured $140\text{--}150\ \mu\text{m}$ in diameter and were individually contained within ovoid capsules $250\text{--}265\ \mu\text{m}$ in diameter. The mass consisted of a spiral string of ova, 2 ova wide, which were formed into loose, irregular coils. There were about 14 ova per mm of ribbon, and 3900 in the entire egg mass. Ova maintained in a flow-through seawater system at 28°C began hatching in 10 days as free-swimming veliger larvae with transparent shells measuring $230\text{--}250\ \mu\text{m}$ in longest diameter.

HABITS: *Bornella anguilla* appears to be exclusively subtidal, and in the Marshall Islands, is strictly nocturnal. Over 30 active specimens have been found at night, and thorough searches of the same areas during the day have yielded only a single individual, well secreted beneath a dead coral block. The specimens collected and observed from Kwajalein were crawling about in ledges and small caves in surge channels on the oceanside of the atoll's leeward reef. All but one of the Enewetak specimens were found in a similar habitat within the lagoon, a "cave" formed by the hull of a world war II concrete ship aground on the steep slope of a lagoon pinnacle west of the deep water pass in the atoll's windward reef.

Many of the Enewetak specimens were found feeding upon a species of hydroid of the genus *Plumularia*. Other *Bornella* species are also hydroid eaters; *B. adamsii* in Hawaii has been observed to prey upon *Sertularia speciosa* Congdon, 1907 (pers. obs.).

Several species of *Bornella* are known to swim by lateral bending of the body (Farmer, 1970; Bertsch, 1980; Thompson, 1980; pers. obs. on *B. adamsii*). Generally, this rhythmic bending of the entire body, first to one side, then the other, raises the individual foot first off the bottom. Little forward progress is made with this swimming method, unless a surge or current carries the animal while it is suspended

in the water column. True to its name, *B. anguilla* utilizes an anguilliform type of swimming behavior both in the field and in aquaria, and when swimming, looks much more like a blennioid fish than a nudibranch. *B. anguilla* swims upright, with its tail flattened and dorsolateral flaps erect and spread out into oval paddles. Most specimens have been observed to swim in this fashion; in fact, they frequently utilize this swimming behavior immediately upon being disturbed by a collector's hands. In a test tank, a 37 mm individual was observed to make forward progress at a rate of 10 cm/sec over short distances. The same specimen swam continuously in one trial for 69 seconds, covering over 400 cm (mostly in a wide circle) and stopping only when it ran into the side of the container.

DISCUSSION: Bertsch (1980) reviewed some of the characters of all the other known *Bornella* species while describing *B. sarape*. The coloration of *B. anguilla* is distinctly different from the yellow brown with black markings of *B. sarape* and the whitish with orange red reticulations of all of the other species. Other *Bornella* species are more tubular in shape rather than strongly laterally flattened, and all lack the paddle-like "swimming fins" present on the rhinophore sheaths and dorsolateral processes of *B. anguilla*.

While noting that the lateral radular teeth of the various *Bornella* species were quite similar, Bertsch (1980: fig. 3) compared the previously published drawings of the central teeth. It can be readily seen that these teeth in *B. anguilla* are distinctly different from those of most other species. *B. sarape* has central teeth with relatively larger cusps and smaller denticles than *B. anguilla*, while those of *B. calcarata* Mörch, 1863 lack denticles entirely. *B. simplex* Eliot, 1904 has teeth with small cusps only slightly larger than the large denticles, and both *B. adamsii* and *B. excepta* Bergh, 1884 have narrower cusps and central tooth shapes that are distinctly different than that of *B. anguilla*. The radula of the new species is most similar to that of *B. japonica* Baba, 1949. However, as noted above, these two species can be readily differentiated by coloration and by the morphology of the rhinophore sheaths and dorsolateral processes; those of *B. japonica* are more branched and less laterally flattened into swimming fins (Baba, 1949; pers. comm. of unpublished drawings).

Reproductive systems of other *Bornella* species have usually not been examined in detail. The penial armature of *B. excepta* and *B. japonica* resemble the hooks of *B. anguilla*, but appear from the figures to be less curved (Bergh, 1902, 1905; Baba, pers. comm.). The hooks of *B. excepta* were also described as dark brown to black in color. In *B. adamsii*, the arrangement of hooks is considerably different; there are 2-3 rows of dark brown hooks, which vary in number and size in the different rows (Bergh, 1905).

DISTRIBUTION: *B. anguilla* appears from the Marshall Island, eastern and western Australian, and South African records, to be a widespread Indo-West Pacific species; its subtidal, nocturnal habits have probably prevented it from being found in more areas. Extensive nocturnal collections in Hawaii, however, have not yielded any specimens (pers. obs.).

ETYMOLOGY: The specific name refers to the eel or blenniid type of swimming observed in *B. anguilla*, which is apparently unique among the nudibranch mollusks.

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References Cited

- Adams, A. 1848. Notes from a journal of research into the natural history of the countries visited during the voyage of H. M. S. Samarang, under the command of Captain Sir E. Belcher, C. B. *In* E. Belcher, Narrative of the voyage of H. M. S. Samarang during the years 1843-1846. 2: 1-574. London.
- Adams, A., and L. Reeve. 1850. Mollusca. Pages 45-87. *In* A. Adams, The zoology of the voyage of H. M. S. Samarang; under the command of Captain Sir Edward Belcher. Part 3. London.
- Baba, K. 1949. Opisthobranchia of Sagami Bay, collected by his Majesty the Emperor of Japan. Iwanami Shoten, Tokyo. 194 p.
- Bergh, L. 1884. Report on the nudibranchiata. Challenger Reports, Zoology 10(26): 1-154.
- . 1902. The Danish expedition to Siam 1899-1900. 1. Gasteropoda Opisthobranchiata. Kgl. Danske Vidensk. Selsk. Skrift. 6. Raekke, Naturvid. og Math. Afd. 12(2) Kjobenhavn: 153-218.
- . 1905. Die Opisthobranchia der Siboga Expedition. Monographie 50: 1-248.
- Bertsch, H. 1980. A new species of *Bornella* from tropical west America (Mollusca, Opisthobranchia). *Spixiana* 3: 33-42.
- Congdon, E. D. 1907. The hydroids of Bermuda. Proc. Amer. Acad. Art Sci. 42: 461-485.
- Eliot, C. N. E. 1904. On some nudibranchs from East Africa and Zanzibar, Part 5. Proc. Zool. Soc. London 1904(2): 83-103.
- Farmer, W. 1970. Swimming gastropods (Opisthobranchia and Prosobranchia). *Veliger* 13: 73-89.
- Gray, M. E. 1850. Figures of molluscous animals 4. London.
- Kuiter, R. 1982. Fishing with film. *The Scuba Diver*. August 1982: 31-39.
- Mörch, O. A. L. 1863. Contributions a la faune malacologique des Antilles Danoises. *Journ. de Conchyl.* 11: 21-43.
- Odhner, N. 1936. Nudibranchia Dendronotacea—a revision of the system. *Mém. Mus. Roy. Hist. Nat. Belgique* (2)3: 1058-1128.
- Rudman, W. B. 1984. The date and authorship of *Bornella* and *Ceratosoma* (Nudibranchia) and other molluscs collected during the voyage of H. M. S. Samarang, 1843-46. *Malac. Rev.* 17: 103-104.
- Thompson, T. 1980. Jamaican opisthobranch molluscs. II. *Journ. Moll. Stud.* 46: 74-99.

Note Added in Proof

Rudman (1984) has recently pointed out that *Bornella adamsii* should be considered a junior synonym of *B. stellifer* (Adams & Reeve in Adams, 1848), making the latter the type species of the genus *Bornella*.