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Two New Species of Dorid Nudibranchs (Gastropoda, Opisthobranchia) from the Indian Ocean

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Two new species of cryptobranch dorid nudibranchs are described from the Indian Ocean. *Chromodoris cazae* sp. nov. is known from the United Arab Emirates, Gulf of Oman. This species is characterized by having a smooth white body with several irregular patches of deep red-maroon found scattered on the mid-dorsal region. Each of these patches has a number of smaller irregular orange spots within it. *Aldisa andersoni* sp. nov. is found from Sri Lanka. This species has a series of rows of low tubercles on the blue dorsum. Black pigmentation demarcates the rows of tubercles. The species also has an opaque yellow saddle posterior to the rhinophores, and other yellow marks on the dorsum. Other species having similar coloration and that also appear to mimic phyllidid nudibranchs are discussed. Both species are distinguished from other described taxa based on differences in body coloration and external and internal morphology and anatomy.

During the past several years, the described opisthobranch taxa of the western Pacific has increased dramatically (Bruncкhorst 1993; Gosliner 1993, 1994; Gosliner and Draheim 1996; Gosliner and Behrens 1997; 1998a and b, 2000; Johnson and Gosliner 1998; Gosliner and Fahey 1998; Gosliner and Johnson 1999; Carlson and Hoff 2000; Fahey and Gosliner 1999a and b; Fahey and Gosliner 2001, 2003; Hamatani 2001; Yonow 2001; Dorgan et al. 2002; Ortiz and Gosliner 2003; Smith and Gosliner 2003; Gosliner and Smith 2003). The Indian Ocean, however, has a richly diverse but reasonably unknown opisthobranch gastropod fauna (Gosliner 1994; Gosliner and Behrens 2000; Valdés, Mollo, and Ortea 1999; Yonow 1984, 1994, Yonow et al. 2002). Increasing awareness of differences in opisthobranch morphology by sharp-eyed, dedicated recreational divers has produced a number of interesting finds. Two such new discoveries are described here.

The family Chromodorididae comprises one of the most colorful and morphologically diverse groups of dorid nudibranchs. More than 600 species have been described to date belonging to the 16 genera within the Chromodorididae. The morphological characteristics and the systematic relationships of members of the family have been comprehensively discussed in recent years (Rudman 1984, 1986, 1987, 1995; Baba 1994, 1995; Hamatani 1995; Gosliner and Behrens 1998a, 2000; Johnson and Gosliner 1998; Gosliner and Johnson 1999; Schrödl 1999; Valdés et al. 1999). The *Chromodoris* species described here broadens the basis for the genus and adds new records to the fauna of a little studied area of the Gulf of Oman.

Millen and Gosliner (1985) defined the diagnostic characters of the genus *Aldisa*, listing eleven species. The genus is characterized by having elongate denticulate teeth, penial spines, conical tubercles and reduced oral tentacles. Several additional species have been added since then (Ortea and Ballesetros 1989; Elwood et al. 2000; Perrone 2001). Perrone (2001) listed twenty

species of *Aldisa* worldwide. He overlooked two species described the year before (Elwood et al. 2000). All but three of these species are white, yellowish or red in color. Perrone (2001) included in his list several undescribed species and the specimen shown in Debelius (1996:213 as *Chromodoris* sp.) as a junior synonym to *Aldisa erwinkoehleri*. We were fortunate to acquire the specimen (pictured in Debelius) from its collector, Dr. Charles Anderson, and describe it here as a new species. To paraphrase Dr. Bill Rudman (Sea Slug Forum, March 13, 2002), we too "used to think of *Aldisa* as a genus of red dorids which mimicked sponges, but now it seems they include a group of nodulose species which mimic phyllidiids."

This paper describes the anatomy and systematic relationships of two new species, one *Chromodoris*, from the United Arab Emirates and the one *Aldisa* mentioned above, from Sri Lanka. Specimens examined in this study are housed in the Department of Invertebrate Zoology and Geology of the California Academy of Sciences (CASIZ).

Species Descriptions

Chromodorididae Bergh, 1891
Chromodoris Alder and Hancock, 1855

Chromodoris cazae **Gosliner and Behrens, sp. nov.**
(Figs. 1A, 2–3)

Chromodoris sp. Coleman, 2001:76.

Material examined.— Holotype (CASIZ 168299). Rashid Wreck, Khawr Fakkan, United Arab Emirates, 12 m, December 1, 1999. Paratype (CASIZ 168300). Jumeirah Reef, Khawr Fakken, United Arab Emirates, 12m, December 23, 2000.

Distribution.— Known only from the Gulf of Oman, United Arab Emirates.

Etymology.— *Chromodoris cazae* is named in recognition of Carole Harris, Dubai, United Arab Emirates, who was the first to bring this species to our attention and was instrumental in collecting the type specimens. The name *cazae* refers to Carole's childhood nickname (Caz).

External morphology.— The living animals are 40–70 mm in length. The body is oval and high, the notal surface is smooth (Fig. 1A), but with low pigmented elevations. The anus is situated within the ring formed by the gill branches. The perfoliate rhinophores have 18–26 lamellae. The branchial plume is made up of nine unipinnate branches. The background color of the body is translucent white. There are several irregular patches of deep red-maroon found scattered on the mid-dorsal region. Each of these patches has a number of smaller irregular orange spots within it. The number of orange spots varies greatly from zero to sixteen or more. Some specimens, as indicated in photographs of specimens not collected, have orange spots outside of the maroon patches, within the white regions. Each colored patch and spot is slightly elevated or raised from the otherwise smooth notal surface. The margin of the mantle has an irregular series of similar patches. Some specimens have a thin blue line along the edge of the mantle. In some specimens the rhinophoral sheaths have a small maroon patch on the posterior side. The gills and rhinophores are uniformly white, with opaque white specks and lines. Ventrally (Fig. 2B), the foot is about a quarter of the width of the notum. The genital aperture is located on the right side in the anterior third of the body. The triangular, conical oral tentacles are well separated from each other.

Mantle glands.— The mantle glands (Fig. 2A) are continuous around the lateral margins of the mantle and are absent from anterior and posterior portions of the notum. The glands consist of simple spherical bodies that are well separated from each other.

Buccal armature.— The buccal mass is composed of an oval to rounded buccal bulb and

FIGURE 1. Living animals. A, *Chromodoris cazae* sp. nov., specimen from Khawr Fakken, United Arab Emirates, photograph by Carole Harris. B. *Aldisa andersoni* sp. nov., specimen from Sri Lanka, holotype (CASIZ 167461), photograph by Charles Anderson.

the short, glandular oral tube (Fig. 2C). The muscular portion is about two-thirds the length of the oral tube. A pair of elongate salivary glands extends posteriorly from the junction of the posterior portion of the buccal bulb and the esophagus. At the anterior end of the muscular portion of the buccal mass there is a chitinous labial cuticle, which bears numerous jaw rodlets. The rodlets (Fig. 3A) have a short base and a curved apex that may be undivided or, more commonly, a short bifid

apex. The radular formula of the paratype is $33 \times 42.1.42$. The rachidian row of teeth is well-developed (Fig. 3B). The rachidian teeth are short, triangular and devoid of denticles. The innermost lateral teeth (Fig. 3B) have a broad triangular cusp. On the inner side of the primary cusp is a single rounded inner denticle. There are 4–5 small, acutely pointed denticles on the outer side of the primary cusp. The subsequent inner lateral teeth lack the inner denticle and possess 5–6 outer denticles. The middle lateral teeth (Fig. 3C) are elongate and sharply curved with 5–6 acutely pointed denticles on the outer side of the primary cusp. The three to four outermost teeth (Fig. 3D) are more elongate with a broad base. They have 3–4 rounded denticles on the outer side of the small primary cusp.

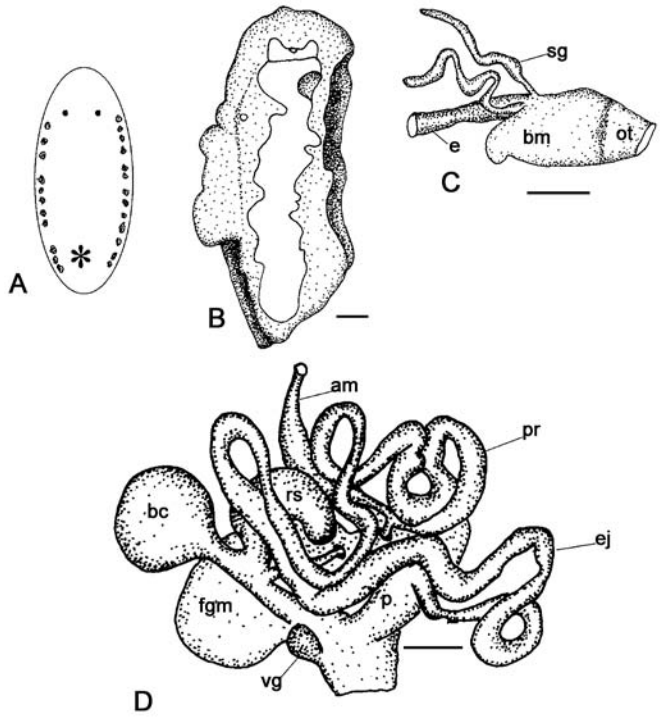

FIGURE 2. *Chromodoris cazae* (CASIZ 168300). A. Schematic distribution of mantle glands. B. Ventral view of anterior border of the foot, scale bar = 1.0 mm. C. Buccal mass, scale bar = 1.5 mm. D. Reproductive system; scale bar = 0.3mm. Abbreviations: am, ampulla; bc, bursa copulatrix; bm, buccal mass; e, esophagus; ej, ejaculatory duct; fgm, female gland mass; o, oral tube; ot, oral tentacle; p, penis; pr, prostate; sg, salivary gland; rs, receptaculum seminis; vg, vestibular gland.

REPRODUCTIVE SYSTEM.— The reproductive system is triaulic (Fig. 2D). The ampulla is relatively short and curved. From its proximal end it bifurcates into the short, thick, slightly convoluted prostate and the short oviduct that enters the female gland mass. From the prostatic portion of the vas deferens, the duct narrows somewhat and changes texture as it becomes the long and convoluted ejaculatory segment. More proximally to the genital atrium, the ejaculatory duct narrows and again abruptly expands into the short muscular penial sac. The thick vaginal duct opens into the genital atrium adjacent to the penis and a short, globular vestibular gland. Proximally, the vaginal duct connects directly with the spherical bursa copulatrix. The curved, pyriform receptaculum seminis enters the vagina immediately below the bursa copulatrix. Just below the entrance of the receptaculum seminis, the vagina is joined by the short, narrow uterine duct, which enters the female gland mass. The female gland mass is large and completely developed.

DISCUSSION.— *Chromodoris cazae* is unique in its white color with patches of maroon with smaller orange spots inside the patches. A few other species have similar colors. *Chromodoris kitae* Gosliner, 1994, has purple spots extending from the edge of the notum and covering the entire dorsal surface. There is a ring of orange patches along the submarginal area of the mantle. The gills and rhinophores are grayish white with opaque white spots. This species is known only from Madagascar. *Chromodoris naiki* Valdés, Mollo, and Ortea, 1999, from India, also has a white body but with purple and orange markings. In this case, the orange markings are not restricted to a sub-

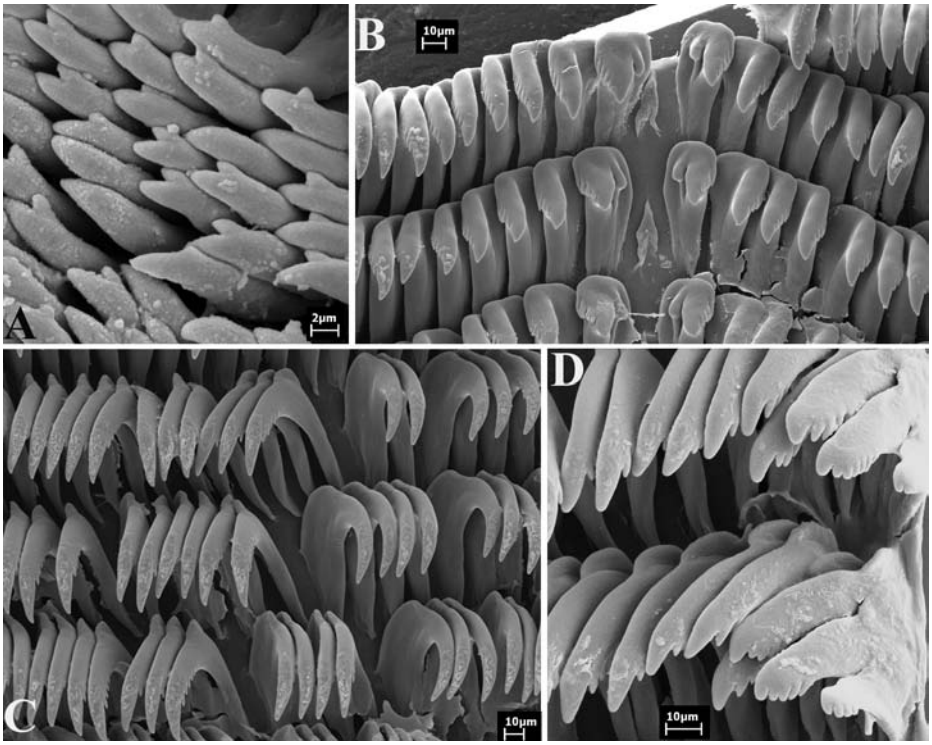

FIGURE 3. *Chromodoris cazae* sp. nov., holotype (CASIZ 168299). A, Scanning electron micrographs. A. Jaw rodlets, scale bar = 2 µm. B. Inner lateral teeth, scale bar = 10 µm. C. lateral teeth from the central portion of half-row, scale bar = 10 µm. D. Outer lateral teeth, scale bar = 10 µm.

marginal band and are found on the notum as well. This differs from the color pattern of *C. cazae*, where the orange spots are much smaller than the purplish ones. Additionally, *C. naiki* bears small opaque white spots on the notum that are absent in both *C. kitae* and *C. cazae*.

Internally, the three species differ as well. In *C. naiki*, a rachidian row of radular teeth is absent, whereas in *C. cazae* and *C. kitae* a row of triangular rachidian teeth is present. In *C. cazae*, the rachidian teeth are far more prominent than in *C. kitae*. In the reproductive system of *C. naiki* and *C. kitae*, the elongate and coiled receptaculum seminis enters directly into the base of the bursa copulatrix at the distal end of the vagina. In *C. cazae*, the receptaculum is pyriform with a shorter duct and enters the vagina in a position that is more proximal to the genital atrium.

Aldisidae Bergh, 1891
Aldisa Bergh, 1878

Aldisa andersoni Gosliner and Behrens, sp. nov.
(Figs. 1B, 4–5)

Chromodoris sp. Debelius, 1996:213 (bottom of page).
Aldisa erwinkoehleri Perrone, 2001: misidentification of specimen in Debelius, 1996.

MATERIAL EXAMINED.— HOLOTYPE (CASIZ 167461). Pigeon Island, Trincomal, Sri Lanka, March 7, 1995, 8 m deep, Charles Anderson. Photographs of two additional specimens taken on the same dive the holotype was collected, taken by Dr. Charles Anderson.

Distribution.— Known only from Pigeon Island, Trincomal, Sri Lanka.

Etymology.— *Aldisa andersoni* is named in recognition of Charles Anderson, Malé, Maldives, who was the first to bring this species to our attention and was instrumental in collecting the holotype.

External morphology.— The living animals are 20–30 mm in length. The body is oval and the notal surface covered with a series of low conical tubercles (Fig. 1B). The tubercles form distinct ridges running longitudinally along the center of the notum, and perpendicular laterally along the margin of the notum. Rows of these tubercles are situated in regions of opaque blue pigment. These regions are separated by areas of black. There is an opaque, bright yellow saddle across the notum behind the rhinophores. This saddle extends right to the edge of the mantle. A few bright yellow patches may partially encircle the gill pocket. Some specimens have yellow patches posterior to the rhinophores. The anus is positioned dorso-ventrally. The perfoliate rhinophores have 17 lamellae. The gill is made up of seven tripinnate branches. The rhinophores and gill are the same blue as the notum. Each rhinophoral pocket has two equally-sized tubercles on either side. The gill sheath has a single row of twelve tubercles along its margin. The anterior portion of the foot (Fig. 4A) is smooth lacking a notch and the oral tentacles are rudimentary, typical of *Aldisa*.

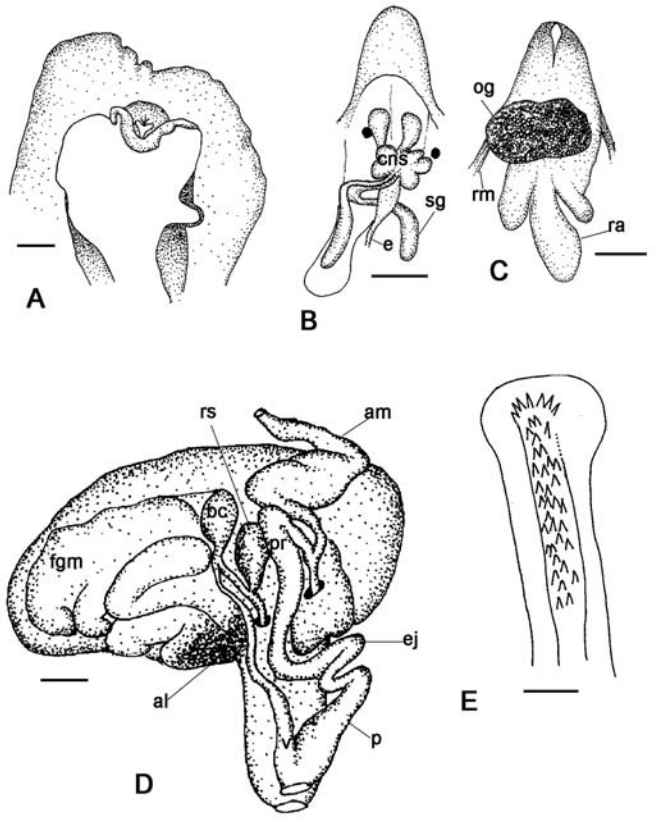

Figure 4. *Aldisa andersoni* sp. nov., holotype (CASIZ 167461) A. Ventral view of the anterior border of the foot, scale bar = 1.0 mm. B. Buccal mass, dorsal view, scale bar = 0.6mm. C. Buccal mass, ventral view, scale bar = 0.5 mm. D. Reproductive system; scale bar = 2.3 mm. E. Penial hooks, scale bar = 35 µm. Abbreviations: al, albumen gland; am, ampulla; bc, bursa copulatrix; cns, central nervous system; e, esophagus; ej, ejaculatory duct; fgm, female gland mass; og, oral gland; p, penis; pr, prostate; ra, radular sac; rm, retractor muscle; rs, receptaculum seminis; sg, salivary glands; v, vagina.

Buccal armature.— The buccal mass is composed of an oval to rounded buccal bulb and the glandular oral tube (Fig. 4B–C). The esophagus opens on the dorsal side of the buccal mass, where two large, darkly pigmented salivary glands attach. Below the posterior end of the oral tube portion of the buccal mass lies a large granular oral gland mass (Fig 4C). The radular formula is impossible to determine given the elongate intertwining radular teeth (Fig. 5A). There is no trace of a rachidian row of teeth. The teeth are all extremely narrow and elongate with a broad, triangular base. The inner lateral teeth (Fig. 5C) are much longer than the outer ones. The inner teeth bear 7–8 sharp denticles with a wide groove extending from the apex to about the middle of each den-

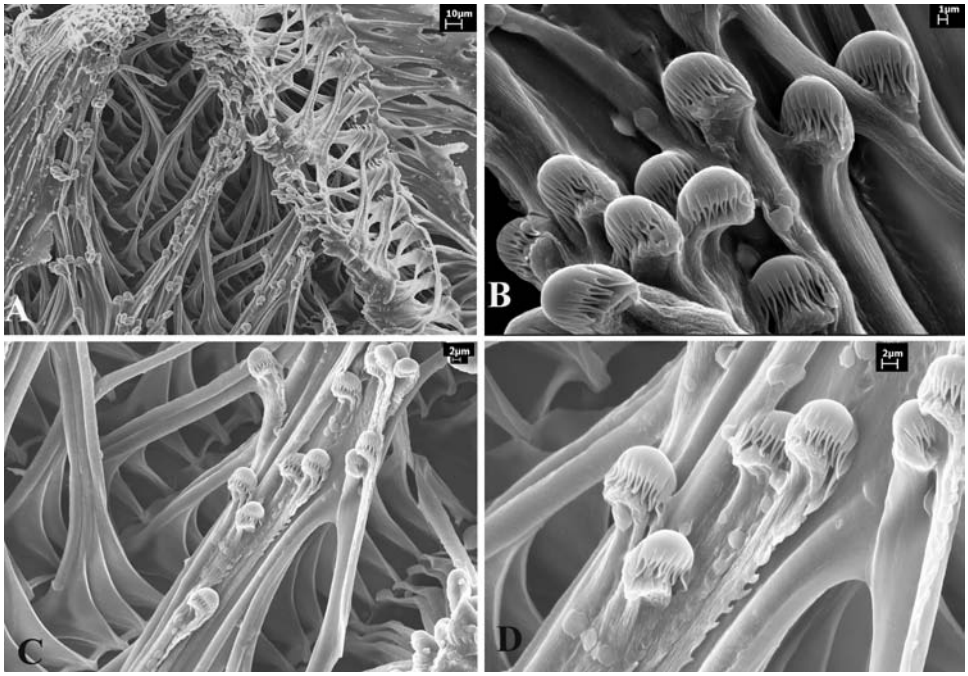

FIGURE 5. *Aldisa andersoni* sp. nov., holotype (CASIZ 167461). Scanning electron micrographs. A. Lateral teeth, scale bar = 10 µm. B. Close up of inner lateral teeth from the central portion of half-row, scale bar = 1 µm. C. Inner lateral teeth, scale bar = 2 µm. D. Close up of inner lateral teeth, scale bar = 2 µm.

ticle (Fig. 5B, D). A series of approximately ten smaller, simply upturned denticles are present along the distal portion of the tooth below the grooved denticles.

REPRODUCTIVE SYSTEM.— The reproductive system is triaulic (Fig. 4D). The ampulla is tubular and thick, winding back on itself before narrowing where the distal portion emerges at the prostate and oviduct. The oviduct connects with the female gland mass beneath the prostate. The prostate is granular and tubular, convoluted, distally narrowing and expanding again into the short muscular ejaculatory portion. The distal portion of the deferent duct exits at a separate genital atrium. The penial bulb is armed with approximately 6 rows of minute hooks (Fig 4E). The hooks have a wide base tapering to a long curved cusp. The vaginal duct is about the same length as the deferent duct, and opens into the bursa copulatrix. The bursa copulatrix is rounded and connects with the seminal receptacle by a short duct. Near the seminal receptacle this duct is joined by the uterine duct, which enters the female gland mass. The pyriform receptaculum seminis is equal in size to the bursa copulatrix.

DISCUSSION.— The revision of the genus *Aldisa* by Millen and Gosliner (1985) diagnosed the genus with the following characteristics: elongate radular teeth with multiple denticulations, a dorsum with low conical tubercles (except *Aldisa pikokai* Bertsch and Johnson, 1982, which lacks tubercles), a ring of tubercles around the rhinophoral and branchial pockets, bi- and tri-pinnate gills, penial spines in most species, absence of oral tentacles and the anterior portion of the foot smooth with no notch.

Aldisa andersoni exhibits all the characteristics of the genus *Aldisa* noted above. Elwood, et al. (2000) added a previously unnoticed character when describing *Aldisa albatrossae* and *A. williamsi*: the presence of a pair of unique hamate radular teeth, which are much wider and more robust than the thin denticulate ones.

Aldisa andersoni is the fourth described tropical Indo-Pacific species exhibiting bright blue coloration with black and/or yellow markings. It is similar, in this regard, to *Aldisa albatrossae*, *A. williamsi* and *A. erwinkoehleri* Perrone, 2001, but it differs in a number of characteristics. All other species, except *Aldisa barlettai* Ortea and Ballesteros, 1989, are species exhibiting subdued white, green, tan, or red coloration making them cryptic on their sponge prey.

In *Aldisa andersoni*, the low conical tubercles are clearly arranged in rows or ridges. Tubercles on the notum of *Aldisa albatrossae*, *A. williamsi* and *A. erwinkoehleri* are randomly distributed. The black coloration on *A. williamsi* and *A. erwinkoehleri* forms concentric rings, and in *A. albatrossae* **it** forms a rectangle on the dorsum with a T-shape mark anterior to the rhinophores. In *A. andersoni*, the black pigmentation is found uniformly over the mantle separating the rows of tubercles. The opaque yellow pigmentation on *Aldisa andersoni* is quite similar to that found on *A. albatrossae* and *A. erwinkoehleri*. There are, however, consistent differences that clearly separate them. *A. williamsi* has no yellow pigmentation. The yellow pigmentation covers the tubercles in *A. erwinkoehleri* and in *A. andersoni*, but not in *A. albatrossae*, where it occurs between the tubercles. The yellow color markings on *A. andersoni* are far more extensive than in the other species, with a yellow saddle extending to the very edge of the mantle that is not isolated into smaller broken patches, as in *A. erwinkoehleri*.

The rhinophores differ in color among all four species. In *Aldisa albatrossae*, they are white-grey; in *A. williamsi*, pale brown; in *A. erwinkoehleri*, black; whereas in *A. andersoni* they are the same blue as the body. The arrangement of tubercles around the rhinophoral pockets also differs among the four species. *Aldisa albatrossae* has four similarly sized equally separated tubercles; *A. erwinkoehleri* has two large and two small tubercles, whereas *A. andersoni* and *A. williamsi* have two equally sized tubercles, which are separated on either side of the pocket. Differences exist also in the tubercles around the gill sheath. *A. albatrossae* has a double row of tubercles; *A. williamsi* has a single row of eight tubercles; *A. erwinkoehleri* a single series tubercles; and *A. andersoni* has a single series of twelve tubercles around the sheath.

Internally, the radular teeth vary in one significant regard. In *Aldisa albatrossae* and *A. williamsi*, there is a pair of smooth, hamate teeth in addition to the elongate teeth typical of species of *Aldisa*. These hamate teeth are absent in *A. andersoni* and were not described either in *A. erwinkoehleri*. A massive granular gland on the ventral surface of the buccal mass is present in *A. andersoni*. Re-examination of type specimens of *A. williamsi* and *A. albatrossae* revealed the presence of a similar gland, but it is proportionately much smaller in these two species than that found in *A. andersoni*.

A few differences were found in the reproductive systems of the four species. The penial spines of *Aldisa andersoni* are similar in shape to those found in *A. williamsi*, but they differ from those of *A. albatrossae*. Perrone (2001) reports no armature at all in the penial bulb of *A. erwinkoehleri*. In the description of *A. erwinkoehleri*, the prostatic portion of the vas deferens was not differentiated, as it is in the other three species. It is not certain whether these discrepancies are due to morphological differences, but they are more likely the result of incomplete description in the case of *A. erwinkoehleri*. The bursa copulatrix is relatively small in all four species, being approximately equal to the receptaculum seminis in size.

Acknowledgments

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