

OPISTHOBRANCHIATE MOLLUSCA FROM GHANA: DORIDIDAE AND CADLINIDAE

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Abstract Descriptions are given of seven species of Dorididae and one of Cadlinidae from Ghana. Three of the species assigned to the genus *Doris* are poorly known so have not been named. Two new species are described, *Doris kpone* and *Doris minuta*, and further information is given of three species known from elsewhere in the Atlantic Ocean, *Doris verrucosa* Linnaeus 1758, *Doris morenoi* Ortea 1989 and *Aldisa smaragdina* Ortea, Perez & Llera 1982.

Key words Dorididae, Cadlinidae, *Doris*, *Aldisa*

INTRODUCTION

The opisthobranchiate molluscan fauna of West Africa is poorly known (see Edmunds, 2007), but the doridoid nudibranchs are now being described (Edmunds, 1981, 2007, 2009, 2010, 2011). The purpose of this paper is to describe the species of doridoid nudibranchs belonging to the families Dorididae and Cadlinidae collected in Ghana between 1963 and 1973. The genera in the Dorididae have been subject to thorough phylogenetic analysis by Valdés (2002) while those in the Cadlinidae have been analysed by Johnson (2011) resulting in the synonymising of some genera, and in this paper I have followed their conclusions.

MATERIAL AND METHODS

All of the material described here was collected near to Accra and Tema in Ghana, close to longitude 0 latitude 5.7 by the author and by Mr Walter Pople. The method of collection, processing and preservation of specimens is described by Edmunds (2007, 2011). Body measurements and drawings of entire animals are from life unless otherwise stated.

The material collected and described in this paper (including microscope slides of radulae but excluding severely damaged specimens) is deposited in the Natural History Museum, London.

SYSTEMATIC DESCRIPTIONS

Family Dorididae Rafinesque 1815

Genus *Doris* Linnaeus 1758

Type species *Doris verrucosa* Linnaeus 1758 by monotypy

Doris verrucosa Linnaeus 1758

Fig. 1A

- Doris verrucosa* Linnaeus 1758: 653
Doris derelicta Fischer 1867: 7–8
Doris biscayensis Fischer 1872: 6–8
Staurodoris januari Bergh 1878: 583–585, pl. 63 fig. 24, pl. 64 figs 8–12
Staurodoris bobretzkii Gadzikiewicz 1907: 509–510
Doris verrucosa mollis Eliot 1910: 338–339

Material examined NHMUK reg. no. 20120306: Teshie under rocks at low tide 1 sp 20 mm long, 4 April 1973.

External features Body elongate oval with broad rounded foot just projecting posteriorly when animal is active; dorsal surface of mantle with thick rounded tubercles of variable size (Fig. 1A); rhinophores with 13 lamellae sloping back to a posterior groove, emerging from between two elongate tubercles; 13 unipinnate gills surrounding anus, anal papilla supported by anterior membrane. Notum dull yellow (buff) merging into broad longitudinal band of dark brown from each rhinophore to gills, this colour largely obscured by greyish brown tubercles (Fig. 1A), mantle ventrally greyish white; foot bright yellow below, dull yellow dorsally; rhinophores dull yellow including tip with greenish grey lamellae; gills dull yellow with brown spots.

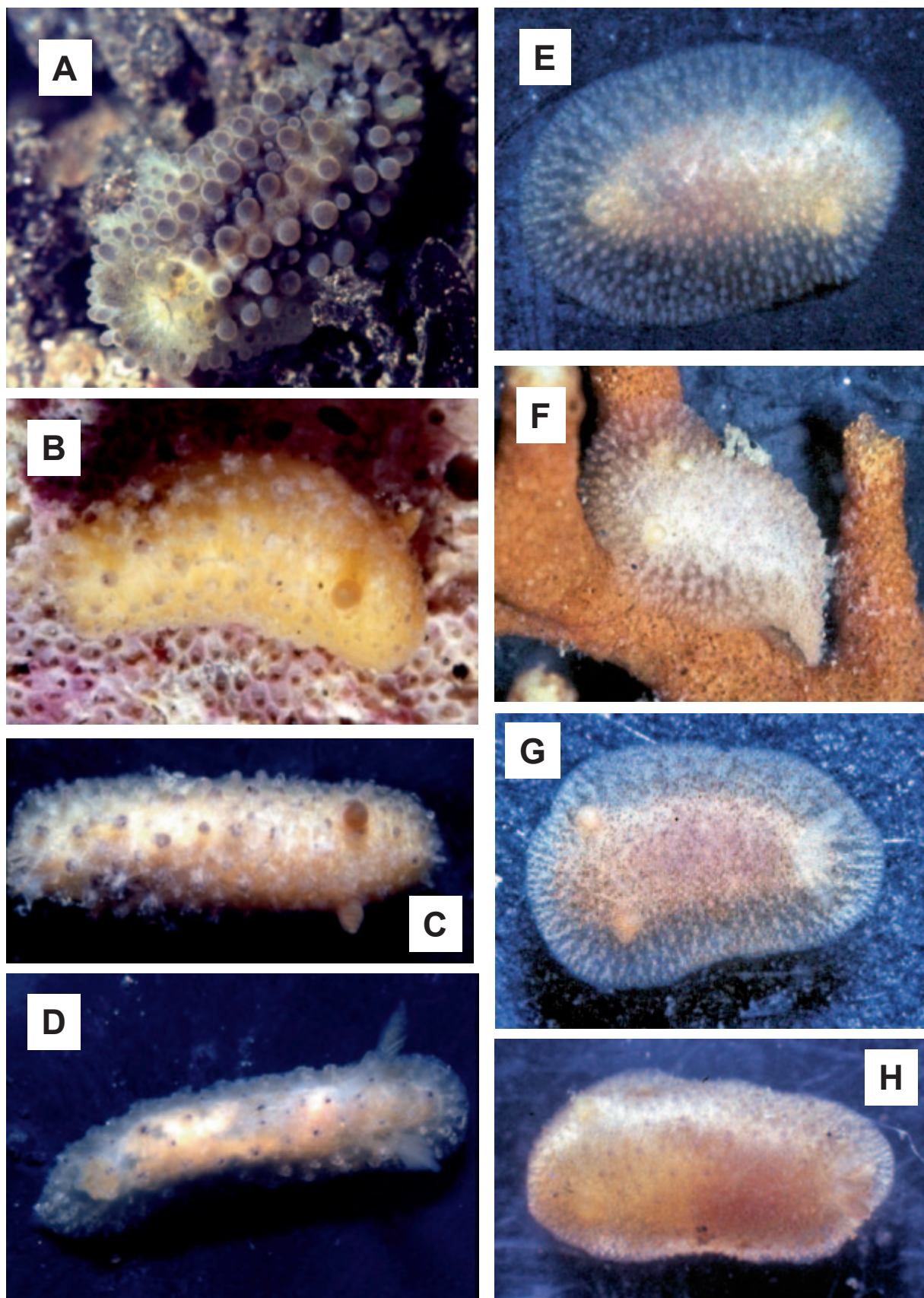


Figure 1 A *Doris verrucosa* Linnaeus 1758, 20 mm long, April 1973. B–D *Doris kpone* n. sp., B, C 9 mm long February 1970 on different backgrounds, D 6.5 mm long, March 1970. E–G *Doris minuta* n. sp., E, F 4 mm long, November 1969 on different backgrounds, G 3 mm long, October 1968. H *Doris* sp. B, 5 mm long, October 1968.

Internal morphology The single specimen was not dissected as it is easily recognisable from external features.

Behaviour A specimen of *Doris verrucosa* from Arcachon (France) has been recorded as secreting acid of pH 1 and the histology of the glands believed to secrete the acid has been described (Edmunds, 1968). Avila & Durfort (1996) also described the histology of the mantle tubercles and reported 'clear vesicles' similar to those described by Edmunds as probably containing inorganic acid, but they found that the skin secretion of specimens from the Mediterranean was neutral. The present specimen was also tested with wide-range indicator paper while being roughly prodded but there was no evidence of an acidic secretion. While an unhealthy animal may not react to molestation in the same way as a healthy one, this animal appeared to be perfectly normal in its behaviour. Why should there be conflicting reports of acidic skin secretions for this species? A negative result could be because the animal requires quite violent stimulation before it will release acid, but similar negative results from different workers suggests that many specimens do not secrete acid. Alternatively there may be geographical variation in the skin secretions of this species related to the local predators, or there may be more than one species with different chemical defences currently included under the name *Doris verrucosa*. This species is known to secrete ichthyotoxic diacylglycerols from the mantle which it probably synthesizes *de novo*, together with other chemicals which it sequesters from its sponge prey (Avila *et al.*, 1990; Avila, 1995). It would be well worth checking the skin secretion of this species from a variety of sites to confirm whether any individuals are able to secrete inorganic acids.

Geographical range West Atlantic from Massachusetts to Brazil; east Atlantic from English Channel, the Mediterranean and the Azores to West Africa (Thompson & Brown, 1984; Valdés *et al.*, 2006). The records from South Africa (Gosliner, 1987) may perhaps be of a different species (Valdés, 2002).

Remarks This well-known species can be recognised by the bulbous tubercles on the mantle, with tubercles also present round the rhinophore and gill openings, and the unipinnate gills. It

varies in colour from dark brown, violet or grey to yellow or almost white with brown markings (Thompson & Brown, 1984; Valdés *et al.* 2006; Sea Slug Forum, 1999–2009). The most recent, discussion of the synonymy of this species is by Valdés (2002).

Doris kpone n. sp.

Figs 1B–D, 2

Etymology The species is named from its occurrence in Kpone Bay, off Tema, Ghana.

Material examined NHMUK reg. nos 20120307/8 & 17 (radula): 10 m reef, Kpone Bay, 1 sp 9 mm long, 6 February 1970; 1 sp 4 mm long, 22 February 1971; dredged from 40 m, Tema Bay, 1 sp 6.5 mm long 17 March 1970; rock pool debris Teshie, 1 sp 3.5 mm long, 4 April 1973.

Holotype NHMUK reg. no. 20120307 from 10 m reef Kpone Bay, Ghana, 6 February 1970, collected by W. Pople.

External features: Body elongate, parallel-sided or with slight taper towards rear, blunt tail barely projecting beyond mantle (Figs 1C, 1D, 2D); dorsal surface of mantle covered with blunt circular tubercles with spicules projecting from them (Fig. 2E), slightly smaller in centre and towards edge; rhinophore stalk short arising from socket with larger outer and smaller inner tubercles, largest specimen with 15 to 20 lamellae sloping from front to back, but basal ones hidden in socket, smaller specimens all with seven lamellae (Fig. 2A); five to eleven unipinnate gills (number depending on size of animal), in largest specimen gills arising from turret with nine tubercles, anterior one the largest, in smaller specimens no turret and gill opening with fewer tubercles; oral tentacles short, blunt ridges, occasionally with slight lateral projections (Fig. 2B, 2C) but not tentacular; foot with transverse anterior groove. Body yellow, buff or brownish yellow (Fig. 1B–D); tips of tubercles brown in centre of mantle, yellow at sides; rhinophores and gills yellow. When on black background the yellow colour is much browner (see Fig. 1B, 1C).

Internal morphology The buccal mass of the 6.5 mm specimen was removed (Fig. 2F). There is no armature to the labial cuticle and the radula has the formula 30×56.0.56. All the teeth are

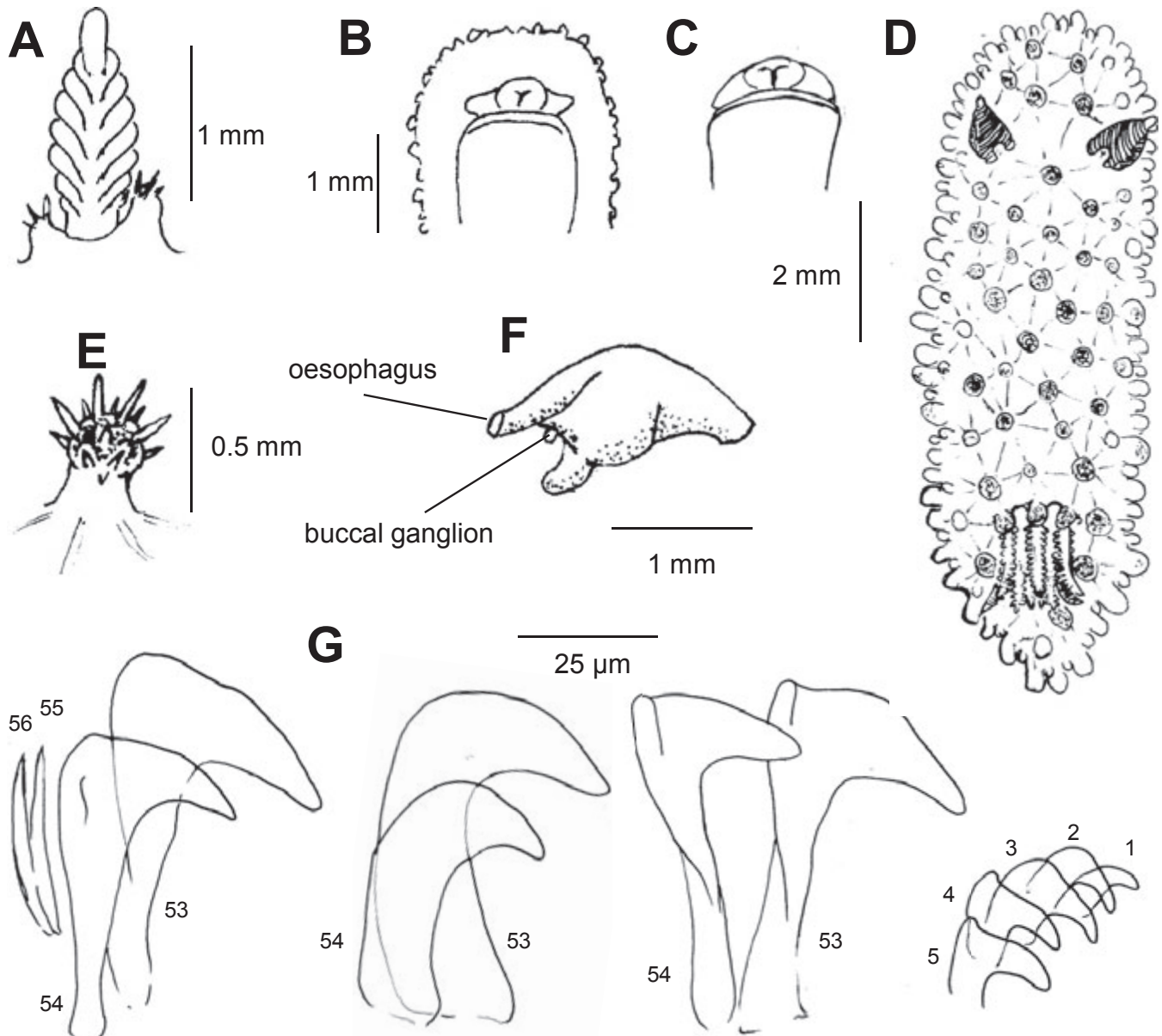


Figure 2 *Doris kpone* n. sp. 6.5 mm long specimen: A rear view of right rhinophore; B ventral view of head. 9 mm long specimen: C ventral view of head; D dorsal view of live animal; E spicular tubercle (stipple on tubercles is brown pigment). 6.5 mm specimen: F buccal mass; G radular teeth with several outer teeth viewed from different angles. Numbers beside radular teeth in all figures mark its position in the row.

hamate apart from the rudimentary outermost teeth, and I could see no trace of a median tooth although this is difficult to confirm because of the almost non-existent space between the left and right first lateral teeth. The teeth appear either smoothly rounded or with a marked shoulder depending on the angle of viewing, as shown in Fig. 2G.

Behaviour One of the specimens was tested for acid secretion but, as with *D. verrucosa* (above) it was neutral.

Geographical range Known only from Ghana.

Remarks This species is characterised by the shape of the dorsal tubercles with projecting spicules, a meshwork of spicules visible through the dorsal body wall, unipinnate gills, and radular teeth which are all hamate. Caryophyllidia can be defined as closely spaced tubercles on the notum, each one with an outer ring of projecting spicules around a central ciliated tubercle (Foale & Willan, 1987), and among Ghanaian dorids they have been illustrated for *Jorunna ghanensis*

Edmunds 2011, *Rostanga rubra* (Risso 1818) and *Rostanga crocea* Edmunds 2011 (Edmunds, 2011). Even the very low and almost rudimentary caryophyllidia of *Platydoris* and *Baptodoris* have the same spicular ring with a central tubercle (Valdés & Gosliner, 2001). Such caryophyllidia are quite different from the sparse tubercles each with an irregular arrangement of projecting spicules in *D. kpone*. This lack of caryophyllidia, together with lobed rather than digitiform oral tentacles, suggests that *D. kpone* is not closely related to the caryophyllidia-bearing discodorids.

Doris kpone n. sp. needs to be compared with several similar species with large dorsal tubercles from Europe, the Atlantic Isles and the Caribbean. The European *Doris sticta* (Iredale & O'Donoghue 1923) grows to 40 mm or more and has tripinnate gills with many close rhinophore lamellae (Thompson & Brown, 1984). *Doris maculata* Garstang 1895 grows up to 20 mm with low ridges joining the dorsal tubercles and all of Garstang's specimens had five unipinnate gills. García-Gómez (1987) has described a specimen from southern Spain (Gibraltar) which he identified as *Doris maculata*, but this is now considered to be *D. sticta* (García-Gómez, 2002; Cervera *et al.*, 2006). Illustrations of specimens identified as *D. sticta* from Gibraltar, Portugal and the Azores have been published by García-Gómez (2002), Gavaia *et al.*, (2003) and Malaquais *et al.*, (2009). However these all differ from *D. kpone* in at least three of the following characters: presence of dorsal ridges, absence of spicules visible through the dorsum, bi- or tri-pinnate gills and number of gills (a 9 mm specimen of *D. kpone* has 11 unipinnate gills).

Doris hayaki Ortea 1998 from the Cape Verde Islands is a larger yellow species with unipinnate gills but it differs from *D. kpone* in lacking projecting spicules in the tubercles (see Ortea's fig. 1B, although the text says it may have a few projecting spicules: "algunos tubérculos presentan espículas"). It also differs in colour pattern, lacking visible spicules in the body, and in having many fewer radular teeth in each row for a much larger animal (42 in each half row for a 20 mm specimen compared with 56 in a 6.5 mm specimen of *D. kpone*).

Staurodoris atypica Eliot 1906 from the Cape Verde Islands resembles the present specimens in its body shape, yellow colouration, spicules in the integument, dorsal tubercles and 10 or

12 unipinnate gills (the text says 10 gills but the illustration, as Eliot notes, shows 12). The tubercles round the rhinophore and gill pockets are similar to those on the dorsum, as in the present material, but the dorsal tubercles are described as "warts of various sizes, bearing smaller prominences". Eliot distinguishes these tubercles from those of *Doris verrucosa* which are "smooth and clavate" by reiterating his description of them as "low rough warts bearing secondary projections". If these secondary projections are spicules then the description agrees with the Ghanaian specimens, but I am sure Eliot would have described these projections as spicules if that is indeed what they were. The radular formula is 38×30.0.30 with all teeth hamate, which is a much smaller radula from a considerably larger specimen than that of my Ghanaian material. I conclude that *Staurodoris atypica* differs from *Doris kpone*, but it may perhaps be conspecific with *Doris hayaki*.

Doris bicolor (Bergh 1884) from the Mediterranean and the Caribbean grows to 17 mm, but differs from *D. kpone* in having white rhinophores and pectinate outer radular teeth (Bergh, 1884; Valdés *et al.*, 2006); Marcus & Marcus (1970) state that it has glandular rather than spicular tubercles. *Doris ocelligera* (Bergh 1881) from the Mediterranean also grows to 17 mm and appears to have spicular tubercles, but Schmekel & Portmann (1982) write: 'the shape of the strongly spiculose tubercles depends on movement, but normally they do not have a narrow base'. Their illustration shows spicules projecting minutely from tubercles, not as much as in *D. kpone*, and there is no mention of spicules visible through the dorsum between the tubercles, nor is this evident from photographs of this species on the Internet. The species most similar to *D. kpone* is one from the west Atlantic labelled *Doris* sp. on page 172 of Valdés *et al.* (2006): it is 10 mm long, yellowish grey with large darker tubercles and with a meshwork of spicules between the tubercles on the dorsum, but it differs in lacking projecting spicules on the tubercles.

In summary, *D. kpone* may possibly be conspecific with some of the Mediterranean animals currently identified as *Doris sticta* (including the *Doris maculata* of García-Gómez, 1987) or with an unnamed Caribbean species, but it is not conspecific with true *Doris sticta*.

Doris sp. A

Fig. 3

Material examined NHMUK reg. no. 20120316: 10 m reef Kpone Bay 3 sp all 7 mm long and 3 more moribund about the same size, 12 January 1965.

External features Body elongate, parallel-sided or with slight taper towards rear, blunt tail barely projecting beyond mantle (Fig. 3A); dorsal surface of mantle covered with blunt circular tubercles with spicules projecting from them (Fig. 3E); rhinophore stalk short arising from socket with larger outer and smaller inner tubercles (Fig. 3F), with 7–8 lamellae sloping from frontal ridge to posterior groove (Fig. 3C); seven or eight unipinnate gills arising from tubercular socket; oral

tentacles vary in appearance from oval lobes to blunt lateral projections (Fig. 3B, 3D, 3G) but not tentacular; foot with transverse anterior groove but not notched. Notum dark red, tubercles darker red with white spicules (Fig. 3E); rhinophores yellow; gills red basally with yellow or buff tips; foot cream, sides spotted with dark red.

Internal morphology The radula was examined and has the formula $20 \times 27.0.27$, with all except the outermost rudimentary teeth hamate. While it was being narcotised one specimen protruded its penis which has a slender stylet (Fig. 3H).

Ecology One specimen laid an egg ribbon comprising a 5 mm diameter coil of $3\frac{1}{2}$ turns, with 3–5 eggs across the diameter of the ribbon.

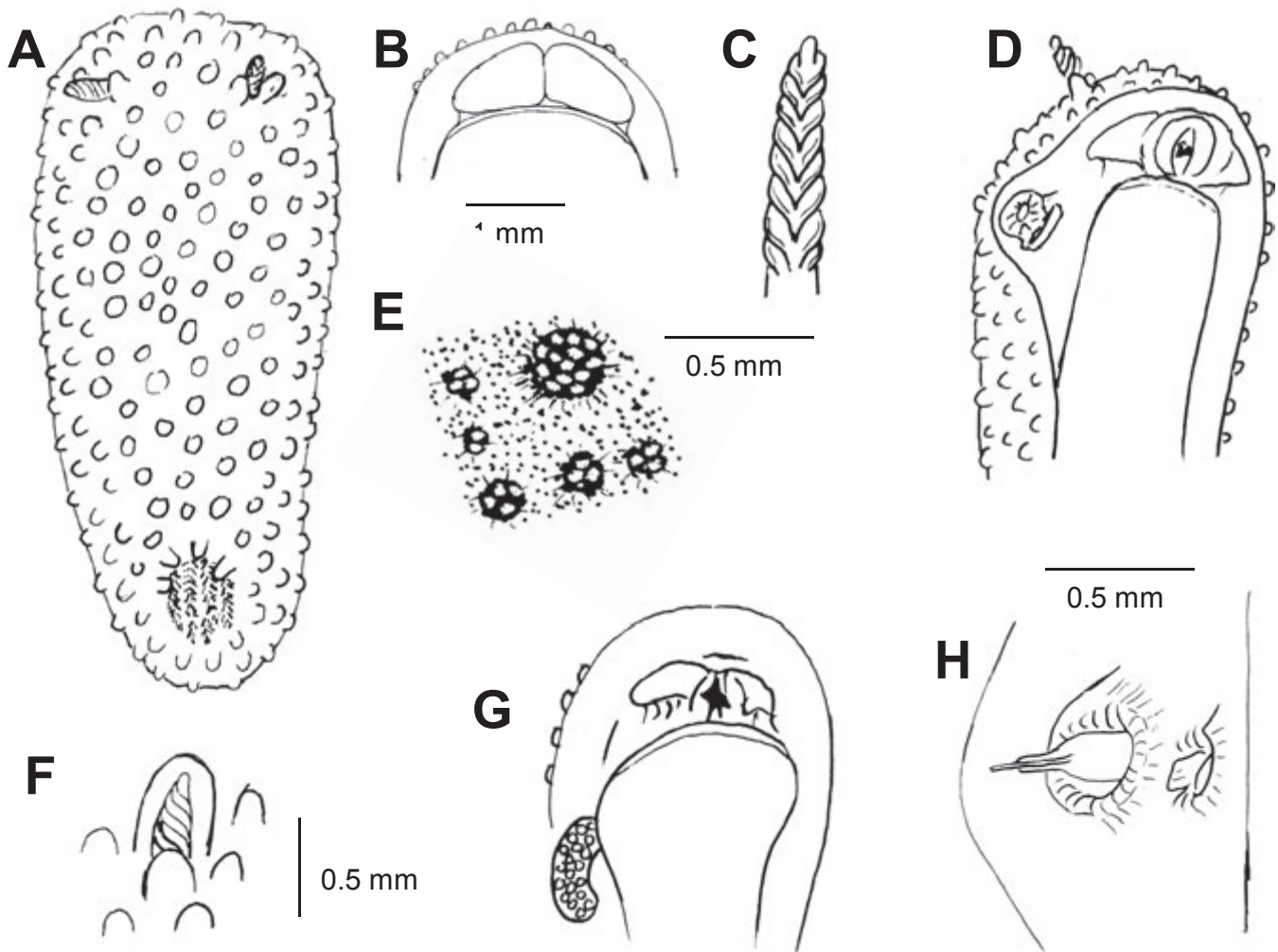


Figure 3 *Doris* sp. A. 7 mm long specimen: A dorsal view of live animal; B ventral view of head. 9 mm long specimen: C posterior view of rhinophore; D ventral-oblique view of animal to show genital openings; E tubercles (stipple and black on tubercles is dark red, white in tubercles is spicules); F partly retracted rhinophore with adjacent tubercles; G ventral view of animal laying egg coil; H detail of genital openings in narcotised specimen.

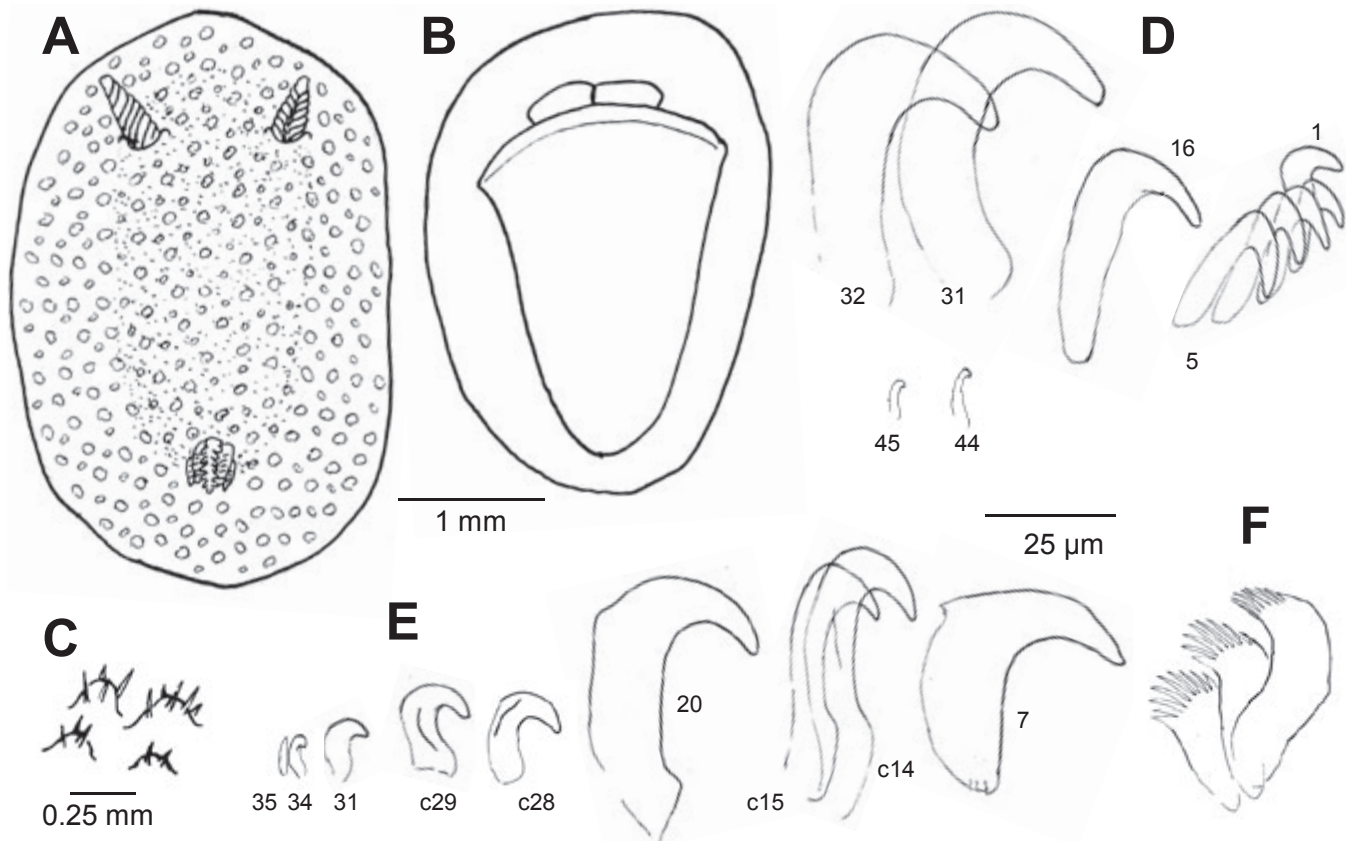


Figure 4 *Doris minuta* n. sp. 4 mm long specimen: A dorsal view; B ventral view; C spicular tubercles; D radular teeth. 3 mm specimen: E radular teeth; F aberrant radular teeth.

Remarks Unfortunately the specimens were all accidentally destroyed so it is not possible to name the species, but the colouration and external morphology indicate that it is an undescribed species of *Doris*, most probably closely related to *Doris kpone*. The site from where these specimens were collected was visited many times over the next eight years yet no further animals were found here or elsewhere.

Doris minuta n. sp.
Figs 1E–G, 4

Etymology This species is named *minuta* because of its small size: no specimens more than 4 mm in length were found, and I can find no trace in the literature of any species of *Doris* with a prior claim to this name.

Material examined NHMUK reg. nos 20120312/13/14 & 21 (radulae 1–3): dredged from Tema Bay: from 35 m 3 sp all 3 mm long, 14 October 1968; from 37 m 3 sp (not measured), 22 March 1969; from 39 m 2 sp 3 & 4 mm long, 29 March 1969; from 40 m 8 sp 2.5, 2.5, 3,

3, 3.5, 3.5, 4 & 4 mm long, 28 November 1969; from 35 m 3 sp 1.5, 2 & 3 mm long, 18 December 1969.

Holotype NHMUK reg. no. 20120313: from 40 m reef Tema Bay, Ghana, 28 November 1969, collected by W. Pople.

External features Body oblong with foot hidden beneath notum; dorsal surface with numerous low tubercles from which spicules project (Fig. 4A, 4C); rhinophores slender with 8 sloping lamellae in larger specimens, with a small tubercle on each side of socket; 5 unipinnate gills with up to 7 pinnae, with small tubercle outside each gill (tubercles beside gills and rhinophores not always easy to see in small preserved specimens); ventrally head and oral lobes form two semi-circles one on each side of the mouth, foot broad, rounded, lacking a notch (Fig. 4B). Notum pale yellow with minute red dots all over, but overall appearance pale yellow (Fig. 1E–G); rhinophores yellow; gills pale yellow; ventrally head, foot and mantle pale orange-yellow with red dots sparser than on notum.

Internal morphology The radulae of three specimens were examined, but not one of them was neatly flattened with complete undamaged rows of teeth. In this species the radula is delicate and easily fragments, and there was no trace of labial rodlets. The radula of one 3 mm specimen has the formula $15 \times 37.0.37$ but the teeth are so similar in refractive index to the Aquamount that it was impossible to see the shape of the innermost teeth. A second specimen of the same size with a damaged radula has at least 9 rows with about 35 teeth in each half row, but the innermost teeth are missing. All other teeth are hamate except for the outermost which have not yet developed hooks, and the largest are in the middle of the row (Fig. 4E). Three detached teeth from towards the outer part of the row are pectinate with slender denticles, similar to those which occur in the outermost teeth of *Doris* sp. B and in many species of the Discodorididae (Valdés & Gosliner, 2001; Edmunds, 2011). However, these teeth are much larger than the outermost teeth of all three radulae of *Doris minuta* which show no trace of denticles, so I conclude that these three teeth are aberrant (Fig. 4F). The radula of a 4 mm specimen that was dying and in a poor state of preservation

was also damaged. It has about 45 hamate teeth on each side, but the row is damaged making precise counting impossible. The inner teeth are simply hamate (Fig. 4D), and the other teeth are similar to those in the 3 mm specimen with no trace of denticulations.

Geographical range Known only from Ghana.

Remarks This species has unipinnate gills, no foot notch and oral lobes instead of conical oral tentacles which, following Valdés (2002), place it in the genus *Doris* in the Dorididae. The small size of the specimens precluded dissection so that the arrangement of the reproductive system is not known, but I can find no trace in the literature of species of *Doris* or of closely related genera which are similar to the present material, so I consider it to belong to a new species, *Doris minuta*.

Doris sp. B
Figs 1H, 5

Material examined NHMUK reg. nos 20120311 & 19 (radula): dredged from 35 m Tema Bay 1 sp 5 mm long, 9 October 1968.

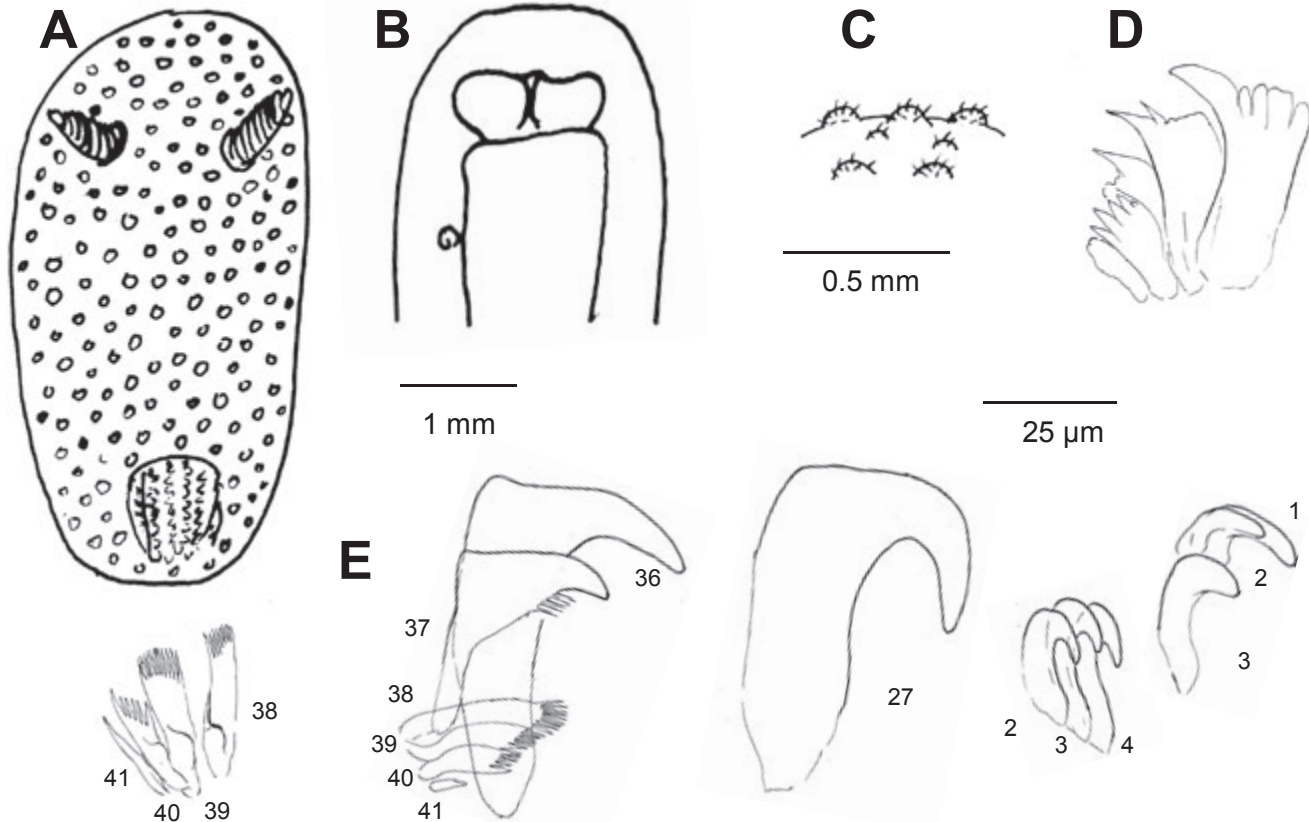


Figure 5 *Doris* sp. B. 5 mm long specimen: A dorsal view; B ventral view; C spicular tubercles; D deformed radular teeth; E normal radular teeth.

External features Body oblong with foot hidden beneath notum (Fig. 5A); dorsal surface with numerous low tubercles from which spicules project (Fig. 5C); rhinophores slender with 10 sloping lamellae; 7 unipinnate gills with up to 10 pinnae; ventrally head and oral lobes form semi-circles on either side of the mouth, foot broad, rounded, lacking a notch (Fig. 5B). Notum brownish yellow with some tubercles brown (Fig. 1H); rhinophores yellow with cream tip; gills pale yellow; ventrally head, foot and mantle yellow.

Internal morphology The radula has the formula $10 \times 41.0.41$. Most of the teeth are simply hamate, increasing in size from the small innermost tooth to the middle of the row and then decreasing slightly towards the outer part of the row (Fig. 5E). The outer four or five teeth are finely pectinate with up to 10 slender denticles, but if the teeth are slightly damaged (e.g. by squashing the radula in order to slightly separate the teeth) then the fine denticles on some of these outer teeth are destroyed (Fig. 5D). In some rows there is a transitional tooth between the pectinate outer and the hamate inner teeth which has both a typical hooked cusp and fine denticles below it (Fig. 5E tooth 37).

Geographical range Known only from the single specimen from Ghana.

Remarks This species is characterised by its pectinate outermost radular teeth, similar to those of *Halgerda*, *Thordisa* and *Taringa* in the Discodorididae (Valdes & Gosliner, 2001; Chan & Gosliner, 2007). However, the Discodorididae have conical oral tentacles unlike the flattened oral lobes of this species. It therefore appears to belong to the Dorididae, but without further material and a more comprehensive description I cannot name it or even allocate it with any confidence to a genus.

Doris sp. C
Figs 6A, 7

Material examined NHMUK reg. nos 20120315 & 22 (radula): dredged from 40 m Tema Bay 1 sp 4 mm long, 10 February 1970.

External features Body oblong with foot hidden beneath notum; dorsal surface with numerous low tubercles slightly larger than those of *Doris*

minuta and *Doris* sp. B, and with spicules visible in notum between tubercles; rhinophore socket with two lateral tubercles, but rhinophores partly retracted so lamellae could not be counted; gills also partly retracted but there are at least 3; head with broad, blunt oral lobes, foot broad, rounded, lacking a notch (Fig. 7B). Notum yellow with spicular network clearly visible in body, larger tubercles between rhinophores and gills tipped brown (Fig. 6A); rhinophores bright yellow; gills pale yellow; ventrally head, foot and mantle pale yellow.

Internal morphology The radula was damaged but 11 rows are preserved with 40 hamate teeth (and sometimes an additional rudimentary outermost tooth) on each side of the midline (Fig. 7C).

Geographical range Known only from this single specimen from Ghana.

Remarks This species clearly belongs to the genus *Doris* because it has oral lobes and hamate radular teeth. It differs from *Doris minuta* and *Doris* sp. B in having larger tubercles on the notum (clearly evident in preserved specimens) some of which are dark brown, conspicuous tubercles on rhinophore sockets, and a conspicuous spicular network beneath the epidermis (as in *Doris kpone*). Because there is just a single specimen which I was unable to examine further without considerable damage, I have not named it.

Doris morenoi Ortea 1989
Figs 6B, 8

Doris morenoi Ortea 1989: 17–19, Figs 1–4

Material examined NHMUK reg. nos 20120310 & 20 (radula): Kpone Bay reef: from 12 m 1 sp 4 mm long, 16 April 1969; from 10 m 1 sp 4 mm long, 2 March 1970.

External features Body oblong with foot just projecting at rear when animal is crawling (Fig. 8A), notum covered with small low tubercles with no noticeable projecting spicules (Fig. 8A inset); rhinophores with 6 or 7 lamellae sloping from shallow frontal groove to deeper posterior groove, socket with five or six low tubercles; 5 unipinnate gills, in one specimen the posterior two are minute unbranched projections; oral lobes rounded, foot narrow with transverse groove and without a notch (Fig. 8B). Notum creamy

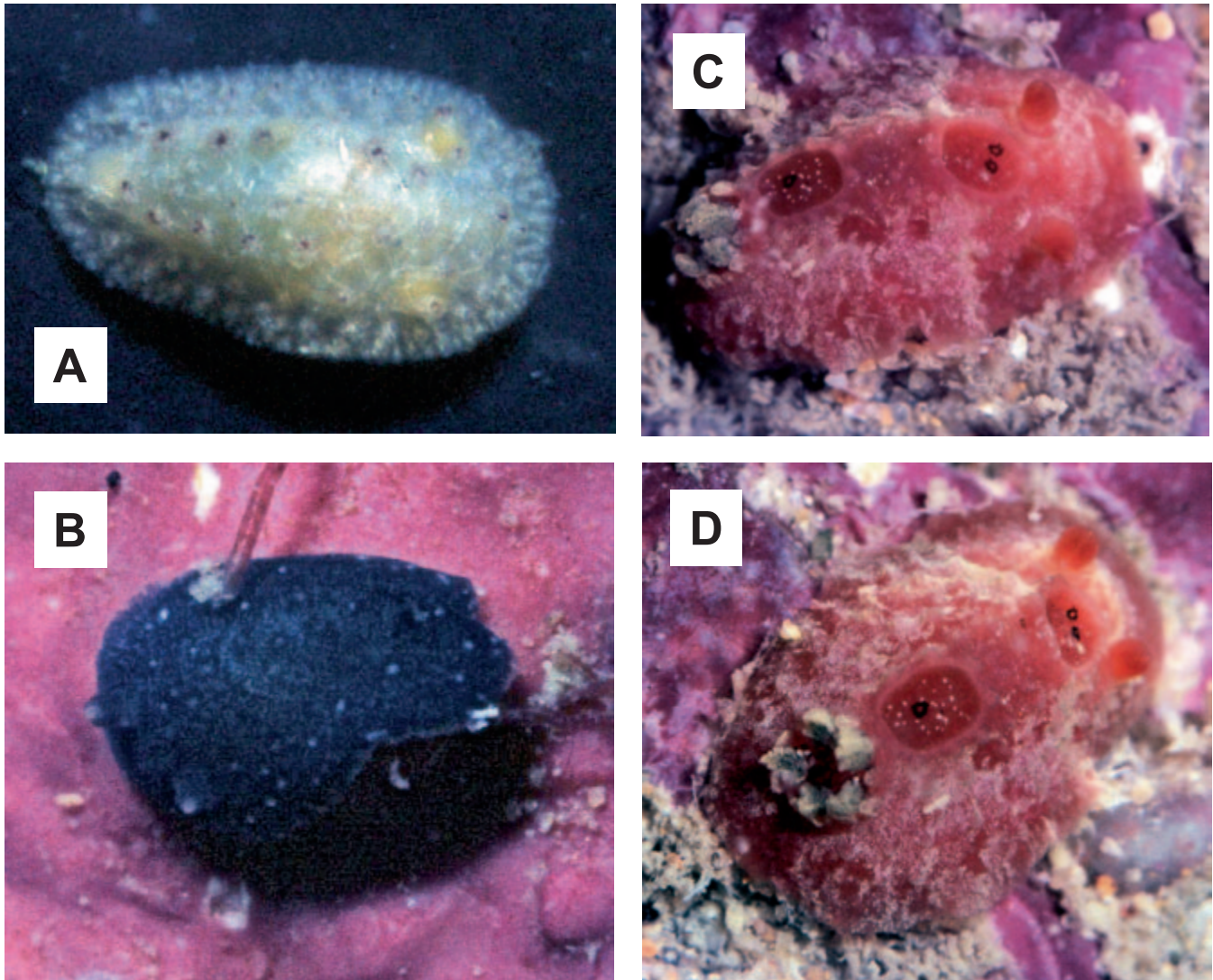


Figure 6 A *Doris* sp. C, 4 mm long specimen, February 1970. B *Doris morenoi* Ortea 1989, 4 mm long, March 1970. C,D *Aldisa smaragdina* Ortea, Perez & Llera 1982, 11 mm long, November 1969.

yellow, clear at edges, but densely covered with irregular meshwork of dark Prussian blue pigment (Figs 6B, 8A inset) so overall appearance is Prussian blue; many tubercles in centre of notum with some white only visible at high magnification, scattered spots of white on surface of notum composed of clusters of minute white dots; rhinophores densely spotted blue with conspicuous white tip; gills blue; oral lobes and foot ventrally cream with sparse blue dots, dense blue dots ventrally on mantle.

Internal morphology The buccal mass from one of the specimens was removed for examination: there is no trace of labial rodlets or of a cuticularised labial region. The radula formula is $4 \times 23.0.23$: with such a short ribbon it is clear

that the specimen is very immature. All teeth are simply hamate increasing in size from the small central teeth to the outer ones (18 to 20) with the outermost smaller (Fig. 8C). Teeth 2–4 have a small shoulder on the side of the cusp: it is only seen in oblique view with the cusp projecting upwards (Fig. 8C: 2a, 3a) and is not visible in lateral view (Fig. 8C: 1, 2, 3, 4).

Geographical range Known only from the Cape Verde Islands (Ortea, 1989) and now Ghana.

Remarks My specimens resemble the original description of *Doris morenoi* Ortea 1989 in the Prussian blue colouration with small dorsal tubercles, white tips to rhinophores, small tubercles fringing rhinophore sockets, broad oral lobes,

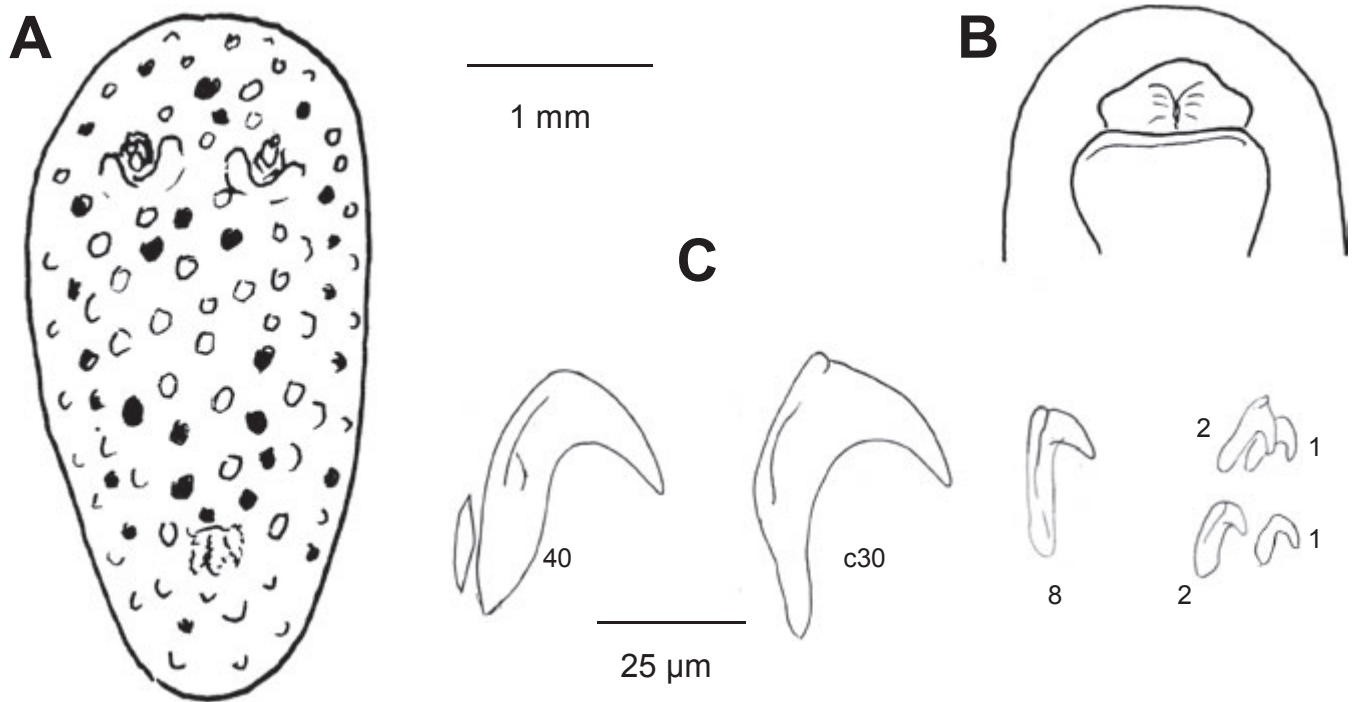


Figure 7 *Doris* sp. C, 4 mm long: A dorsal view; B ventral view; C radular teeth. Black spots in A are dark brown tubercles.

unipinnate gills, general shape of radular teeth and absence of labial cuticle. They differ in having white spots on the dorsum, no white on the rhinophore lamellae, blue rather than black gills, and the outermost 3 or 4 radular teeth decreasing in size (instead of the penultimate tooth being very large). My Ghanaian specimens were both smaller than those described from the Cape Verde Islands so some of these differences may be due to immaturity; alternatively they may reflect variation resulting from partial isolation and evolutionary divergence of the two populations. Further material and DNA profiling would distinguish between these two hypotheses, but for the present I consider that my specimens from Ghana are conspecific with *Doris morenoi*.

Family Cadlinidae Odhner 1968

Genus *Aldisa* Bergh 1878

Type species *Doris zetlandica* Alder & Hancock 1854 by monotypy

Aldisa smaragdina Ortea, Perez & Llera 1982
Figs 6C–D, 9

Aldisa smaragdina Ortea, Perez & Llera 1982:
14–18, pl. 1B, figs 4,5

Material examined NHMUK reg. nos 20120309 & 18 (radula): 10–12 m reef Kpone Bay 1 sp 13 mm long, 9 October 1968, 1 sp 11 mm long, 2 November 1969; 1 sp 8 mm long 30 November 1969; 1 sp 8 mm long, 11 December 1971.

External features Body oval, slightly longer than broad, tail barely projecting beyond mantle (Fig. 9A); dorsal surface covered with sparse, low pyramidal tubercles without projecting spicules (Fig. 9A inset), two median circular depressions between rhinophores and gills with 7–10 small tubercles on rim; rhinophore arising from socket with four oval tubercles, 13 mm specimen with 12 lamellae sloping back from frontal ridge to posterior groove, 11 mm specimen with 10 lamellae; 5 bipinnate gills, typically held in a cone (Fig. 9C), arising from socket with 10 tubercles, alternate larger ones between the gills; oral tentacles short, blunt (Fig. 9B) but not noticeable preserved when head forms a semicircle; foot with transverse anterior groove but no notch. Notum bright red with large areas of dense creamy white spots, forming bands in largest specimen (Fig. 9A) but irregular in 11 mm specimen (Fig. 6C, 6D), scattered minute black dots (much smaller than white spots) all over surface (Fig. 9A inset), depressions with several white spots and 0, 1 or 2

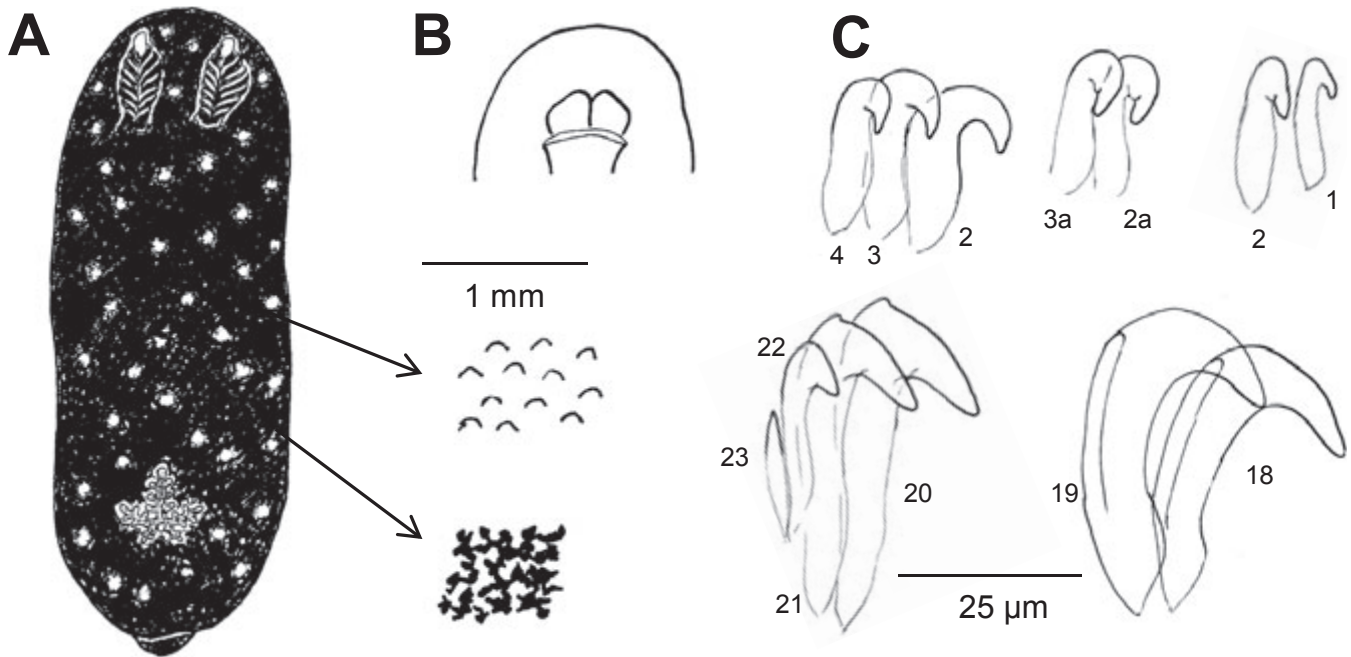


Figure 8 *Doris morenoi* Ortea 1989, 4 mm long, March 1970. A dorsal view with detail of minute tubercles and Prussian blue pigment. B ventral view of head. C radular teeth. White spots in A are white in life. Teeth 2a & 3a show a small shoulder on the side of the cusp.

conspicuous black circles formed of dense black dots in larger specimens, two smaller specimens lacking black circles; rhinophores vermilion with sparse minute black dots, stalk paler; gills of 13 mm specimen vermilion proximally, greyish white distally, tips white with dense minute black dots all over, gills of 11 mm specimen brown with cream spots especially towards tips together with dense black dots; ventral surface of mantle and foot pale vermilion with sparse minute black dots. Black circles and dots remain in specimens preserved in Bouin's fluid and stored in alcohol for 40 years except that they have been lost in the smallest specimen.

Internal morphology The buccal mass from the 11 mm specimen was removed for examination of the radula, but the animal was clearly immature with small reproductive organs (this is consistent with it belonging to *A. smaragdina* which commonly exceeds 20 mm in length). It is quite impossible to count the number of teeth in each row of the radula in species of *Aldisa* because they are so slender and overlap one another. The longest teeth are at least 0.4 mm long and each tooth has a diameter of 6–8 µm, slightly less than shown by Ortea, Perez & Llera (1982). The shaft of the tooth has 3–4 denticles pointing downwards followed by 20–30 denticles pointing upwards; the tip itself is curved with 4–5

denticles at right angles to the denticles on the shaft (Fig. 9D). The way in which these remarkable radular teeth function in species of *Aldisa* has never been investigated.

Geographical range Known from the Mediterranean, the Atlantic coast of Spain and Portugal, Madeira, the Azores, the Canaries and now from Ghana (Cervera *et al.*, 2006).

Remarks The genus *Aldisa* has been revised by Millen & Gosliner (1985) and is characterised by exceptionally long and slender finely denticulate radular teeth. The phylogenetic analysis by Valdés (2002) showed that *Aldisa* belongs in the Dorididae, but the more recent analysis including many more species by Johnson (2011) shows very clearly that *Aldisa* is closest to *Cadlina*, and that these two genera are sufficiently distinct from the Dorididae, Discodorididae and Chromodorididae to justify resurrecting the family name Cadlinidae (Odhner, 1968, who elevated Bergh's subfamily Cadlininae to family rank).

The Mediterranean and east Atlantic species of *Aldisa* with two circular depressions on the notum are *Aldisa banyulensis* Pruvot-Fol 1951 from France, *Aldisa binotata* Pruvot-Fol 1953 from Morocco and *Aldisa smaragdina* Ortea, Perez & Llera 1982 from the Canaries. The description of *A. banyulensis* given by Pruvot-Fol (1954) is

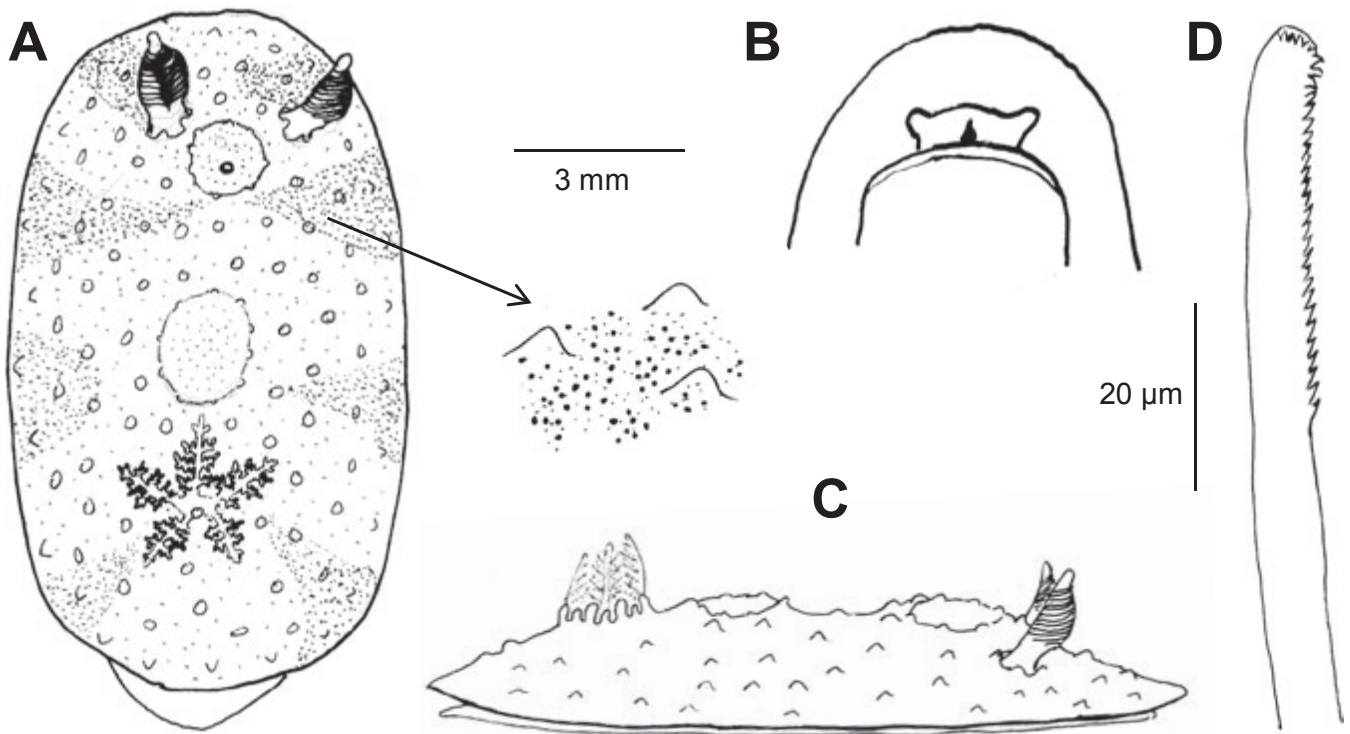


Figure 9 *Aldisa smaragdina* Ortea, Perez & Llera 1982, 13 mm long: A dorsal view showing two oval depressions, one with black circle, and inset of papillae and pigment; B ventral view of head; C lateral view; D part of one of the radular teeth. Stipple in A and coarse stipple in inset is white, fine stipple in inset is black dots.

not entirely the same as her original description in 1951, but further material has been well described by García, García-Gómez & Cervera (1986). Millen & Gosliner regard *A. smaragdina* as a junior synonym of *A. binotata*, but later authors have ignored *A. binotata* as a possible synonym, probably because Pruvot-Fol's description lacks detail (for example, her drawing of some of the slender radular teeth does not adequately show the fine denticulations, and she describes the colour of the living animal as varying from orange to red with 7–11 yellow gills) and because the holotype specimen has been lost. *A. smaragdina* typically has just 5 gills and they are brownish rather than yellow (Ortea, Perez & Llera, 1982). So until further material of *A. binotata* from Morocco is available for study I follow other workers in regarding it as of uncertain status and I use the name *A. smaragdina* for the larger and more widespread species of *Aldisa* in the east Atlantic.

A. banyulensis is confined to the Mediterranean whereas *A. smaragdina* occurs both in the Mediterranean and the Atlantic from northern Spain to the Azores. Following García *et al.* (1986), and Rudman (2002) they can be easily

distinguished: *A. banyulensis* is up to 11 mm long, red, often with a transverse white stripe laterally, spicules projecting from the low tubercles, rhinophore and gill openings smooth and 7–8 unipinnate red gills, while *A. smaragdina* grows up to 29 mm, is red with more irregular cream to brown markings, smooth low tubercles, crenulate rhinophore and gill openings and 5 bi- or tripinnate predominantly brownish gills which are red basally. While the present specimens are all small they clearly belong to *A. smaragdina*. There does, however, appear to be some geographical variation in this species. Images of *A. smaragdina* from Portugal and the Canaries (Mediterranean opisthobranchs, 2011) show red animals with one or two small dark red circles in the circular depressions on the notum. In the present material from Ghana these small dark circles are black, not red.

DISCUSSION

In this paper seven species of Dorididae and one of Cadlinidae are described of which two are new (*Doris kpone* and *Doris minuta*) and a further three are probably undescribed species

but the material is insufficient to formally name them. The previously known species are *Aldisa smaragdina* which occurs widely in the east Atlantic, *Doris verrucosa* which occurs on both sides of the Atlantic, and *Doris morenoi* previously known only from the Cape Verde Islands. These are the first records of these three species from the Gulf of Guinea. Two other species of Cadlinidae have already been described from Ghana by Edmunds (1981) who included them in the Chromodorididae (*Cadlina rumia* Marcus 1955, which is another amphiatlantic species, and *Cadlina dubia* Edmunds 1981), so three species of Cadlinidae are now known from Ghana. A third species of *Cadlina* described by Edmunds (1981), *Cadlina evelinae* Marcus 1958, from both Ghana and the west Atlantic, has now been shown to belong in the Chromodorididae where it is placed in the genus *Tyrinna* Bergh 1898 (Johnson, 2011).

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