OPISTHOBRANCHIATE MOLLUSCA FROM GHANA: TERGIPEDIDAE, WITH A CHECKLIST AND A REVIEW OF THE ECOLOGY AND DIVERSITY OF THE AEOLIDIOIDEA

MALCOLM EDMUNDS

97 St David's Road, Otley, West Yorks LS21 2RG. Formerly at School of Built & Natural Environment, University of Central Lancashire, Preston PR1 2HE, UK

Abstract *Descriptions are given of seven species of Tergipedidae from Ghana of which three are new,* Cuthona ghana *n. sp.,* Cuthona kpone *n. sp. and* Cuthona *species A, while a fourth is a very immature unnamed species of Tergipedidae.* Cuthona perca, Cuthona ghana *n. sp., and* Tenellia adspersa *are all part of the fouling community in harbours and on boats while* Cuthona kpone *n. sp.,* Cuthona *species A,* Catriona tema *and the unnamed tergipedid all occur on shallow reefs. Thirty-two species of aeolid nudibranchs have been recorded from Ghana, the most biodiverse site being the 10m deep offshore reef. It is estimated that a more intensive study might have yielded a few more species. Thirteen of the 32 species are currently only known from Ghana, probably because west African nudibranchs are so poorly known. Others also occur elsewhere in the Gulf of Guinea, Angola, the Azores, Canaries, Madeira, the Mediterranean and even northern Europe. There are 6 amphiatlantic species and 3 recorded from the Indo-Pacific, these latter probably being transported by boats.*

Key words *Tergipedidae,* Cuthona, Catriona, Tenellia, *biodiversity.*

INTRODUCTION

Aeolid nudibranchiate molluscs have been poorly known from West Africa but twenty-five species have recently been described from Ghana, the most species rich family being the Facelinidae (Edmunds, 2015a, b, c). The purpose of this paper is to describe the aeolid nudibranchs belonging to the family Tergipedidae (= Cuthonidae) collected in Ghana between 1963 and 1973.

MATERIAL AND METHODS

All of the material described here was collected near to Accra and Tema in Ghana, close to longitude 0° latitude 5.7° by the author and by Mr Walter Pople. The method of collection, processing and preservation of specimens is described by Edmunds (2015a) and in earlier papers (Edmunds, 2007, 2011). Body measurements and drawings of entire animals are from life unless otherwise stated.

The material collected and described in this paper (including microscope slides of specimens serial sectioned and stained with Masson's trichrome to reconstruct the reproductive systems but excluding severely damaged specimens) is deposited in the Natural History Museum, London.

Contact author : medmunds@phonecoop.coop

SYSTEMATIC DESCRIPTIONS

Family Tergipedidae Bergh, 1889 (= Cuthonidae Odhner, 1934)

Diagnosis Aeolids with anus laterally in interhepatic space (acleioproctic), radula uniseriate, rhinophores usually smooth, foot usually with rounded corners, penial gland opening into vas deferens distal to prostate, penis often with a tubular terminal stylet, defensive glands usually present at tips of cerata, larval shell inflated.

Remarks There is ongoing controversy as to whether the family name should be the older Tergipedidae Bergh, 1889 based on the aberrant genus *Tergipes* Cuvier, 1805 or the more recent Cuthonidae Odhner, 1934 based on the most species diverse genus *Cuthona* Alder & Hancock, 1855 (summarised by Miller, 1977; Williams & Gosliner, 1979; Brown, 1980 and Platts, 1985). Both names were placed on the official list of family names in zoology by the International Commission of Zoological Nomenclature (1966), but WoRMS uses Tergipedidae (Bouchet, 2015). In this paper I have used the older name, Tergipedidae.

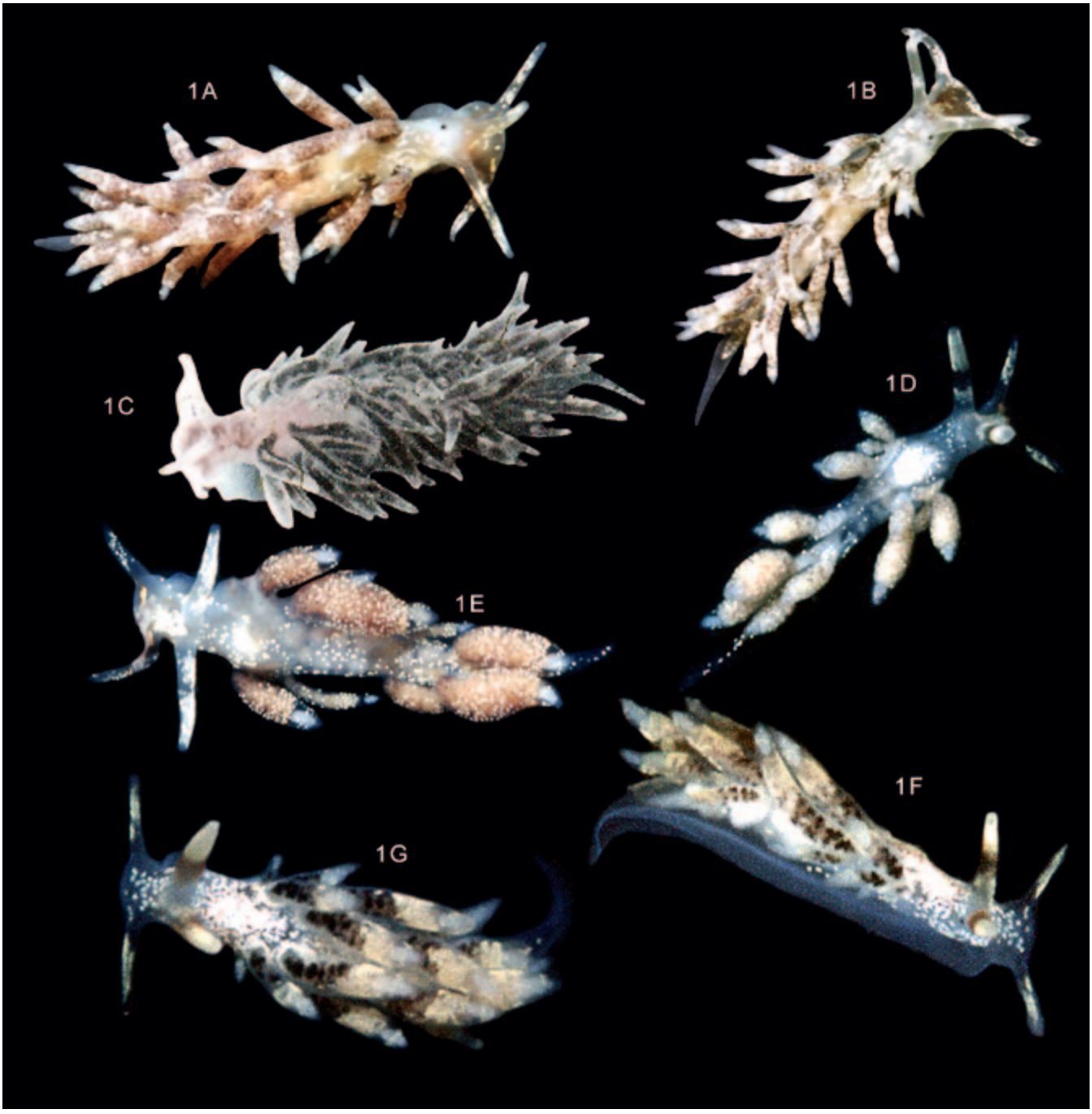
Genus *Cuthona* Alder & Hancock, 1855

Type species *Eolis nana* Alder & Hancock, 1842 by monotypy.

Diagnosis (based on Thompson & Brown, 1984) Tergipedids with median cusp of radula teeth longer than or almost as long as lateral denticles, pre-radular tooth never retained in mature animals, penial stylet often present, usually with defensive glands concentrated in cnidosac region of cerata.

***Cuthona perca* (Marcus, 1958)**
Figs 1 A–C, 2

Catriona perca Marcus, 1958: 45–52, Figs 81–87.
Trinchesia perca—Edmunds, 1970: 20.
Non *Trinchesia perca* Marcus & Hughes, 1974: 523–525, Figs 48–49.



Figures 1A–C *Cuthona perca* (Marcus, 1958): **A**, **B** from Tema, Ghana, two specimens 7mm long, February 1969; **C** from Jamaica, 15mm long, December 1961. **Figs D–E** *Cuthona kpone* n. sp. from Kpone Bay, Ghana: **D** 5mm long & **E** 5.5mm long, October 1969. **Figs F–G** *Cuthona* species A from Kpone Bay: two views of 4mm long specimen, October 1969.

Cuthona reflexa Miller, 1977: 216–220, Pl. 1D, Figs 7–9.
Cuthona perca—Gosliner, 1980: 43–45, Fig. 3.

Material examined Among *Zoobotryon* with hydroids from boat bottom, Tema harbour, 13 spec. 9, 7 (x 3), 6.5 (x 4), 6 (x 5) mm long 18 December 1968 Reg. no. NHMUK 20150534, 35 spec. 7 (x 4), 6 (x 4), 5 (x 7), 4.5 (x 3), 4 (x 4), 3.5 (x 3), 3 (x 7), 2.5 (x 3) mm long 15 February 1969 Reg. no. NHMUK 20150533, 13 spec. 7, 6.5 (x 2), 6 (x 2), 5.5, 5 (x 2), 4.5 (x 3), 4 (x 2) mm long 10 March 1969, 1 spec. 4mm long 22 February 1973, 3 spec. (not measured) 19 June 1973 Reg. nos. NHMUK 20150535 & 20150555 (12 slides).

External features Body slender, foot rounded anteriorly with no trace of a notch, pointed tail extending beyond last cerata (Figs 1A, B; 2A, B); oral tentacles up to 2mm long, arising from semicircular oral veil; rhinophores smooth up to 2.5mm long; two rows of cerata arise in front of the heart and, in 6–9mm long animals, 5, 6 or occasionally 7 rows arise posterior to the heart, with typical numbers of cerata in each row as shown in Fig. 2C. Cerata up to 2mm long, each ceras broadly elongate tapering to a point.

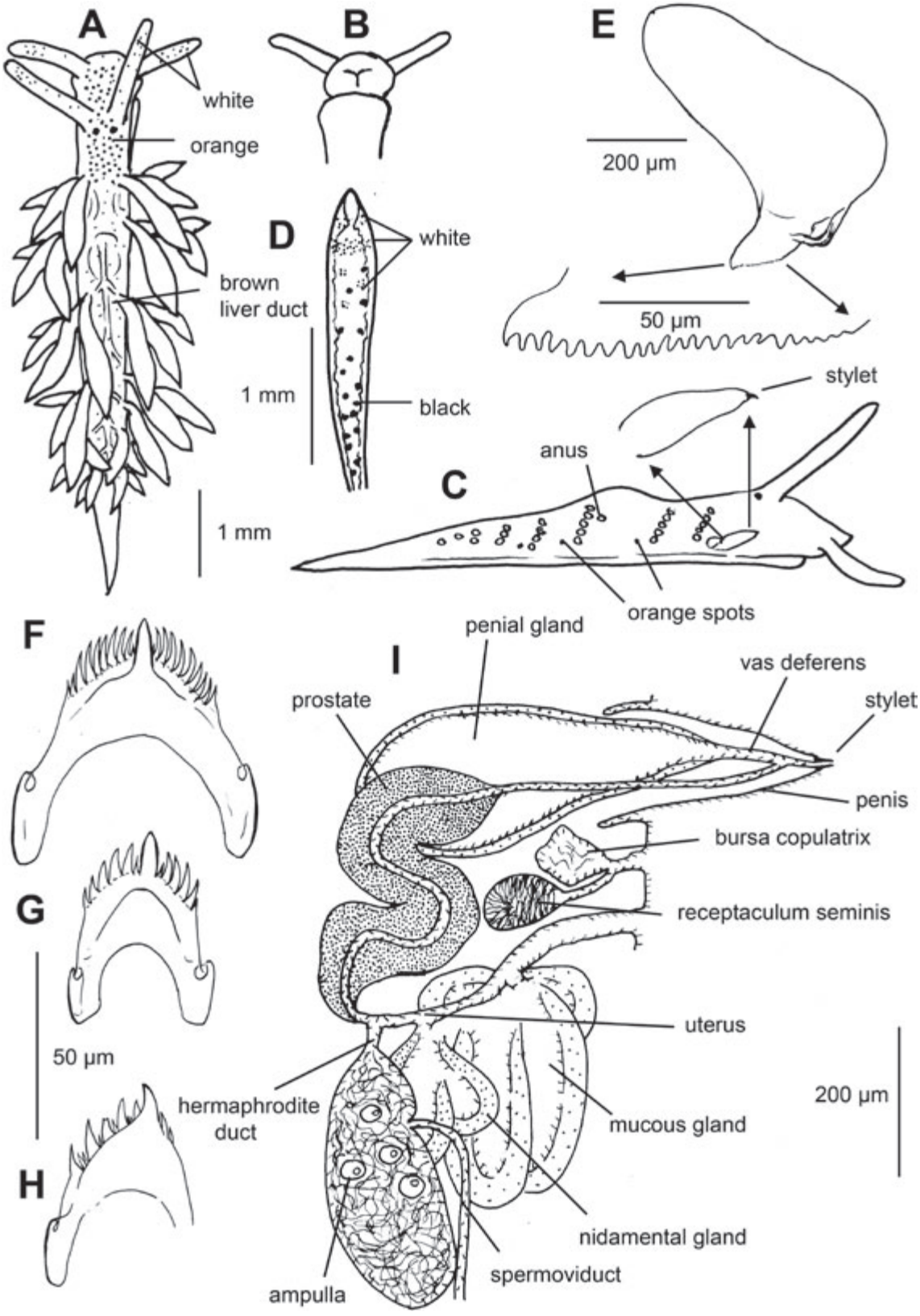
Colouration Body pale grey, head tinged orange or orange-brown, body behind rhinophores paler orange but the hue varies from more strongly orange to just a faint tint (Figs 1A, B; 2A); orange ovotestes and brownish or grey-brown digestive gland ducts visible dorsally; scattered spots and irregular patches of white on dorsal surface (especially behind rhinophores), dark brown, dark maroon or blackish spots on head and sometimes back to the first cerata; sides and tail without white spots but sometimes with 3–4 orange spots on flanks; oral tentacles greyish with white spots concentrated distally but tip clear; rhinophores tinged pale orange with white spots concentrated distally but tip clear grey; digestive gland in cerata yellow-brown or ochre, often with yellow tubercles distally and with sparse or dense blackish tubercles concentrated basally, white spots often form two partial or complete bands, one in the cnidosac region and a wider one just below this, with a few white spots lower down, cnidosac white (Fig. 2D).

Internal morphology The buccal mass was removed from two of the larger specimens one of which was then serial sectioned. The jaws are elongate with 18 rounded denticles and a few more worn ones on the cutting edge (Fig. 2E). The radula of the same animal has 25 teeth with two more developing. There is a marked difference in size between the oldest and the youngest teeth (Figs 2F, G), but the angled basal processes of the latter may be an artefact due to partial crushing under the coverslip. The teeth have from 5 to 11 needle–like denticles on each side of the median cusp which does not project far beyond them. The second specimen had slightly larger jaws and 32 teeth of which the oldest, in dorsal view, are damaged through wear and tear with several broken denticles. Under high magnification and in oblique view the younger teeth have several minute needle-like teeth between the lateral denticles (Fig. 2H).

The reproductive system is similar to that of other species of *Cuthona* with a penial gland, penial stylet and receptaculum arising distal to the female glands (Fig. 2I). The penis was everted and the stylet was cut obliquely with 20µm length and c15µm diameter at the base in one section but in the next section it is distorted into a slender partial ring, perhaps because the hardness of the chitin prevented the microtome from cutting it cleanly. There are two unusual features in the reproductive system: first, there is a sac adjacent to the receptaculum which is presumably the bursa copulatrix – it contains just a few spermatozoa while the receptaculum is full of sperm attached to the wall by their heads; and second the opening to the duct leading to the receptaculum and bursa is distinct from the opening of the duct from the nidamental and mucous glands. Which of these two ducts is the vagina, which receives the penis of a partner during copulation, is not known.

Geographical range Caribbean, Massachusetts, California, Mediterranean, Hawaii, New Zealand and now Ghana (Marcus, 1958; Edmunds, 1964; Miller, 1977; Gosliner, 1980; Perrone, 1995; Valdés *et al*., 2006; this paper).

Remarks The overall appearance of the present specimens is that they are mottled in shades of brown whereas Caribbean specimens are much blacker (compare Figs 1A & B with C). However careful comparison of the colour markings shows that they are actually very similar



Figures 2A–I *Cuthona perca* (Marcus, 1958), all specimens 6–7mm long: **A** dorsal view; **B** ventral view of head; **C** side view, semi-diagrammatic to show arrangement of cerata and inset with detail of everted penis; **D** ceras; **E** jaw with detail of cutting edge at greater magnification; **F** 24th radular tooth; **G** 1st radular tooth from same specimen; **H** 9th radular tooth from different specimen in oblique view to show minute needle-like denticles between the normal denticles; **I** reconstruction of reproductive system from serial sections.

Table 1 Specimens of *Cuthona perca* from Ghana compared with those from the Caribbean

Character	Ghana	Caribbean
Body colour	Grey, pale orange behind rhinophores, with white spots	Pale orange or grey with white spots
Head	Tinged orange-brown with darker spots	Dark brown, may be tinged pinkish
Oral tentacles	White distally	White distally
Rhinophores	Tinged orange, white distally	White distally
Digestive gland in body	Brown	Dark brown
Digestive gland in cerata	Yellow-brown/ochre with dark brown tubercles	Dark brown
White on cerata	1 or 2 distal bands & spots	One distal band and spots
Radular teeth	5–11 regular needle-like lateral denticles each side, none exceeding cusp	6–10 irregular needle-like lateral denticles each side, some longer than cusp
References	This paper	Marcus, 1958; Edmunds, 1964; Valdés *et al*., 2006

(Table 1). Comparable minor differences in colouration occur in *C. perca* from Hawaii and from New Zealand with each population having a slightly different range of colours (Gosliner, 1980; Miller, 1977 as *Cuthona reflexa*). There are also differences in the radular teeth with irregular denticles in Caribbean specimens but evenly graded denticles in those from Ghana (Table 1): a similar range of variation in the lateral denticles occurs in specimens from Hawaii and from New Zealand (Gosliner, 1980; Miller, 1977). The reproductive system of specimens from each of the four populations (from the Caribbean, Ghana, Hawaii and New Zealand) have been examined and are very similar to one another if allowance is made for different styles of drawing. I therefore consider that all of these specimens are *Cuthona perca*. The *C. perca* from Barbados (Marcus & Hughes, 1974, as *Trinchesia perca*) is very different in colouration and has been shown to be a different species, *Cuthona barbadiana* Edmunds & Just, 1983.

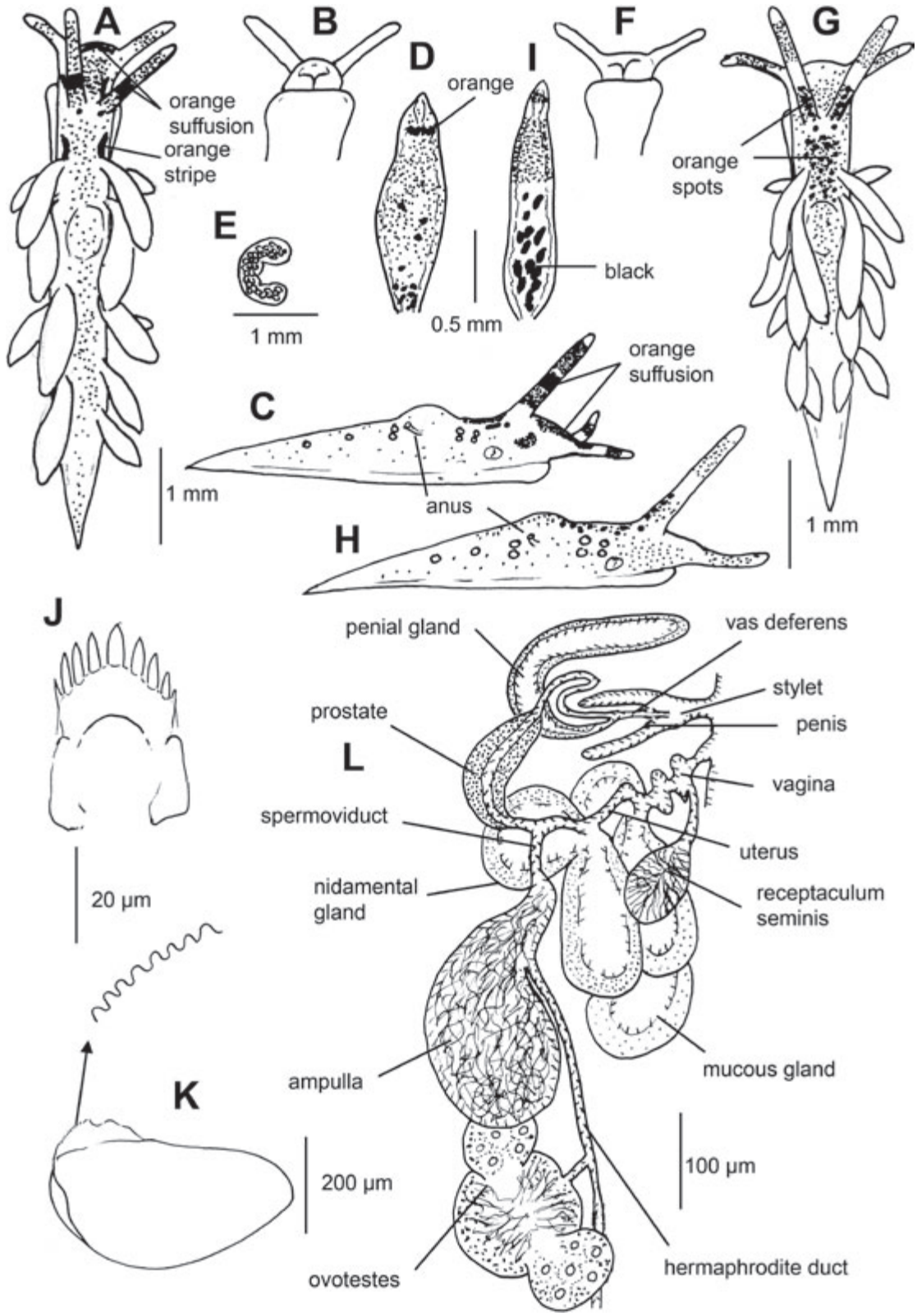
Although *C. perca* occurs in natural environments on mangroves and shallow reefs in the Caribbean, many of the records, including the present ones from Ghana, are from harbours among the fouling community. This species is thus almost cosmopolitan in its geographical occurrence in warm waters with each population exhibiting a slightly different range of variation in colouration and morphology. *C. perca* is unusual among tergipedids in feeding on the sea anemone *Aiptasia* sp. (Gosliner, 1980) as well as on a variety of species of hydroid, so it is possible that the different spectrum of colouration found in each population reflects different foods.

***Cuthona kpone* n. sp.**
Figs 1D, E; 3A–E, J–L

Holotype Reg. no. NHMUK 20150537 10m reef Kpone Bay 5.5mm long 2 October 1969, collected by W. Pople.

Material examined 10m reef Kpone Bay 1 spec. 2mm long 2 December 1968, 2 spec. 3.5 & 2mm long 2 October 1969, 9 spec. 5.5 (x 3), 5, 4.5, 4 (x 2) & 3.5mm long 8 October 1969, 1 spec. 3mm long 1 March 1971, 1 spec. 3.5mm long 11 March 1971, 1 spec. 3mm long 23 March 1971 Reg. nos. NHMUK 20150536, 20150538, 20150539 & 20150554 (11 slides).

External features Body slender, foot rounded anteriorly with very slight indentation medially, pointed tail extending slightly beyond last cerata (Figs 1D, E; 3A, B); oral tentacles 1mm long, smooth rhinophores 1.5mm long in 5.5mm animal; cerata arranged in short rows with 2, 2; 2, 1, 1 on each side in animals from 3 to 5.5mm length (though often with one or more missing), one 5.5mm specimen with a third ceras just anterior to the first row so it is not clear if this is a third ceras in the first precardiac row or if it belongs to a separate row (Fig. 3C), a 2mm specimen had only 1, 2; 1, 1 cerata; cerata up to 1.5mm long, each ceras broadly elongate oval usually slightly



Figures 3A–E *Cuthona kpone* n. sp. 5.5mm long, October 1969: **A** dorsal view; **B** ventral view of head; **C** side view, semi-diagrammatic to show arrangement of cerata; **D** ceras; **E** egg mass. **Figs 3F–I** *Cuthona* species A 4mm long: **F** ventral view of head; **G** dorsal view; **H** side view, semi-diagrammatic to show arrangement of cerata; **I** ceras. **Figs 3J–L** *Cuthona kpone* n. sp. 5mm long: **J** 46th radula tooth; **K** jaw with arrow to detail of cutting edge; **L** reconstruction of reproductive system from serial sections. In **A**, **C**, **D**, **G**, **H** & **I** stipple is white spots forming white patches in **D**, **G**, **H** and **I** (see text).

indented below cnidosac, tip narrower than in *C. ghana* n. sp. (see below).

Colouration Body pale grey with scattered creamy white spots dorsally from head to tip of tail, denser in front of and just behind rhinophores (forming solid white patches in some smaller specimens), very sparse on sides (Figs 1D, E; 3A); with orange stripes on each side between rhinophores and oral tentacles and between rhinophores and first cerata, though sometimes short and pale. Sometimes also with dorso-lateral stripe in front of first postcardiac cerata, and with orange suffusion at front of head between oral tentacles; one small specimen with orange behind rhinophores reduced to about 10 small spots and no orange between rhinophores and oral tentacles. Oral tentacles with white spots centrally, occasionally with orange tint at base anteriorly; rhinophores with white spots forming two bands separated by band at one third of length which may be grey, orange or tinted orange, but tip and base lacking spots. Digestive gland in cerata pale or reddish brown with scattered blackish spots concentrated near base, creamy white spots densely scattered over entire ceratal surface but sparse at base and in cnidosac region, cnidosac white (Fig. 3D); specimens of all sizes with orange dots forming a partial ring just below cnidosac, but this is lacking in others.

Internal morphology The radula and jaws from a 5mm specimen were examined. The jaws have about 10 rounded denticles on the cutting edge (Fig. 3K). The radula has 52 teeth with 6 more developing. Each tooth is tall with, in the larger teeth, four dagger-shaped denticles on each side of the cusp (Fig. 3J).

The reproductive system was reconstructed from serial sections and is similar to that of other species of *Cuthona* (e.g. *C. ghana* n. sp., below) (Fig. 3L). A possibly significant character is the long and slender penial gland, quite different from that of *C. ghana*. The stylet is cut almost longitudinally and passes through three sections: it is about 25µm long, 6µm diameter at the base and about 3µm diameter for most of its length to the tip.

Behaviour One of the specimens laid a semicircular white egg ribbon (Fig. 3E).

Geographical range Known only from Ghana (this paper).

Etymology The species is named from its occurrence on the reef in Kpone Bay, Ghana.

Remarks *Cuthona kpone* n. sp. is characterised by pale orange stripes laterally between oral tentacles and rhinophores and between rhinophores and first cerata with pale suffusion of orange in front of head and elsewhere in some specimens (see above and Fig. 3A). The colour is so pale that it does not show in photos of this species (Figs 1D, E). This is different from the conspicuous orange markings in *C. miniostriata*, *C. tina*, *C. ghana* (Table 3) and *C. albopunctata* (Ballesteros, Madrenas & Pontes, 2012b), while *C. granosa* (Schmekel, 1966) has bright orange distally on both oral tentacles and rhinophores (Schmekel, 1966; Schmekel & Portmann, 1982; Ballesteros, Madrenas & Pontes, 2012a). *C. kpone* n. sp. is otherwise similar in external features to *C. granosa* but the radular teeth are distinctive: its tooth is longer than broad with four denticles on each side of the cusp whereas *C. granosa* has a much broader tooth with 6–9 lateral denticles on each side (Schmekel, 1966).

Cuthona species A

Figs 1F, G; 3F–I

Material examined 10m reef Kpone Bay 3 spec. 4, 2.5 & 2mm long 2 October 1969 Reg. no. NHMUK 20150540.

External features 4mm specimen (Figs 1F, G; 3F, G): body slender, foot rounded anteriorly with very slight indentation medially, pointed tail extending beyond last cerata; oral tentacles 0.8mm long, smooth; rhinophores 1.2mm long; cerata arranged in short rows with 2, 2; 2, 1, 1 on each side in larger animal (Fig. 3H), 1, 2; 1, 1in smaller one, cerata up to 1.7mm long, each ceras broadly elongate tapering to pointed tip.

Colouration Body pale grey with scattered creamy white spots dorsally and on sides of head, sparse on sides and absent from tail, very dense forming an almost solid patch just behind rhinophores (Figs 1F, G; 3F, G); with pale orange spots dorsally from head to just behind heart (both orange and white spots the same size or slightly larger than eyes); oral tentacles with white patch

in distal two-thirds, tip clear; rhinophores with orange band from a third to half-way up, white patches distally and basally, tinged orange adjacent to orange band, tip and part of base clear. Digestive gland in cerata pale brown with large blackish brown blotches in basal half (Fig. 3I), superficial cream patch in distal half of cerata ending just below cnidosac, often with smaller cream spot in cnidosac region, cnidosac and epidermal glands white.

The 2mm specimen has ceratal colouration and white patches on rhinophores as in the 4mm specimen but also has some orange marks on head and in front of first group of cerata not unlike those of *C. kpone*. The 2.5mm specimen is similar to the 4mm one but has white spotted cerata and 3 orange spots in front of heart.

Internal morphology Not examined.

Remarks This species differs from *Cuthona kpone* n. sp. in the position of orange markings on the head and over the heart; the large white patches on body and cerata; and in the dark blotches of the digestive gland in the cerata. Colour of digestive gland can vary with diet, but presence or absence of blotches (or lobules) are likely to be species specific. Thus although the specimens were collected from precisely the same site on the same day as *C. kpone*, I consider that they probably belong to a different species.

***Cuthona ghana* n. sp.**

Figs 4A, B; 5

Holotype Reg. no. NHMUK 20150542 Buoy in Tema harbour 4.5mm long 10 March 1968, collected by W. Pople.

Material examined Buoy in Tema harbour 2 spec. 4.5 & 3mm long 10 March 1968; among *Zoobotryon* on boat hull at Tema 10 spec. 4, 3 (x 4), 2.5 (x 4) & 2mm long 15 February 1969, 3 spec. 5, 3 & 2mm long 17 February 1969, 1 spec. 3.5mm long 9 March 1969, 2 spec. 2.2 & 1.7mm long 18 June 1969; 10m reef Kpone Bay 1 spec. 2mm long 22 February 1971; rock pool at Teshie 1 spec. 3mm long 4 April 1973 Reg. nos. NHMUK 20150541, 20150543 & 20150553 (3 slides).

External features Body slender, foot rounded anteriorly with very slight indentation medially, pointed tail extending beyond last cerata (Figs 4A, B; 5A, B); rhinophores smooth, slightly longer than oral tentacles, 1mm long in a 5mm animal; cerata arranged in short rows (with the numbers of cerata per row and per animal shown in Table 2 and Fig. 5C), longest cerata of same length as rhinophores, each ceras elongate oval, sometimes slightly indented below cnidosac, tip broadly rounded.

Colouration Body pale grey with circular white dots scattered all over, typically these form solid white patches on head, between rhinophores and dorsally back to the last cerata, also on sides of head in front of first cerata (Figs 4A, B; 5A), but in a few specimens the white is much sparser, one 3mm animal had just one white spot on head, 5 between rhinophores and heart and 6 more behind heart; side of foot anteriorly sometimes faintly tinged orange; oral tentacles grey with faint reddish orange suffusion basally, but forming a band half way along with a lateral basal orange stripe in the largest specimen, sometimes with a few white spots; rhinophores grey with bright reddish orange ring from half to two-thirds length, sometimes only on rear side, with narrow faint stripe extending from ring to base posteriorly ending in a brighter spot beside the eye, white spots dense distally on rhinophore (though tip is clear) with few or no spots below orange ring; cerata have pale yellowish grey to yellow-brown digestive gland with slightly darker blotches, mostly obscured except basally by superficial white pigment forming irregular patches (Fig. 5D), cnidosac white but obscured by pearly white glands as in other species of *Cuthona* (Edmunds, 1966), sometimes also with a superficial white ring in this region.

Internal morphology The jaws and radula from a 3mm specimen were prepared in 1968 and mounted in the usual way in glycerine jelly. However the fine structure of the radula has deteriorated over the years. The jaw outline is still clear (Fig. 5G) but the fine structure of the cutting edge is not. There are about 38 radular teeth of which the arches and the side edges are clear but the teeth have deteriorated and are not resolvable with either ×40 or ×100 objective lenses. The anterior side edge of each tooth appears to have a small pocket to hold the base of the succeeding tooth as in many other aeolids.

The radula and jaws from another 3mm long specimen were examined. While attempting

Figures 4A–B *Cuthona ghana* n. sp. from Tema, Ghana: **A** 5mm long, February 1969, **B** 4.5mm long, March 1968. **Figs 4C–E** *Catriona tema* Edmunds, 1968 from Teshie, Ghana: **C** 6mm long, April 1973; **D**, **E** 11mm long, December 1964 (holotype). **Fig, 4F** *Catriona maua* Marcus & Marcus, 1960 from Jamaica: 9mm long, February 1962. **Fig. 4G** *Tenellia adspersa* (Nordmann, 1845) from Tema, Ghana: 2.5mm long, February 1969.

to flatten the radula the jaws and some of the radular teeth were distorted, but I could see no denticles on the cutting edge of the jaw (Fig. 5F). The radular teeth have up to 16 denticles which are irregular in length with some very short ones, and there is no obvious median cusp in the teeth which were well flattened (Fig. 5E). Two further buccal masses from slightly smaller specimens were extracted but after treatment with KOH they were so small and fragile that one could not be found and the other was crushed while trying to flatten the radula.

One of the larger specimens was serial sectioned and the reproductive system reconstructed (Fig. 5H). The animal was sexually mature and about to lay eggs with ova in the hermaphrodite duct, ampulla, capsule and mucous glands. The spermoviduct from the ampulla is very short before branching to the equally short sperm duct and oviduct. The sperm duct leads to a short, curved

Table 2 Ceratal numbers in specimens of *Cuthona ghana* n. sp.

Body length (live)	Left side	Right side	Total
5mm	3, 2; 1, 2, 1, 1	3, 3; 1, 2, 1, 1	21
4.5mm	2, 2; 2, 2, 1, 1	2, 3; 2, 2, 1, 1	21
3mm	2, 2; 2, 2, 1	2, 2; 2, 1, 1	17
3mm	2, 2; 2, 1, 1	2, 2; 2, 1, 1	16
2mm	1, 2; 1, 1	2, 1; 1, 1	10

In Tables 2 & 4, and in the text, numbers of cerata before the semi-colon are in rows anterior to the heart, numbers after the semi-colon are in rows posterior to the heart. The anterior digestive gland supplies the cerata on the right side anterior to the heart, all the other cerata are supplied by the posterior digestive gland.

prostate and the vas deferens then runs into the penis which opens through a small stylet. A large penial gland discharges through a short duct into the vas deferens in the penis. The oviduct opens into the nidamental part of the female gland mass quite close to the distal mucous part of the gland which opens into the vagina. A short-stalked spermatheca also opens into the vagina.

Geographical range Known only from Ghana (this paper).

Etymology The species is named from its occurrence in Ghana.

Remarks This species appears to be closely related to two very small aeolids: *Cuthona miniostriata* (Schmekel, 1968) from the Mediterranean and *Cuthona tina* (Marcus, 1957) from Brazil and the Caribbean, both of which have pale white pigmented bodies, short cerata with ochre or brownish digestive glands in the cerata, and a few orange or vermilion marks on the head. While the intensity of the orange varies intraspecifically the positioning of the orange pigment in these species and also in *Cuthona thompsoni* García, López-González & García-Gómez, 1991, *Cuthona kpone* n. sp. and *Cuthona* species A is quite different from that in *C. ghana* (Table 3).

In addition to these differences in orange pigmentation, the present species further differs from *C. tina*, *C. miniostriata* and *C. thompsoni* in its radular teeth: although the tooth illustrated in Fig. 5E was asymmetrical (possibly deformed) it has many more lateral denticles than occur in either *C. tina* or *C. miniostriata*, and it is broader than long whereas the teeth of *C. thompsoni* are long and slender (Marcus, 1957; Schmekel, 1968; García *et al*., 1991). I therefore consider that it represents a new species, *C. ghana*, but it is to be hoped that further material may become available so that a phylogenetic analysis using molecular characters of Atlantic species can be carried out.

Although *C. ghana* was found on shallow reefs in Ghana it also occurred in the fouling communities amongst *Zoobotryon* in Tema harbour so it may be capable of oceanic travel.

Genus *Catriona* Winckworth, 1941

Type species *Eolis aurantia* Alder & Hancock, 1842 by original designation.

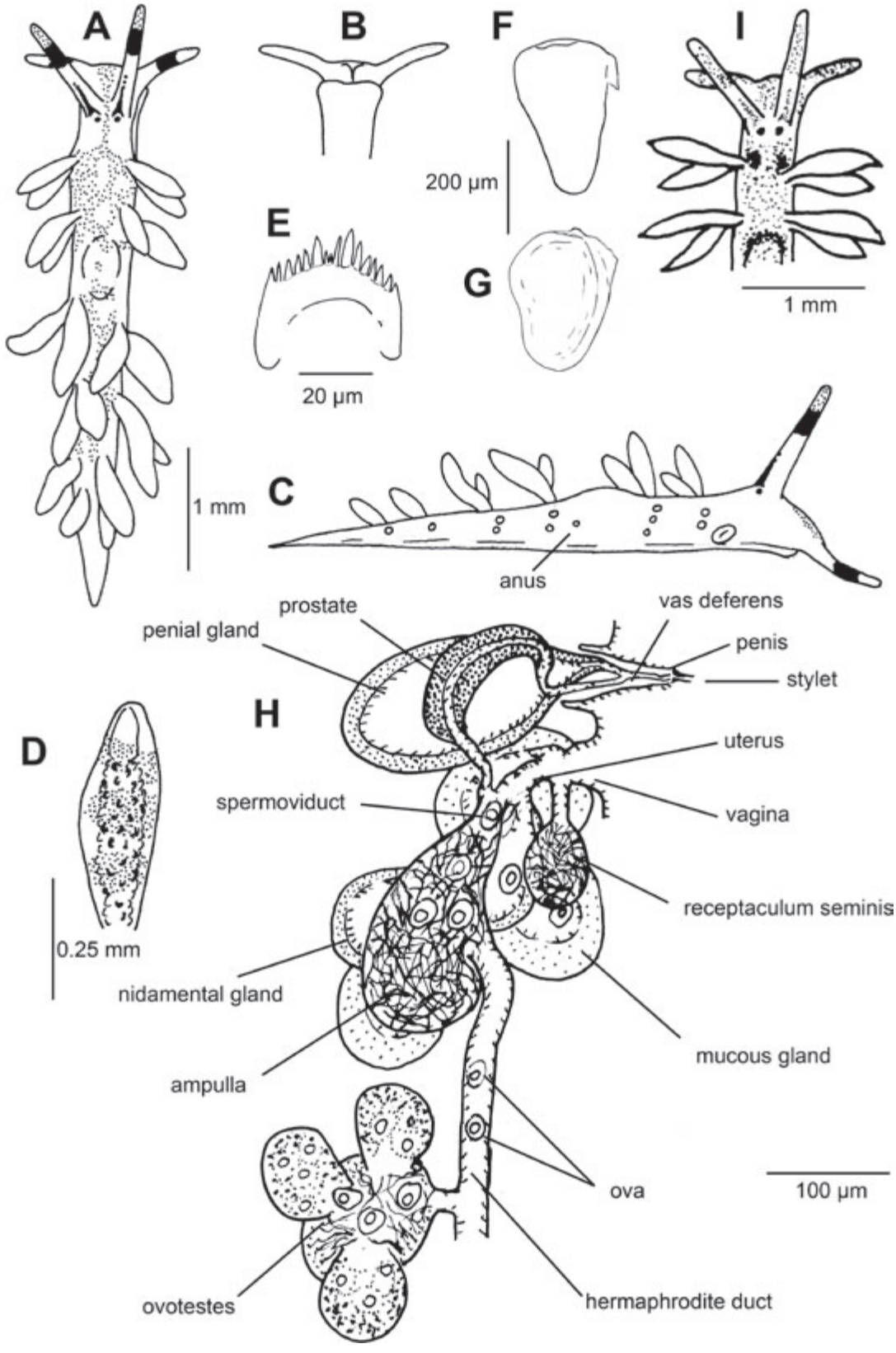
Diagnosis (based on Edmunds, 1968a) Tergipedids with median cusp of radular teeth receded, shorter than adjacent lateral denticles, pre-radular and oldest teeth often retained in older animals, usually with bristles on cutting edge of jaw, defensive glands concentrated in cnidosac region of cerata.

Williams & Gosliner (1979) and Brown (1980) both reviewed the literature concerning the genera *Catriona* and *Cuthona*, but while Williams & Gosliner concluded that the two genera should remain distinct, Brown presented a case for synonymising *Catriona* with *Cuthona*. However, pending a comprehensive phylogenetic analysis using both morphological and molecular characters I prefer to retain the group of species clearly defined above as the genus *Catriona*.

Catriona tema Edmunds, 1968
Figs 4C–E

Catriona tema Edmunds, 1968a: 203–208, Figs 1, 2, 3A.

Material examined On *Halocordyle disticha* (Goldfuss) in rock pool 5 spec. 6, 5, 5, & 3mm long 4 April 1973 (the fifth spec. crawled out and dried up before measurement) Reg. nos. NHMUK 20150545; on *Tubularia* on buoy in Tema harbour collected & preserved in Bouin's fluid by D. W. Ewer, 1 spec. 2.5mm long 10 March 1968 (but see below under *Remarks*) Reg. no. NHMUK 20150544.



Figures 5A–H *Cuthona ghana* n. sp. 4.5mm long, March 1968: **A** dorsal view; **B** ventral view of head; **C** side view, semi-diagrammatic to show arrangement of cerata; **D** ceras; 3mm long: **E** 29th radula tooth; **F** jaw; **G** jaw from 1968 preparation from similar sized specimen; **H** reconstruction of reproductive system from serial sections. **Fig. 5I** *Cuthona tina* (Marcus, 1957) from Jamaica, November 1961: dorsal view of head to show colour markings. In **A**, **C** and **I** solid black and coarse stipple is orange, fine stipple white.

Table 3 Position of orange marks in *Cuthona ghana* n. sp. compared with other small species of *Cuthona*.

Species	Position of orange marks	References
Cuthona ghana n. sp.	Base of oral tentacles tinged and brighter medial ring; ring in middle of rhinophore with stripe down back ending in spot adjacent to eye.	This paper, Figs 4A, B, 5A, C
Cuthona miniostriata (Schmekel, 1968)	Oral tentacle may have orange base (faint) and ring in middle; ring in middle of rhinophore, more intense behind; stripe from base of rhinophore running back close to eye but no clear spot near eye.	Schmekel, 1968; Schmekel & Portmann, 1982; Ballesteros, Madrenas & Pontes, 2014
Cuthona tina (Marcus, 1957)	Ring in middle of rhinophore, a few spots in front of first cerata & medially in front of heart; sometimes a stripe down back of rhinophore from ring to base, but this stripe is more often white.	Marcus, 1957; Edmunds, 1964; Valdés *et al.*, 2006; this paper Fig. 5I
Cuthona thompsoni García, López-González & García-Gómez, 1991	Streaks dorsally on head, lateral to rhinophores and behind eyes, but not on rhinophores; this is a larger species reaching 8mm alive.	García, López-González & García-Gómez, 1991
Cuthona kpone n. sp.	Stripes from rhinophores to base of oral tentacles, & between rhinophores and first cerata; suffusion at front of head and ring near base of rhinophore.	This paper, Figs 1D, E; 3 A, C
Cuthona species A	Pale spots dorsally from rhinophores to back of heart; orange ring at base of rhinophore	This paper, Figs 1F, G; 3G, H

External features The external features of the 11mm holotype have been described by Edmunds (1968a), so this description is based on the holotype together with the smaller specimens collected subsequently. Oral tentacles arise from a semi-circular oral veil and are slightly shorter than the smooth rhinophores. Foot rounded anteriorly with slight indentation medially, extending posteriorly into a long slender tail. Up to 3 precardiac rows of cerata and 4 postcardiac rows. The numbers of cerata in each row for animals of different sizes are given in Table 4. In several specimens many of the cerata were very small and regenerating, while others may have been autotomized but not yet started to regenerate, so the true numbers of cerata may be greater than shown here. In the smallest specimen the precardiac cerata may have been in 3 rows, but the rows are so close together that it was not possible to decide to which row a particular ceras belongs. The cerata are rounded at the tip, those of the holotype are slender (Figs 4D, E) while those of subsequent specimens are more bulbous (Fig. 4C) depending on the state of the animal: resting animals have retracted, swollen cerata while animals that have been disturbed and are crawling extend the cerata (Fig. 4D). The penis opens below the anterior row of the right digestive gland, and the anus is acleioproctic (i.e., just in front of and ventral to the first ceratal row of the posterior digestive gland).

Table 4 Ceratal numbers in specimens of *Catriona tema*.

Body length (live)	Left side	Right side	Total
11mm (holotype)	5, 4, 4; 2, 2, 2, 1	4, 4, 4; 2, 2, 3, 1	40
6mm, 5mm preserved	3, 3, 3; 1, 2, 1	1, 3, 2; 1, 1, 1	22
5mm, 4mm preserved	2, 2, 3; 2, 1, 1	2, 3, 2; 2, 2, 1	23
5mm, 4mm preserved	2, 3, 1; 1, 2, 2	2, 3, 2; 1, 2, 1	22
2.5mm preserved, probably 4mm live*	5, 3; 2, 2, 1	5, 3; 2, 2, 1	26

* This specimen could possibly be *Catriona maua* (see text).

Colouration The body is pearl grey in colour (Figs 4C–E). There is a white band across the

head in front of the rhinophores in all specimens extending back laterally almost to the base of the first ceras. There are white flecks on the dorsum forming an almost solid area of white between the rhinophores and the heart in the holotype, while in smaller specimens the white extends between the rhinophores to the white on the head. Oral tentacles and rhinophores tipped with white, rhinophores with posterior orange stripe ending in a ring half way up. Digestive gland ducts in cerata yellowish with a few orange and numerous black tubercles in holotype, buff or pink with small brown spots in other specimens, this variation may depend on whether it fed solely on *Halocordyle* or on other hydroids as well (Figs 4C–E); surface of cerata with scattered white spots (holotype) or forming large patches of white in smaller specimens; dense pale white glands in the cnidosac region as in other species of the genus (Edmunds, 1966).

Internal morphology The radula of the 11mm holotype had 137 teeth with the five oldest teeth 28, 18, 10, 10 and 10µm long (Edmunds, 1968a Fig. 2C). The radula from the 2.5mm specimen (whose identity is uncertain, see below) has 42 teeth (with one more in process of formation) and the first three teeth are 27, 15 and 12µm long. However, in both radulae the first tooth has articular surfaces at each end so is likely to be the second or third tooth, not the first (or pre-radular) tooth.

The reproductive system (illustrated in Edmunds, 1968a Fig. 3A) is similar to that of other species of *Catriona* and *Cuthona* but the receptaculum is broadly oval and the penial gland elongate.

Behaviour As with the north Atlantic *Catriona gymnota*, *C. tema* was found on gymnoblastic hydroids (*Halocordyle disticha* and *Tubularia* sp.) where its pink colouration gives it good camouflage, and it probably feeds on these rather than on calyptoblasts. One 3mm long specimen was seized by a crab (*Dromia* sp.) which cut it in half, so its nematocyst and glandular defences (Edmunds, 1966) appear to be inadequate protection against this predator.

Geographical range Known from Ghana (Edmunds, 1968a; this paper) and Cape Verde (Ortea, Caballer & Moro, 2002).

Remarks The radula of an 8mm specimen from Cape Verde identified as *C. tema* by Ortea *et al*. (2002) has 147 teeth of which the oldest three are 16, 13 and 6µm long. The oldest tooth has an articular surface basally and the dimensions suggest it may be the third or fourth tooth.

Because *C. tema* is very similar to *C. maua* Marcus & Marcus, 1960, and because the dimensions of the oldest teeth may prove to be species-specific, I give here tooth dimensions for *C. maua* and also of one specimen of *C. gymnota* (Couthouy, 1838). In *C. maua* from Florida the oldest, pre-radular, tooth (with no proximal articulation) is 33µm long while in my Jamaican specimen it is 37.5µm with succeeding teeth 22.5, 16, 8.5 and 7.5µm long (Marcus & Marcus, 1960; Edmunds, 1964). The first three radular teeth from a specimen from Barbados are 28, 19 and 14.5µm long, but again the oldest tooth is not the first pre-radular tooth as it has articulating surfaces at both ends (Edmunds & Just, 1983).

A specimen of *Catriona gymnota* collected by the author at Plymouth (U.K.) has 63 radular teeth with the lengths of the first four teeth 22.5, 20, 13, 11 and 7µm long; however, the oldest tooth has articular processes at both ends so cannot be the first pre-radular tooth.

Three species of *Catriona* have been described from the North Atlantic: *Catriona gymnota* (Couthouy, 1838) [= *Catriona aurantia* (Alder & Hancock, 1842)] from temperate waters of both North America and Europe extending south to the Mediterranean; *Catriona maua* Marcus & Marcus, 1960 from the Caribbean; and *Catriona tema* Edmunds, 1968 from Ghana. *C. gymnota* is well known and differs markedly in morphology and colouration from the other two species (e.g. Thompson & Brown, 1984; Picton & Morrow, 2010) so will not be considered further here.

Specimens identified as *Catriona maua* have now been reported from the Mediterranean, the Atlantic coast of Portugal, Cape Verde Islands, the Canaries and the Azores (Schmekel, 1968; Schmekel & Portmann, 1982; Ortea *et al*., 2002; Cervera, Calado, Gavaia, Malaquias, Templado, Ballesteros, García-Gómez & Megina, 2006; Malaquias, Calado, Padula, Villani & Cervera, 2009), while a specimen identified as *C. tema* has also been described from Cape Verde Islands (Ortea *et al*., 2002). Thus these two species overlap in their geographical ranges so it is pertinent

to ask if they really are different species. Table 5 presents the colour markings for *C. maua* and *C. tema* citing all of the papers which include descriptions of their colours, and the two species are illustrated in Figs 4C–F). There are clear differences between *C. maua* and *C. tema* in orange and white markings so I conclude that both species occur in the Atlantic Ocean, *C. maua* in both East and West Atlantic and in the Mediterranean while *C. tema* is currently only known from Ghana and the Cape Verde Islands. Some other records of *C. maua* require confirmation, for example a specimen from Barbados has an orange stripe along the dorsum (Edmunds & Just, 1983) while a specimen from the Azores has bright orange rhinophores (Malaquais *et al*., 2009). If these really are *C. maua* then the intraspecific colour variation in this species is considerably wider than shown in Table 5; alternatively they may belong to currently undescribed species of *Catriona*. A specimen labelled *Cuthona* species 5 by Rudman (2000) from the French Atlantic also has bright orange rhinophores and may belong to another undescribed species (Koehler, 2000; Cervera, 2000; Picton, 2001). Finally Gosliner & Griffiths (1981) describe two species of *Catriona* from Cape Town docks on the Atlantic coast of South Africa, *C. columbiana* (O'Donoghue, 1922) and *C. casha* Gosliner & Griffiths, 1981. These species differ in colouration from both *C. maua* and *C. tema* and they have projecting cusp-like lateral denticles on the radular teeth unlike the raised ridge-like denticles of *C. tema* and *C. maua*.

In addition to the colour differences between *C. maua* and *C. tema* shown in Table 5 there could be other morphological differences in the jaws, radula and reproductive systems. However, published details of the jaws and radular teeth show that they are very similar, and while the dimensions of some of the genital organs differ this may simply be individual variation depending on the state of maturity or on idiosyncracies in the drawings by different authors (Marcus & Marcus, 1960; Edmunds, 1964, 1968; Schmekel & Portmann, 1982; Ortea *et al*., 2009).

C. maua occurs both in 'natural' habitats such as on mangrove roots (Edmunds, 1964) and in the 'artificial' habitat of the marine fouling community on piers and in docks (e.g. Marcus & Marcus, 1960). This suggests that its occurrence in East Atlantic islands and the Mediterranean is probably due to recent travel on boats. By contrast, most specimens of *C. tema* come from natural habitats in the East Atlantic apart from one small (2.5mm) specimen found in Tema harbour. This suggests *either* that *C. tema* can also travel on boats, *or* that *C. tema* only occurs in 'natural' habitats in the East Atlantic and that this small specimen was actually *C. maua*. Unfortunately this specimen was preserved by the collector before its colour markings could be recorded, so it could be either *C. tema* or *C. maua*. The smallest radular tooth dimensions of the two species are very similar (see above) so its identity must remain uncertain. The two South African species, *C. columbiana* and *C. casha*, were also found amongst the fouling community in Cape Town docks (Gosliner & Griffiths, 1981). There is no evidence that they have spread a significant distance north along the Atlantic African coast

Table 5. Differences in colour markings between *Catriona tema* and *Catriona maua*.

	Catriona tema	*Catriona maua*
Oral tentacles	White tip	White distal half
Rhinophores	White tip, orange posterior stripe ending in ring half way up	White distal half, red/orange posterior stripe to half way up, no ring
Head	White band	White markings
Dorsum	White patch or spots at front, spots posteriorly	White markings, oesophagus red
Ceras	White spots or dense patches	Tinged orange, 2 white bands
Digestive gland in cerata	Buff/pink, brown/black spots	Pale red/orange/brown, cream/dark red spots
Locality	Ghana, Cape Verde	Jamaica, Mediteranean, Cape Verde
References	Edmunds, 1968a; Ortea *et al*., 2002; this paper	Edmunds, 1964; Thompson, 1980; Schmekel, 1968; Schmekel & Portmann, 1982; Valdés *et al*., 2006; Ortea *et al*., 2002

but this region has been little studied. Perhaps surprisingly, they both occur further east in the Indian Ocean with *C. columbiana* also known from Japan and California (Gosliner & Griffiths, 1981; Gosliner, 1987).

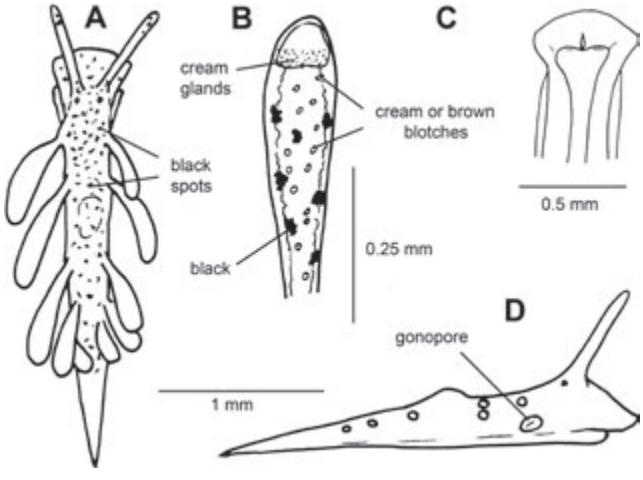
Genus *Tenellia* A. Costa, 1866

Type species Tenellia mediterranea A. Costa, 1866 by monotypy.

Diagnosis (based on Thompson & Brown, 1984) Tergipedids with semicircular oral veil continuing into short transverse oral tentacles; short rows of cerata on each side of body.

***Tenellia adspersa* (Nordmann, 1845)**
Figs 4G; 6

Tergipes adspersus Nordmann, 1845: 498, Pl 1, Figs 4–5.
Tergipes lacinulatus Schultz, 1849: 268, Figs 1–11.
Eolis ventilabrum Dalyell, 1853: 318, Pl 45 Fig. 28.
Embletonia pallida Alder & Hancock, 1854: 105.
Tenellia mediterranea A. Costa, 1866: 76, Pl III Fig. 7.
Embletonia grayi Kent, 1869: 109, Pl 8.
Embletonia mediterranea—Vannucci & Hosoe, 1953: 103, Pl 1–6.
Tenellia ventilabrum—Pruvot-Fol, 1954: 413, Fig. 160.
Tenellia pallida—Marcus & Marcus, 1960: 180, Fig. 80.
Tenellia adspersa—Turpaeva, 1969: 415–417.



Figures 6A–D *Tenellia adspersa* (Nordmann, 1845) 2.5mm long, February 1969: **A** dorsal view; **B** ceras; **C** ventral view of head; **D** side view, semi-diagrammatic to show arrangement of cerata.

Material examined Among *Zoobotryon* with hydroids from boat bottom, Tema harbour 3 spec. 2.5, 2.5 & 2.0mm long 15 February 1969, 1 spec. 3.5mm long 9 March 1969 Reg. no. NHMUK 20150546.

External features Minute aeolids with slender body, long smooth rhinophores, very short oral tentacles in largest specimen, no oral tentacles in smaller ones but oral veil with broad angular corners, foot narrow, with rounded corners and mouth in a slight notch (Figs 4G; 6A, C). Anus in interhepatic space just lateral to the back of the pericardial hump (acleioproctic). Two rows of precardiac cerata with just one or two cerata in each row, and three rows of postcardiac cerata with just one ceras in each row (rarely two) (Fig. 6D).

Colouration Body greyish with irregular shaped blackish blotches dorsally, sparse in one small specimen, denser in others, and in the largest specimen many blotches coalesce so that the appearance is black (Figs 4G; 6A); some black spots lateral to rhinophores in small specimens, sides and tail lack spots, but there are a few on the edge of the foot. Rhinophores pale grey with a few black spots near tip in one specimen, several black spots basally in the largest animal. Digestive gland in cerata brown or pale brown with scattered cream and brown or dark brown blotches, and a few blackish epidermal blotches in smaller specimens, many more in the largest so that the appearance is black; large circular greyish cnidosac with a band of epidermal cream glands surrounding it (Fig. 6B).

Internal morphology Not examined.

Behaviour Two 2.5mm animals were observed in reciprocal copulation with long, 0.5mm penises.

Geographical range Cosmopolitan: Scandinavia including Lofoten Islands & Baltic, North Sea, East Atlantic from British Isles to Portugal, Mediterranean to Sea of Azov and Black Sea, West Atlantic from Massachusetts & Virginia to Brazil, California & Oregon, Japan (Roginskaya, 1970, and Schmekel & Portmann, 1982 give numerous references), and now Ghana (this paper).

Remarks This is a small but well known aeolid which can tolerate brackish water of very low

salinity and can also thrive on the hydroids growing on boat hulls.

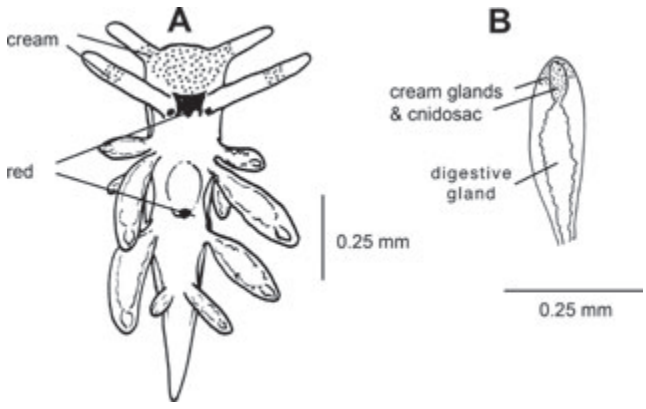
Eyster (1979) has described both pelagic and non-pelagic development in this species with the planktotrophic larvae surviving for up to five days (117 hours). Chester (1996) found that starved mature animals produce pelagic lecithotrophic larvae but well fed adults produced eggs some of which developed directly into metamorphosing juveniles. Thus if there is plenty of food a population on a boat hull could persist for several generations with direct development but if the hydroid food became scarce the adults could produce planktonic larvae which would disperse and be competent to colonise new substrates. This explains how a population reached Ghana where, in 1969, it was only known from boat hulls; whether since then it has established a resident population in the harbour at Tema is not known. The population reported here probably originated in Europe. Records of this species from the West Atlantic and the Indo-Pacific demonstrate that its habit of thriving on boats has enabled it to become cosmopolitan in its occurrence.

Tergipedidae species A
Fig. 7

Material examined 10m reef Kpone Bay 1 spec. 1mm long 12 February 1971.

External features This minute specimen has smooth rhinophores and rounded, notched foot with no projecting or angled corners (Fig. 7A). The spindle-shaped cerata are rounded at the tip with a large spherical cnidosac (similar to *Selva rubra* Edmunds, 1964 and *Tergipes tergipes* (Forskål, 1775) (Edmunds, 1966)), but with glands. Three precardiac cerata on each side arise close together in an inverted V; there follow two branches to the posterior digestive gland on each side with just a single ceras arising from each making a total of 10 cerata. The anus could not be seen and there is no trace of a gonopore.

Colouration The body is pale grey with cream pigment on the head, bases of oral tentacles and half way up the rhinophores; there is a dark red patch between the rhinophores and a dark red spot just behind the heart (Fig. 7A). The digestive gland in the cerata is brown and at the tip the cnidosac and terminal glands are cream (Fig. 7B).



Figures 7A–B Tergipedidae species A 1mm long, February 1971: **A** dorsal view; **B** ceras.

Internal morphology Not examined.

Geographical range Known from this single specimen from Ghana.

Remarks Although this minute specimen is very immature it differs in colouration from all other species of tergipedid found in Ghana.

DISCUSSION

This paper describes seven species of aeolid belonging to the family Tergipedidae from Ghana. Two species, *Cuthona perca* and *Tenellia adspersa* form part of the fouling community and are widespread in coastal waters of the Atlantic Ocean. *Cuthona ghana* n. sp. also lives in the fouling community at Tema but, together with *Cuthona kpone* n. sp., *Cuthona* species A, *Catriona tema* and Tergipedid species A, is also present on shallow water reefs.

Ecology and Diversity of Aeolid Nudibranchs in Ghana

This paper completes the description of aeolid nudibranchs from Ghana collected by the author and colleagues between 1963 and 1973 (Edmunds, 1968a, b, 2015a, b, c). The four main collecting sites were the 10m offshore reef at Kpone Bay (ranging from 9 to 12m deep), the 30m reef off Tema (ranging from 25 to 40m deep), the intertidal zone extending to about one metre depth of water below low water mark, and the fouling community of Tema harbour including buoys and boat hulls. The 30m 'reef' actually comprises both solid and fine grain substrates, the latter extending into deeper waters, and because the

Table 6. Numbers of aeolids found at the three 'natural' sites and in Tema harbour

Species	10m reef	30m reef	Intertidal	Tema harbour	All sites	'Natural' sites
Flabellina rubromaxilla	1				1	1
Flabellina albomaculata		2			2	2
Piseinotecus sphaeriferus	6				6	6
Piseinotecus minipapilla	4				4	4
Eubranchus rubrocerata	1				1	1
Eubranchus prietoi	1				1	1
Embletonia pulchra		1			1	1
Embletonia species A		1			1	1
Cuthona perca				65	65	
Cuthona ghana	1		1	18	20	2
Cuthona kpone	15				15	15
Cuthona species A	3				3	3
Catriona tema			6	1	7	6
Tenellia adspersa				3	3	
Tergipedidae species A	1				1	1
Phidiana lynceus				134	134	
Facelina coenda	2			5	7	2
Pruvotfolia pselliotes	6	4			10	10
Learchis poica			12		12	12
Learchis evelinae	2	1			3	3
Cratena tema	5	1		2	8	6
Favorinus ghanensis				279	279	
Godiva quadricolor				1	1	
Godiva brunnea		2			2	2
Facelinidae species A		1			1	1
Facelinidae species B			1		1	1
Facelinidae species C	1				1	1
Spurilla neapolitana			5		5	5
Spurilla species A		1			1	1
Berghia benteva			1		1	1
Berghia ghanensis	1		2		3	3
Berghia columbina	1				1	1
Number of individuals	**51**	**14**	**28**	**508**	**601**	**93**
Number of species	**16**	**9**	**7**	**9**	**32**	**27**

Table 7. Species diversity of aeolid nudibranchs in Ghana 1963–1973.

Sites	10m reef	>30m deep	Intertidal	Three 'natural' sites	Dorid 'natural' sites	Tema harbour
Number of individuals	51	14	28	93	343	508
Number of species	16	9	7	27	53	9
Shannon Index (H)	2.328	2.045	1.546	2.869	2.642	1.184
Evenness Value (E)	0.592	0.775	0.464	0.633	0.666	0.190
Simpson Index (1-D)	0.860	0.847	0.730	0.922	0.937	0.611

number of animals from this reef was small it has been combined in Table 6 with animals from deeper waters. Samples from all four habitats are small so conclusions are tentative, but the 10m site was the most diverse and the intertidal region the least diverse (Tables 6 & 7) just as with the dorids (Edmunds, 2013). The diversity indices for both the 30m site and the intertidal site are

very similar to the indices for dorids (Edmunds, 2013), but the 10m site has substantially lower values (Shannon Index 2.3 compared with 3.2 for dorids, Evenness Value 0.59 compared with 0.92, and Simpson Index 0.86 compared with 0.95). However, when all three sites are combined the three indices for aeolids are very close to those of dorids (Table 7). The results for Tema harbour are quite different because of the small number of species present and the very large number of individuals of the dominant species.

The species diversity plot shows that the aeolids from the 'natural' sites fit a logarithmic curve with a high correlation (Fig. 8). The aeolids from the fouling site in Tema harbour also fit a logarithmic curve (Fig. 9) but the correlation is even better for a straight line relationship (R^2=0.967), probably because the number of species in this habitat was small and was dominated by two very abundant species. Combining all sites the species diversity plot fits a logarithmic curve with a high correlation (Fig. 10), similar to that for dorids (R^2=0.991 for aeolids compared with R^2=0.982 for dorids) (Edmunds, 2013).

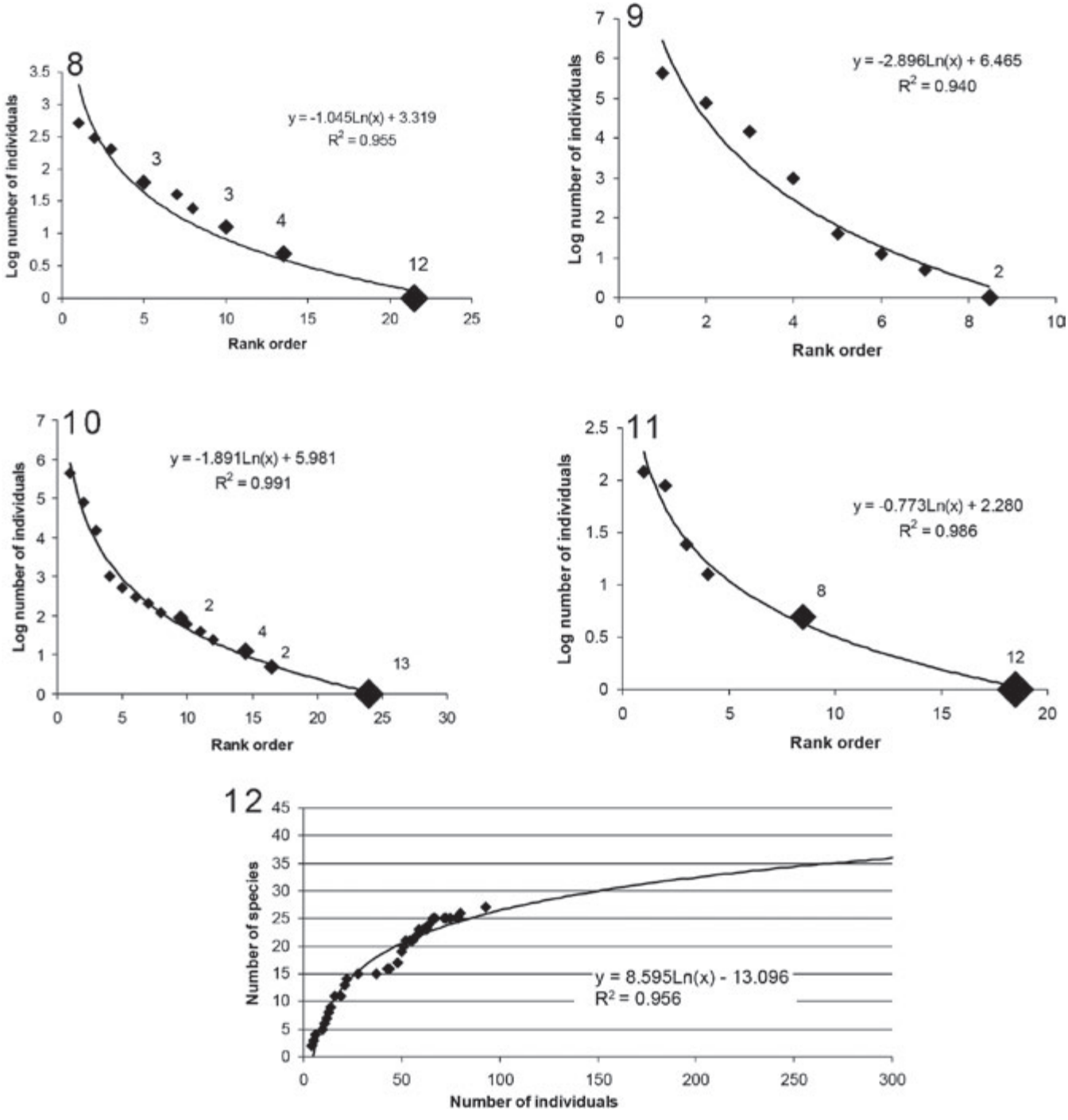
The species diversity curve for a smaller number of aeolids from Tanzania has very different×and y constants (Fig. 11) (data from Edmunds, 1969, 1970). This is probably because the habitats from which they came were less diverse than those from Ghana with no Scuba diving or dredging from offshore. In spite of this the number of species found in Tanzania in just two months was comparable to that from Ghana in 10 years (50 individuals belonging to 24 species compared with 93 individuals belonging to 32 species from Ghana) implying that the diversity and number of species present in the area would have been far greater than in Ghana. This is in line with the overall greater abundance of nudibranchs in the tropical Indian Ocean compared with the tropical Atlantic.

Ignoring species where less than four individuals were found, three species were confined to the 10m reef, two to the intertidal region and three to the fouling community in Tema harbour (Table 6).

How many species of aeolid are there in the Ghanaian fauna had I collected for another 10 years? Fig. 12 plots the cumulative number of individuals against the cumulative number of species from the 'natural' habitats' (the Tema harbour species have been omitted because the large numbers of three species would make the curve unreliable). The weakness of this procedure is that it assumes more or less equal sampling of the various habitats with time, which is not true. Nevertheless the data points are a reasonable fit to a logarithmic curve, which, by extrapolation, would give 35 species for a sample of 270 individuals. By comparison with the aeolid fauna of the Mediterranean this is a very small number: there are over 53 species on the Spanish Mediterranean coast (Cervera *et al*., 2006), but the Mediterranean has been intensively studied for over 100 years, with a wider variety of different habitats than those studied in Ghana, so the difference is not surprising. The tropical Indo-Pacific has an even richer aeolid fauna (see list in Sea Slug Forum, 1998–2010) and is one of the most species diverse marine ecosystems, probably because it includes coral reefs which do not occur off the West African coast.

Zoogeography and Check list of Ghanaian Aeolids

Table 8 lists the 32 species of Aeolidoidea collected by the author and colleagues in Ghana. The large number of apparently endemic species is due to the paucity of records of nudibranchs from West Africa: with more collecting most of these species will probably be found to occur from Senegal to Angola including the islands in the Gulf of Guinea. Nine of the Ghanaian species occur also in some of the Atlantic Isles (Canaries, Madeira and Azores) while 9 also occur in the Mediterranean: this affinity is to be expected given that west African coastal waters experience a cold current and so are not significantly warmer than Mediterranean waters from a much higher latitude. What is more surprising is that 5 species occur also in the North Atlantic from Morocco and Portugal northwards. Six species occur on both sides of the Atlantic, and three also occur in the Indo-Pacific. These three were all found in the fouling community of Tema harbour so are probably transported regularly on boat hulls. Three of the species found in the West Atlantic are also members of the fouling community so may have crossed the Atlantic on boats, but the other West Atlantic species (*Learchis poica*, *L. evelinae* and *Berghia benteva*) were only found in 'natural' habitats. This suggests that they may have long-lived (teleplanic) larvae which can drift across the Atlantic and then metamorphose successfully, or they may cross occasionally



Figures 8–12 **Fig. 8** Species Diversity curve for Ghanaian aeolids from the three 'natural' habitats (the 10m & 30m reefs and intertidal). In Figs 8–11 the small numbers beside points are numbers of species with same rank. **Fig. 9** Species Diversity curve for Ghanaian aeolids from the fouling community in Tema harbour. **Fig. 10** Species Diversity curve for Ghanaian aeolids from all sites. **Fig. 11** Species Diversity curve for Tanzanian aeolids (data from Edmunds, 1969, 1970). **Fig. 12** Cumulative plot of individuals and species of Ghanaian aeolids from 'natural' habitats showing numbers of species expected if trend is continued to 300 individuals.

either on boats or on the hydroids or anemones living on *Sargassum* (Edmunds, 2015a, c). If this is a regular occurrence then the populations on the two sides of the ocean may be conspecific, but if it is rare then the two populations may have diverged and be genetically distinct and have undergone speciation as in *Spurilla neapolitana* (Carmona, Pola, Gosliner & Cervera, 2013; Carmona, Lei, Pola, Gosliner, Valdés & Cervera, 2014).

Table 8. Zoogeoographic affinities of Ghanaian aeolids.

Species	Endemic	Mediterranean	East Atlantic Isles	West Africa Senegal to Angola	West Atlantic	North-east Atlantic	Indo-Pacific	References
Flabellinidae								
Flabellina rubromaxilla Edmunds, 2015				√				4
Flabellina albomaculata Pola, Carmona, Calado & Cervera, 2015			√					4
Piseinotecidae								
Piseinotecus sphaeriferus (Schmekel, 1965)		√	√					4
Piseinotecus minipapilla Edmunds, 2015	√							4
Eubranchidae								
Eubranchus rubrocerata Edmunds, 2015	√							4
Eubranchus prietoi Llera & Ortea, 1981				√		√		4
Embletoniidae								
Embletonia pulchra Alder & Hancock, 1844		√				√		4
Embletonia species A	√							4
Cuthonidae								
Cuthona perca (Marcus, 1958)		√			√		√	**6**
Cuthona ghana n. sp.	√							**6**
Cuthona kpone n. sp.	√							**6**
Cuthona species A	√							**6**
Catriona tema Edmunds, 1968			√					**1, 6**
Tenellia adspersa (Nordmann, 1845)		√				√	√	**6**
Tergipedidae species A	√							**6**
Facelinidae								
Phidiana lynceus Bergh, 1867			√		√			**5**
Facelina coenda Marcus, 1958					√			**5**
Pruvotfolia pselliotes (Labbé, 1923)		√	√	√				**5**
Learchis poica Marcus & Marcus, 1960			√		√			**5**
Learchis evelinae Edmunds & Just, 1983					√			**5**
Cratena tema Edmunds, 2015	√							**5**
Favorinus ghanensis Edmunds, 1968		√	√					**2, 5**
Godiva quadricolor (Barnard, 1927)		√				√	√	**5**
Godiva brunnea Edmunds, 2015	√							**5**
Facelinidae species A	√							5
Facelinidae species B	√							5
Facelinidae species C	√							5
Aeolidiidae								
Spurilla neapolitana (Delle Chiaje, 1841)		√	√			√		3
Spurilla species A	√							3
Berghia benteva (Er. Marcus, 1958)				√	√			3
Berghia ghanensis Edmunds, 2015				√				3
Berghia columbina (García-Gómez & Thompson, 1990)		√	√	√				3
Totals	**13**	**9**	**9**	**6**	**6**	**5**	**3**	

References: 1: Edmunds, 1968a; 2 Edmunds, 1968b; 3 Edmunds, 2015a; 4 Edmunds, 2015b; 5 Edmunds, 2015c; 6 Edmunds, this paper.

ACKNOWLEDGEMENTS

I am grateful to Walter Pople for collecting the specimens found offshore; the University of Ghana Zoology Department and the University of Central Lancashire School of Built & Natural Environment for laboratory facilities; Mr David Roberts for cutting and staining the serial sections; Drs Terry Gosliner, Manuel Malaquias and Angel Valdés for providing invaluable references; Dr Graham Oliver for careful editing of the colour figures; Drs Lucas Cervera and Leila Carmona Barnosi for sharing their knowledge and valuable discussions; and Dr Janet Edmunds for supporting me throughout the study.

REFERENCES

BALLESTEROS M, MADRENAS E & PONTES M 2012a "*Cuthona granosa*" in *OPK–Opistobranquis*, published 17.5.2012 at http://www.opistobranquis.info/en/guia/nudibranchia/dexiarchia/aeolidida/cuthona-granosa, accessed December 2014.

BALLESTEROS M, MADRENAS E & PONTES M 2012b "*Cuthona albopunctata*" in *OPK-Opistobranquis*, published 18.9.2012 at http://www.opistobranquis.info/en/guia/nudibranchia/dexiarchia/aeolidida/cuthona-albopunctata, accessed December 2014.

BALLESTEROS M, MADRENAS E & PONTES M 2014 "*Cuthona miniostriata*" in *OPK-Opistobranquis*, published 11.9.2014 at http://www.opistobranquis.info/en/guia/nudibranchia/dexiarchia/aeolidida/cuthona-miniostriata, accessed December 2014.

BOUCHET P 2015 Tergipedidae Bergh, 1889. In: MolluscaBase (2015), World Register of Marine Species at WoRMS, online at http://www.marinespecies.org at VLIZ, accessed December 2015.

BROWN GH 1980 The British species of the aeolidacean family Tergipedidae (Gastropoda: Opisthobranchia) with a discussion of the genera. *Zoological Journal of the Linnean Society* **69**: 225–255.

CARMONA L, LEI BR, POLA M, GOSLINER TM, VALDÉS A & CERVERA JL 2014 Untangling the *Spurilla neapolitana* (Delle Chiaje, 1841) species complex: a review of the genus *Spurilla* Bergh, 1864 (Mollusca: Nudibranchia: Aeolidiidae). *Zoological Journal of the Linnean Society* **170**: 132–154.

CARMONA L, POLA M, GOSLINER TM & CERVERA JL 2013 A tale that morphology fails to tell: a molecular phylogeny of Aeolidiidae (Aeolidida, Nudibranchia, Gastropoda). *Plos One* **8** (5): e63000, 1–13.

CERVERA JL 2000 Re: *Cuthona*? from France. *Sea Slug Forum* July 27 2000. Australian Museum online at http://www.seaslugforum.net, accessed December 2014.

CERVERA JL, CALADO G, GAVAIA C, MALAQUIAS MAE, TEMPLADO J, BALLESTEROS M, GARCÍA-GÓMEZ JC & MEGINA C 2006 (for 2004) An annotated and updated checklist of the opisthobranchs (Mollusca: Gastropoda) from Spain and Portugal (including islands and archipelagos). *Boletín Instituto Espaňol de Oceanografía* **20**: 5–111.

CHESTER CM 1996 The effect of adult nutrition on the reproduction and development of the estuarine nudibranch *Tenellia adspersa* (Nordmann, 1845). *Journal of Experimental Marine Biology and Ecology* **198**: 113–130.

EDMUNDS M 1964 Eolid Mollusca from Jamaica, with descriptions of two new genera and three new species. *Bulletin of Marine Science* **14**: 1–32.

EDMUNDS M 1966 Protective mechanisms in the Eolidacea (Mollusca Nudibranchia). *Journal of the Linnean Society (Zoology)* **47**: 27–71.

EDMUNDS M 1968a Eolid Mollusca from Ghana, with further details of West Atlantic species. *Bulletin of Marine Science* **18**: 203–219.

EDMUNDS M 1968b Opisthobranchiate Mollusca from Ghana. *Proceedings of the Malacological Society of London* **38**: 83–100.

EDMUNDS M 1969 Opisthobranchiate Mollusca from Tanzania. I. Eolidacea (Eubranchidae and Aeolidiidae). *Proceedings of the Malacological Society of London* **38**: 451–469.

EDMUNDS M 1970 Opisthobranchiate Mollusca from Tanzania. II. (Cuthonidae, Piseinotecidae and Facelinidae). *Proceedings of the Malacological Society of London* **39**: 15–57.

EDMUNDS M 2007 Opisthobranchiate Mollusca from Ghana: Dendrodoridídae and Corambidae. *Journal of Conchology* **39**: 253–264.

EDMUNDS M 2011 Opisthobranchiate Mollusca from Ghana: Discodoridídae. *Journal of Conchology* **40**: 617–649.

EDMUNDS M 2013 Opisthobranchiate Mollusca from Ghana: Onchidoridídae and Aegiridae, with a checklist and a review of the ecology and diversity of the Doridoidea. *Journal of Conchology* **41**: 423–438.

EDMUNDS M 2015a Opisthobranchiate Mollusca from Ghana: Aeolidiidae, with consideration of several Caribbean species. *Journal of Conchology* **42**: 1–20.

EDMUNDS M 2015b Opisthobranchiate Mollusca from Ghana: Flabellinidae, Piseinotecidae, Eubranchidae & Embletoniidae. *Journal of Conchology* **42**: 105–124.

EDMUNDS M 2015c Opisthobranchiate Mollusca from Ghana: Facelinidae. *Journal of Conchology* **42**: 125–161.

EDMUNDS M & JUST H 1983 Eolid nudibranchiate Mollusca from Barbados. *Journal of Molluscan Studies* **49**: 185–203.

EYSTER LS 1979 Reproduction and developmental variability in the opisthobranch *Tenellia pallida*. *Marine Biology* **51**: 133–140.

GARCÍA FJ, LÓPEZ-GONZÁLEZ PJ & GARCÍA-GÓMEZ JC 1991 A new species of Tergipedidae (Nudibranchia:

Aeolidoidea) from the Atlantic coast of southern Spain. *Journal of Molluscan Studies* **57**: 217–222.

GOSLINER TM 1980 The systematics of the Aeolidacea (Nudibranchia: Mollusca) of the Hawaiian Islands, with descriptions of two new species. *Pacific Science* **33**: 37–77.

GOSLINER TM 1987 *Nudibranchs of Southern Africa*. Sea Challengers/Jeff Hamann, EJ Brill, Monterey, El Cajon, Leiden, 136 pp.

GOSLINER TM & GRIFFITHS RJ 1981 Description and revision of some South African aeolidacean Nudibranchia (Mollusca, Gastropoda). *Annals of the South African Museum* **84**: 105–150.

INTERNATIONAL COMMISSION OF ZOOLOGICAL NOMENCLATURE 1966 Opinion 773, *Tergipes* Cuvier, 1805 (Gastropoda): validated under the plenary powers. *Bulletin of Zoological Nomenclature* **23**: 84–86.

KOEHLER E 2000 *Cuthona*? from France. *Sea Slug Forum* July 25 2000. Australian Museum online at http://www.seaslugforum.net, accessed December 2014.

MALAQUAIS MAE, CALADO GP, PADULA V, VILLANI G & CERVERA JL 2009 Molluscan diversity in the North Atlantic Ocean: new records of opisthobranch gastropods from the archipelago of the Azores. Online: *JMBA2 –Marine Biodiversity Records* **2** e**38**: 1–9.

MARCUS ER 1957 On Opisthobranchia from Brazil (2). *Journal of the Linnean Society of London, Zoology* **43**: 390–486.

MARCUS ER 1958 On Western Atlantic opisthobranchiate gastropods. *American Museum Novitates* no. **1906**: 1–82.

MARCUS EV & MARCUS ER 1960 Opisthobranchs from American Atlantic warm waters. *Bulletin of Marine Science* **10**: 129–203.

MARCUS EV & HUGHES HPI 1974 Opisthobranch molluscs from Barbados. *Bulletin of Marine Science* **24**: 498–532.

MILLER MC 1977 Aeolid nudibranchs (Gastropoda: Opisthobranchia) of the family Tergipedidae from New Zealand waters. *Zoological Journal of the Linnean Society* **60**: 197–222.

ORTEA J , CABALLER M & MORO L 2002 El género *Catriona* Winckworth, 1941 (Mollusca: Nudibranchiata) en las islas de Cabo Verde. *Revista de la Academia Canaria de Ciencias* **13**: 133–140.

PERRONE AS 1995 Una specie di Nudibranchi del genere *Cuthona* Alder & Hancock, 1855, nuova per il Mediterraneo: *Cuthona perca* Marcus, 1958 (Opisthobranchia: Nudibranchia). *Bolletino Malacologico* **31**: 28–36.

PICTON BE 2001 Re: *Cuthona* sp. 5. *Sea Slug Forum* March 20 2001. Australian Museum online at http://www.seaslugforum.net, accessed December 2014.

PICTON BE & MORROW CC 2010 *[In] Encyclopedia of Marine Life of Britain and Ireland*. Online at http://www.habitas.org.uk/marinelife/species, accessed December 2014.

PLATTS E 1985 An annotated list of the North Atlantic Opisthobranchia. In: Just H & Edmunds M *North Atlantic Nudibranchs (Mollusca) seen by Henning Lemche*. Ophelia Publications, Helsingør, 150–170.

ROGINSKAYA IS 1970 *Tenellia adspersa*, a nudibranch new to the Azov Sea, with notes on its taxonomy and ecology. *Malacological Review* **3**: 167–174.

RUDMAN WB 2000 *Cuthona* sp. 5. *Sea Slug Forum* July 18, 2000. Australian Museum online at http://www.seaslugforum.net, accessed December 2014.

SCHMEKEL L 1966 Zwei neue Arten der Familie Cuthonidae aus dem Golf von Neapel: *Trinchesia granosa* n. sp. und *Trinchesia ocellata* n. sp. (Gastr. Opisthobranchia). *Pubblicazione Stazione Zoologica di Napoli* **35**: 13–28.

SCHMEKEL L 1968 Vier neue Cuthonidae aus dem Mittelmeer (Gastr. Opisthobranchia): *Trinchesia albopunctata* n. sp., *Trinchesia miniostriata* n. sp., *Trinchesia ilonae* n. sp., und *Catriona maua* Marcus & Marcus, 1960. *Pubblicazione Stazione Zoologica di Napoli* **36**: 437–457.

SCHMEKEL L & PORTMANN A 1982 *Opisthobranchia des Mittelmeeres*. Springer-Verlag, Berlin Heidelberg New York, 410 pp.

SEA SLUG FORUM 1998–2010 Australian Museum online at http://www.seaslugforum.net, accessed December 2015.

THOMPSON TE 1980 Jamaican opisthobranch molluscs II. *Journal of Molluscan Studies* **46**: 74–99.

THOMPSON TE & BROWN G 1984 *Biology of Opisthobranch Molluscs*, Volume II. Ray Society, London, 229 pp.

VALDÉS A, HAMANN J, BEHRENS DW & DUPONT A 2006 *Caribbean Sea Slugs*. Sea Challengers, Washington, 289 pp.

WILLIAMS GC & GOSLINER TM 1979 Two new species of nudibranchiate molluscs from the west coast of North America, with a revision of the family Cuthonidae. *Zoological Journal of the Linnean Society* **67**: 203–223.