

REVISION OF THE GENUS *GOODALLIA* (BIVALVIA: ASTARTIDAE) WITH THE DESCRIPTION OF TWO NEW SPECIES

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ABSTRACT

A revision of the Recent species of the genus *Goodallia* (Astartidae) is presented. Adult shell and prodissoconch morphology of all the species are described and figured. In total, five species are recognized: *G. triangularis* (Montagu, 1803), *G. pusilla* (Forbes, 1844), *G. macandrewi* (Smith, 1881), *G. micalii* new species, and *G. gofasi* new species. *G. triangularis* and *G. pusilla* are widespread distributed in the Atlantic coasts of Europe and North Africa, and in the Mediterranean. *G. macandrewi* is restricted to the type locality in the Canary Islands, while what has been called *G. macandrewi* from the Mediterranean corresponds to an undescribed species here named *G. micalii*, distributed in the Central and Eastern Mediterranean. A second undescribed species from off the Atlantic Moroccan coast is named *G. gofasi*, and is known only from the type material of station B33 of the expedition *CINECA CHARCOT III*. The named forms, variability and distribution of *G. triangularis* are discussed.

INTRODUCTION

The bivalve genus *Goodallia* comprises a few small species of the family Astartidae that are characterized, at least, by their particular hinge plate. Other characters have been erroneously described (e.g. ligament internal; Turton, 1822: 77), and some possible anatomical characters (e.g. presence of a single demibranch, and the position of the anus situated more anteriorly than in species of *Astarte*; Saleuddin, 1965) have only been studied in one species. *Goodallia* species have been reported from the Atlantic Ocean and the Mediterranean Sea, with three recent species described to date: *G. triangularis* (Montagu, 1803) the type species, *G. pusilla* (Forbes, 1844) and *G. macandrewi* (Smith, 1881).

Goodallia triangularis (Montagu, 1803) is widely distributed along the Atlantic European coasts to the Mediterranean and north-western Africa (Montagu, 1803; 1808; Jeffreys, 1862; Smith, 1881; Hidalgo, 1917; Dautzenberg, 1927; Nobre, 1936; Pasteur-Humbert, 1962; Tebble, 1966; Cadée, 1968; Nordsieck, 1969; Parenzan, 1974; Nicolay & Angioy, 1984; van Aartsen, Menkhurst & Gittenberger, 1984; van Aartsen, 1985; Salas & Sierra, 1986; Bonnin & Rodríguez Babío, 1990; Basso, 1993; Salas, 1996; Giribet & Peñas, 1997). It occurs offshore to about 600 m depth in sandy, muddy, coralligenous and fine gravel bottoms (Tebble, 1966; Parenzan, 1974). Miocene, Pliocene and Pliopleistocene fossil specimens are known from Atlantic and Mediterranean regions (Wood, 1841; 1853; Dollfus & Dautzenberg, 1902; Gilbert, 1945; Heering, 1950; Janssen & Van Der Slik, 1974; Caldara, D'Alessandro & Dio Geronimo, 1981; Aimassi & Ferrero-Mortara, 1983).

Goodallia pusilla (Forbes, 1844) is rare and has been reported from the Mediterranean Sea (Forbes, 1844; Smith, 1881; Nordsieck, 1969; Parenzan, 1974; Carrozza, 1983; Nicolay & Angioy, 1984; Cecalupo & Giusti, 1989) and from the Atlantic Ocean (Hidalgo, 1917; Nobre, 1936). The third species, *Goodallia macandrewi* (Smith, 1881), was originally described from the Canary Islands, but some material from the Mediterranean Sea assigned to this species has been reported (Smith, 1881; Monterosato, 1891; van Aartsen, 1985; Albani, 1998). The specimens identified by van Aartsen (1985) as *G. macandrewi* were dredged between 10 and 100 m depth from several localities off the Italian continental coast, Sicily, Isle of Capri and Haifa Bay in Israel. The specimens from Albani (1998) were collected in Malta. Nevertheless, careful examination of some specimens

collected in Italy, the specimens figured by van Aartsen (1985), and the syntypes of *G. macandrewi*, revealed that the Mediterranean specimens assigned to *G. macandrewi* are a new undescribed species. Material examined from the expedition *CINECA CHARCOT III* resulted in the recognition of a second undescribed species from off the Atlantic Coast of Morocco.

In this paper we review the species of genus *Goodallia* based on adult shell and prodissococonch morphology. A review of the genus is needed due to the confusion created by van Aartsen (1985), the existence of unrecognized species, and the poorly understood variability in the shell morphology of *G. triangularis*.

METHODOLOGY

Specimens for scanning electron microscopy (SEM) were boiled in distilled water and treated with ultrasound to remove external debris from the shells. Lately, we used a more standard protocol, and shells were cleaned in 10% sodium lauryl phosphate for 15 minutes. The shells were mounted on bi-adhesive conductive tape and coated with a 30 nm thick layer of colloidal gold or gold-palladium. Images were obtained using a Hitachi S-2300 at 10–15 KV at the Universitat de Barcelona, or a Zeiss Digital Scanning Microscope DSM 950 at the AMNH. Two valves (syntypes) of *Goodallia macandrewi* were examined using a Cambridge (Leo) Leika 360 scanning electron microscope at low voltage (500 V) without coating at the University of Barcelona.

Abbreviations used in the text are:

AMNH: American Museum of Natural History, New York (USA).

BMNH: The Natural History Museum, London (UK).

MNCN: Museo Nacional de Ciencias Naturales, Madrid (Spain).

MNHN: Muséum National d'Histoire Naturelle, Paris (France).

USNM: U.S. National Museum, Washington D.C. (USA).

AP: A. Peñas private collection.

GG: G. Giribet private collection.

JC: Jeffreys collection.

LD: L. Dantart private collection.

PM: P. Micali private collection.

PZ: P. Zanni private collection.

MS: M. Strufaldi private collection.

S: specimen with dried animal inside or empty shell (with both valves).

V: valve.

Stat.: station.

coll.: collection.

fth.: fathoms (1 fathom is approximately 1.85 m)

SYSTEMATIC DESCRIPTIONS

Order Veneroida H. & A. Adams, 1857

Family Astartidae d'Orbigny, 1844

Genus *Goodallia* Turton, 1822

Type species by subsequent designation by Herrmannsen, 1847: *Mactra triangularis* Montagu, 1803

Goodallia triangularis (Montagu, 1803) (Figs. 1–15)

Mactra triangularis Montagu, 1803: 99, pl. 3 fig. 5.

Mactra minutissima Montagu, 1808: 37.

Astarte triangularis (Montagu, 1803)—Forbes & Hanley, 1853: 467–469, pl. 30, figs. 4–5.—Jeffreys, 1863: 318–319.—Sowerby, 1874: pl. 2, fig. 16.—Jeffreys, 1881: 712–713.—Pasteur-Humbert, 1962: 38, pl. 15, fig. 57.—Saleuddin, 1965: 229–257.—Tebble, 1966: 71–72, fig. 30.

Goodallia triangularis (Montagu, 1803)—Turton, 1822: 77, pl. 6, fig. 14.—Nordsieck, 1969: 71, pl. 12, fig. 40.50.—Parenzan, 1974: 150, pl. 36, fig. 151.

Goodallia minutissima (Montagu, 1808)—Turton, 1822: 77, pl. 6, fig. 15.

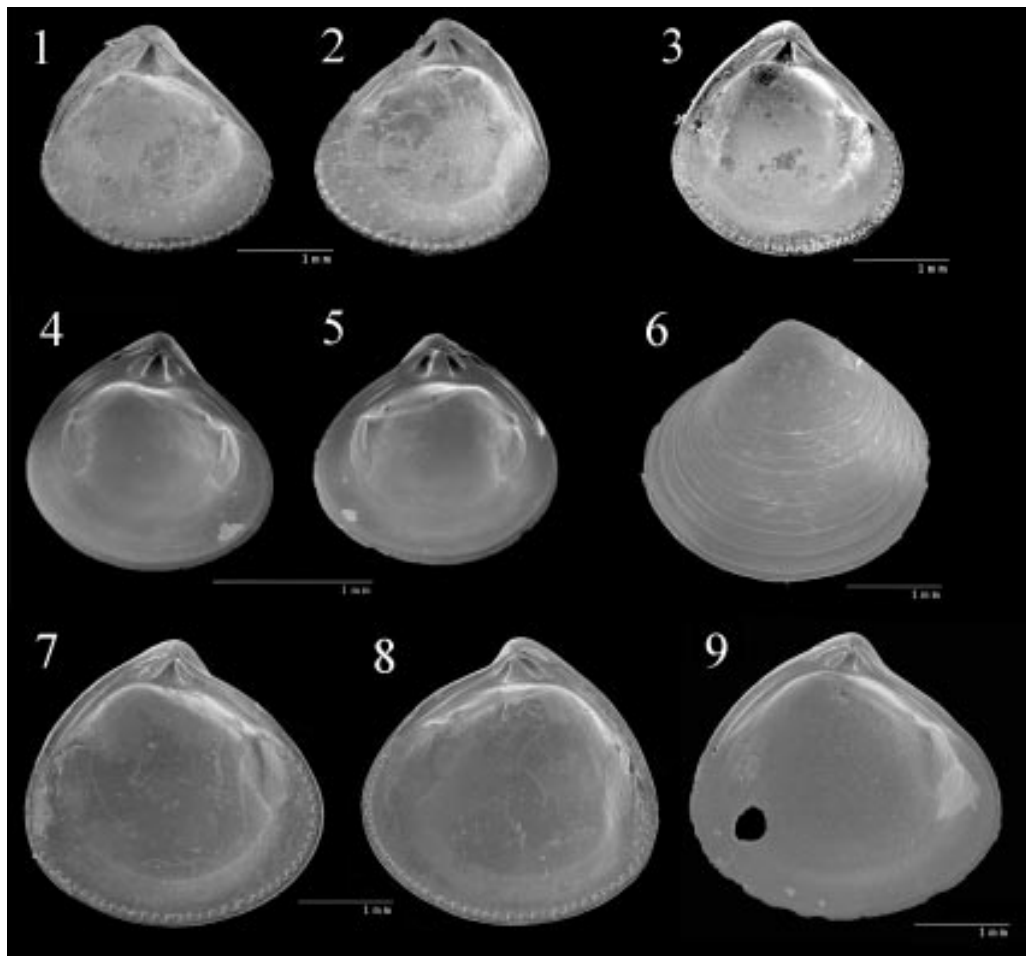
Astarte subtrigona Wood, 1841 (non Sowerby, 1874): 249.

Astarte triangularis form *subtrigona*—Wood, 1853: 174.

Type material: Not examined.

Material examined: **Mediterranean: Spain**: 26 S, 97 V, Alborán Island, 200 m (AP); 41 S, m, Jul 1992 (AP); 9 V, Rincón de la Victoria (Málaga), 20–40 m, industrial dredge, Gofas and Salas, leg., Jul 1990 (MNHN); 2 S, 3 V, Cabo de Gata (Almería), 23 m, artificial reef (36°42.4'N, 02°10.6'W). Moreno leg., Sep 22 1995 (MNHN); 4 S, 1 V, Cap Farrutx (Menorca), 23 m (GG); 7 S, 89 V, 'Mar de Nacre', off Garraf (Barcelona), 105 m, dredged, muddy bottom, Oct 1996 (AP); 43 V, 'El Parrusset', off Vallcarca (Barcelona) 41°06'59"N, 1°54'23"E, 250–350 m, dredged, white coral biocenosis, May 1995 (AP); 261 S, 212 V, Several localities of the Maresme region¹ (Barcelona), fine and coarse sand, 5–25 m (LD); 3 S, 2 V, Blanes (Girona), dredged (LD); 1 V, I. Medes (L'Estartit, Girona), 55 m (LD). **Italy**: 1 S, Livorno, 150 m (AP); 14 S, M52A station, I. Capraia (Tuscan Archipelago), 180–220 m (PM); 3 S, I. Capraia (Tuscan Archipelago), 250–350 m, dredged, muddy bottom with brachiopods, Sep 1991 (PZ); 5 S, 5 V, I. Capraia (Tuscan Archipelago), 350 m (AP); 86 S, 46 V, Tuscan Archipelago, 30–70 m (MS); 1 S, 6 V, I. Favignana (Sicilia) (PM); 6 S, Capo Corso, 180 m, dredged, muddy bottom, Aug 1984 (PZ); 5 S, Catolica (Forlì), 50–60 m, Sep 1989 (PZ); 2 S, Secca Murelle (Tarquinia), 33 m, muddy and rocky bottom,

¹ Due to space limitation the exact localities are not listed, but can be provided by the authors.



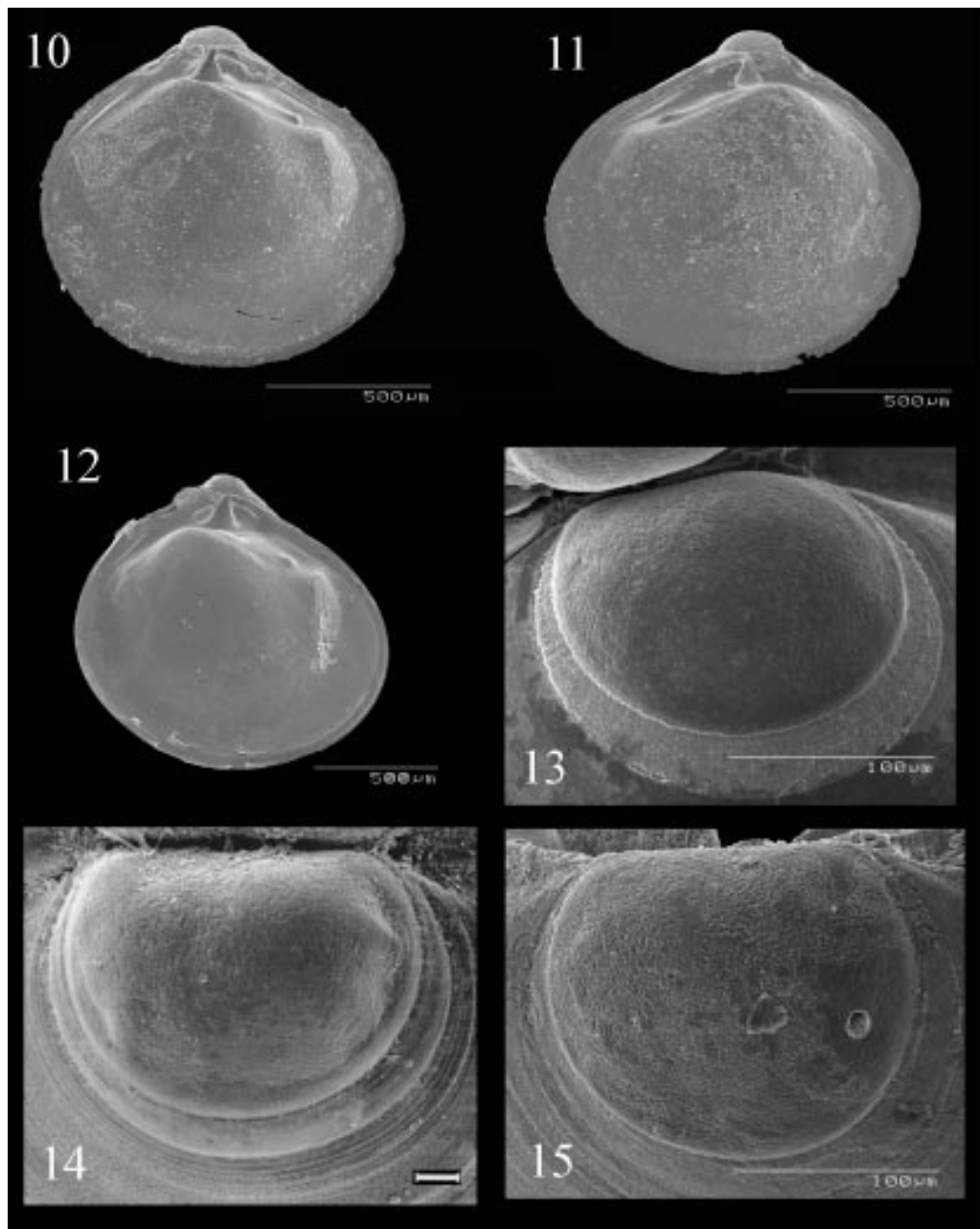
Figures 1–9. *Goodallia triangularis* (Montagu, 1803).

Fig. 1. Adult specimen (forma *tipica* from the Atlantic), internal view of the left valve, Brittany (France). **Fig. 2.** Adult specimen (forma *tipica* from the Atlantic), internal view of the right valve, Brittany (France). **Fig. 3.** Adult specimen (forma *tipica* from the Mediterranean), internal view of the left valve, Fuengirola (Málaga, Spain). **Fig. 4.** Young specimen, internal view of the left valve, Fuengirola (Málaga, Spain). **Fig. 5.** Young specimen, internal view of the right valve, Fuengirola (Málaga, Spain). **Fig. 6.** Adult specimen, External view of the left valve, Alborán Island (Spain). **Fig. 7.** Adult specimen (crenulated forma *subtrigona*), internal view of the left valve, Alborán Island (Spain). **Fig. 8.** Adult specimen (crenulated forma *subtrigona*), internal view of the right valve, Alborán Island (Spain). **Fig. 9.** Adult specimen (non-crenulated forma *subtrigona*), internal view of the left valve, ‘El Parrusset’, off Vallcarca (Barcelona, Spain).

Sep 1987 (PZ); **Other:** 3 S, Qammieck (Malta), 40–60 m, Aug 1991 (PZ); 1 S, 13 V, *Shearwater* expedition 1871, (Carpenter) (JC², USNM 200666); 1 S, 38 V, *Shearwater* expedition 1871, Adventure and Skerki Banks (between Sicily and North Africa), 40–120 fth. (JC, USNM 200667, 200668); 1 V, *Travailleur* expedition 1881, 2018 m (JC, USNM 200668); 35 V, Mediterranean Sea, 40–60 fth, Tunisia, 50–100 fth. (JC, USNM 200669); 6V, Nares, 30 fth. (JC, USNM

² A list and description of the expeditions, which molluscs were worked up by Jeffreys was published by Warén (1980).

200670–200671). **Atlantic: Scotland (UK):** 4S, Clyde, (ex. Smith coll.; Henderson coll., USNM 217688); 3 S, I. of Skye (Henderson coll., USNM 217689); several S, several V, Skye (JC, USNM 200636); several S, Balfour Bay (Orkney Islands) (JC, USNM 168814); 1 S, Gairloch, Aug 1843 (JC, USNM 200639); **Shetland Is.:** 40 S, 20 V, St. Magnus Bay (JC, USNM 168815); 11 S, 1 V, Figured type Brit. Conch. (JC, USNM 200625); 16 S, 8 V, Lerurch Sound, 3–5 fth., Jun 1848 (JC, USNM 200630); 5 lots containing > 150 S, 90 V (JC, USNM 200626–200629, 200631); **Hebrides:** 30 S



Figures 10–15. *Goodallia triangularis* (Montagu, 1803).

Fig. 10. Juvenile, internal view of the left valve, 'El Parrusset', off Vallcarca (Barcelona, Spain). **Fig. 11.** Juvenile, internal view of the right valve, 'El Parrusset', off Vallcarca (Barcelona, Spain). **Fig. 12.** Juvenile, internal view of the left valve, 'El Parrusset', off Vallcarca (Barcelona, Spain). **Fig. 13.** Prodissoconch, Alborán Island (Spain). **Fig. 14.** Prodissoconch, Brittany (France) (scale bar 20 μm). **Fig. 15.** Prodissoconch, 'El Parrusset', off Vallcarca (Barcelona, Spain).

(JC, USNM 200633); > 100 S, Jarbert Lewis Is., 1847 (JC, USNM 200634, 200636). **Ireland:** 7 S, Galway Bay (USNM 337252); > 100 S, Arran Id. Co. Galway, 1848–1855 (JC, USNM 200638); 1 V, Bantry Bay (JC, USNM 200637); **Wales (UK):** 1 S, 2 V, Barmouth, 1857 (JC, USNM 200640); 5 V, Whitstand Bay (JC, USNM 200643). **England (UK):** 2 S, 9 V, Nanley (Marshall coll., USNM 95723); 4 S, Lulworth (JC, USNM 200644); 6 S, 6 V, Lynn Weep (JC, USNM 200645); 3 S, Falmouth Harbor (JC, USNM 200647, 200648); 29 S, 53 V, Exmouth (JC, USNM 200649–200652, 200654); 50 V, Plymouth (JC, USNM 200655); 5 V, 150 m off Land's End, 200 fth. (JC, USNM 200656). **Channel Islands (UK):** 12 S (Marshall coll., USNM 95724); 11 V, Guernsey (Henderson coll., USNM 305020); 5 lots of about 400 S, Guernsey (JC, USNM 200657–200661). **France:** 9 S, Brittany (AP); 174 S (159 juveniles), 5 V, 'Les Cochons Noirs' (Roscoff, Finistère, Brittany), 20 m, Jul 1994, Gofas leg. (MNHN); 77 S, 58 V, Concarneau (Finistère, Brittany), 10–20 m, maërl, 1973–1978, Gofas leg. (MNHN). **Spain:** 1 S, 119 V, Zarautz (Guipúzcoa), Aug 12th 1935, (Staad coll., MNHN); 13 S, Getares (Cádiz), 6 m, detritus (AP); 1 V, Gibraltar (ex McAndrew coll., USNM 21887); 1 S, 7 V, Gran Canaria (Canary Is.), *Seamount 2* Stat. DW 133 (28°01.29'N, 15°53.50'W), 215 m, Gofas, Métivier, Warén leg. Jan 6 1993 (MNHN). **Morocco (Vanneau expedition):** 1 V, Stat. 21, 150 m, rocky bottom (34°12'N, 07°07'W), Jul 22 1923 (MNHN); 1 S, 3 V, Stat. 44, 145 m, sandy bottom with rocks (34°54'N, 07°54'W), Jun 24 1924 (MNHN); 3 S, Stat. 26, 53 m, conchiferous sand (33°47'N, 07°21'W), Jul 23 1923 (MNHN). **Other:** > 100 V, *Porcupine expedition*, 1870 (JC, USNM 200664–200665).

Description: Shell small, up to 3.4 mm from umbo to ventral margin; thick or thin-walled shell, equivalve; slightly inequilateral, beaks just behind the midline directed inward and slightly forward; subtriangular in outline, with the anterior dorsal margin almost straight, and the posterior dorsal margin slightly convex (Figs. 1–3); thin-walled specimens more rounded (Figs. 6–9); juveniles more rounded (Figs. 10–12); white to yellow in colour. Periostracum light yellow, reddish-brown or dark brown. Ligament external. Sculpture of very fine concentric lines, and small pits (only visible at high magnifications, Figs. 13–15); lunule and escutcheon present. Growth stages clear (Fig. 6). Right valve with two cardinal teeth, the anterior broad and the posterior thin, and there is a long, smooth, ridge-like projection along dorsal line just in front of posterior adductor scar resembling a lateral tooth; left valve with two prominent cardinal teeth and an anterior ridge near the dorsal line rather like a lateral tooth. Hinge line width extremely variable, much wider in thick shells (Figs. 1–3). Inner margin crenulate (Figs. 1–3, 7–8) or

smooth (Figs. 9) in adult specimens, but smooth in juveniles (Figs. 4–5, 10–12). Adductor muscle scars well developed; pallial sinus not present.

Prodissoconch small (Figs. 13–15), oval to semicircular in shape, with a clear division between prodissoconch I and prodissoconch II. Maximum diameter of PI between 160 and 180 µm; maximum diameter of the prodissoconch between 180 and 220 µm. PI with a granular sculpture; with depressions at the margin of PI not following any clear pattern; PII not granulated; clearly separated from the teleoconch.

The anatomy of the animal has been studied by Saleuddin (1965) (see comments on page 262).

Remarks: This is the most common and widespread species of the genus, and can be easily distinguished from *G. macandrewi*, *G. micalii* and *G. pusilla* by the shape and size of the shell, which is larger and more equalateral in *G. triangularis*. The most equalateral forms are similar to *G. gofasi*, although this is much smaller with the inner margin strongly crenulated, while juvenile shells of *G. triangularis* of the size of *G. gofasi* were never crenulated. The prodissoconch is smaller than in *G. macandrewi* (Fig. 23) and *G. micalii* (Fig. 28); it is similar in size to that of *G. pusilla* (Figs. 20–21), from which it can be differentiated by the absence of clearly defined and arranged depressions; and it is larger than in *G. gofasi* (Fig. 32), from which can also be differentiated in the general shape (mucronate and directed much more inwards in *G. gofasi*).

Distribution: Widespread along Atlantic European coasts to the Western Mediterranean and north-western Africa.

Habitat: Living specimens have been reported from dredging from sand and gravel bottoms, in 5–600 m. Valves have been found in shell sand. Some of the specimens reported were collected in a locality named 'Mar de Nacre', 13 Km off the coast between Vallcarca and Garraf (Barcelona, Western Mediterranean), from sand and mud bottom, 105 m. This sand is rich in SiO₂ up to 50% of the total (excluding mud). The sediment is rich in living micromolluscs, principally of the families Eulimidae and Pyramidellidae, associated with a large colony of the feather star *Leptometra phalangium* (Müller). Bivalves of the family Pinnidae were formerly abundant in the area which gave rise to the name to the site ('nacre' means pen shell in Catalan). Additional dead specimens from

'El Parrusset; (41°06'59''N, 1°54'23''E) have been dredged from a white coral biocenosis, 250–350 m (for a more detailed description, see Giribet & Peñas, 1997).

***Goodallia pusilla* (Forbes, 1844)**
(Figs. 16–21)

Astarte pusilla Forbes, 1844: 192.—Jeffreys, 1881: 713, pl. 61. Fig. 10.

Goodallia pusilla (Forbes, 1844)—Nordsieck, 1969: 71, pl. 12., fig. 40.52.—Parenzan, 1974: 150, pl. 36, fig. 152. Carrozza, 1983: 68, 2 figs.

Type material: Not examined.

Material examined: **Vanneau expedition** (*Atlantic Ocean, Morocco*): 30 V, Stat. 21, 150 m, rocky bottom (34°12'N, 07°07'W), Jul 22 1923 (MNHN); 1 V, Stat. 53, 160 m, fine and coarse sand (33°54'N, 08°10'W), Jun 21 1924 (MNHN); 9 V (subfossil), Stat. 110, 110 m, (30°23'N, 09°55'W), 1923–1929 (MNHN). **Porcupine expedition 1870**): 1 V, North Atlantic (JC, USNM 200614); 2 V, Stat. 36, off Cape Sagres (Morocco), (35°35'N, 06°26'W), 72–128 fth. (JC, USNM 200616); 8 V, Adventure Bank, 92 fth. (JC, USNM 200618). **Italy**: 2 V, I. Capraia (Tuscan Archipelago) (AP); 1 V, M52A station, I. Capraia (Tuscan Archipelago), 180–220 m (PM); 3 S, 4 V, I. Favignana (Sicily) (PM); 1 V, I. Favignana (Sicily) (MS); 4 V, I. Favignana (Sicily), 35 m, muddy detritus, Jul 1987 (PZ); 1 S, I. Correnti (Pozzallo), 3 m, muddy detritus, Jul 1987 (PZ); 1 S, Secca Motesi, 42 m, Aug 1987 (PZ). **Other**: 30 V, Agadir region (Morocco), 'CINECA CHARCOT III' Stat. B 33 (29°23'N, 10°50'W), 132 m, 1972 (MNHN); 6 V, *Shearwater* expedition 1871, W. Soloom Bay (Mediterranean), 40–120 fth. (JC, USNM 200615); 1 V, Tunisian Coast, 50–100 fth. (JC, USNM 200617).

Description: Shell small, up to 1.6 mm from umbo to ventral margin; thick-walled shell, equivalve; inequilateral, beaks just behind the midline, directed inward but not forward, subtriangular in outline, with the anterior dorsal margin almost straight and sloping steeply forwards, and the posterior dorsal margin convex and sloping a little less steeply backwards; shell width very variable (i.e. compare Figs. 17 and 18); white, yellow, reddish-brown, or pink in colour. Ligament external. Sculpture of well-marked concentric lamellae (Fig. 19), and small pits (visible only at high magnifications, Figs. 20–21); lunule and escutcheon present. Hinge as in *G. triangularis*. Inner margin crenulate. Adductor muscle scars well developed; pallial sinus not present.

Prodissoconch (Figs. 20–21) small, oval to semicircular in shape, with a clear division between prodissoconch I and prodissoconch II.

Maximum diameter of PI about 180 µm; maximum diameter of the prodissoconch between 193 and 213 µm. PI with a granular sculpture; with four clear depressions at the margin of PI arranged in a rhomboidal pattern; PII not granulated; clearly separated from the teleoconch.

Animal unknown.

Remarks: This species is easily distinguishable from others of the genus by the presence of well-marked concentric ribs in the adult shell. The prodissoconch is smaller than those of *G. macandrewi* (Fig. 23) and *G. micalii* (Fig. 28), larger than that of *G. gofasi* (Fig. 32), and similar in size to that of *G. triangularis* (Figs. 13–15), although its clear rhomboidal-arranged depressions make it easily distinguishable from the other species. In outline it is more similar to the other inequilateral species, *G. macandrewi* and *G. micalii*.

Distribution: Western Mediterranean and Atlantic coast of Europe and Morocco.

Habitat: Specimens have been dredged between 3–600 m.

***Goodallia macandrewi* (Smith, 1881)**
(Figs. 22–24)

Astarte macandrewi Smith, 1881: 229–230.

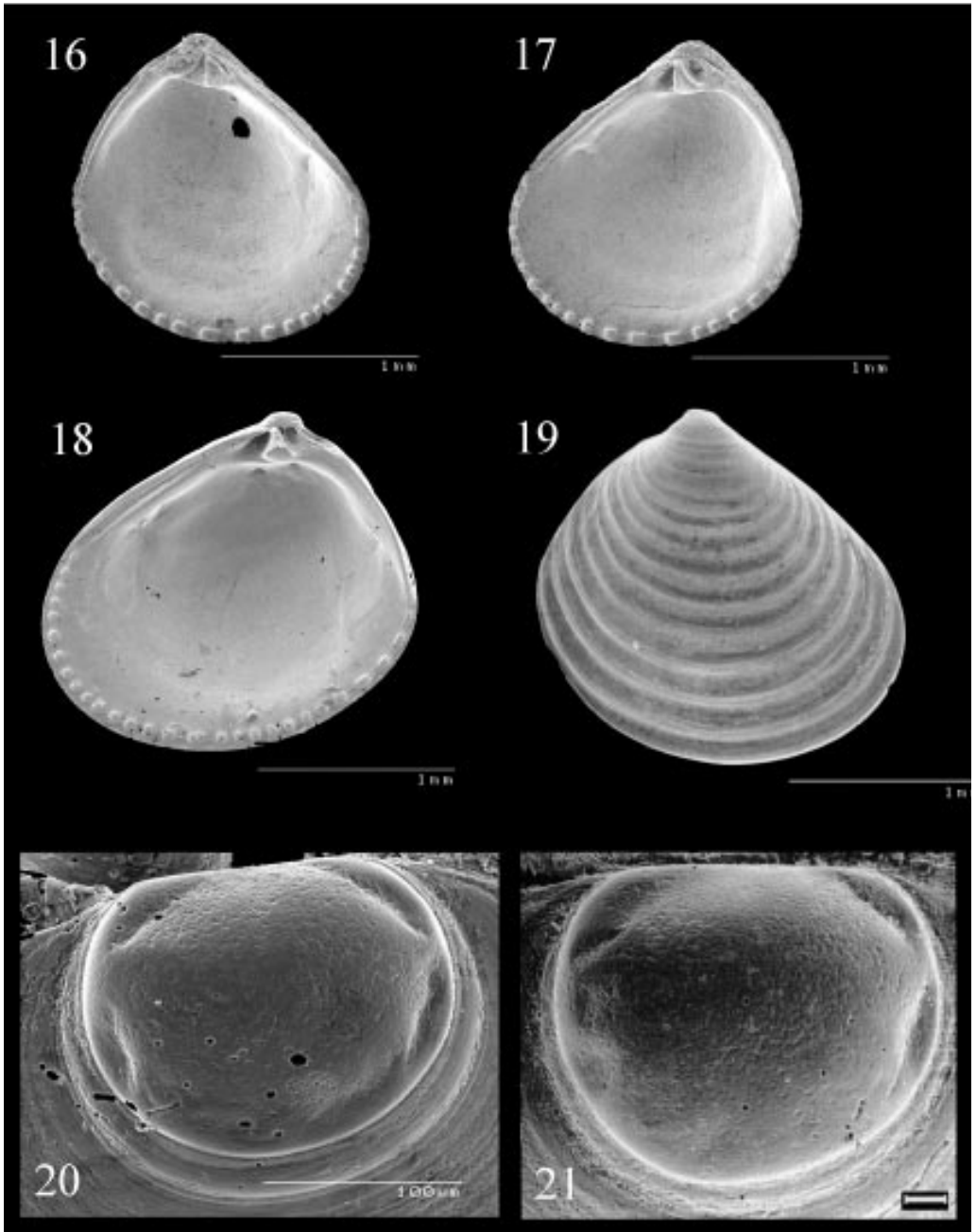
Astarte triangularis (Montagu, 1803)—McAndrew 1852: 103.

Type material: 9 S, Orotava (Canary Islands, Spain), Syntypes BMNH 1855.4.4.50, (R. McAndrew coll.).

Other material examined: 3 S, 6 V, Canary islands (Spain) (ex. McAndrew coll.) (JC, USNM 200674); 1 V, Canary Is. (Spain) (ex. McAndrew coll.) (JC, USNM 200675).

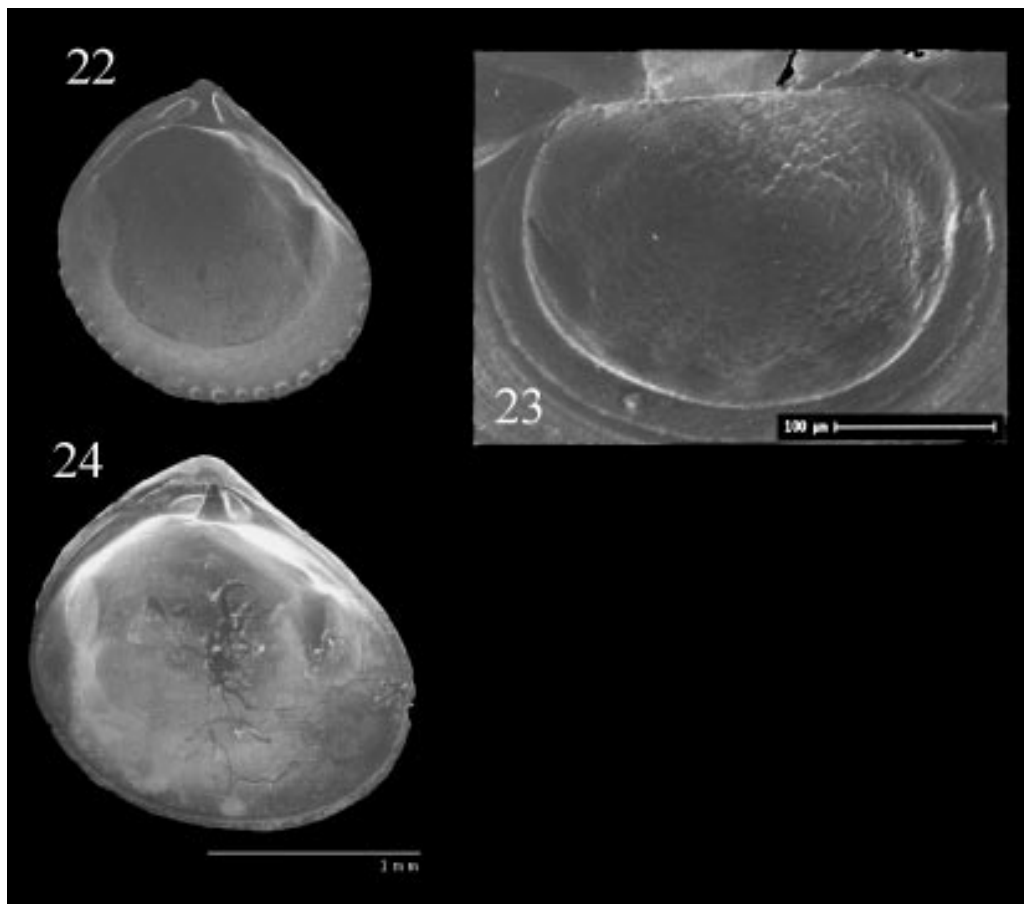
Description: Shell small, up to 2 mm from umbo to ventral margin; thick-walled shell, equivalve; inequilateral, beaks just behind the midline directed inward but not forward; subtriangular in outline, with the anterior dorsal margin almost straight and the posterior dorsal margin convex; white in colour. Periostracum light yellow. Ligament external. Sculpture of very fine concentric lines only; lunule and escutcheon present. Growth stages clear. Hinge as in *G. triangularis*. Inner margin crenulate (Fig. 22) or smooth (Fig. 24). Adductor muscle scars well developed; pallial sinus not present.

Prodissoconch (Fig. 23) large, semicircular in shape, with a clear division between prodissoconch I and prodissoconch II. Maximum



Figures 16–21. *Goodallia pusilla* (Forbes, 1844).

Fig. 16. Adult specimen, internal view of left valve, Isola di Capraia (Tuscan Archipelago, Italy). **Fig. 17.** Adult specimen, internal view of right valve, Isola di Capraia (Tuscan Archipelago, Italy). **Fig. 18.** Adult specimen, internal view of right valve, Isola Favignana (Italy). **Fig. 19.** Adult specimen, external view of right valve, *CINECA CHARCOT III* expedition, stat. B33. **Fig. 20.** Prodissocoach of the specimen from Fig. 18. **Fig. 21.** Prodissocoach, *CINECA CHARCOT III* expedition, stat. B33 (scale bar 20 µm).



Figures 22–24. *Goodallia macandrewi* (Smith, 1881).

Fig. 22. Syntype, internal view of left valve, Orotava (Canary Islands, Spain) (low voltage [500 V] microphotograph of an uncoated specimen), 2.05 mm. **Fig. 23.** Prodissoconch of the same specimen. **Fig. 24.** Internal view of left valve, Canary Islands (Spain), USNM 200674.

diameter of PI of 275 μm ; maximum diameter of the prodissoconch of 320 μm . PI with a granular sculpture; with slight depressions throughout the margin of PI; PII not granulated; clearly separated from the teleoconch.

Animal unknown.

Remarks: According to Smith (1881), this species appears cited by MacAndrew (1852) under the name *A. triangularis*. *G. macandrewi* has the largest prodissoconch in the genus, which clearly differentiates it from all the other species, including the Mediterranean species *G. micalii*, misidentified as *G. macandrewi* by van Aartsen (1985). The shell shape is similar to that of *G. micalii*, although it is larger in *G. macandrewi*, lacks the posterior expansion

of the ligament, and has a larger posterior cardinal tooth in the left valve. The prodissoconch of *G. macandrewi* is less tall than that of *G. micalii*. In shell shape it is clearly distinguishable from the most equilateral species *G. gofasi* and *G. triangularis*, as well as from the inequilateral species *G. pusilla*.

Distribution: Canary Islands (Smith, 1881).

***Goodallia micalii* new species** (Figs. 25–28)

Goodallia macandrewi (Smith, 1881)—Nordsieck, 1969: 71, pl. 12., fig. 40.51.—van Aartsen, 1985: 11, fig. 3.—Albani, 1988: 41.

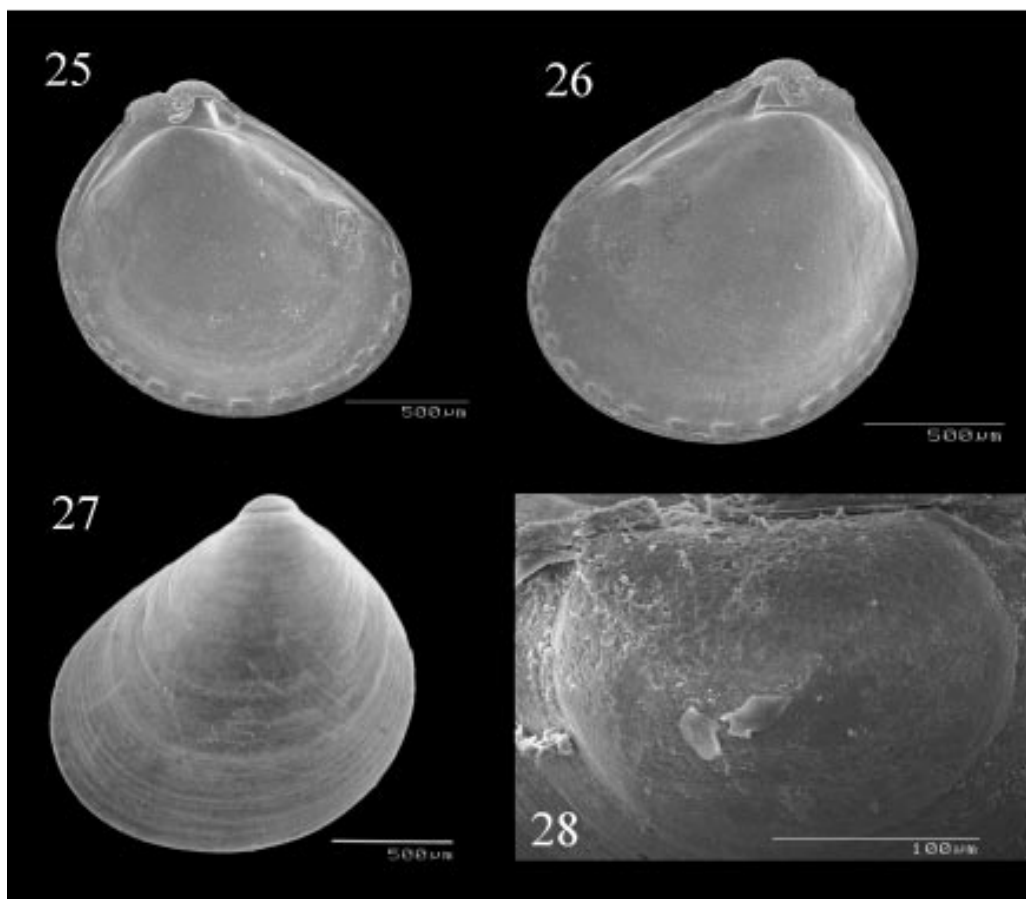
Type material: Holotype: MNCN, 1 S, Tor Vaianica (Roma, Italy), 15–24 m (P. Micali, leg.). Paratype: MNCN, 1 left valve, Tor Vaianica (Roma, Italy), 15–24 m (P. Micali, leg.). Paratype: AMNH, 1 S, Tor Vaianica (Roma, Italy) (M. Strufaldi, leg.). Paratype: MNHN, 1 S, Tor Vaianica (Roma, Italy) (M. Strufaldi, leg.).

Type locality: Tor Vaianica (Roma, Italy)

Other material examined: 1 V, Tor Vaianica (Roma, Italy), 15–24 m (P. Micali, leg.) (AMNH); 1 S, I. di Capraia (Italy); 1 S, Tuscan Archipelago (Italy), 30–70 m (MS); 7 S, Tor Vaianica (Roma, Italy) (MS); 2 S, I. Ponza (Italy), 35 m, muddy bottom with stones, May 1993 (PZ); 1 S, I. Vendicari (Sicily, Italy), 34 m, muddy bottom with stones, Jul 1987 (PZ); 1 L. I. Favignana (Sicily, Italy), 35 m, muddy bottom with stones, Jul 1990 (PZ).

Description: Shell small, up to 1.3 mm from umbo to ventral margin; equivalve; inequilateral, beaks just behind the midline directed inward; subtriangular in outline, with the anterior dorsal margin almost straight and the posterior dorsal margin slightly convex; yellow in colour. Periostracum light yellow to brown. Ligament external, with a clear posterior expansion. Sculpture of very fine concentric lines only; a lunule and escutcheon are present. Growth stages clear. Hinge as in *G. triangularis*, but with the posterior cardinal tooth of the left valve smaller than the anterior. Inner margin crenulate. Adductor muscle scars well developed; pallial sinus not present.

Prodissoconch (Fig. 28) small, semicircular in shape, with a division between prodissoconch I and prodissoconch II. Maximum



Figures 25–28. *Goodallia micalii* new species.

Fig. 25. Internal view of left valve, Isola di Capraia (Tuscan Archipelago, Italy). **Fig. 26.** Internal view of right valve, Isola di Capraia (Tuscan Archipelago, Italy). **Fig. 27.** External view of the left valve, Tor Vaianica (Roma, Italy). **Fig. 28.** Prodissoconch, Isola di Capraia (Tuscan Archipelago, Italy).

diameter of PI of 222 μm ; maximum diameter of the prodissococonch of 234 μm . PI with a granular sculpture; without depressions at the margin of PI; PII not granulated; clearly separated from the teleococonch.

Animal not studied. Albani (1998) has reported several hundred specimens (most of them alive), but information on the anatomy is not given.

Remarks: The hinge of *G. micalii* differs from *G. macandrewi* in the shape and size of the posterior cardinal tooth of the left valve, which is smaller in *G. micalii*, and in the absence of the posterior expansions of the ligament in *G. macandrewi*. However, this character may lead to confusion because van Aartsen (1985) used it to describe the Canarian *G. macandrewi* (specimens illustrated in his Fig. 1) that do not show these expansions. Thus, his specimens from Fig. 1 (syntypes of *G. macandrewi*, Orotava, Canary Islands; the same specimens examined here) do not match the drawings from Fig. 3 (Mediterranean '*G. macandrewi*', which correspond to our *G. micalii* new species). The smaller size of the adult animal in *G. micalii*, the smaller size of the prodissococonch (although is higher), and the lack of depressions in the prodissococonch clearly differentiates it from *G. macandrewi*. The prodissococonch is larger than in the other three species of the genus: *G. gofasi*, *G. pusilla*, and *G. triangularis*.

Distribution: Restricted to the central and eastern Mediterranean. Known from the localities here reported and from the localities named by van Aartsen (1995) (continental Italian coast: Gaeta, Secca di Tore Flavia, Secca di Macchia Tonda, Capo Linaro, Secca delle Murelle; coast of Sicily: Acitrezza, I. Correnti, I. Vendicari; I. di Capraia; Haifa Bay, Israel) and by Albani (1998) (St. Julian's Bay, 5 Km N of La Valetta, Malta).

Habitat: The type material was collected between 15 and 24 m; other specimens are reported from 35 m. Specimens of van Aartsen (1985) were dredged mainly in 10–100 m. Albani (1998) has recently reported several hundred specimens collected in St. Julian's Bay (5 Km N of La Valetta, Malta) in a bottom of fine sand with patches of *Posidonia* at 15 m.

Etymology: This species is named for Pasquale Micali, Italian malacologist who provided part of the type material.

Goodallia gofasi new species (Figs. 29–32)

Type material: Holotype: 1 S Agadir region (Morocco), '*CINECA CHARCOT III*' Stat. B33 (29°23'N, 10°50'W), 132 m, 1972 (MNHN). Paratypes: MNHN, 1 S, 4 V Agadir region (Morocco), '*CINECA CHARCOT III*' Stat. B33 (29°23'N, 10°50'W), 132 m, 1972; AMNH, 1 S, 4 V Agadir region (Morocco), '*CINECA CHARCOT III*' Stat. B 33 (29°23'N, 10°50'W), 132 m, 1972; MNCN, 1 S, 4 V Agadir region (Morocco), '*CINECA CHARCOT III*' Stat. B33 (29°23'N, 10°50'W), 132 m, 1972.

Other material examined: 9 S, 33 V, Agadir region (Morocco), '*CINECA CHARCOT III*' Stat. B 33 (29°23'N, 10°50'W), 132 m, 1972 (MNHN).

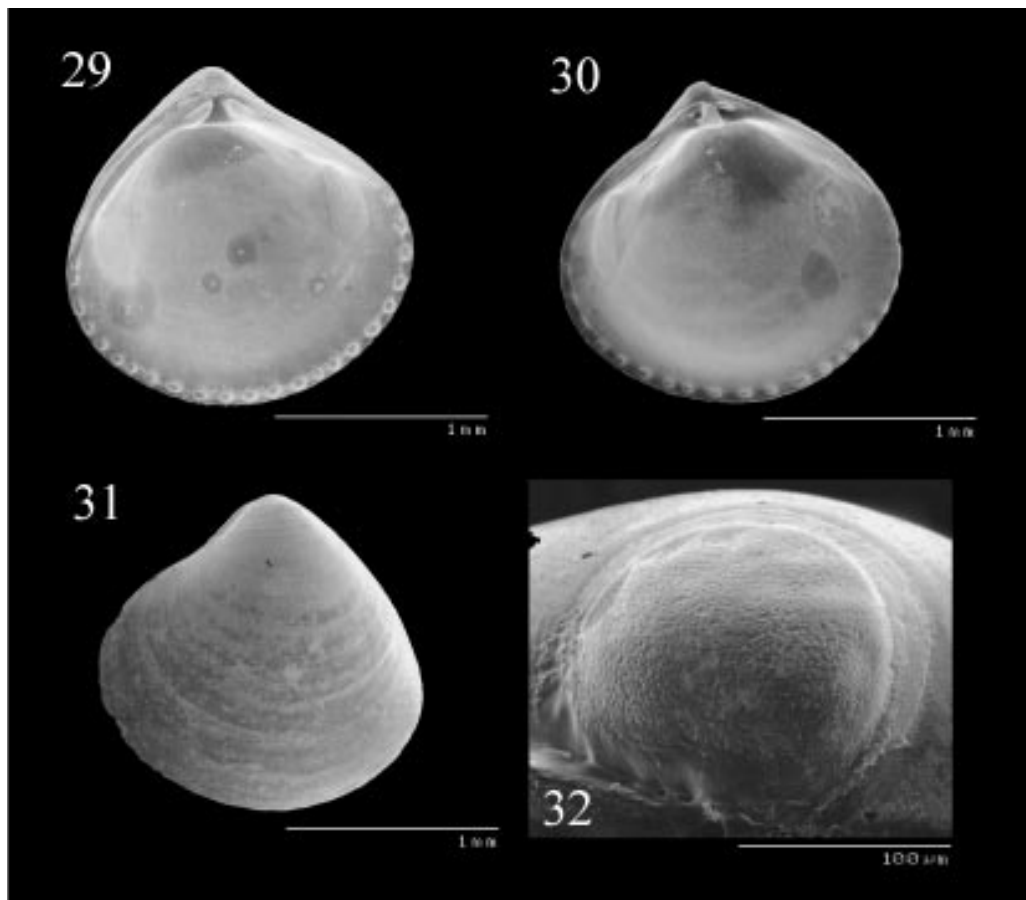
Type locality: 29°23'N, 10°50'W (off Agadir region, Morocco).

Description: Shell small, up to 1.5 mm from umbo to ventral margin; medium-walled shell, equivalve; almost equilateral, beaks just behind the midline directed inward and slightly forward; sub-circular in outline, with the anterior dorsal margin almost straight, and the posterior dorsal margin slightly convex; whitish in colour, with a clear radial brown banding pattern. Periostacum light yellow in colour. Ligament external. Sculpture of very fine concentric lines only; lunule and escutcheon present. Growth stages clear. Hinge as in *G. triangularis*. Inner margin crenulate or smooth. Adductor muscle scars well developed; pallial sinus not present.

Prodissococonch (Fig. 32) small, oval in shape, mucronate and strongly directed inwards, so the top of the prodissococonch of both valves almost touch each other; with a clear division between prodissococonch I and prodissococonch II. Maximum diameter of PI about 140 μm ; maximum diameter of the prodissococonch between 150 and 170 μm . PI with a granular sculpture; with depressions throughout the margin; PII not granulated.

Animal unknown.

Remarks: The distinctive prodissococonch of this species, makes it easily distinguishable from the other four species of the genus. The prodissococonch is clearly smaller, and its shape as well as the fact that is directed much more inward than in the other species are diagnostic characters. The shell shape differentiates it from the inequilateral species (*G. macandrewi*, *G. micalii* and *G. triangularis*), but it could be confounded with the most equilateral forms of *G. triangularis*. The smaller size of *G. gofasi* (it



Figures 29–32. *Goodallia gofasi* new species.

Fig. 29. Paratype, internal view of left valve, *CINECA CHARCOT III* expedition, stat. B33. **Fig. 30.** Paratype, internal view of right valve, *CINECA CHARCOT III* expedition, stat. B33. **Fig. 31.** Paratype, external view of the left valve, *CINECA CHARCOT III* expedition, stat. B33. **Fig. 32.** Paratype, prodissoconch, *CINECA CHARCOT III* expedition, stat. B33.

has the size of juveniles of *G. triangularis*, but the hinge looks like an adult *G. triangularis*, as well as the presence of an internal margin crenulate in most specimens (while it is smooth in the juvenile specimens of *G. triangularis* of this size) are clear distinctions.

Distribution: Known only from the type locality.

Habitat: The type material was dredged on a maërl bottom at 132 m.

Etymology: This species is named for Serge Gofas (MNHN, Paris) who provided the type material.

DISCUSSION

The systematic position of the species of the genus *Goodallia* has been controversial. Originally it was described as *Macra* (Montagu, 1803), although it was stated that ‘the hinge does not strictly correspond with the characters of the genus, but we could not with more propriety place it elsewhere’ (Montagu, 1803: 99). Later, what was supposed to be another species of the genus, was described also under the genus *Macra* ‘because the shell to which it is so nearly allied [*G. triangularis* (Montagu, 1803)] has already been placed here’ (Montagu, 1808: 37). However, the author comments that ‘both shells are however so extremely sim-

ilar in shape, and appear so nearly connected by the teeth to *Venus tripla* of Linnæus, as may be seen by consulting Chemnitz, vol. vi. tab. 31, fig. 330, that perhaps they might with as much propriety be removed to that genus'. Other genera (*Venus*, *Mastrina*, *Cyrina*, etc.) have been used.

Turton (1822: 77) erected the new generic name *Goodallia* because 'the minute shells of this genus differ materially from the *Mastra*, both in the form and disposition of the teeth'. Finally, the genus *Goodallia* was placed within the Astartidae, adopting the genus name *Astarte*, although some authors used first *Goodallia* as a subgenus, and then as a generic epithet for the family Astartidae.

Some aspects of the original description of the genus (Turton, 1822) are unclear. First, the author describes the hinge as 'with two teeth in one valve and a triangular cavity between them, in the other valve a single tooth: lateral teeth obscure'. All the authors agree on the presence of two teeth in one valve (the left one) but, although original descriptions (Montagu, 1803; 1808; Turton, 1822; Smith, 1881) agree in the presence of a single central strong cardinal tooth in the right valve, other authors describe the 'right valve with two cardinal teeth of which the front one is broad and the posterior thin' (Tebble, 1966: 72). We agree with Tebble in this aspect, which is evidenced by studying earlier stages of the development of the shell (Fig. 11).

Secondly, Turton describes the presence of 'ligament internal' (Turton, 1822: 72). Although many fresh specimens have been studied, none of them seemed to have an internal ligament. This has also been previously noticed by other authors (Wood, 1853; see also Jeffreys, 1863; Saleuddin, 1965; van Aartsen, 1985; Basso, 1993). However, there are some expansions at the posterior side of the hinge of *Goodallia micalii* n. sp. (Figs. 25–26; see also Fig. 3 from van Aartsen, 1985), that were identified as possible internal ligament by van Aartsen (1985). Such structures are not present in any other species of the genus, and certainly are not present in the specimens of *G. macandrewi* from the Canary Islands.

The anatomy of *G. triangularis* has been studied by Saleuddin (1965), and compared to some *Astarte* species (*A. sulcata*, *A. elliptica*, *A. borealis*, and *A. montagui*) from which it differs in having only one demibranch (probably the inner one), and in the position of the anus which in *G. triangularis* is more anterior than in the species of the genus *Astarte*, since the

rectum curves forwards round the posterior adductor muscle to end along its mid-ventral wall (Saleuddin, 1965). Although these characters can be used to differentiate *G. triangularis* anatomically from the studied *Astarte* species, it is not possible to define them as synapomorphies of the genus until they are found in the other species.

We have illustrated and redescribed the shell and prodissococonch of the three known species of the genus *Goodallia*. We have also discussed the confusion created for the Mediterranean '*G. macandrewi*' by the presence of a previously unrecognized species, here named *G. micalii*, and described a second new species from the Moroccan Atlantic coasts. Unfortunately, anatomical descriptions of the animals of the new species are unknown. We also have no reports of alive specimens of *G. pusilla* or *G. macandrewi*.

The identity of *G. triangularis* is problematic. Montagu (1808) created a new taxon, *Mastra minutissima*, to separate specimens with a smooth inner margin. This name was synonymized with *M. triangularis* by Dollfus & Dautzenberg (1902). Adult shells with a smooth inner margin also show other distinctive characters: thinner shells, a more rounded shape, more convex and less steep dorsal margins, and a reduced hinge plate. Wood (1841: 249) erected the new species *Astarte subtrigona* without a formal description, stating that '... the new names are merely provisional, as they are affixed to species in my Cabinet ...', and later Wood (1853: 174) reduced his new taxon to a variety of *Astarte triangularis* (forma *subtrigona*) based on a few shell characters.

Basso (1993) studied 250 valves of *G. triangularis* taken off Montecristo Island (Tuscan Archipelago, Italy). A morphometric study was carried out, showing high variability in the later growth stages, with a morphocline whose ends correspond to the forma *tipica* and *subtrigona* of Wood (1853). She also studied the preservation state of both forms, and found that the best preserved shells belong to the forma *subtrigona*. The oxygen isotopic composition of carbonate in forma *tipica* shells is in equilibrium with sea waters colder than at present, suggesting that the morphocline (ecocline) could represent the response of the species to a changing environment during the last Holocene transgression (Basso, 1993).

We have also found differences in shells from different habitats and localities. For example, the specimens from Brittany and Fuengirola (Figs. 1–3) represent the forma *tipica*, with a

crenulated inner margin, thick-walled shell, triangular shape and wide hinge plate. On the other hand, shells from Alborán or from 'El Parrusset' represent the forma *subtrigona*, either with smooth or crenulated inner margin, thin-walled shell, more rounded outline and narrower hinge plate (Figs. 7–9). Generally it seems that forma *tipica* is Atlantic (or from colder Mediterranean waters in past geological times), while forma *subtrigona* is the current Mediterranean form. However, after studying the variation in shell of this species throughout a large range on localities and depth, both in the Atlantic and the Mediterranean, we cannot conclude that both forms represent different species. Furthermore prodissoconchs of the two most extreme forms do not show more variation than the intrapopulation variation.

Juveniles of *Goodallia* are difficult to identify. Extremely small juveniles that have not definitely developed the cardinal teeth (Figs.

10–11), have been confounded with the species *Mancikellia pumila* (J. de C. Sowerby, 1846) by Cecalupo & Giusti (1989) and may represent any of the Mediterranean species of the genus, most probably co-occurring *G. pusilla*. This problem has been recently addressed by van Aarttsen & Carrozza (1997).

Shell characters, although sufficient for species-level identification, are not adequate to establish phylogenetic relationships among these species. Therefore, no such analysis has been attempted here.

In conclusion, the genus *Goodallia* is widely distributed along European Atlantic coasts into the Mediterranean and north-western Africa (Fig. 33), and includes at least five species. Two of these species seem restricted to small areas: *G. gofasi* new species is so far known only from the type locality off the coast of Agadir and *G. macandrewi* (Smith, 1881) is also known only from the type locality in the Canary

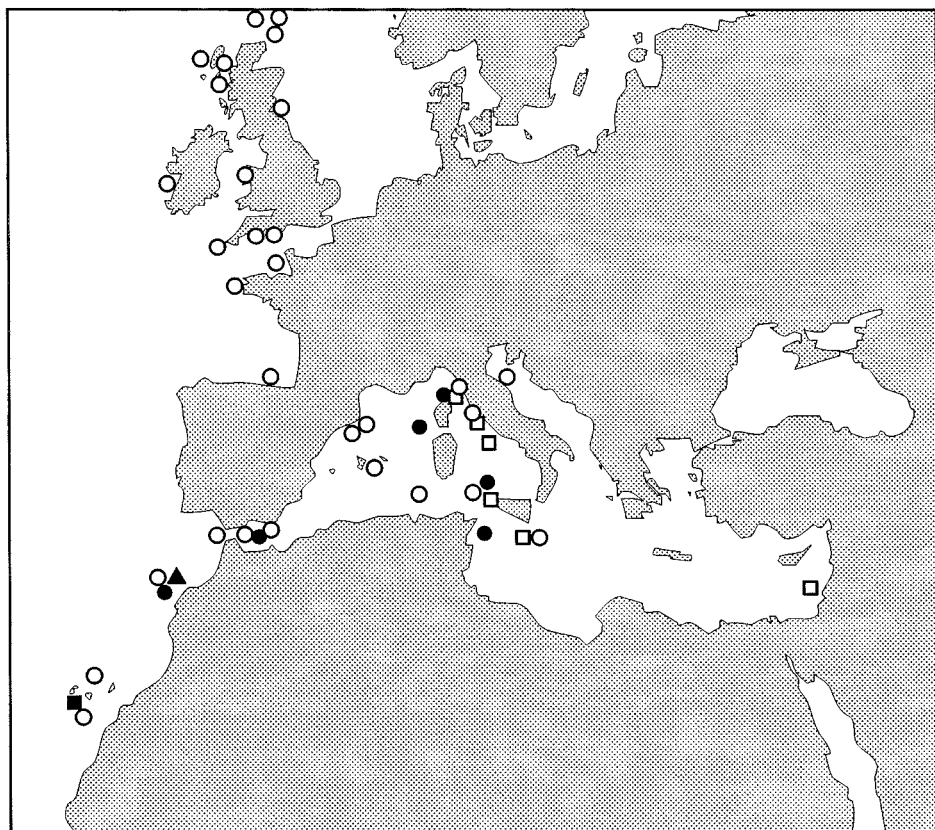


Figure 33. Distribution map of the five species of the genus *Goodallia*: ○—*G. triangularis* (Montagu, 1803); ●—*G. pusilla* (Forbes, 1844); ■—*G. macandrewi* (Smith, 1881); □—*G. micalii* new species; ▲—*G. gofasi* new species.

Islands. *G. micalii* new species is restricted to the central and eastern Mediterranean.

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