

OPISTHOBANCHIATE MOLLUSCA FROM GHANA: DISCODORIDIDAE

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Abstract Descriptions are given of eleven species of Discodorididae belonging to nine different genera collected in Ghana between 1963 and 1973; seven are described as new species while an eighth is also only known from Ghana but was described by the author over 40 years ago. The remaining three species have been recorded from Europe and east Atlantic islands, so it is probable that many of them will be found to have similar geographical ranges. The secretion of sulphuric acid by *Geitodoris tema* is described and evidence is presented to confirm that a characteristic of the genus *Geitodoris* Verrill 1880 is the presence of large acid-secreting subepidermal glands in the notum. There is no evidence at present that the superficially similar subepidermal glands of *Paradoris* also secrete acid. Five of the eleven species belonging to the genera *Baptodoris*, *Jorunna* and *Rostanga* have well-developed caryophyllidia covering the dorsal surface which give them a texture similar to that of sponges.

Key words Atlantic nudibranchs, Discodorididae, Ghana

INTRODUCTION

The opisthobranchiate molluscan fauna of West Africa is poorly known (see Edmunds, 2007, 2009, 2010). The purpose of this paper is to describe the species of doridoid nudibranchs belonging to the family Discodorididae collected in Ghana between 1963 and 1973. The genera in this family have been subject to thorough phylogenetic analysis in recent years by Terry Gosliner's Laboratory (e.g. Valdés & Gosliner, 2001; Garovoy, Valdés & Gosliner, 2001; Valdés, 2002; Dorgan, Camacho-García & Gosliner, 2002; Dayrat, 2005, 2006, 2010; Chan & Gosliner, 2007; Camacho-García & Gosliner, 2008). These studies have resulted in the synonymising of many old discodorid genera, and in this paper I have followed their conclusions. A major division in the family is between those genera possessing and those genera lacking complex dorsal structures on the notum called caryophyllidia, indeed it may be that the family should be split into two families on the basis of presence or absence of these remarkable structures.

MATERIAL AND METHODS

Unless otherwise stated, all of the material described here was collected near to Accra and Tema in Ghana, close to longitude 0° latitude 5.7°. Collections were made by the author searching under stones etc. at low tide and by Mr Walter

Pople either by SCUBA diving on the 10 m deep reef at Kpone Bay off Tema (actually from 9 to 12 m depth) or dredging in Tema Bay at 20–40 m depth. Rocks and detritus obtained by diving or dredging were kept in aquaria for a few days to encourage the smaller animals to crawl out. Most of the animals were first described alive, then narcotised with magnesium chloride and fixed, usually in Bouin's fluid, before storage in 70% ethanol. Body measurements and drawings of entire animals are from life unless otherwise stated. The buccal mass of some specimens was removed for examination of the radula and labial cuticle. Muscle was softened in potassium hydroxide and the radula teased out before mounting in Gurr's 'Aquamount' for microscopical examination. Drawings of radular teeth were made with the aid of a camera obscura. Further details are given in Edmunds (2007).

Radular formulae are traditionally given as $n \times a.b.c.b.a$ where n is the number of rows, a is the number of marginal teeth, b is the number of lateral teeth and c is the median tooth (which is often absent). Marginal teeth differ in morphology from lateral teeth and in goniodorids and polycerids there is typically a clear distinction between the two with no teeth of intermediate morphology. In the Dorididae and Discodorididae there is normally no clear distinction between the outer and the inner teeth but they gradually change in form as one moves along the row. All teeth are therefore called lateral teeth. The outermost teeth of all are often rudimentary, but as the animal

grows and adds additional teeth to the outer ends of the row, these rudimentary teeth change to have the tooth-form typical of outer laterals for the species. However, in some discodorids there is a very marked difference in morphology along the tooth row. Thus in *Thordisa* Chan & Gosliner (2007) recognised three types of tooth of very different morphology giving a formula of $n \times a.b.c.d.c.b.a$ where a is the number of outer lateral teeth, b is the number of mid-lateral teeth, c is the number of inner lateral teeth and d is the median tooth (if present). In this type of radula there may be one or two teeth intermediate between the three types of tooth so giving a precise formula can be difficult. In this paper I have adopted this method of presentation of the radula formula for the genus *Thordisa*.

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 Discodorididae Bergh 1891

Genus *Peltodoris* Bergh 1880

Type species *Peltodoris atromaculata* Bergh 1880, by subsequent designation by O'Donoghue (1929)

Peltodoris temarensis n. sp. Figs 1A, 1B, 2

Etymology The specific name was chosen because both specimens were found at Tema.

Material examined East Tema rocks under stone at low tide 1 sp 33 mm long 3 December 1967; NHMUK Reg. No. 20110391: West Tema under stone at low tide 1 sp 20 mm long 31 December 1970.

Holotype NHMUK Reg. No. 20110390/1, 2: East Tema rocks under stone at low tide, Ghana, 3 December 1967, collected by M. Edmunds.

External features Because there are slight differences between the two specimens they are described separately here, but I consider that

they belong to the same species. Larger 33 mm specimen (Figs 1A, 2A): body elongate oval, foot barely projecting behind mantle posteriorly when animal is crawling; dorsal surface of mantle with closely spaced short tubercles, smaller in centre and edge of mantle, smallest ones rounded or lanceolate with rounded tips, larger ones tapering with ring of spicules distally not projecting beyond blunt tip; rhinophore sockets slightly raised in life but forming short cylindrical turret preserved, rhinophore with short stalk, 20 lamellae sloping back from frontal groove to posterior ridge (Fig. 2C); cirlet of six irregularly bipinnate gills; oral tentacles digitiform; foot with anterior notch (Fig. 2B). Part of the mantle posteriorly on the left side has been removed probably by autotomy or by a predator. Notum purple-brown with scattered darker patches over viscera and paler greyish patches towards edge, with sparse patches of white dots and a pair of larger white patches centrally between rhinophores and gills (Figs 1A, 2A); rhinophore stalk grey basally suffused purple-brown distally, lamellae dark purple-brown with white spots especially near tip (Fig. 2C); gill stalks grey-brown, pinnae yellow-brown with brown and white dots, anus ringed with yellow-brown and white dots; mantle ventrally and oral tentacles mottled brown, foot cream with sparse brown mottling (Fig. 2B).

Smaller 20 mm specimen (Figs 1B, 2E): body elongate oval, foot barely projecting behind mantle posteriorly when animal is crawling; dorsal surface of mantle with closely spaced short, rounded tubercles, each tubercle with ring of about 10 spicules scarcely projecting above tubercle and only visible with difficulty; rhinophore with short stalk, 18 lamellae sloping back from frontal groove to posterior ridge (Fig. 2F); cirlet of six bipinnate gills; oral tentacles digitiform; foot with anterior notch (Fig. 2D). Overall appearance yellow-brown with darker purple-brown centrally; ground colour yellow mostly obscured by brown mottling with irregular white patches (Figs 1B, 2E); rhinophore stalk yellowish with brown dots, clavus dark brown with buff spots, tip buff (Fig. 2F); gill rhaches brown, pinnae yellow with brown and white dots; foot yellow with purple-brown spots dorsally and laterally, two spots ventrally, oral tentacles yellow with purple-brown spots, ventral surface of mantle yellow with purple-brown spots concentrated towards edge (Fig. 2D).

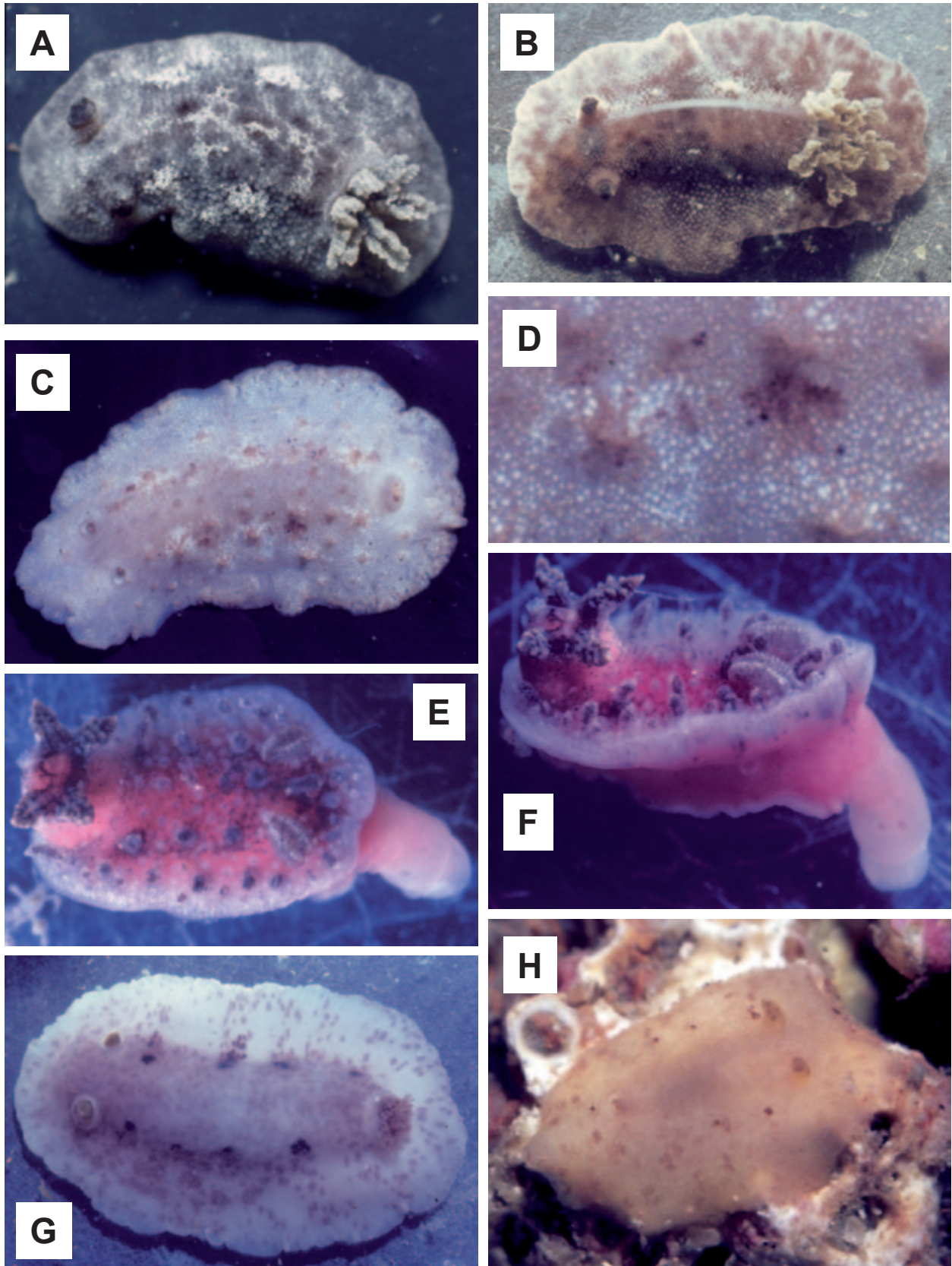


Figure 1 A *Peltodoris temarensis* n. sp., 33 mm long, December 1967. B *Peltodoris temarensis* n. sp., 20 mm long, December 1970. C, D *Paradoris indecora* (Bergh 1881) with higher magnification of two tubercles and small white glands in D. E, F *Thordisa poplei* n. sp., 5 mm long, October 1968. G *Discodoris ghanensis* n. sp., 46 mm long, December 1967. H *Platydoris* sp., 8 mm long, March 1970.

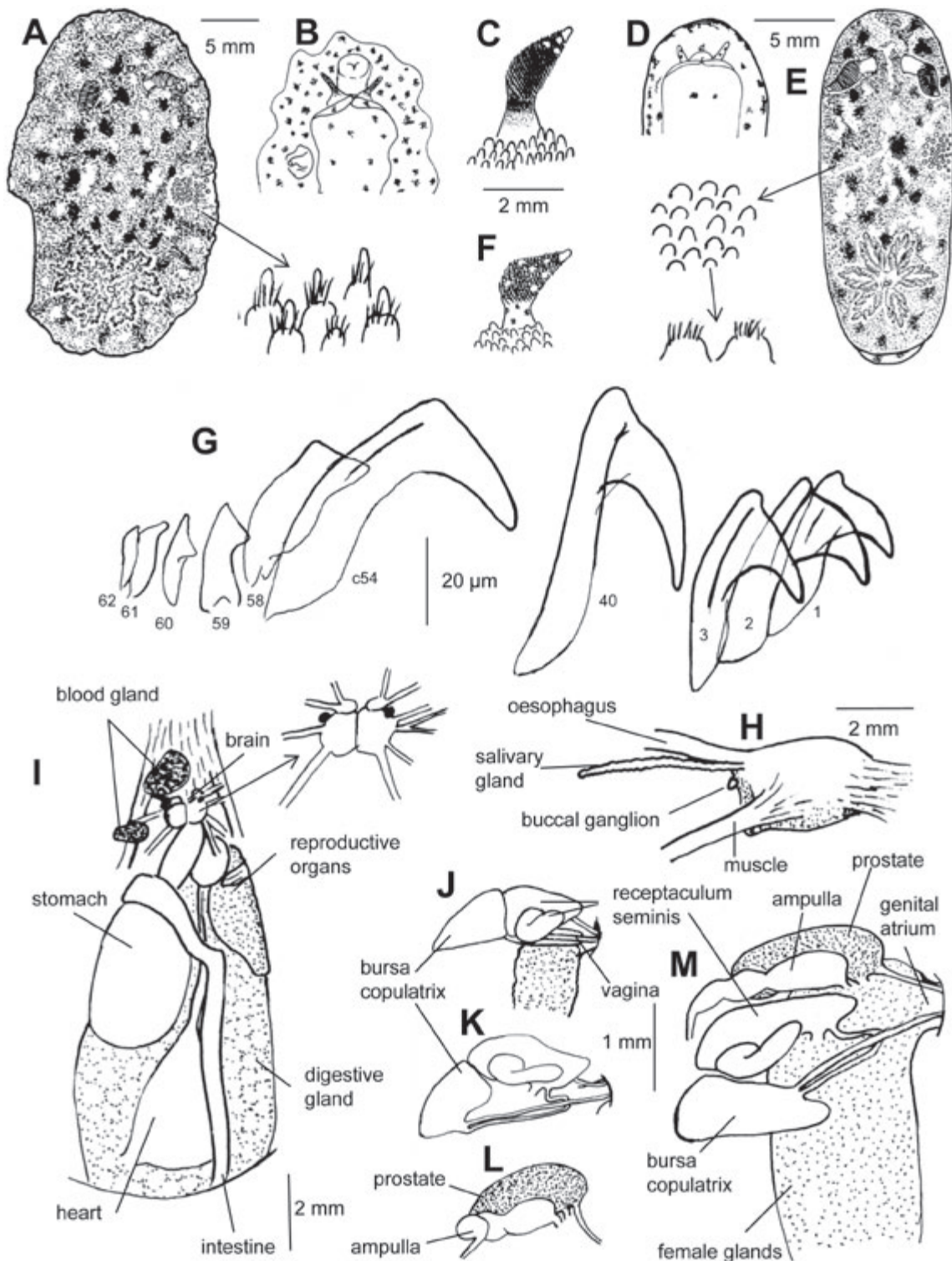


Figure 2 *Peltodoris temarensis* n. sp., 33 mm long: A dorsal view with inset detail of tubercles; B ventral view of head; C lateral view of rhinophore; 20 mm long; D ventral view of head; E dorsal view with inset detail of tubercles; F lateral view of rhinophore. Stipple indicates purple-brown mottling with darker patches; white patches in A & E and spots in C & F lack stipple; ground colour (not stippled) in D and F is yellow. 33 mm long specimen: G radular teeth with numbers indicating position in row; H lateral view of buccal mass; I dorsal view of internal anatomy with inset detail of brain; J appearance of reproductive structures when oesophagus is removed; K relationships of bursa copulatrix and receptaculum seminis; L appearance of prostate and ampulla when receptaculum and bursa are moved to one side; M semi-diagrammatic drawing of reproductive system to show interrelationships of organs.

Internal morphology In the buccal mass the slender salivary glands insert close to the oesophagus (Fig. 2H). I found no trace of labial rodlets. The radula formula of the larger specimen is $34 \times 62.0.62$. In row 6 there are 60 teeth in each half row increasing to 62 in row 28. The teeth are hamate with no denticles, the first two or three smaller than the succeeding teeth, and the outer six or seven also smaller with the outermost two or three lacking a cusp (Fig. 2G).

When the animal was opened up dorsally the black pigmented blood gland, which is divided into a larger anterior and a smaller posterior lobe, partly overlies the cerebral ganglion (Fig. 2I). The oesophagus, stomach, intestine and heart are arranged as in many other dorids, but the only reproductive structures immediately visible are the female glands, the vagina, the receptaculum and the looped duct joining the bursa to the receptaculum. The reproductive system was partially dissected with the organs carefully teased apart to reveal their interrelationships while leaving them as near as possible *in situ*. When the oesophagus is removed the main structures visible from a dorsal view are the bursa copulatrix, the receptaculum seminis, the genital ducts approaching the gonopore, and the female glands (Fig. 2J). The connection between the ampulla and the prostate was not resolved, but the vas deferens runs directly from the prostate to the gonopore (Fig. 2L, 2M). The penis was very slightly protruding and no stylet was visible. So as not to further damage the specimen the penis was not removed and mounted for microscopical examination, but if there is a stylet or other armature it must be very small. There is no accessory gland. Neither the bursa copulatrix nor the receptaculum seminis is circular or oval in shape (as they often are in dorids) and the unusually large receptaculum terminates in an elongate lobe (Fig. 2K, 2M).

Geographical range Currently known only from Tema, Ghana.

Remarks The spicular tubercles of this species are not true caryophyllidia: they lack stalks and a terminal knob but are instead low tubercles with irregular rather than a regularly spaced ring of spicules. Comparison with the genera of cryptobranch dorids lacking caryophyllidia recognised by Valdés (2002) shows that this species

agrees with *Peltodoris* in having small tubercles with irregular projecting spicules, notched foot, smooth labial cuticle, smooth hamate radular teeth, unarmed penis and no accessory gland. Dayrat (2010) adds two further characters: 10 to 15 innermost radular teeth much smaller than the outer ones and two blood glands. Although I could not distinguish two regions of the prostate, which *Peltodoris* should have, and only the first 2 or 3 radular teeth are significantly smaller than the rest, the present material has all the other characters, so I consider that on the available evidence it belongs to this genus. *Peltodoris temarensis* differs from *P. atromaculata* Bergh 1880 from the Mediterranean in colouration, while *Peltodoris punctifera* (Abraham, 1877) from the Canaries must be transferred to another genus because it possesses caryophyllidia (Ortea & Bacallado, 1981).

Peltodoris temarensis should be compared with the brown mottled dorids from the Mediterranean and the east Atlantic in the *maculosa-fragilis* complex described by Ballesteros, Llera & Ortea (1985). It differs from *Discodoris maculosa* Bergh 1884 and *Discodoris confusa* Ballesteros, Llera & Ortea 1985 in lacking labial rodlets, in the number of radular teeth per row for animals of similar size, in the shapes of the teeth, and in having a large, elongate receptaculum. *Discodoris confusa* resembles *Discodoris lilacina* (Gould 1852) (= *Discodoris fragilis* (Alder & Hancock, 1864)) from the Indo-Pacific in its habit of autotomising large parts of the mantle if it is violently disturbed: this behaviour was not observed when the present specimens were roughly handled although the larger specimen did have a part of the mantle missing. *Peltodoris temarensis* also resembles *Discodoris ketos* (Marcus & Marcus, 1967) from the west Atlantic in colouration but differs in lacking labial rodlets.

Genus *Discodoris* Bergh 1877

Type species *Discodoris boholiensis* Bergh 1877, by subsequent designation by O'Donoghue (1926)

Discodoris ghanensis n. sp.
Figs 1G, 3

Etymology The specific name was chosen because the single specimen was found in Ghana.

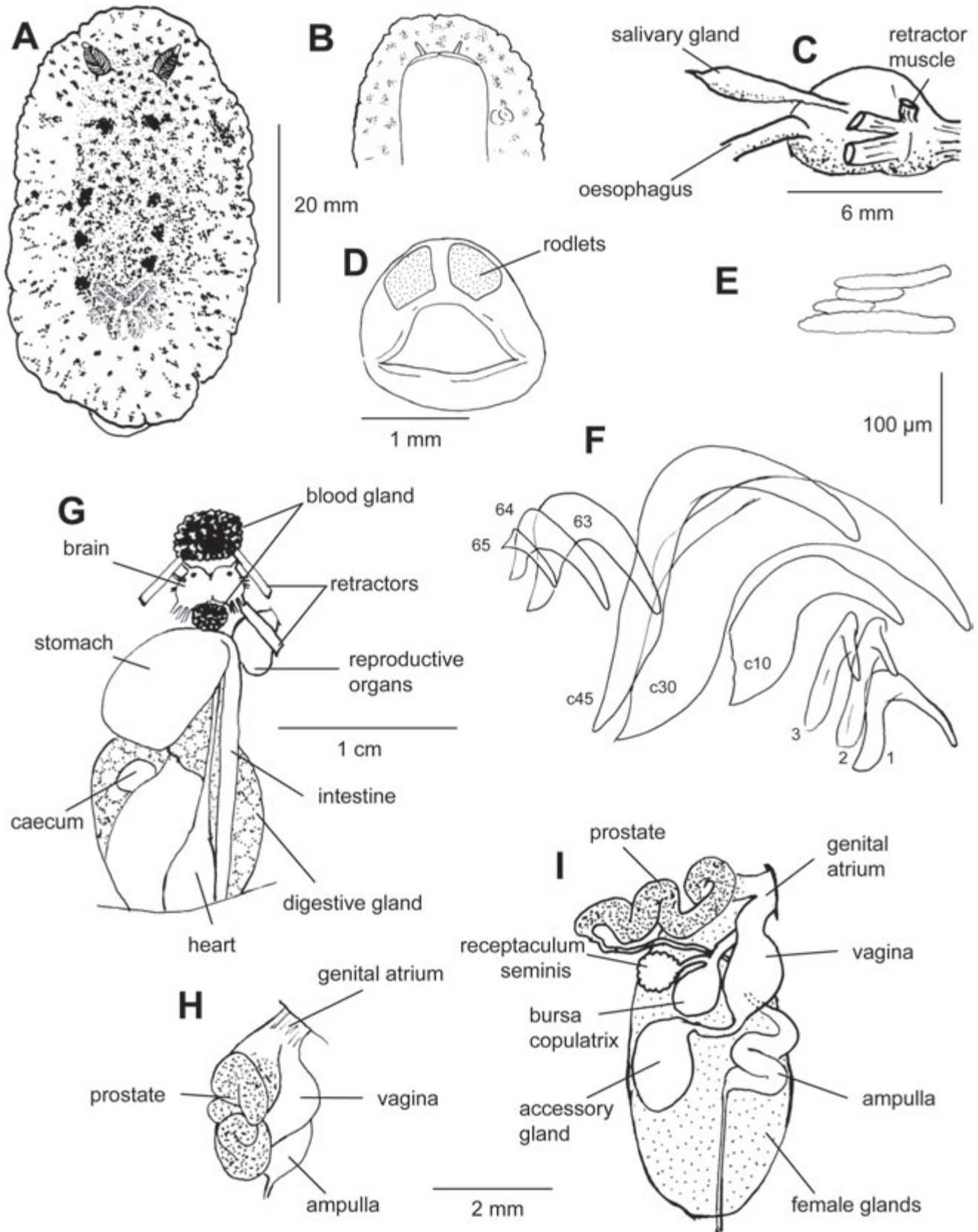


Figure 3 *Discodoris ghanensis* n. sp., 46 mm long: A dorsal view; B ventral view of head; C lateral view of buccal mass; D labial cuticle, flattened, showing two areas of rodlets; E labial rodlets; F radular teeth with numbers indicating position in row; G dorsal view of internal organs with body wall removed; H dorsal view of reproductive organs before dissection; I reproductive system with organs separated to show relationships.

Material examined East Tema rocks under stone at low tide 1 sp 46 mm long 3 December 1967.

Holotype NHMUK Reg. No. 20110389/1, 2: East Tema rocks under stone at low tide, Ghana, 3 December 1967, collected by M. Edmunds.

External features Body elongate oval, foot barely projecting behind mantle posteriorly when animal is crawling (Figs 1G, 3A); dorsal surface of mantle with closely spaced minute pustules, smaller and closer together than in *Peltodoris temarensis*; rhinophore sockets slightly raised, rhinophores never extended far enough to see stalk, with at least 30 lamellae sloping down from frontal groove to posterior groove; circling of six bi- to tri-pinnate gills; oral tentacles digitiform; foot with anterior notch (Fig. 3B). Notum cream, tinted pinkish brown centrally over viscera, with pinkish brown spots scattered irregularly over surface, densest over viscera, each spot elongated radially towards edge, with four pairs of blackish brown spots between rhinophores and gills (Figs 1G, 3A); rhinophores yellow-brown with a few white and dark brown spots, tip white; gills pinkish brown; foot and mantle ventrally cream with diffuse brown patches on mantle (Fig. 3B).

Internal morphology The stomach, intestine, heart and caecum are all visible when the animal is opened dorsally with the blood gland in two parts one in front of and one behind the cerebral ganglion (Fig. 3G). The oval-shaped buccal mass has relatively short salivary glands (Fig. 3C). The lips are cuticularised with two patches of rodlets (Fig. 3D, 3E). The radula has the formula 26×65.0.65. All teeth are simply hamate (Fig. 3F) but the middle and outer ones are curved rather than abruptly hooked, and they decrease in size towards the centre and peripherally.

In the reproductive system the broad, coiled prostate covers the structures to the left of the genital mass (Fig. 3H). The short deferent duct leads directly to the genital atrium which was not dissected. A broad duct lies to the right of the genital mass leading to the vagina and partly hiding the deeper ampulla (Fig. 3H). This duct narrows and then expands again underneath the prostate into a sac which I interpret as an accessory gland (Fig. 3I). The connection between the ampulla and the male duct leading to the prostate is beneath the distal part of the accessory gland

and was not dissected out so as not to damage the single specimen further. When the prostate is moved to one side the receptaculum seminis and the larger bursa copulatrix can be seen (Fig. 3I).

Geographical range Known only from Tema, Ghana.

Remarks *Discodoris ghanensis* n. sp. should be compared with other discodorids from the Mediterranean and Atlantic Ocean. It differs from *Discodoris sauvagei* (Rochebrune, 1881) in colouration and in having many more radular teeth in each row for a very much smaller animal (Ortea, Espinosa & Moro, 1998). It differs from *Discodoris muta* Bergh 1877 and *Discodoris* sp. from the Cape Verde Islands in colouration (Eliot, 1906), but these species require further examination and description. *Discodoris confusa* Ballesteros, Llera & Ortea 1985 and *Discodoris maculosa* Bergh 1884 differ in colour and in having larger tubercles (Ballesteros *et al.*, 1985). The west Atlantic species also differ in colouration and other characters (Valdés, Hamann, Behrens & Du Pont, 2006).

In his phylogenetic analysis of the cryptobranch dorids Valdés (2002) synonymises many genera and clearly defines those that he recognises (see also Fahey & Gosliner, 2003). The present species agrees with *Discodoris* in having labial rodlets, small tubercles and smooth outer radular teeth but it differs in having an accessory gland and no obvious division of the prostate into two regions. *Hoplodoris* and *Geitodoris* both have an accessory gland, but this gland appears to arise from the vagina proximally rather than distally as in the present species. While it is desirable to examine the prostate and the accessory gland in further material, this species clearly does not precisely fit any of the genera defined by Valdés (2002). The more recent revision of discodorids by Dayrat (2010) concludes that only one character is a synapomorphy unique to *Discodoris*: slender, more elongated and less sharply curved hooks on the radular teeth than are found in other discodorids. Four other characters are synapomorphies of the Discodorididae: notched upper lip of bilabiate foot, digitiform or conical oral tentacles that are not expansions of the lateral mouth lips, flattened prostate divided into two parts, and two blood glands. He concludes that *Discodoris* is an informal clade name and must remain so until it is 'phylogenetically defined and formally

registered'. Clearly more work is required to define *Discodoris*, but Dayrat's key character of elongated slightly curved radular teeth may prove difficult to sustain as there may be intermediate states between this and the broader hooked teeth of other genera: Fig. 3 shows that some teeth in the present specimen are slender, most are gently curved, but some are strongly hooked.

The generic placement of species that do not precisely fit with genera defined on the basis of thorough phylogenetic analysis has been discussed by Dayrat & Gosliner (2005) and by Dayrat (2010) so this somewhat unsatisfactory situation is not uncommon in the Discodorididae. Dayrat (2005) has argued strongly for an epithet-based name rather than one with a genus name that is unsatisfactory, in which case the present species would be '*ghanensis* Edmunds', and could be referred to as '*Discodorididae ghanensis*'. However, until this proposal is approved by the ICZN I prefer to place it provisionally in the genus *Discodoris sensu lato*.

Genus *Thordisa* Bergh 1877

Type species *Thordisa maculigera* Bergh 1877, by monotypy

Thordisa poplei n. sp.
Figs 1E, 1F, 4

Etymology The specific name was chosen in honour of Walter Pople who collected this and so many other nudibranchs from the reef.

Material examined 10 m reef Kpone Bay 1 sp 5 mm long 21 October 1968.

Holotype NHMUK Reg. No. 20110398/1, 2: 10 m reef Kpone Bay, Ghana, 21 October 1968, collected by W. Pople.

External features When found in reef debris left overnight in an aquarium, the single specimen was moribund with the proboscis everted, adding a further 1.7 mm to its body length of 5 mm (Figs 1E, 1F, 4A). Body oval, dorsal surface covered with papillae of variable length, c25 elongate (almost digitiform) rounded at tip, smaller ones more numerous, rounded, tubercular; rhinophores curved backwards with 17 lamellae arising from deep frontal groove; four unipinnate

gills with lower pinnae longer than upper, arising from a turret; oral tentacles minute knobs (Fig. 4B); proboscis broad, everted; foot rounded at front. Notum suffused bright orange-red with greyish edge, papillae dark purple-brown distally, tubercles mostly transparent greyish but some purple-brown (Figs 1E, 1F, 4A); rhinophores yellow-brown heavily overlaid with dark purple-brown or black and with cream dots on ridges anteriorly; gills purple-brown with some paler brown on pinnae; proboscis, foot and ventral surface of mantle pale orange with some maroon spots showing through, edge of mantle grey.

Internal morphology The buccal mass has very slender salivary glands (Fig. 4C). There is no obvious cuticularization of the labial region. The radula is flexed at half its length but has the approximate formula $40 \times 7-8.7-9.28-31.0.28-31.7-9.7-8$ (the full stops delineating outer lateral, mid-lateral and inner lateral teeth, see Material and Methods above). The shapes of the teeth are exceptionally difficult to interpret under the light microscope: the tooth bases are easy to see but most of the cusps are not visible, probably because they are particularly thin and do not show up when superimposed on the thicker tooth bases. The clearest ones are where the radula is folded rather than flattened in the standard way, or have been dislodged. The c30 inner lateral teeth are small with very small hooks (Fig. 4D₁₋₃) which are usually hidden under neighbouring teeth. These teeth gradually become larger away from the centre of the radula. The next 7-9 mid-lateral teeth are much larger, hamate with large cusps (Fig. 4D_{mid-laterals}), the sizes of the outer three teeth being progressively smaller. The outer 7 or 8 lateral teeth have curved needle-like blades (Fig. 4D_{outer laterals}), whose appearance varies according to the angle of viewing, but they are smooth, not pectinate.

No attempt was made to examine the reproductive system of the specimen because it is so small and would be severely damaged by further dissection.

Geographical range Known only from this single specimen from Ghana.

Remarks In their preliminary phylogenetic review of Indo-Pacific *Thordisa* Chan & Gosliner (2007) include fimbriate or pectinate outermost

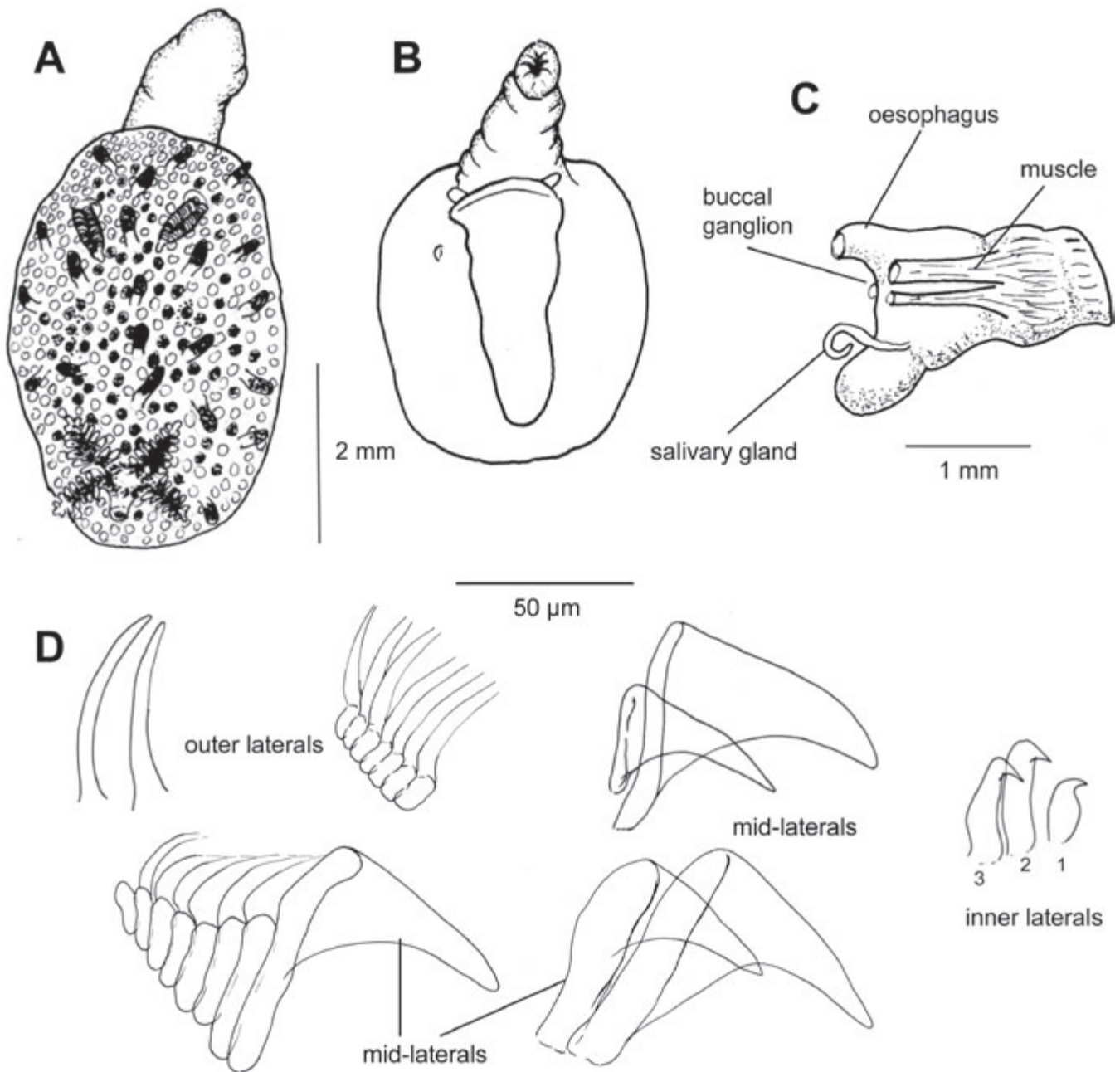


Figure 4 *Thordisa poplei* n. sp., 5 mm long: A dorsal view, showing main areas of dark purple-brown stippled; B ventral view of head of narcotised animal; C lateral view of buccal mass; D radular teeth with position in row indicated.

radular teeth as a characteristic of the genus. Although the present specimen lacks this character, the elongate dorsal papillae, absence of labial rodlets, and radula with three types of tooth all agree with the genus *Thordisa*, so I consider it belongs to this genus. *T. poplei* differs in colour and in details of the radula from *Thordisa diuda* Marcus 1955, *T. lurca* (Marcus & Marcus, 1967) and *T. harrisi* Chan & Gosliner 2006 (from the west Atlantic), *T. filix* Pruvot-Fol 1951 and *T.*

azmanii Cervera & García-Gómez 1989 (from the east Atlantic), and from the Indo-Pacific species of *Thordisa*. It is very similar in external features to *Thordisa aculeata* Ortea & Valdés 1995 from Angola: it is more pinkish but has similar gills and rhinophores while the shorter dorsal papillae may be a consequence of the specimen being moribund. However, the radula is quite different: while my 5 mm Ghanaian specimen has 40 rows with about 42–48 teeth in each half row, the

30 mm Angolan *T. aculeata* had 51 rows with 54 teeth in each half row. *T. poplei* has three types of radular tooth, as is typical for the genus (Chan & Gosliner, 2007) (see above), whereas all of the teeth in *T. aculeata* are slender with only a few that can be described as hamate, and these much more slender than those of *T. poplei* (compare fig. 3 of Ortea & Valdés, 1995 with my Fig. 4D). It is possible that juveniles of a dorid species may have different radular teeth reflecting a different food from an adult, but the differences between the radular teeth of *T. aculeata* and those of *T. poplei* are so great that they must surely be different species.

Genus *Paradoris* Bergh 1884

Type species *Paradoris granulata* Bergh 1884, by monotypy

Paradoris indecora (Bergh 1881)
Figs 1C, 1D, 5

Discodoris indecora Bergh, 1881: 108–112, pl. J, figs 26–33

Paradoris indecora – Templado, 1984: 519

Paradoris granulata Bergh, 1884: 686–691, pl. LXXVI, figs 10–24

Discodoris cavernae Starmühlner, 1955: 219–223, figs 5–9

Paradoris inversa Ortea, 1995: 14–17, figs 1C, 6–8

Paradoris mollis Ortea, 1995: 18–20, figs 1B, 9–12

Paradoris ceneris Ortea, 1995: 21–25, figs 1A, E, 13–15

Doris porri Verany, 1846: 97–102 (Dayrat, 2010, explains why this name should not have priority over *indecora*)

Material examined NHMUK Reg. No. 20110397: 10 m reef Kpone Bay 1 sp 27 mm long 8 November 1968.

External features Body elongate oval, foot just projecting behind mantle posteriorly when animal is crawling (Figs 1C, 5A); dorsal surface of mantle with numerous low pustules of variable size (Fig. 5D), those in middle of back in three rows, edge of mantle coarsely crenulate; rhinophores with 15 slightly irregular lamellae sloping

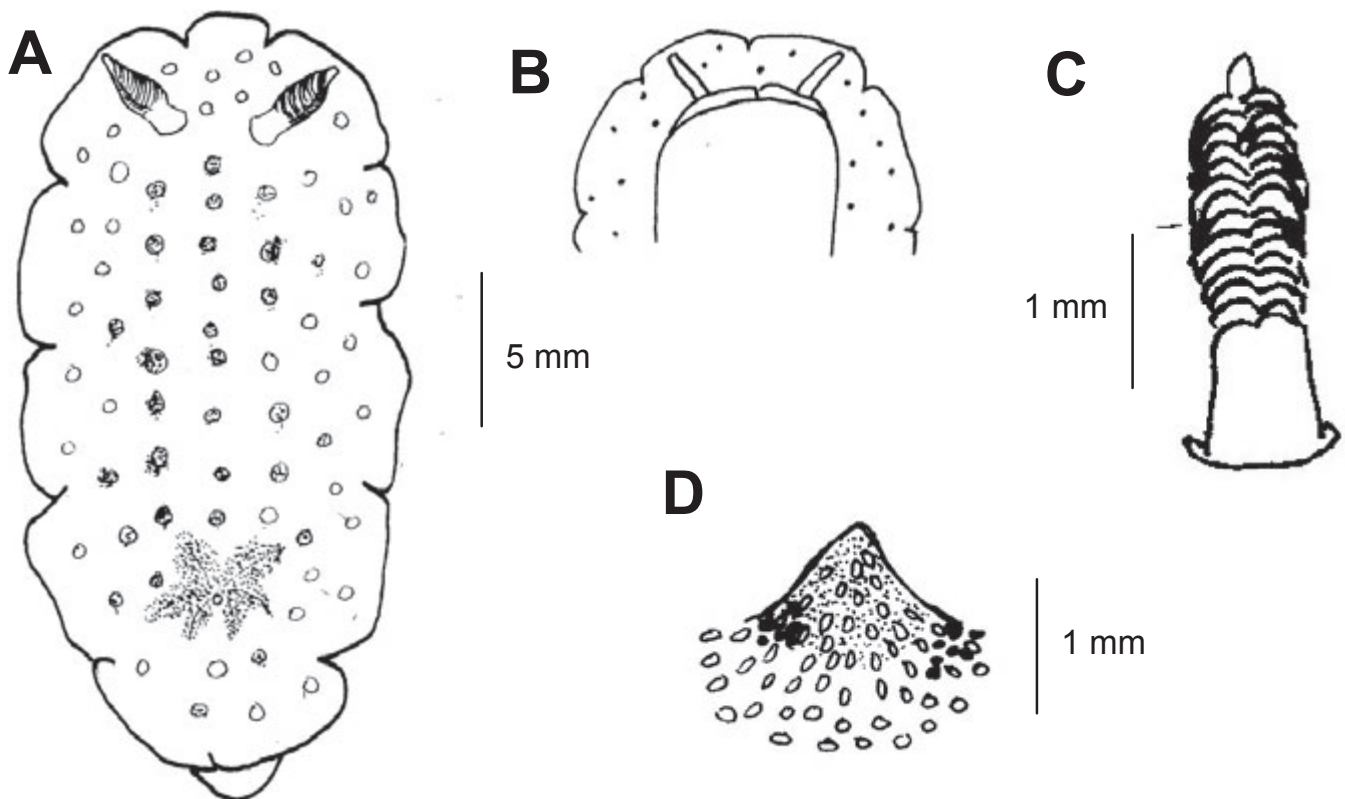


Figure 5 *Paradoris indecora* (Bergh 1881) 27 mm long: A dorsal view showing main pustules (circles) and darkest brown areas (stipple); B ventral view of head with scattered brown spots on mantle; C anterior view of rhinophore; D dorsal pustule with dark brown spots (coarse stipple) brownish suffusion (fine stipple) and white glandular spots (circles).

back from frontal groove to posterior groove (Fig. 5C); six bi- or tripinnate gills surrounding anus; oral tentacles digitiform; foot with anterior notch (Fig. 4B). Notum whitish grey due to dense oval white spots especially towards sides of mantle and on tubercles, and brown spots, yellow-brown suffusion and grey-brown suffusion scattered over surface especially on tubercles (Figs 1C, 1D, 5A, 5D); rhinophores brown with darker brown and white spots (Fig. 5C); gills grey with white spots on rhaches and brown tips; mantle white below with brown spots (Fig. 5B); foot and oral tentacles white, sides and posterior part of foot with oval white (probably glandular) spots. When preserved the pustules form low rounded knobs, some conspicuous, others barely projecting above the rest of the mantle surface.

Internal morphology As the identification can be confirmed from the characteristic external features and there is just a single specimen which would be considerably damaged by dissection, the buccal mass was not removed for examination.

Behaviour When prodded simulating an attack and when being narcotised the animal discharged a copious white secretion.

Geographical range Known from the Mediterranean, the east Atlantic including the Canary and Cape Verde Islands, Ghana, Príncipe and São Tomé (Dayrat, 2006, and see below).

Remarks Dayrat (2006, see also Dayrat, 2010) has reviewed the genus *Paradoris* including a meticulous examination of all available specimens. He concludes that *Paradoris* are discodorid nudibranchs with grooved oral tentacles, three jaw plates, jaw rodlets perpendicular to surface of labial cuticle, curved rodlet tips, long narrow radula, radular teeth at an angle of 45° to the axis, grooved outer edge to tooth hooks. All of these characters apart from the first cannot be seen without dissecting the animal. My drawing (Fig. 5B) was of a live but partly anaesthetised animal and there was no sign of a groove on the oral tentacles. Unfortunately the preserved specimen contracted when it was fixed in Bouin's fluid so that the head is bent down and the whole animal is firm rather than flexible. I have tried to prise the anterior end upwards, but all I can see is the contracted mouth with no sign of the evidently shrunken oral tentacles. To examine it further

would involve damage to the specimen with no certainty that I would even then be able to see the intact oral tentacles.

Dayrat (2006) has reviewed *Paradoris indecora* and concluded that it is primarily a Mediterranean and east Atlantic species occurring as far south as the Canary Islands. He is undecided as to whether the records from the Cape Verde Islands (Eliot, 1906), Príncipe and São Tomé (Ortea, 1995) belong to this species because of the substantial range extension that this would imply, but his comparison suggests that they do belong to *P. indecora*. Eliot (1906) quotes Crossland's description of specimens from the Cape Verde Islands: "Cool grey above with a bluish bloom minute black specks thickly sown over the dorsal surface an irregular line of irregular white blotches made up of opaque white specks, larger than the black ones". This is similar to the present specimen and to photographs of many of the Mediterranean specimens on the Internet (e.g. Mediterranean Opisthobranchs, 2011; Nudi Pixel, 2011; Sea Slug Forum, 2011) although others indicate much browner colouration. The range of variation in colour and other external features is summarised by Dayrat (2006) who argues that although there may possibly be more than one species in this region, there are at present no good characters which could be used for dividing the assemblage into two species. Instead he considers the species to be polymorphic. If the Cape Verde and Ghanaian specimens are indeed *P. indecora*, then the records from Príncipe and São Tomé (Ortea, 1995) which Dayrat has queried are probably also this species. Certainly the colour photographs and drawings of Ortea closely resemble the present specimen and the published descriptions of *P. indecora*. It is possible that *Paradoris mulciber* Marcus 1970 from Brazil and the Caribbean is conspecific with *P. indecora* (the photograph in Valdés *et al.*, 2006 is very similar to *P. indecora*), but examination of further material is required before this can be confirmed (Dayrat, 2006).

If I am correct in my identification, then living *P. indecora* are characterised by sparse low tubercles and numerous minute oval white spots. The tubercles are low and pyramidal in life but more rounded when preserved. The white spots are easily seen under a dissecting microscope and the copious white secretion exuded when the animal is attacked appears to come from these

rather than from the larger subepidermal glands described below. Identical behaviour has been described for the Indo-Pacific *Paradoris dubia* (Bergh, 1904) from South Australia (Rudman, 2007), but is not mentioned in the exhaustive review of Dayrat (2006). Dayrat has published SEM images and dissecting microscope drawings of the notum of many species of *Paradoris* and has shown that several of them, including *P. indecora*, have numerous holes in the surface. These holes are openings of subepidermal glands similar to those in species of *Geitodoris* which may indicate a phylogenetic relationship between the two genera (Dayrat & Gosliner, 2005; Dayrat, 2010). However, while the subepidermal glands of several species of *Geitodoris* secrete sulphuric acid (see below), there is no evidence that any species of *Paradoris* secretes acid (contrary to Dayrat, 2010: p. 202, who states that both genera have acidic skin secretions). Further, the copious white secretion which occurs in species of *Paradoris* has not been described for any species of *Geitodoris*, so I do not agree that 'holes' in the notum is necessarily an indication of phylogenetic affinity between *Paradoris* and *Geitodoris*. These holes are probably an artefact of fixation and subsequent treatment before examination as with a light microscope I could see no trace of such glands in either live or preserved specimens of *Paradoris indecora* or *Geitodoris tema* (see below), although the surface of the latter is pitted. It is of course possible that these subepidermal glands indicate phylogenetic affinity but that they have subsequently evolved to produce very different secretions in these two genera, but the gland morphology for producing inorganic acids and viscous mucopolysaccharides or mucoproteins is very different (Thompson, 1960; Edmunds, 1968b), so I cannot agree without further evidence that *Paradoris* and *Geitodoris* are closely related on the basis of possessing subepidermal glands.

Genus *Geitodoris* Bergh 1891

Type species *Doris complanata* Verrill 1880, by monotypy

Geitodoris tema (Edmunds 1968)

Fig. 6A–C, 7D, 7E

Discodoris tema Edmunds, 1968: 89–93, figs 6–8
Geitodoris tema – Schrödl, 2000: 208

Material examined B.M.(N.H.) Reg. no. 19677 W (holotype): East Tema rocks under stone 1 sp 24 mm long 9 January 1967; NHMUK Reg. No. 20110393: scuba diving off East Tema rocks by Mr W. Pople 1 sp 33 mm long 1 February 1968; NHMUK Reg. Nos. 20110394, 20110395, 20110396: West Tema rocks under stones 9 sp of which 7 collected and 6 measured at 28, 23, 22, 20, 12 & 8 mm long 31 December 1970.

External features This description includes the holotype (Edmunds, 1968a) together with additional material obtained subsequently. Body elongate oval; dorsal surface of mantle with numerous low, circular tubercles 0.2 to 0.5 mm diameter, openings of subepidermal glands in the intertubercular spaces (Fig. 7D); rhinophores with 17–20 lamellae sloping back to a posterior groove, socket with wavy slightly raised margin; 6–8 tripinnate gills surrounding anus, margin wavy; oral tentacles short, slender; foot notched with transverse anterior groove. Notum orange-pink (intense red in the 1968 specimen) with scattered brown spots (especially on larger tubercles), more numerous minute brown dots and patches of white dots which vary in extent in different specimens (Fig 6A–C), orifices of subepidermal glands often orange or brown; foot, ventral surface of mantle and everted proboscis orange; rhinophore stalk tinged orange or pink with a few brown dots, clavus brown or pale brown with darker brown dots, tip creamy white or with dense white dots; gills orange-pink or red below, brown and white distally, anterior gills more brown posterior gills more pink or red. The criss-cross pattern of orange lines on the notum shown in the drawing by Edmunds (1968a) is not present in any of the subsequent specimens examined (Fig. 6A–C).

Internal morphology The holotype was dissected and details of the buccal mass and reproductive system have been illustrated by Edmunds (1968a) so will only be summarised here. The labial cuticle contains curved rodlets. The radular formula of the 24 mm long holotype is 24×7.28.0.28.7. The inner lateral teeth are simply hamate and smooth; the outer laterals are more gently curved with minute serrulations below the cusp but the outermost rudimentary teeth lack serrulations.

In the reproductive system there are two distinct regions to the prostate, the penis has no

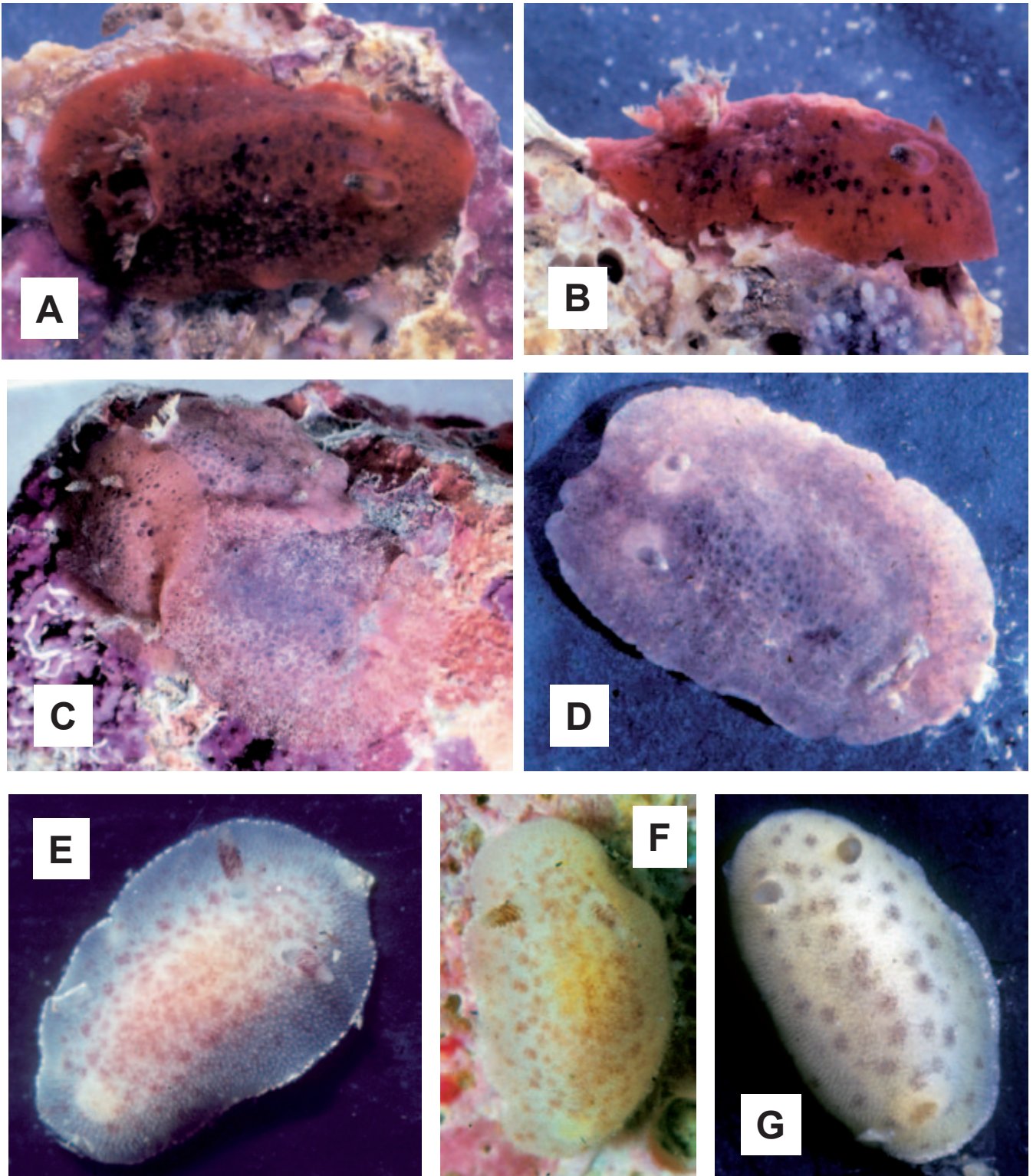


Figure 6 A, B *Geitodoris tema* (Edmunds 1968), 33 mm long, February 1968. C *Geitodoris tema* (Edmunds, 1968), three specimens December 1970. D *Geitodoris pusae* (Marcus, 1955), 35 mm long, Port Royal, Jamaica, 22 February 1962. E, F *Baptodoris perezii* Llera & Ortea 1982, 7 mm long, February 1970, the same specimen on different backgrounds. G *Baptodoris perezii*, 6 mm long, December 1969.

armature, the bursa copulatrix and smaller receptaculum seminis are typical of the family, there

are no hooks or other armature in the vagina but there is an elongate accessory gland.

Ecology and behaviour The stone which had seven animals under it also had two white egg ribbons, an oval coil of $3\frac{1}{2}$ turns 16–20 mm diameter, and a circular coil of $3\frac{1}{4}$ turns 16 mm diameter. After four days they turned pale mauve before hatching into veligers (NHMUK Reg. No. 20110396).

Geographical range Currently known only from Ghana (Edmunds, 1968a; this paper).

Remarks Schrödl (2000) transferred several species of *Discodoris* including *D. tema* to the genus *Geitodoris* because it has spatulate outer radular teeth. In his phylogenetic analysis of cryptobranch dorids Valdés (2002) concluded that *Geitodoris* is

characterised by small tubercles, notched foot, labial rodlets, hamate inner lateral and finely serrate outer lateral radular teeth, two regions to the prostate, unarmed penis and an accessory or vestibular gland, all of which are present in *G. tema*, thus confirming this generic placement.

Cervera, Calado, Gavaia, Malaquias, Templado, Ballesteros, García-Gómez & Megina (2006) list six species of *Geitodoris* from Spain, Portugal and the east Atlantic Islands, to which a seventh can now be added, *Geitodoris pusae* (Marcus, 1955), originally described from the west Atlantic. The colouration and radular teeth of these seven species are compared with *G. tema* in Table 1: *G. tema* is most similar to, and could be conspecific with,

Table 1 Colouration and radular teeth of east Atlantic species of *Geitodoris*.

Species of <i>Geitodoris</i>	Geographical occurrence	Colouration	Radular teeth	References
<i>G. planata</i> (Alder & Hancock, 1846)	Norway to Mediterranean, Canary Islands, Madeira, Azores	mottled shades of brown with dark spots & cream star-shaped marks, with both large & small tubercles	all teeth smooth, outer needle-like but serrulations illustrated by Schmekel & Portmann	Thompson & Brown, 1984; Ortea, 1990; Cervera <i>et al.</i> , 1985; Albuquerque <i>et al.</i> , 2009
<i>G. portmanni</i> (Schmekel, 1970)	Mediterranean	orange or red with star-shaped white marks, white rhinophores and gills	inner smooth or serrulate, outer needle-like with blunt serrations, some spatulate	Schmekel, 1970; Schmekel & Portmann, 1982; Perrone, 1984
<i>G. bonosi</i> (Ortea & Ballesteros, 1981)	Biscay & Mediterranean	yellowish with brown dots, rhinophores dark brown	all teeth smooth, outer spatulate & needle-like	Ortea & Ballesteros, 1981
<i>G. perfossa</i> (Ortea, 1990)	Canary Islands & Madeira	yellow or orange with brown marks and white reticulation	all teeth smooth, outer needle-like	Ortea, 1990
<i>G. bacalladoi</i> (Ortea, 1990)	Canary Islands & Mediterranean	orange to red, with conical tubercles	all teeth smooth, outer needle-like, but Sánchez Tocino <i>et al.</i> illustrate a bifid tip with fine serrulations to outermost tooth	Ortea, 1990; Sánchez Tocino <i>et al.</i> , 2006
<i>G. pusae</i> (Marcus, 1955)	West Atlantic, Canary Islands, Madeira & Mediterranean	tawny, yellowish, creamy pink or orange-red with brown spots and white markings	inner teeth smooth or with 1–2 denticles; outer usually smooth but may have fine serrations (see text)	Marcus, 1955, 1970; Ortea <i>et al.</i> , 1988; Cervera <i>et al.</i> , 2006; Sánchez Tocino <i>et al.</i> , 2006
<i>G. tema</i> (Edmunds, 1968)	Ghana	orange-pink to red, brown spots especially on small tubercles, tiny brown dots & patches of white dots	curved with minute serrulations below cusp	Edmunds, 1968, this paper

G. pusae. The serrations on the outer radular teeth of *G. tema* are similar to those in a specimen of *G. pusae* from Brazil drawn by Marcus but differ from those in a Mediterranean animal (compare Edmunds, 1968a Fig. 7 with Marcus, 1970 Fig. 44 and Sánchez Tocino, Ocaña & Cervera, 2006 Fig. 2B). Both *G. pusae* and *G. tema* have numerous low tubercles of variable size interspersed with the openings of subepidermal glands which secrete sulphuric acid (Edmunds, 1968b). The reproductive systems of the two species are similar with a slender accessory gland. This gland has five spicules in *G. pusae* according to Ortea *et al.* (1988) and Marcus (1955) but these were not seen by Edmunds (1968b) in *G. tema*, however, Marcus states that they are only developed in the largest specimens.

The *G. pusae* that I found in Jamaica in 1962 were 12 and 35 mm long with the notum yellow with a scattering of brown especially on the tubercles (Fig. 6D). The rhinophores had blackish brown lamellae with a white tip, and the 8 gills were also blackish brown, the anterior ones with much white. The foot was orange-yellow and there were a few small brown dots on the underside of the mantle and on the foot posteriorly. This is similar to the specimen, also from Jamaica, illustrated in Valdés *et al.* (2006). The problem with identifying many doridaceans is that some aspects of colouration can vary with diet: yellow or red pigment suffused throughout the notum may simply reflect a diet of a yellow or a red sponge and sequestration of the sponge pigment into the skin. Brown and white patterning on the notum is unlikely to be affected by diet, and while such markings can still vary between individuals there is probably a clearly defined limit to such variation for each species. Unfortunately most descriptions of colour pattern are not sufficiently detailed to help in delimiting species in this way. The variation in colour pattern and radular teeth in the published records of *G. pusae* could either indicate that this is a very variable species or that more than one species is currently confused under this name. Thompson (1980) reports that *G. pusae* swims and also readily autotomises its mantle as does the Indo-Pacific *Discodoris lilacina* Gould 1852 (= *Discodoris fragilis* Alder & Hancock, 1864). However, mantle autotomy has not been reported by any of the other workers who have found live *G. pusae*, and since Thompson also reported that his specimens did not secrete

acid I conclude that he actually had a different species.

Are the west and east Atlantic populations of *G. pusae* the same species? Amphiatlantic species may have teleplanic larvae capable of crossing the Atlantic in one or in both directions (Edmunds, 1977) – if this occurs frequently then the populations on both sides of the Atlantic will experience regular gene flow and be effectively a panmictic population, but if it occurs rarely then there may be only occasional gene flow and the two populations could differentiate considerably and even form distinct species. Other amphiatlantic nudibranchs travel as eggs, settled juveniles or adults on boat hulls so may only have occurred on both sides of the Atlantic for, at the most, a few hundred years. These include some of the Goniodorididae and Polyceridae which feed on bryozoans that can live on moving boat hulls (e.g. *Polycerella emertoni* Verrill 1880, *Thecacera pennigera* (Montagu, 1815) and *Okenia impexa* Marcus 1957, in Edmunds, 2009, 2010). It is not known if any of the sponge eating dorids can travel in this way because sponges are less likely to survive on a fast moving boat than are bryozoans, but there are a few amphiatlantic warm water spongivorous dorids (e.g. *Doris verrucosa* L. 1758). For the present I accept that *G. pusae* is another amphiatlantic species and that *G. tema* is a distinct but closely related species currently only known from Ghana. It can be distinguished from *G. pusae* by its pink or red colouration, anterior gills darker than posterior gills, finely serrulate outer lateral radular teeth, lack of spicules in accessory gland, and possibly smaller size at sexual maturity (largest specimen 28 mm with eggs laid by this or by smaller animals nearby compared with *G. pusae* which can reach 40 mm (Sánchez Tocino *et al.*, 2006). However, a resolution of whether these two species really are distinct may have to await a more thorough examination, preferably using molecular techniques.

Acid secretion and systematics The secretion of acid of pH 1 or 2 in dorid nudibranchs was first reported by Edmunds (1968b) and a review of its occurrence in nudibranchs is given in Avila (1995). Edmunds described acid secretion and large subepidermal glands in *Discodoris pusae* with similar but less well fixed glands also in *Discodoris tema* (both now placed in *Geitodoris*, see Schrödl, 2000,

Valdés, 2002 & Dayrat, 2010). Edmunds also described acid secretion and presence of similar subepidermal glands in a species he identified as *Anisodoris stellifera* (Vayssière, 1903), but this must surely have been *Geitodoris planata* (Alder & Hancock, 1846) (Thompson & Brown, 1984; see also Perrone, 1987, and extensive discussion of Vayssière's species in Dayrat, 2010). Edmunds (1968b) showed that in an excised piece of mantle from an anaesthetised specimen of *G. planata*, liquid BDH wide range indicator was taken up by the subepidermal glands thus demonstrating that these are the source of the acid. When a specimen of *G. pusae* was placed in barium chloride enriched sea water and prodded the secretion from these glands turned milky indicating the presence of SO_4^{2-} anions, so the exudate contains sulphuric acid. In 1968 additional material of *G. tema* was available so further observations were made to confirm whether similar secretions occur in this species.

BDH wide range indicator paper was placed on the surface of a live animal under water and the animal was then prodded with forceps: it immediately registered pH 2. When the animal was removed from water the indicator paper registered pH 1. The animal was then anaesthetized and an excised piece of mantle in sea water extruded a cloudy secretion in patches above the openings of the subepidermal glands (Fig. 7E) which also registered pH 2. When transferred to a barium chloride-formol-saline mixture (5 ml 1% BaCl_2 + 5 ml 0.5% NaCl + 1 ml 40% formalin) the cloudy secretion produced a white precipitate confirming that it contained SO_4^{2-} anions, so the subepidermal glands in this species also contain sulphuric acid. Acid secretion gives protection to other opisthobranchs against predatory fish (Thompson, 1960), but a small species of trigger fish (*Balistes* sp.) was seen to nibble an 8 mm long specimen of *G. tema* in Ghana though without actually eating it.

Secretion of sulphuric acid from large subepidermal glands has thus been demonstrated for *Geitodoris pusae*, *G. tema* and *G. planata* (Edmunds, 1968b; Ortea *et al.*, 1988; Picton, 2001). The openings of what are probably similar glands have been described and/or illustrated for *G. perfossa* (Ortea, 1990), *G. bonosi* (Perrone, 1992), *G. sticta* Miller 1996 and *G. patagonica* Odhner 1926 (Schrödl, 2000), while acidic secretions have been demonstrated for *Geitodoris heathi* (McFarland,

1905; Thompson, 1969) and a species identified by Thompson (1975) as *Discodoris palma* Allan 1933, but this was probably a misidentification (Dayrat, 2010) so it too could be a species of *Geitodoris*. I conclude that presence of subepidermal glands containing sulphuric acid is a good generic character for *Geitodoris*, as has been suggested by Dayrat (2010).

Large subepidermal glands opening on the notum have been described for several species of *Paradoris* (Dayrat, 2006), but as discussed under *Paradoris indecora* (above) there is no evidence that these glands secrete acid and their histology has not yet been examined for comparison with that of species of *Geitodoris*.

Genus *Platydoris* Bergh 1877

Type species *Doris argo* Linnaeus 1767 [= *Platydoris argo* (Linnaeus 1767)], by subsequent designation by O'Donoghue (1929)

Platydoris sp.
Figs 1H, 7A–C

Material examined NHMUK Reg. No. 20110392: dredged from 20 m reef Tema Bay 1 sp 8 mm long 13 March 1970.

External features Body ovate, flat and hard as in other species of *Platydoris* (Figs 1H, 7A); mantle covered densely with minute low spicular papillae; rhinophores with nine lamellae; six small unipinnate gills; oral tentacles digitiform, foot narrow and sometimes folded longitudinally anteriorly (Fig. 7B, 7C). Dorsal surface dusky yellow, brightest medially, with many small, irregular pale and darker purple-brown spots (Figs 1H, 7A); ten small cream glands round edge of posterior part of mantle, each one covered with a brown spot; rhinophores and gills pale yellow with purple-brown spots.

Internal morphology As there was just a single small specimen of this species it was not dissected.

Geographical range Known only from Ghana.

Remarks Dorgan *et al.* (2002) list only two species of *Platydoris* from the east Atlantic, *P. argo* (Linnaeus, 1767) from the Mediterranean, Portugal, Madeira, the Canary and Selvagens

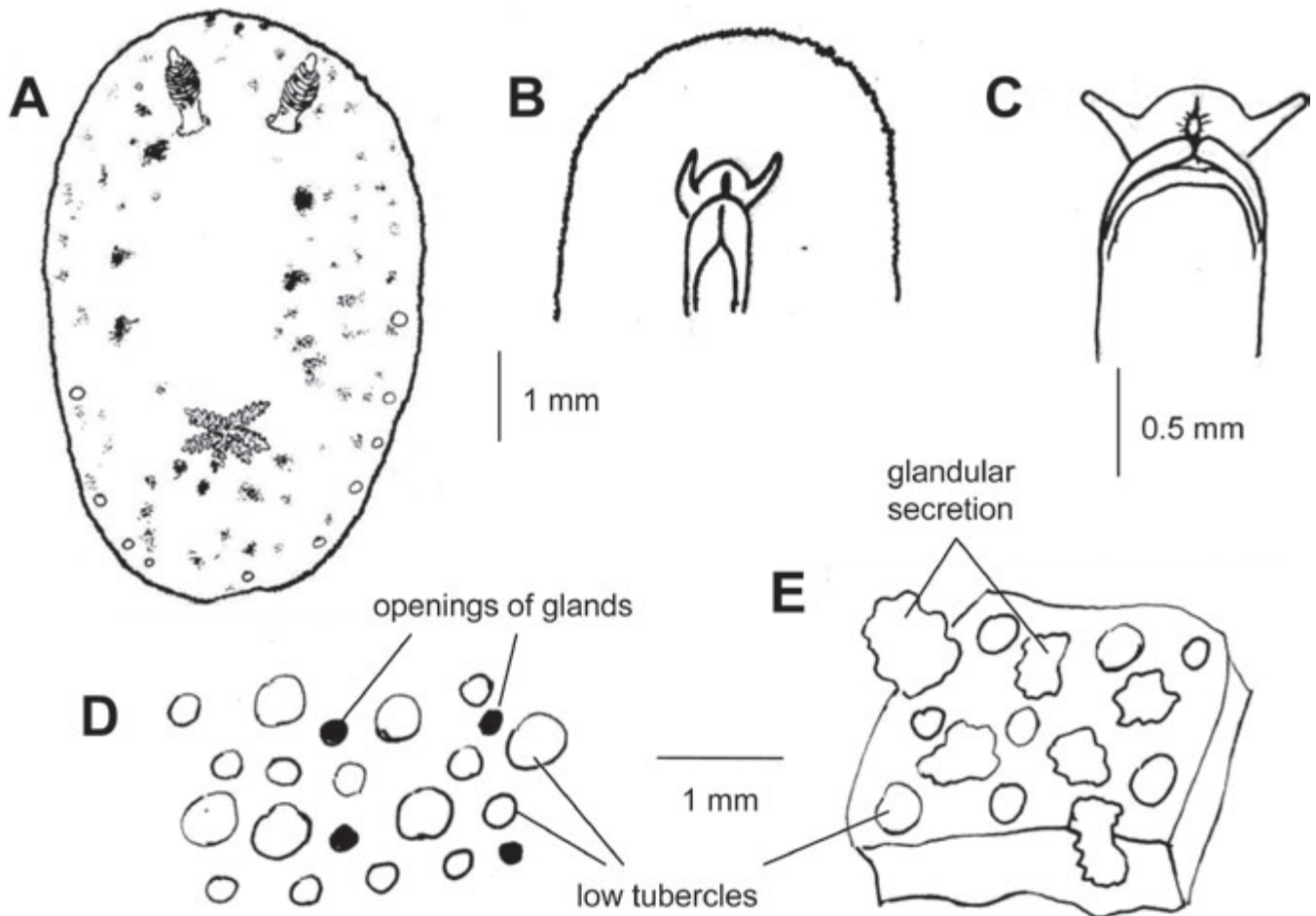


Figure 7 *Platydoris* sp.: A dorsal view of live animal; B ventral view of head of live narcotised animal; C Ventral view of head of preserved specimen. Stipple in A represents clusters of minute purple-brown spots. *Geitodoris tema*: D tubercles and gland openings of 23 mm specimen, preserved; E fragment of mantle in formol-barium chloride solution (see text) to show white precipitate in acid glands and on surface.

Islands, the Azores (Albuquerque, Borges & Calado, 2009; Avila, 2000) and the Cape Verde Islands, and *P. rolani* Dorgan, Valdés and Gosliner, 2002 from São Tomé and Príncipe in the Gulf of Guinea. The present animal is much smaller than fully grown specimens of these two species so it could be immature, but it differs in colouration and in possessing conspicuous white subepidermal glands. The west Atlantic *Platydoris angustipes* (Mörch, 1863) is also much larger and differs in colouration. *Platydoris stomascuta* Bouchet 1977 is a deep-water species which Dorgan *et al.* (2002) have transferred to *Baptodoris* although Fischer and Cervera (2005) and Cervera *et al.* (2006) retain it in *Platydoris* pending more information. I conclude that the present specimen belongs to an undescribed species of *Platydoris* characterised by possessing white subepidermal glands peripherally in the posterior half of the body.

Further material is required including a description of the radula and (if possible) other internal organs so that it can be named.

Genus *Baptodoris* Bergh 1884

Type species *Baptodoris cinnabarina* Bergh 1884, by monotypy

Baptodoris perezii Llera & Ortea 1982

Fig. 6E–G, 8A–F

Baptodoris perezii Llera & Ortea, 1982 in Ortea, Perez & Llera, 1982: 24–29, pl. 1C, figs 9–11

Material examined NHMUK Reg. No. 20110399: 12 m reef Kpone Bay 1 sp 5 mm long 16 April 1969; NHMUK Reg. No. 20110400/1, 2: 10 m reef Kpone Bay 1 sp 6 mm long 14 December 1969, 1 sp 7 mm long 6 February 1970.

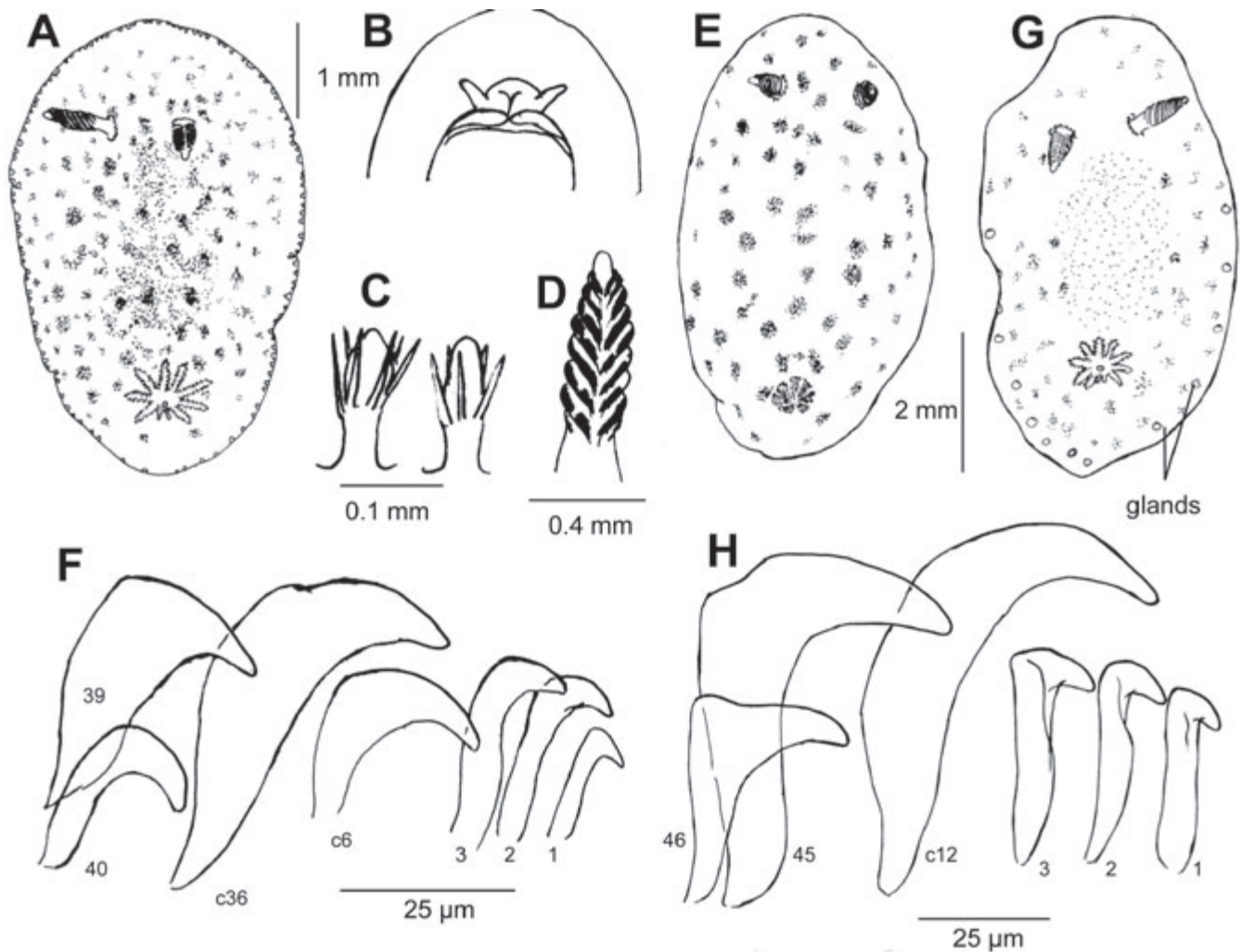


Figure 8 *Baptodoris perezii*, 5 mm long: A dorsal view; B ventral view of head; C two caryophyllidia; D posterior view of rhinophore. *Baptodoris perezii*, 6 mm long: E dorsal view; F radular teeth. *Jorunna glandulosa* n. sp., 7 mm long: G dorsal view; H radular teeth.

External features Body elongate oval, foot not normally projecting behind mantle posteriorly (Fig. 6E–G, 8A,E); dorsal surface of mantle with closely spaced small caryophyllidia with large elongated central tubercle (Fig. 8C), similar to those of *Jorunna tomentosa*, projecting spicules not visible when preserved; rhinophores slender with 8 to 10 lamellae sloping back to a posterior groove (Fig. 8D); five unipinnate gills surrounding anus in 5 mm specimen, 10 in 7 mm specimen and 11 in 6 mm specimen, with up to 9 pinnae on each side of rhachis alternately long and short; oral tentacles short, digitiform, foot with anterior notch (Fig. 8B). Notum of 5 and 7 mm specimens cream, more brownish in centre, with mottling of maroon pigment spots smaller and sparser towards edge of mantle, larger and denser towards centre, each spot comprised of

minute dots (Figs 6E, 6F, 8A); closely spaced white spots round edge of mantle, probably not glandular and not visible preserved; rhinophores pale yellow with dark brown or maroon on most lamellae, tip clear with white spots; gills greyish. The appearance of the animal varies depending on its background, thus Figs 6E and 6F are the same animal on different backgrounds. The 6 mm specimen is slightly different: notum creamy yellow with mottling of about 30 maroon spots and several smaller ones peripherally, each spot composed of dense minute dots of pigment (Figs 6G, 8E); closely spaced white spots round edge of mantle not visible preserved, rhinophores pale yellow with dark brown or maroon spots, tip clear; gills pale yellow with maroon spots.

Compared with the other two specimens, the body of the 6 mm animal is higher mid-dorsally

(i.e. less flat), the pigment is in more discrete spots, there is no reticulation of pigment mid-dorsally and many of the white spots on the mantle edge are situated just inside the edge instead of being right at the edge. However, the three specimens are so similar that I consider all to belong to the same species. When preserved all specimens appear identical in finer morphology of the notum and other external features.

Internal morphology The radula formula of the 6 mm specimen is 42×40.0.40. All teeth are hamate, smoothly curved with no secondary cusps or denticles (Fig. 8F). The innermost tooth is smaller than the succeeding teeth, and so too is the outermost tooth. There is no trace of labial rodlets indeed there is no obvious cuticularisation of the labial epithelium.

Geographical range Known from Italy, the Mediterranean and Atlantic coasts of southern Spain, Canary Islands, Madeira and now Ghana (Ortea *et al.*, 1982; Cervera, García-Gómez, Luque & Ortea, 1986; Perrone, 1986; Cervera *et al.*, 2006).

Remarks This species is characterised by all radular teeth hamate with no denticles, no labial rodlets, unipinnate gills, and tall caryophyllidia with elongated tubercles. In all of these characters it agrees with the original description of *Baptodoris perezii* (Ortea *et al.*, 1982). The type material has conical non-spicular tubercles in the centre of the notum with caryophyllidia confined to the edges, and the colouration is bright yellow, whereas the present specimens have caryophyllidia over the entire surface and the colour is cream rather than yellow. These differences, however, may not be significant as a specimen from Gran Canary was much whiter while those from Spain appear to have caryophyllidia distributed over the entire surface of the notum (Ortea *et al.*, 1982; Cervera *et al.*, 1986). Furthermore a photo of this species from the Mediterranean (Mediterranean Opisthobranchs, 2011) is very similar to some of the specimens described here, so I am confident that it belongs to *Baptodoris perezii*.

Because of the small size and limited number of specimens I did not attempt to dissect the reproductive organs. This is unfortunate because diagnosis of many of the genera of caryophyllidia-bearing dorids requires this information (Valdés & Gosliner, 2001), but the reproductive

organs have been described by Ortea *et al.* (1982) and by Cervera *et al.* (1986). Following a thorough phylogenetic analysis, the genera of caryophyllidia-bearing dorids have been reviewed and redefined by Valdés & Gosliner (2001). *B. perezii* is compared with these genera in Table 2 and it can be seen that it differs from all of them in at least two of the seven characters. It agrees with *Atagema* in five characters, but *Atagema* are large animals with pronounced dorsal tubercles and ridges and with rhinophoral and gill lobes or sheaths. It agrees with *Alloiodoris*, *Diaulula*, *Gargamella*, *Nophodoris*, *Taringa* and *Thorybopus* in four characters, and of these I consider it to be most similar to *Taringa*, but this genus has a stylet rather than numerous hooks on the penis and denticulate instead of smooth outer radular teeth. Therefore I have left it in *Baptodoris* even though it clearly differs from other species in this genus in lacking an accessory gland, having two regions to the prostate and denticulate outer radular teeth.

Only another phylogenetic analysis similar to that of Valdés & Gosliner (2001) but using many more species is likely to lead to redefinition of genera and so to a resolution of this issue.

Genus *Jorunna* Bergh 1876

Type species *Jorunna johnstoni* Alder & Hancock 1845 [= *Jorunna tomentosa* (Cuvier, 1804), by monotypy]

Jorunna glandulosa n. sp.
Figs 8G,H, 9A

Etymology The specific name was chosen because of the conspicuous subepidermal mantle glands which are unusual in caryophyllidia-bearing dorids.

Material examined Dredged from 27 m Tema Bay 1 sp 7 mm long 8 March 1970.

Holotype NHMUK Reg. No. 20110401/1, 2: 27 m Tema Bay, Ghana, 8 March 1970, collected by W. Pople.

External features Body elongate oval, foot not normally projecting behind mantle posteriorly (Figs 8G, 9A); dorsal surface of mantle with closely spaced caryophyllidia typical of *Jorunna*, projecting spicules not visible when preserved;

Table 2 Principal characters of caryophyllidia-bearing dorids as defined by Valdés & Gosliner (2001) compared with *Baptodoris perezii*.

Character genus	Gill pinnae	Labial rodlets	Radular teeth	Caryophyllidia	Prostate regions	Penis armed	Accessory gland
<i>Alloiodoris</i>	2/3	yes	some denticulate	long	1	yes	no
<i>Baptodoris</i>	2	no	outer denticulate	long	2	yes	yes
<i>Diaulula</i>	2/3	no	all hamate smooth	long	2	no	no
<i>Gargamella</i>	2/3	no	all hamate smooth	long	2	yes	yes
<i>Jorunna</i>	2/3	varies	usually hamate smooth	long	2	yes	yes
<i>Nophodoris</i>	2/3	yes	all hamate smooth	long	1	varies	yes
<i>Platydorid</i>	2/3	no	all hamate smooth	short	2	yes	yes
<i>Rostanga</i>	1/2	varies	some bicuspid or denticulate	long	2	no	no
<i>Sclerodoris</i>	2	no	outer denticulate	long	2	yes	yes
<i>Taringa</i>	2/3	no	outer denticulate	long	2	yes	no
<i>Thorybopus</i>	2	yes	all hamate smooth	short	1	yes	no
<i>Atagema</i>	2/3	no	all hamate smooth	long	1	no	no
<i>Baptodoris perezii</i>	1	no	all hamate smooth	long	1	yes	no

rhinophores with 12 lamellae sloping back to a posterior groove; eleven unipinnate gills surrounding anus; oral tentacles short, digitiform, foot with anterior notch. Notum creamy yellow with brown markings denser and almost continuous in centre, a few irregular pale brownish spots towards edge of mantle, white spots close to edge of mantle as in the 6 mm specimen of *Baptodoris perezii*, but also 14 larger cream or pinkish cream glands just in from the edge of the mantle in posterior half of body (Fig. 8G); rhinophores brown basally, paler with white spots distally; gills orange with brown spots.

Internal morphology The radula formula is 39×46.0.46. All teeth are hamate, the innermost is slender and small, and teeth become progressively larger and broader towards the centre of the row (Fig. 8H). The outermost are again small

but with more of a pronounced shaft supporting the cusp.

Geographical range Known only from Ghana.

Remarks With just a single specimen I did not attempt to dissect it apart from removing the buccal mass. It is very similar in external features and radula to *Baptodoris perezii* but differs in possessing conspicuous white subepidermal glands round the edge of the mantle and more slender rhinophores with a longer stalk. There are also small differences in colouration and in the shapes of radular teeth, though with only a single specimen it is difficult to place any reliance on these characters. When preserved specimens of both species appear identical in finer morphology of the notum and other external features, and the cream glandular spots in *J. glandulosa* are not visible.

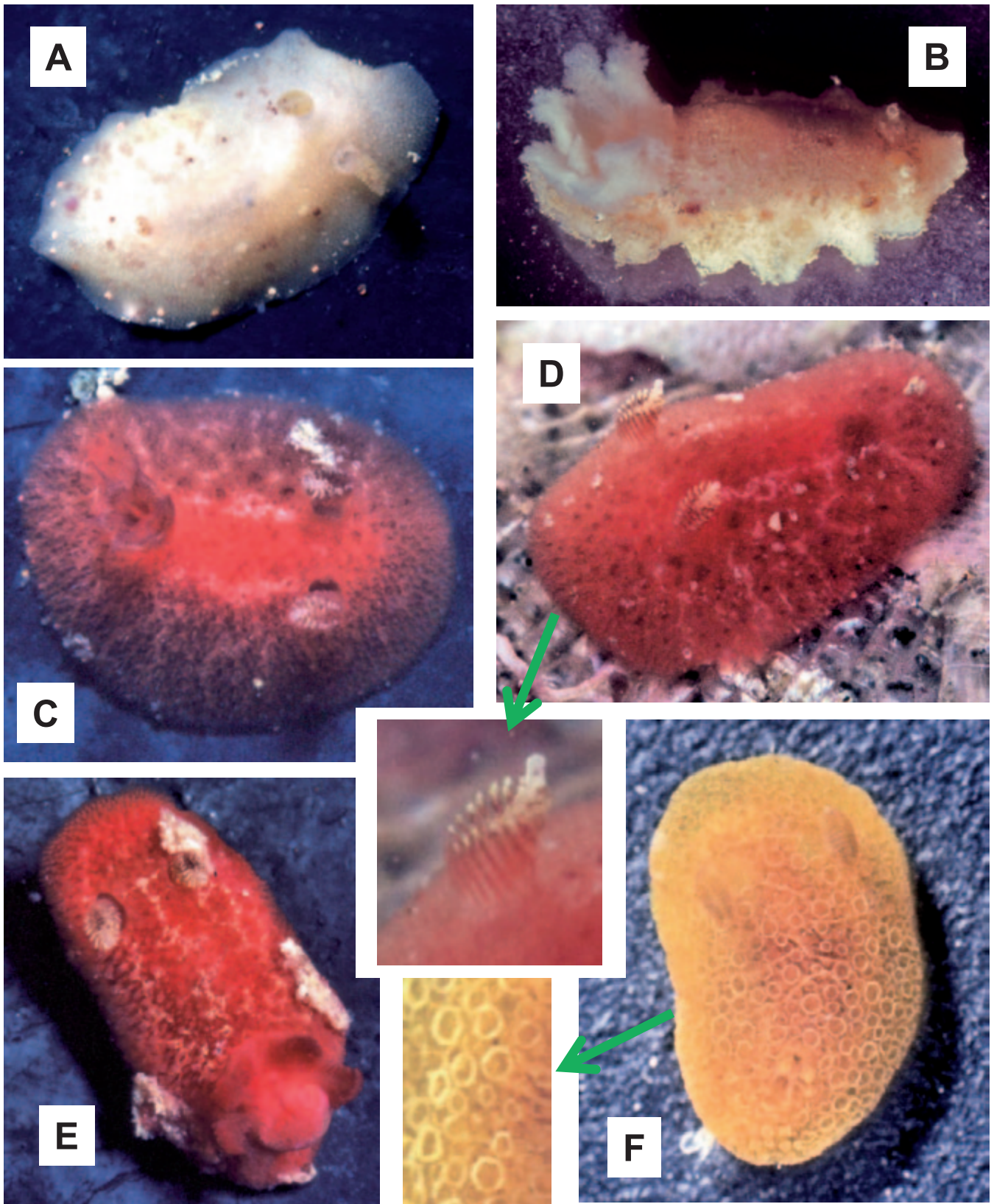


Figure 9 A *Jorunna glandulosa* n. sp., 7 mm long, March 1970. B *Jorunna ghanensis* n. sp., 40 mm long, October 1967. C, D *Rostanga rubra* (Risso, 1818) 7.5 mm long, March 1970 with enlargement of rhinophore. E *Rostanga rubra* 6.5 mm long, December 1969. F *Rostanga crocea* n. sp., 6 mm long, February 1968.

Is it possible for such conspicuous glands to be present in some individuals of a species but absent in others? Rudman & Avern (1989) reported that *Rostanga arbutus* usually has subepidermal white mantle glands which are clearly visible in a photo in Sea Slug Forum (2011), but these are not visible in all specimens. *Jorunna parva* (Baba, 1938) also usually has obvious glands in this position (Sea Slug Forum, 2011; Debelius & Kuitert, 2007). Similar white defensive glands are widespread in species of *Cadlina* and the Chromodorididae where they vary in number and position in different individuals (e.g. six species in Edmunds, 1981, and review by Wägele, Ballesteros & Avila, 2006) but they rarely occur in spiculate dorids. I consider it is unlikely that such glands can be present in some individuals of a species and absent in others, except perhaps in very young specimens, because if they are indeed of value in deterring predators then one would have expected selection to fix this characteristic in all individuals. However, if these glands store noxious chemicals sequestered from sponge prey, then they are only likely to be fully developed (and full of defensive chemicals) if the animal had fed on a species of sponge containing these chemicals. Individuals that fed on other sponges would then have rudimentary glands not easily visible without microscopical examination. Thus while it is possible that the present specimen belongs to a species that often lacks such glands (such as *B. perezi*), for the present I consider it to belong to a different species *J. glandulosa*.

The problematic generic placement of *Baptodoris perezi* has been discussed above: similar considerations apply to *J. glandulosa* which I place provisionally in the genus *Jorunna* because at least one species of this genus (*J. parva*) is known to possess similar glands, and because this genus includes species with smooth labial cuticle and all radular teeth smooth and hamate. It clearly differs in colour and radula teeth from the European and Atlantic species of *Taringa* summarised by García-Gómez, Cervera & García-Martin (1993).

Jorunna ghanensis n. sp.
Figs 9B, 10A–I

Jorunna malcolmi Marcus 1976, specimen from Ghana: 41–43, figs 29, 30
non *Jorunna malcolmi* Marcus 1976, holotype specimen from Tanzania: 41–43, fig. 28

Etymology The species is named from its geographical occurrence in Ghana.

Material examined NHMUK Reg. No. 20110402/1, 2: from bottom of Russian trawler in Tema harbour 4 sp 40, 40, 32 & 32 mm long 16 October 1967.

Holotype NHMUK Reg. No. 20110403: from bottom of Russian trawler in Tema harbour, Ghana, 16 October 1967, collected by W. Pople.

External features Body elongate oval with margin undulating (Figs 9B, 10A), foot projecting behind mantle posteriorly when animal is crawling; dorsal surface of mantle with closely spaced caryophyllidia with long central knob (Fig. 10D); rhinophores with short stalk, bulbous club with about 18 lamellae sloping back from frontal groove to posterior groove; circlet of ten large bipinnate gills often held in a vertical cylinder (Fig. 10C); oral tentacles digitiform; foot with anterior notch (Fig. 10B). Notum yellow-brown with scattered small brown or red-brown spots, suffused with minute white dots, with three or four larger dark brown spots on each side between rhinophores and gills (Figs 9B, 10A, 10C), caryophyllidia grey or grey-brown sometimes with white tip; rhinophores yellow-brown with a few white and dark brown spots, distal annulae dark brown, tip grey or yellow-brown; gills pale brown or grey-brown, some with inconspicuous white dots; foot and mantle ventrally yellow-brown.

Internal morphology In the buccal mass the slender salivary glands open close to the buccal ganglia (Fig. 10E). The labial cuticle has dense rodlets similar to those found in *J. malcolmi* from Tanzania (Edmunds, 1971, as *J. tomentosa*) (Fig. 10F). The radula formulae of two large specimens are approximately 23×24.0.24 and 30×26.0.26. All teeth are hamate without any denticles; the outermost are gently curved rather than hook-shaped (Fig. 10G).

I examined the reproductive system of one of the specimens in 1975 and made sketches at various stages of the dissection. A composite drawing of the reproductive system was then sent to Eveline Marcus who was preparing a revision of the genus, and she published a figure based on my drawing under the name *Jorunna malcolmi* (Marcus 1976: fig. 30).

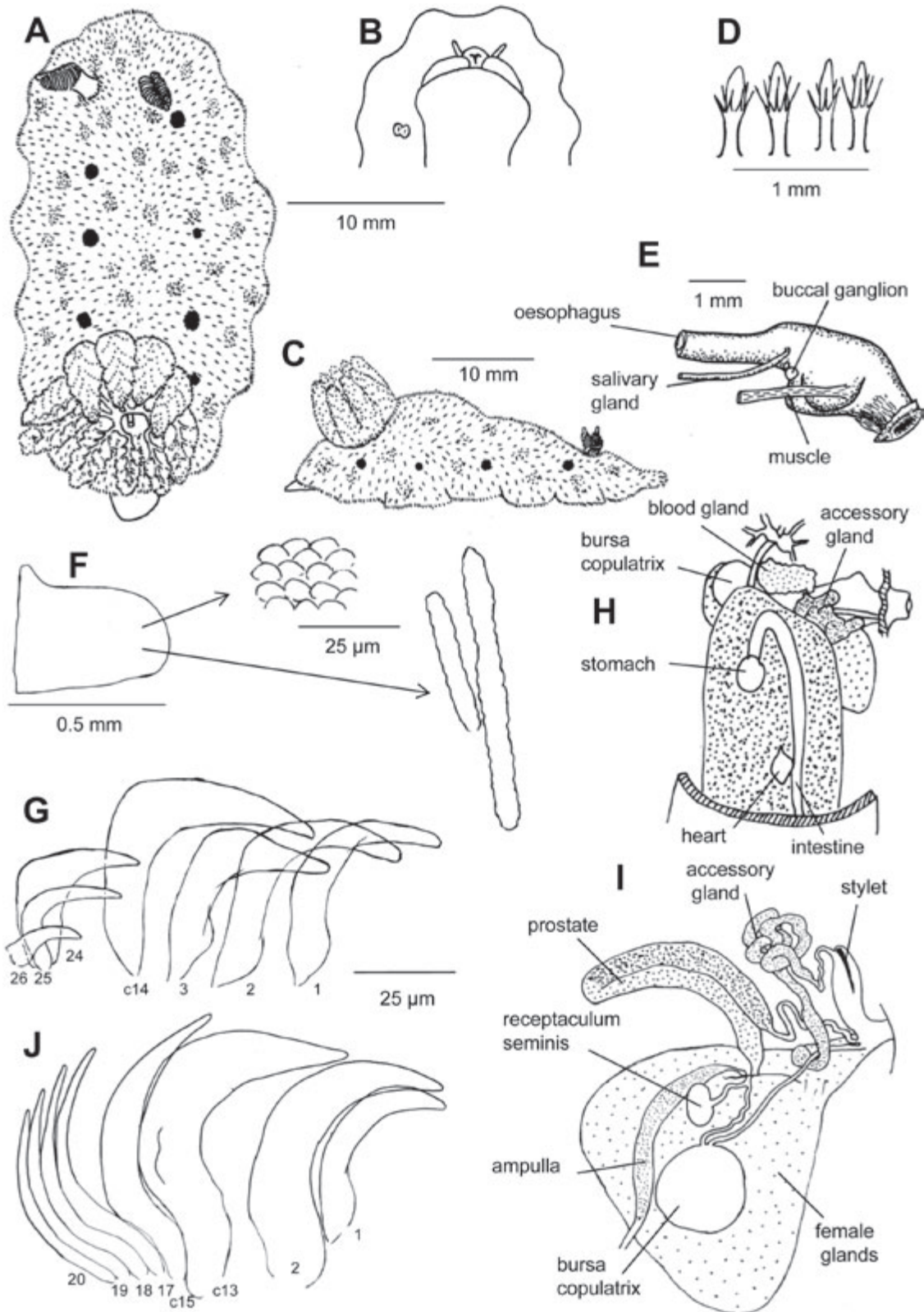


Figure 10 *Jorunna ghanensis* n.sp., 32 mm long: A dorsal view; B ventral view of head; C lateral view; D caryophyllidia; E buccal mass; F labial cuticle (flattened and slightly distorted) with surface sculpture and two rodlets; G radular teeth including the innermost 3 teeth and the outermost 3 teeth from two different rows; H initial dissection of specimen from dorsal side; I diagram of reproductive organs based on dissection. *Jorunna tomentosa* (Cuvier, 1804): J radular teeth from British specimen with formula 18×20.0.20. A–D are drawn from life with stipple showing darker markings and spots in A and C. Numbers in G and J refer to position of tooth in row.

When the animal is dissected from the dorsal surface most of the reproductive system is hidden beneath the blood gland, the accessory gland and the digestive gland (Fig. 10H); these have to be either removed or pushed to one side in order to see the other structures. The ampulla, bursa copulatrix, receptaculum seminis, female glands, and looped prostate are similar to those of many other dorids although the connections between the ampulla, the prostate and the female ducts were hidden by a fold of the female glands in the specimen dissected. The proximal half of the prostate was cream and the distal part lying parallel to it was brown, implying that the two regions have different types of gland (Fig. 10I). A large, convoluted accessory gland opens beside a small stylet just in front of the other genital openings. In the description and drawing prepared by Marcus (1976) based on my own unpublished drawing and notes, the accessory gland is shown opening into the female gland mass, just as it is in the drawing given by Pruvot-Fol (1954: Fig. 109d): I now believe that this is incorrect. The distal end of the accessory gland is certainly close to the female glands but my drawings clearly show that I inferred but did not observe any connection between them. Furthermore, the careful drawings of Cervera, García-Gómez & García (1986) and the numerous dissections and drawings of species of the genus *Jorunna* by Camacho-García & Gosliner (2008) show that the accessory gland is not connected to the other genital ducts.

Geographical range Only known from these records from Ghana.

Remarks The caryophyllidia bearing dorids have been reviewed by Valdés & Gosliner (2001) and the genus *Jorunna* further revised by Camacho-García & Gosliner (2008). *Jorunna* is characterised by tall caryophyllidia each with long spicules and a small rounded tubercle, low rhinophoral and gill sheaths, gills uni- to tri-pinnate, prostate with two distinct sections, vagina unarmed, penis unarmed or occasionally with hooks, large accessory gland with a prominent spine, inner and mid-lateral radular teeth hooked, outer ones smooth or pectinate.

The reproductive system of *Jorunna* is "one of the most difficult reproductive systems to draw among dorids" (Camacho-García & Gosliner, 2008), indeed it is often difficult to elucidate the

relationships and connections between the various organs. Camacho-García & Gosliner made up to three drawings of each animal during the course of their dissections and they dissected dozens of specimens of the genus *Jorunna*, yet the precise connections between the various structures in their revision of the genus are not always clear. The general configuration of the reproductive system is shown diagrammatically by Schmekel & Portmann (1982: fig. 7.9e), but the accessory gland is often very large and sometimes lies on top of the other structures. This gland has been variously called a vestibular gland (Marcus, 1976), accessory gland (Camacho-García & Gosliner, 2008) or masculine gland (Thompson & Brown, 1984). The stylet and gland probably stimulate the partner during copulation in the same way that a penial stylet normally does: for *J. labialis* (= *malcolmi*) Edmunds observed that the stylet "is everted when the animal is sexually activated" (Edmunds, 1971: p. 364).

A conical gill cirlet is characteristic of *Jorunna tomentosa* (Cuvier, 1804) from Europe (see photos in Anderson, 1999–2010) and the present Ghanaian specimens also had this feature (Fig. 10C, but not evident in Fig. 9B). *Jorunna tomentosa* is common and widespread in Europe so should be well known, but when Marcus (1976) examined specimens thought to be *J. tomentosa* more carefully she was able to distinguish four additional species, *J. alisonae* Marcus 1976 from Hawaii, *J. lemchei* Marcus 1976 from Ireland, *J. luisae* Marcus 1976 from Naples (Italy) and *J. malcolmi* from Tanzania and Ghana. Looking back at my extensive correspondence with Dr Marcus in 1974 and 1975 I see that she invited me to collaborate with her in this revision of *Jorunna*, but I declined as I felt I had not contributed sufficiently to justify joint authorship. However, when she proposed creating four new species I wrote (in January 1975) "I think that the best course is to make several species and so force future workers to look carefully at the reproductive systems to unravel them." I later (April 1975) suggested that the type of *J. malcolmi* should be the Tanzanian specimen because I was not convinced that the Ghanaian material belonged to the same species, and it had not been described in sufficient detail.

Thompson & Brown (1984) did not accept that all of Marcus's species are valid, but the most recent and thorough revision by Camacho-García & Gosliner (2008) recognises all four of them as

distinct from *J. tomentosa*, but with *J. luisae* conspecific with (and hence a junior synonym of) the west Atlantic *Jorunna spazzola* (Marcus, 1955) and *J. malcolmi* conspecific with the east African *Jorunna labialis* (Eliot, 1908). *Jorunna malcolmi* was based on three specimens (including the holotype) from Tanzania previously described under the name *J. tomentosa* by Edmunds (1971) and five specimens from Ghana of which the four large ones are here identified as *Jorunna ghanensis* n. sp. while the small, immature fifth specimen is described separately as it may be a different species. *Jorunna labialis* (= *malcolmi*) differs from the present material in greyish colour with scattered darker spots (instead of yellow-brown with two rows of brown spots), and more teeth in each radular row (33) for a smaller animal (22 mm).

The present material from Ghana should be compared with all of the Atlantic species of *Jorunna*: *J. tomentosa*, *J. spazzola*, *J. lemchei* and *J. onubensis* (Cervera *et al.*, 1986) which have been distinguished by Camacho-García & Gosliner (2008: Table 4). It resembles *J. tomentosa* and differs from the other species in colour of the mantle, rhinophores and gills (colour illustrations from various sources including Debelius & Kuitert, 2007 and Cervera *et al.*, 1986 [for *J. onubensis*] and Just & Edmunds, 1985 [for *J. lemchei*]), but it differs from *J. tomentosa* in possessing jaw rodlets and short rather than slender outermost radular teeth (compare Fig. 10G and J: radula J is from one of two specimens of *J. tomentosa* collected at Plymouth with radular formulae 16×20.0.20 and 17×18.0.18). It differs from *J. spazzola* in lacking denticulate outermost radular teeth; from *J. lemchei* in having projecting rather than pitted caryophyllidia (illustrated by Henning Lemche in Just & Edmunds, 1985: pl. 22D); and from *J. onubensis* in lacking two distinct regions to the vas deferens. One further species from the Atlantic is *Jorunna evansi* (Eliot, 1906) from the Cape Verde Islands, originally placed in *Rostanga* but shown by Camacho-García & Gosliner (2008) to belong to *Jorunna*. It differs from the present specimens in having fewer radular teeth per row for a much larger body size, and in colouration; it may be a synonym of *J. spazzola*.

Camacho-García & Gosliner (2008) describe the labial cuticles of *J. tomentosa* and *J. lemchei* as smooth while *J. spazzola* and *J. onubensis* as well as several other species have 'jaw elements'. These jaw elements are 25 µm long rods in

J. onubensis, 10–20 µm long rods in *J. spazzola* (Camacho-García & Gosliner, 2008) and 40–50 µm long rods with a diameter of 6–8 µm in *J. labialis* (as *J. tomentosa* in Edmunds, 1971) from Tanzania. Camacho-García & Gosliner's SEM pictures show them as irregular corrugations or pustules in *J. labialis* and *J. alisonae*, each with a diameter of 4–6 µm. These pustules could be the tips of short rods, but this is not clear from the photographs. It may be that the SEMs normally show just the surface of the cuticle and that it is necessary to damage it in order to see the full length of these elements, as in their photo of *J. spazzola* (their Fig. 12D). In *J. ghanensis* the sculpturing on the labial cuticle comprises small raised pustules 4–5 µm diameter; they appear rounded rather than showing the irregular surface illustrated by Camacho-García & Gosliner (2008) in *J. alisonae* and *J. labialis*, but are of similar size, the difference in surface texture perhaps relating to the greater resolving power of the SEM compared with the light microscope. However, because the radula was not well flattened, I remounted it teasing away some of the tissue still adhering to the labial cuticle. This time labial rodlets were clearly displayed (compare the two enlarged drawings of Fig. 10F). Thus the appearance of the labial cuticle can vary depending on the precise details of its preparation either for the light microscope or for the SEM.

Camacho-García & Gosliner (2008) noted that in *J. tomentosa* there is considerable variation in radular tooth shape, even in a single specimen, with the outermost teeth sometimes smooth and sometimes denticulate. However, in all *J. tomentosa* the outermost three or four teeth are slender and curved (Fig. 10J; Marcus, 1976; Cervera *et al.*, 1986; Camacho-García & Gosliner, 2008) whereas in *J. ghanensis*, apart from the outermost tooth, they are hamate.

The recent redescription of *J. tomentosa* by Camacho-García & Gosliner (2008) describes 'small, white, spherical glandular structures surrounding mantle edge'. These have not been reported by previous workers but are clearly seen in the photograph in Gosliner (1987) and in some (but not all) of the photos of European specimens available on the Internet. They were not seen in *J. ghanensis* but it is possible that the brown pigment may obscure these small white structures. They clearly resemble the small white structures at the mantle edge of *Baptodoris perezii*

(Figs 6E, 6F, 8A, and see above) but whether they are glandular is not known.

The Russian trawler on which *J. ghanensis* was found had been anchored in Tema harbour for some time (months and possibly years from my memory). In this habitat they could have been transported from Europe or elsewhere and simply survived growing to a large size on sponges attached to the boat hull. However, sponges of the genera *Halichondria* and *Haliclona* on which *J. tomentosa* feeds in Europe (Thompson & Brown, 1984) are unlikely to thrive on a moving boat, so it is more likely that these sponges colonised the boat while in Tema harbour and that local veligers then settled on the sponge and grew to maturity. I therefore consider that the species is probably not a transient immigrant but is resident in Ghanaian waters.

It is not surprising that west African specimens should belong to a different species to the north European and Mediterranean *J. tomentosa* because of the very different marine communities in these areas, but it is surprising that *J. tomentosa* should be reported from South Africa as well as Europe and the Azores yet be absent from the intermediate region of Ghana. Camacho-García & Gosliner (2008) give a detailed account of the South African material and compare it very carefully with specimens from Europe and the Azores before concluding that they are unable to find any significant differences which would justify erecting a new species, so it is necessary to be equally cautious before proposing a new species from an intermediate region in this wide distribution. However, because of the differences in the radula and the labial cuticle I cannot assign my Ghanaian material to *J. tomentosa* but conclude that it belongs to a hitherto undescribed species *J. ghanensis*.

Jorunna sp.

Material examined NHMUK Reg. No. 20110404: 8.8 m reef Kpone Bay 1 sp 3 mm long 15 December 1967.

External features The small specimen has caryophyllidia covering the notum, 6 rhinophore lamellae and 6 unipinnate gills; body golden yellow dorsally and ventrally, 3 pairs of irregular brown spots on dorsum, a dozen minute white spots on mantle edge and rhinophore socket

edge, rhinophores white with 4 brown blotches near base, each gill cream with white tip and 3–4 brown spots.

Remarks Although this juvenile specimen resembles *J. ghanensis* (above) in having 6 brown spots on the notum, its yellow colour and occurrence in a different habitat suggest it may belong to a different species. As it was so immature I cannot identify it further than to tentatively place it in the genus *Jorunna*.

Genus *Rostanga* Bergh 1879

Type species *Doris coccinea* Forbes in Alder & Hancock 1848 [= *Rostanga rubra* (Risso 1818)], by original designation

Rostanga rubra (Risso 1818)

Fig. 9C–E, 11

Doris rubra Risso 1818: 369

Doris coccinea Forbes 1844: 133 (*nomen nudum*); Forbes in Alder & Hancock, 1845–55: 42, pl. 7, pl. 46, fig. 6

Rostanga perspicillata Bergh 1881: 104–107, pl. J, figs 1–15

Rostanga rufescens Iredale & O'Donoghue 1923: 197, 227

Rostanga temarana Pruvot-Fol 1953: 78–80, figs 26, 26 bis

Rostanga rubra – Pruvot-Fol, 1954: 277–279

Material examined NHMUK Reg. No. 20110405/1, 2, 3: 10 m reef Kpone Bay 1 sp 2.5 mm long 21 December 1967, 1 sp 2 mm long 4 February 1968, 3 sp 3.5, 5 & 5.5 mm long 2 November 1969, 2 sp 6.5 & 1.5 mm long 14 December 1969, 1 sp 1.5 mm long 10 December 1971; dredged from 24 m in Tema Bay 1 sp 7.5 mm long 2 March 1970.

External features Body elongate oval, foot just projecting behind mantle posteriorly when animal is crawling (Figs 9C,D, 11A); dorsal surface of mantle with closely spaced caryophyllidia, each caryophyllidium with 7–8 spicules forming a cirlet round the small central tubercle (Fig. 11G); rhinophore with short stalk, lamellae sloping back almost vertically from deep frontal groove to shallower posterior groove, 10 in 7.5 mm specimen, 6 in 2.5 mm specimen (Fig. 11C); cirlet of six small unipinnate gills; oral tentacles digitiform; foot with anterior notch

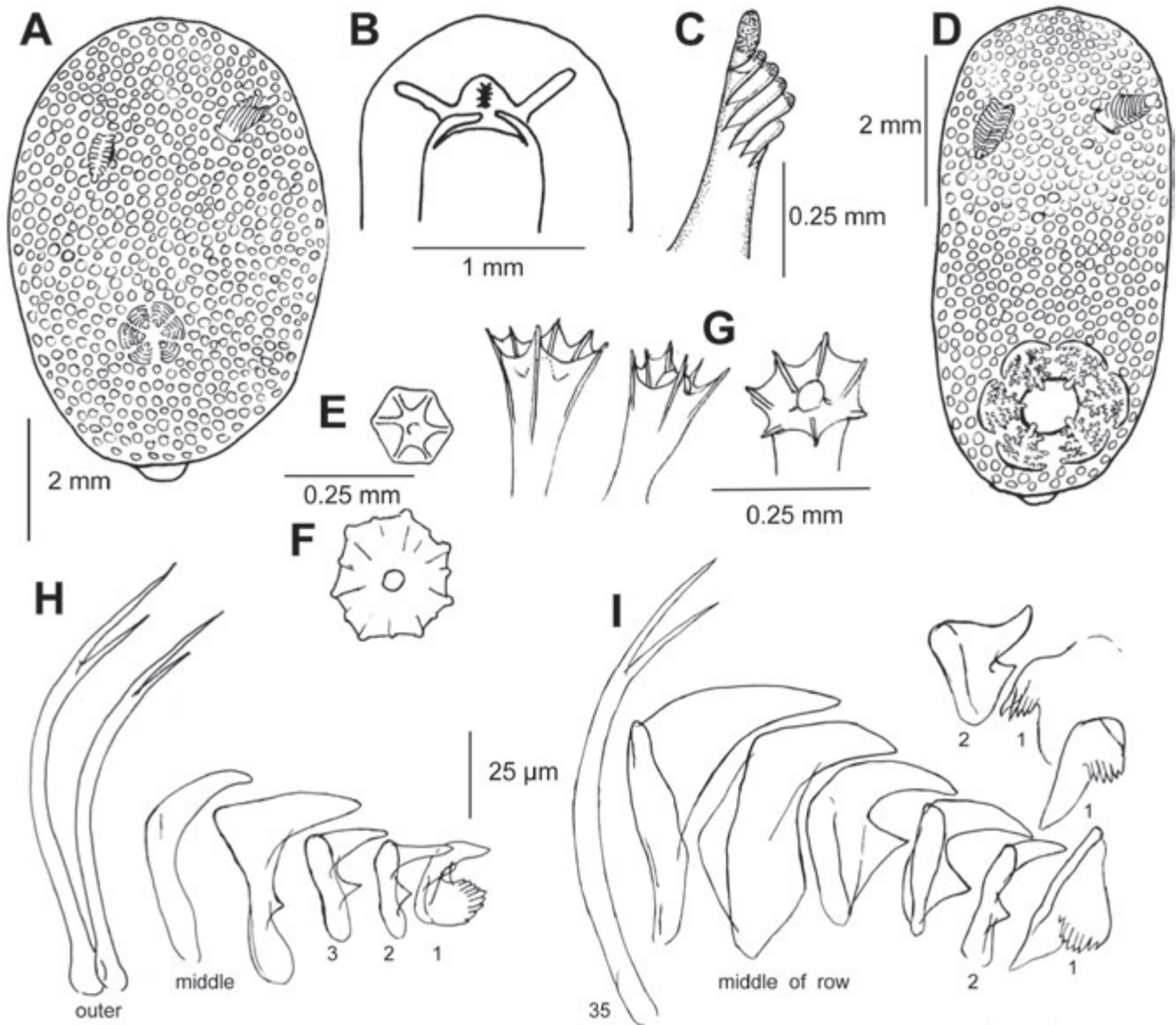


Figure 11 *Rostanga rubra* (Risso, 1818) A dorsal view of 7.5 mm long specimen; B ventral view of 2.5 mm specimen; C rhinophore of 2.5 mm specimen from left side; D dorsal view of 6.5 mm long specimen with bipinnate gills; E top view of caryophyllidium of 6.5 mm specimen; F top view of caryophyllidium of 7.5 mm specimen; G three caryophyllidia from different angles of 2.5 mm specimen; H radular teeth of 5.5 mm specimen, two outermost teeth, two from middle of row, and three innermost teeth (3,2,1); I radular teeth from 6.5 mm specimen, outermost tooth, four teeth at intervals towards the centre of the row, first two lateral teeth in different views (1, 2). A–D & G all drawn from life, E & F drawn from preserved specimens.

(Fig. 11B). Notum including caryophyllidia vermilion (paler in smallest specimens), paler at edge, with scattered small black spots and some cream spots near mantle edge and sometimes as small patches more centrally (Figs 9C, 9D, 11A); rhinophore stalk pale vermilion, clavus pale vermilion or orange with distal lamellae cream and purplish brown (especially in larger specimens), tip cream; gills pale vermilion with

some brown on rhaches and at edges of pinnae; ventral surface of mantle and foot pale vermilion, with yellowish viscera showing through.

The description above applies to all specimens except for the 6.5 mm specimen from 14 December 1969. This differed in the following features: caryophyllidia smaller (Fig. 11E compared with Fig. 11F); rhinophore with 12 lamellae; anal region damaged and bulging between

circlet of six bipinnate gills; notum including caryophyllidia scarlet with minute black dots and irregular meshwork of creamy brown; rhinophore clavus brown, lamellae brown and cream, tip cream; gills scarlet; ventral surface of mantle and foot pale scarlet.

Internal morphology The radula of the 5.5 mm specimen has the approximate formula $35 \times 35.0.35$. The innermost lateral tooth has a broad pectinate cusp i.e. with 7–9 slender ridges ending in teeth (Fig. 11H). Succeeding teeth are hamate with a secondary cusp arising from the shaft; they become progressively larger towards the middle of the row, the secondary cusps not easy to see in overlapping rows; the outer lateral teeth are longer and more slender with no secondary cusp, gradually changing to very long and slender teeth, most with bifid tips (Fig. 11H). There are at least 9 slender outermost lateral teeth in some rows, but they are closely adherent and difficult to distinguish under the microscope, so there may be a few more.

The radula of the 6.5 mm specimen is similar with the approximate formula $42 \times 35.0.35$. As in the previous specimen the first lateral is pectinate, succeeding laterals are hamate with a secondary cusp, further out the laterals lack the secondary cusp and are progressively longer merging into about a dozen very slender teeth of which all the outer ones are bifid (Fig. 11I). Individual teeth are slightly larger than in the previous specimen but the animal itself was slightly larger.

Geographical range From Norway to the Mediterranean and Morocco, Madeira, Canary Islands and the Cape Verde Islands (Thompson & Brown, 1984; Valdés & Gosliner, 2001; Segers, Swinnen & Prins, 2009).

Remarks Because one of my specimens differs from the others in having bipinnate gills, smaller caryophyllidia and scarlet colouration I had first to decide if there are two species of *Rostanga* rather than one in Ghana. In Europe García-Gómez (1986) distinguished *R. perspicillata* Bergh from *R. rubra* on the basis of bipinnate instead of unipinnate gills, but other authors have considered that *R. perspicillata* is conspecific with *R. rubra* (Schmekel & Portmann, 1982; Thompson & Brown, 1984; Rudman & Avern, 1989; Valdés & Gosliner, 2001), and while most workers only observed unipinnate gills in this species Valdés

& Gosliner (2001) also reported bipinnate gills in some animals. If this decision is correct then presence of bipinnate gills on its own is not sufficient to justify recognising a second species in Ghana. Of the other two characters, size of caryophyllidia varies even in a single specimen, and the size difference reported here is very small. Body colouration also varies in *Rostanga rubra* (see photos on Sea Slug Forum, 2011) and probably reflects feeding on different species of sponge with different pigments which are then sequestered. Furthermore the radular formulae of the uni- and bi-pinnate specimens from Ghana are very similar, and although the mid lateral teeth are rather different in shape, the shapes of most of the radular teeth are also very similar. So while I consider it possible that there are two different species of *Rostanga* in Ghana, without more material I cannot justify splitting the small collection into two species.

Can the Ghanaian specimens be identified with European *R. rubra*? *Rostanga rubra* is well known in Europe (Alder & Hancock, 1845–1855 as *Doris coccinea*; Schmekel & Portmann, 1982; Thompson & Brown, 1984) where it characteristically has a transverse cream band (sometimes quite slender) dorsally between the rhinophores. However the cream band is not always present (Thompson & Brown, 1984; García-Gómez, 1986), so its absence in Ghanaian material may simply reflect geographical variation and lack of (or very little) gene flow from European populations. *R. rubra* also typically has 8–10 gills compared with only 6 in the present material, but gill number in dorids often increases with body size and my specimens were smaller than those recorded by Schmekel & Portmann (1982) and by Thompson & Brown (1984) (up to 7.5 mm body length compared with up to 15 or 20 mm for European material). The radular formulae reported here are smaller than those of specimens of comparable size from Europe: $35 \times 35.0.35$ and $42 \times 35.0.35$ for specimens 5.5 and 6.5 mm long from Ghana compared with $60 \times 55.0.55$ for specimens 7 and 8.5 mm from Cornwall, $58 \times 65.0.65$ for a 15 mm specimen from Lundy (Thompson & Brown, 1984) and $56 \times 46.0.46$ for a 14 mm specimen from the Mediterranean (Schmekel & Portmann, 1982). Number of radular rows and number of teeth per row both increase with body size but there may also be geographical variation in these characteristics. More important for specific identification

in *Rostanga* are the shapes of the radular teeth. In *R. rubra* the innermost lateral has 4–7 fine teeth (Valdés & Gosliner, 2001); the next batch of lateral teeth have a secondary cusp on the shaft, outer teeth are hooked with no secondary cusp, and the outermost are needle-like with bifid tips. The radula teeth of the present material are very similar but with up to 9 serrations on the innermost lateral tooth. Radular teeth, especially the innermost lateral, of other species of the genus differ considerably from both typical *R. rubra* and from the present material. The labial cuticle of *R. rubra* exhibits ‘honeycombing’ (Thompson & Brown, 1984), the pattern comprising minute rodlets (Valdés & Gosliner, 2001), but I was unable to examine the labial cuticle on the Ghanaian specimens. Finally *R. rubra* is characterised by almost vertically aligned lamellae on the rhinophores which are scooped out anteriorly. This is not well shown by Thompson & Brown (1984) but is beautifully illustrated by Alder & Hancock (1845–55). The present specimens have a similar concave anterior face to the rhinophores (Figs 9D inset, 11C).

On the basis of the above comparisons I conclude that the present material from Ghana belongs to *Rostanga rubra*, and that the geographical range of this species must now be extended to include Ghana.

Rostanga elandsia Garovoy, Valdés & Gosliner 2001 from South Africa is a larger red species with very different shaped inner lateral teeth and transverse lamellae on the rhinophores. *R. byga* Marcus 1958 from the west Atlantic is another similar species but with narrower innermost radular tooth, no secondary cusp on the next batch of lateral teeth and with multiple needle-like cusps on the outermost teeth (Muniain & Valdés, 2000). *Discodoris rosi* Ortea 1979 from the Mediterranean and Portugal, which may be a *Rostanga* (Dayrat & Gosliner, 2005; Dayrat, 2010, although not supported by Cervera *et al.*, 2006) differs in colouration and radular teeth.

Garovoy *et al.*'s (2001) phylogenetic analysis of the genus suggests that the three South African species with transverse lamellae on the rhinophores are closely related to one another and also (surprisingly) to the Norwegian *Rostanga setidens* (Odhner, 1939). The two Atlantic species (*R. rubra* and *R. byga*) with vertical lamellae on the rhinophores are more closely related to *R. pulchra* from the west coast of the Americas. This analysis

would suggest that the South African species originated in the Indo-Pacific region while the ancestors of the American west coast *R. pulchra* migrated round Cape Horn from the Atlantic. This is certainly possible, but it should be noted that phylogenetic analyses are only reliable as a guide to evolutionary relationships if they are based on a large number of independent characters.

Rostanga crocea n. sp.

Figs 9F, 12

Etymology The species is named after its golden yellow colouration. Although several other species of nudibranch mollusc have the specific epithet *croceus*, there are none that I can trace in the Dorididae or Discodorididae, so there should be no confusion with them.

Material examined NHMUK Reg. No. 20110407: 10 m reef Kpone Bay 1 sp 4 mm long 21 January 1968, also 1 sp 6 mm long 4 February 1968.

Holotype NHMUK Reg. No. 20110406/1, 2, 3 from 10 m reef Kpone Bay, Ghana, 4 February 1968, collected by W. Pople.

External features Body elongate oval, foot just projecting behind mantle posteriorly when animal is crawling (Figs 9F, 12A); dorsal surface of mantle with closely spaced caryophyllidia giving the appearance of flat circular projections when viewed from above (Fig. 9F inset), each caryophyllidium large with 5–9 spicules forming a circlet round the small central tubercle (Fig. 12E); rhinophore with long stalk, lamellae sloping back from deep frontal groove to shallower posterior groove, 17 in larger specimen, 13 in smaller one (Fig. 12D); six unipinnate gills; oral tentacles digitiform; foot with anterior notch (Fig. 12B). The proboscis was everted in the smaller specimen while it was being narcotised and it had about a dozen small denticular projections (Fig. 12C). Notum, caryophyllidia, rhinophore stalk and gills orange-yellow (Fig. 9F), rhinophore clavus, edge of mantle and foot golden yellow; minute black dots scattered over notum and gills; a few white streaks on notum and edging some of larger caryophyllidia; viscera (visible through foot ventrally) golden orange, everted proboscis pinkish.

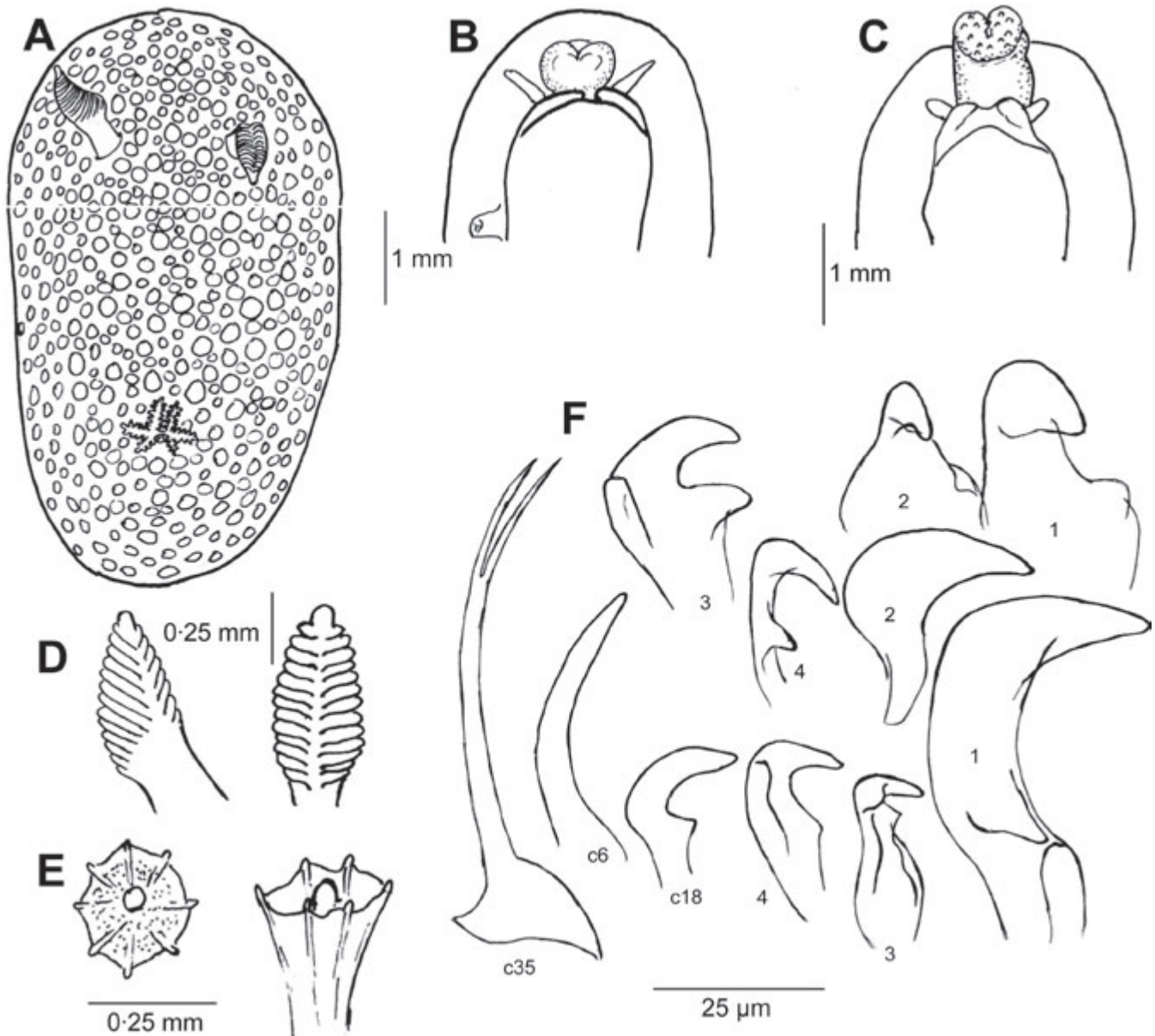


Figure 12 *Rostanga crocea* n. sp.: A dorsal view & B ventral view of 6 mm long specimen; C ventral view, D rhinophore & E caryophyllidia of 4 mm specimen; F radular teeth of 6 mm specimen.

Internal morphology There was no trace of rodlets in the labial cuticle. The radula formula is $40 \times 36.0.36$. Innermost tooth large, hamate with small secondary cusp, at some angles of viewing forming a shoulder (Fig. 12F); second tooth smaller, hamate, succeeding teeth much smaller and more slender with a secondary cusp; towards the outer region of the row the teeth are progressively longer and more slender without a secondary cusp, while the outermost dozen teeth are curved, needle-like, and finely bifid. The cerebral ganglion is mounted on a slide NHMUK Reg. No. 20110406/3.

Geographical range Known only from the present two specimens from Ghana.

Remarks Although the caryophyllidia are of similar size to those of *Rostanga rubra*, the notum appears to be covered with circular saucers of variable diameter. *R. crocea* n. sp. differs from all other species of the genus in its colouration, rhinophore shape, and its radular tooth morphology with hamate innermost tooth lacking fine denticles, succeeding teeth mostly bicuspid, and outermost teeth needle-like and bicuspid. *R. aureamala* Garovoy, Valdés & Gosliner 2001

from South Africa is another orange-yellow species, but it is much larger with a central rachidian tooth and other teeth of very different shape. *Rostanga anthelia* Perrone 1991 from the Mediterranean is poorly known; it differs from *R. crocea* in colouration and in possessing white glands near the mantle margin, and it appears to be rather similar to the Australian *R. arbutus* (Garovoy *et al.*, 2001).

DISCUSSION

Eleven species of discodorid nudibranchs are described here from Ghana (together with one very immature unidentified specimen) of which three are already known from Europe and the Atlantic Islands. One of these (*Paradoris indecora*) has also been recorded from islands in the Gulf of Guinea, but the other eight species are currently known only from Ghana. The west African coast must surely be one of the least well explored regions of the world as far as nudibranch molluscs are concerned with just a handful of records in the literature. Although the species described here are the result of ten years of collecting in Ghana the numbers of specimens of each species are very small, and towards the end of the ten years new species were still being found. Consequently the total number of species of discodorid in Ghana and the Gulf of Guinea must be very much larger.

It is not normally considered good practice to name new species on the basis of a single animal, but I have done this for three species in this paper. The criterion I use in making this decision is not whether they can be placed with confidence into a particular genus, but whether they can be readily identified by future workers. Using this criterion I decided that specific names should be given to three species but not to the *Platydoris* or the immature *Jorunna*.

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