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A new species and genus of enigmatic turriform Fasciolariidae from the Central Indo-Pacific

(Gastropoda: Neogastropoda)

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Abstract

A new genus and species of Fasciolariidae, *Angulofusus nedae* n. gen. n. sp. conchologically superficially resembling some Conoidea is described. Radula, anatomy and coloration of the body of the new species suggest that it belongs to subfamily Fusininae, being very similar in anatomy to species of the genus *Amiantofusus*. The species is broadly distributed in the Indo-Pacific, from the Philippines, through Vanuatu and New Caledonia to Wallis and Futuna in 40 to 105 m.

Key words: Fasciolariidae, Fusininae, *Angulofusus*, new genus, new species, Indo-Pacific, anal sinus.

Introduction

Among Neogastropoda the superfamily Conoidea (= Toxoglossa) is one of the most variable in shell shape. Most of the genera that are included currently in Conoidea were previously treated as members of the very large family Turridae, which proved to be polyphyletic (Taylor & al. 1993) and are now referred to as “turrids”.

Conoidea are well known for a high rate of homoplasy in shell characters and their uncanny ability to impersonate many families of Neogastropoda. Numerous members of the Conoidea were originally described in different families — among Columbellidae (e.g. *Columbella* (*Anachis*) *nana* G. Dunker 1871 and several other species now referred to the family Mitromorphidae), Buccinidae (e.g. *Colus* (*Aulacofusus*) *mitrellaformis* Nomura 1940 which belongs to *Daphnella* Hinds 1844, Raphitomidae), Nassariidae (e.g. *Bullia valida* W. Dunker 1852, later referred to *Pusionella* Gray 1847, Clavatulidae) not to mention many others. Alternatively, many species of varied neogastropod families were originally described as conoideans, or “turrids”, including some *Exilia* Conrad 1860 (Ptychatractidae), *Belomitra* Fischer 1882 and *Antimitra* Iredale 1917 (Buccinidae) and *Daphnellopsis* Schepman 1913 (Muricidae) (for more examples, see Bouchet & al. (2011b: appendix 1).

Recent collecting efforts in the West Pacific (Bouchet & al. 2011a) have yielded specimens of a characteristically looking gastropod species, notable in having distinct anal sinus and, therefore, originally tentatively regarded as a conoidean. However, our subsequent studies have shown that its anatomy and radular structure place it in Fasciolariidae, although, the species doesn’t fit any genus of the family described to date.

The family Fasciolariidae comprises carnivorous marine gastropods, widely distributed in tropical and tem-

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perate waters of the World Ocean, mainly at subtidal depths (Harasewych 1998; Snyder 2003). Members of the family usually have medium-sized to large shells, fusiform to biconic, in most cases elaborately sculptured, with well defined siphonal canal (Harasewych 1998). Among the superfamily Buccinoidea the family Fasciolariidae appears first in fossil records, being traced back to Aptian (Lower Cretaceous) (Taylor & al. 1980). Currently the family includes more than 100 genera with high proportion of extinct ones (38 genera are Recent ones), forming three subfamilies, Fasciolariinae, Fusininae and Peristerniinae (WoRMS — Appeltans & al. 2012).

In the present paper we describe the new genus *Angulofusus*, its anatomy and radular morphology and discuss its relationships within the family Fasciolariidae.

Material and methods

The bulk of the material for present study was collected in Balicasag Island (Bohol, Philippines) in January 2008 with lumun-lumun nets (Seronay & al. 2010). Additional specimens were collected previously in New Caledonia, Wallis and Futuna and Santo by several expeditions conducted by the Muséum National d'Histoire Naturelle (Paris, France), including one specimen (Santo 2006, station DS99) that was sequenced for mitochondrial cytochrome oxidase subunit one (courtesy of Nicolas Puillandre) and stored in the MNHN barcode collection. It was photographed alive during the Santo 2006 expedition.

The radula of the holotype was extracted. The shell of this specimen was photographed and bored with a microdrill; the soft body was then extracted and dissected. The radular sac was separated and placed in 5% solution of potassium hypochlorite until the soft tissues were completely dissolved. The radula then was cleaned in several shifts of distilled water, unfolded, air-dried and mounted for SEM analysis.

Abbreviations:

AL	aperture length;
BWL	body whorl length;
SB	shell breadth;
SL	shell length;
MNHN	Muséum National d'Histoire Naturelle, Paris, France;
SMF	Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt a. M., Germany;
ZIN	Zoological Institute, Russian Academy of Sciences, St.-Petersburg, Russia

Results

Systematics

Family Fasciolariidae Gray 1853

Subfamily Fusininae Wrigley 1927

Type genus: *Fusinus* Rafinesque 1815

Genus ***Angulofusus*** n. gen.

Type species: *Angulofusus nedae* n. sp.

Diagnosis: shell small, height around 9–10 mm, fusiform, with high spire. Whorls strongly angulated, with distinct shoulder at mid-height. Suture distinct. Sculpture consists of broadly spaced, strong, sharp axial ribs and regularly spaced spiral cords intercalated with fine spiral rows of small dense tubercules. Siphonal canal well defined, sometimes recurved abaxially. Aperture narrow oval, outer lip thickened and turned inward. Inner lip reflected; columella with 3–4 low folds. Distinct subsutural rounded anal sinus delimited from aperture by strong denticle, formed by callus on parietal region of aperture. Operculum corneous, elongated with terminal nucleus shifted adaxially. Radula very long, consists of more than 150 transversal rows of teeth, with narrow tricuspidate central tooth and two massive laterals, bearing six strong cusps.

Angulofusus nedae n. sp.

Figs 1–3

1986 *Lienardia* sp., – Springsteen & Leobrera: 279, Plate 80(6).

Type material (Fig. 1, A–L): Holotype (MNHN 25056): 10.85 × 4.65 mm, 9°30.9'N 123°41.2'E, Balicasag Is., Bohol, Philippines, lumun-lumun net, 40–60 m (Fig. 1 A–C). — Paratypes: paratypes 1–5: same locality as holotype; paratype 1 (MNHN 25057): 9.65 × 4.2 mm, (Fig. 1 D, E); paratype 2: 9.15 × 4.25 mm, (Fig. 1 F–H) (SMF 339726); paratype 3: 8.9 × 3.95 mm, (Fig. 1 I, J) (SMF 339727); paratype 4: 8.15 × 3.75 mm, (Fig. 1 K) (ZIN 61538); paratype 5: 7.8 × 3.65 mm, (Fig. 1 L) (ZIN 61538); paratype 6: 7.1mm, Santo 2006, St. DS99, 15°32.4'S 167°16.9'E; 100–105 m (Fig. 2 A, B) (MNHN 25148, sequenced specimen, GenBank accession no. ****).

Type locality: Philippines: Bohol: Balicasag Island, 40–60 m.

Additional material examined: Philippines: 9.1 × 4.3 mm, Mactan Island, Cebu, 40 m; PANGLAO 2004, Balicasag Island, Stn. L42, 9°31.2'N 123°40.7'E, 80–90 m 1

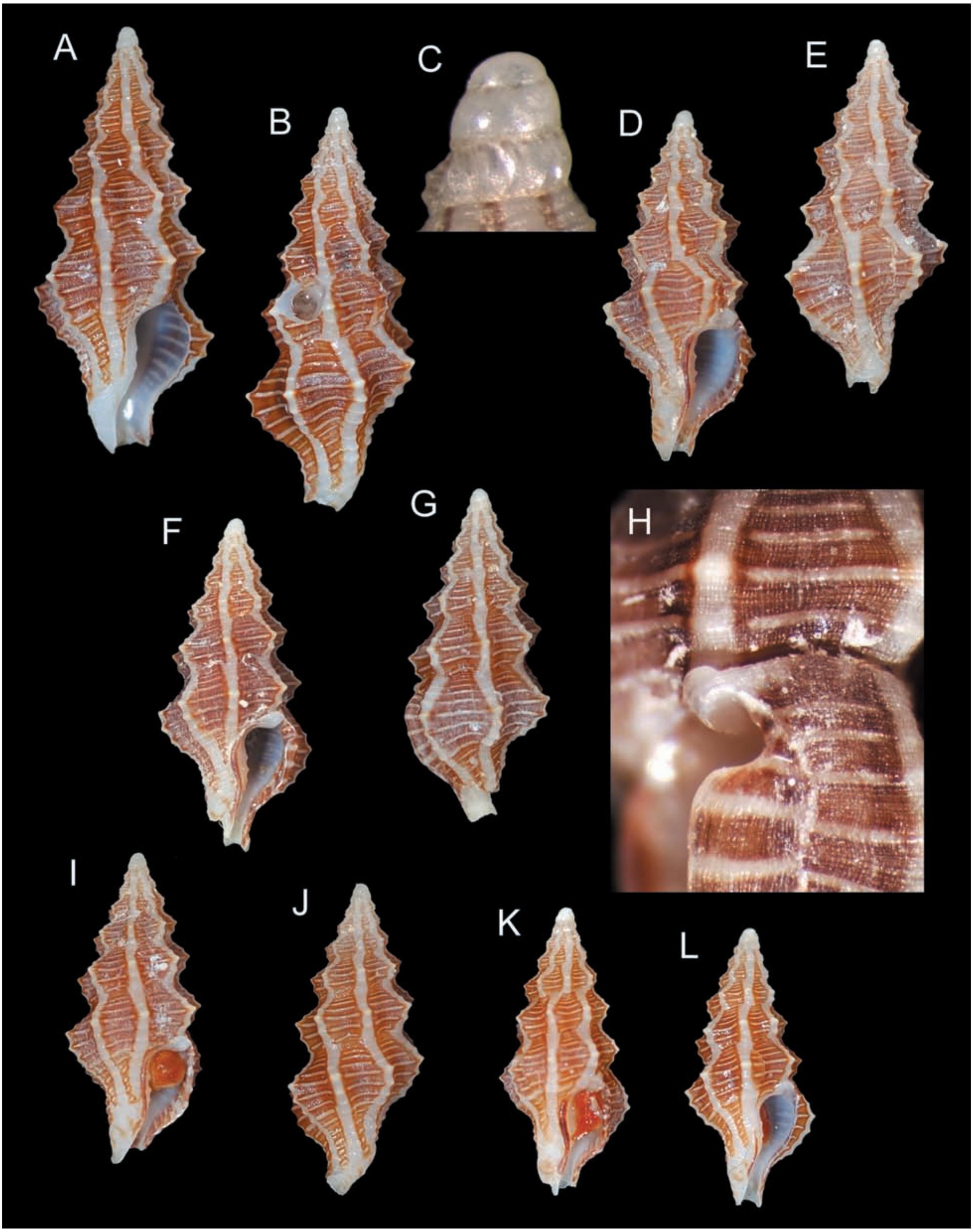

Figure 1. Type series of *Angulofusus nedae* n. sp. A–C – Holotype, 10.85 mm; D, E – paratype 1, 9.65 mm; F–H – Paratype 2, 9.15 mm; I, J – paratype 3, 8.9 mm; K – paratype 4, 8.15 mm; L – paratype 5, 7.8 mm.

dead shell; Stn. L44, 9°30.8'N 123°41.0'E, 85–100 m, 1 dead shell; Stn. L46, 9°30.9'N 123°41.2'E, 90–110 m, 1 dead shell; Stns. L69-73, 9°30.7'N 123°40.9/41.0'E, 90–98 m, 1 dead shell; Stns. L74-75, 9°30.7'N 123°40.9/41.0'E, 120–139 m, 2 dead shells; Stn. P3, 9°31.1'N 123°41.5'E, ca. 100 m, tangle nets from local fishermen, 1 dead shell; Panglao Island, off Momo

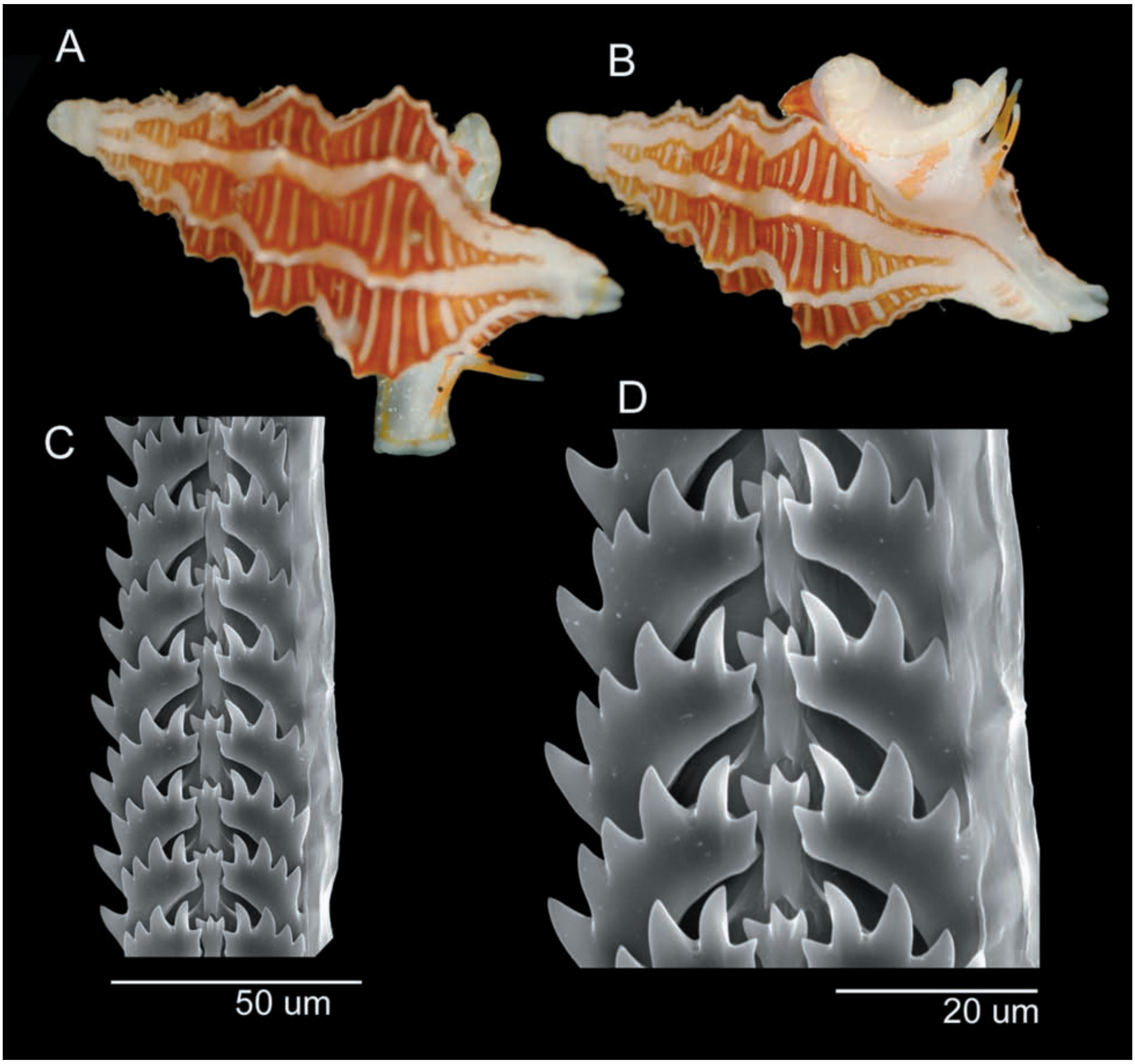

Figure 2. Morphology of *Angulofusus nedae* n sp. A, B – Live specimen, paratype 6 (sequenced specimen), shell length 10 mm, Santo 2006, Stn. DS99, 65–120 m; C, D – Radula (extracted from holotype).

Beach, Stn. L76, 9°36.5'N 123°45.3'E, 80 m, 9 dead shells; Bohol Island, Maribohoc Bay, Stn P1, 9°36.1'N 123°45.0'E, 90–200 m, tangle nets from local fishermen, 1 dead shell. New Caledonia: LAGON, Stn. 830, 20°49'S 165°19'E, 105–110 m, 4 dead shells; BATHUS 1, Stn. DW678, 20°49'S, 165°19'E, 94–100 m, 1 dead shell; BATHUS 1, Stn. DW692, 20°35'S, 164°59'E, 140–150 m, 1 dead shell (MNHN). Vanuatu, Santo'06, Stn. DS99, NW Tutuba Island, 15º32'28.02"S 167º16'5.18"E, 100–105 m, 1 dead shell (MNHN). Fiji: MUSORSTOM 10, Stn DW1333, 16°50'S 178°13'E, 200–215 m, 1 dd. SW Pacific. Wallis and Futuna, MUSORSTOM 7, Stn. DW601, 13º19'S 176º17'W, 350 m, 1 dead shell (MNHN).

Range: Central Philippines, New Caledonia, Vanuatu, Fiji, Wallis and Futuna, alive in 40–105 m, dead shells down to 350 m.

Etymology: the species is named after NEDA BARGHI in Marine Science Institute, University of the Philippines, Manila. She joined the authors in the collecting trip to Balicasag Island and was fascinated by the idea of naming animal species after people; her personal fascination obviously deserves a species named after her.

Description: Shell fusiform to turriform in larger specimens (SB/SL 0.43 in larger to 0.47 in smaller specimens; AL/SL 0.38 to 0.46). Protoconch orthoconoid, of 3 white convex whorls, two initial whorls smooth, the third whorl with fine opisthocyrt widely spaced axial ribs progressively more pronounced towards teleoconch. Protoconch/teleoconch transition abruptly marked by appearance of definite spiral sculpture. Teleoconch of 5.5 to 7 (holotype) whorls, strongly angulated at periphery starting from 3rd. Suture distinct. Besides numerous growth lines axial sculpture of strong, sharp, axial ribs (7 per whorl, slightly shifting in position from whorl to whorl), separated by deep concave interspaces. Spiral sculpture of 4–6 narrow, evenly spaced spiral cords on spire whorls, which form minute nodules when intersecting spiral ribs. Interspaces between spiral cords sculptured by dense rows of spirally arranged tubercles (Fig 1 H), up to 6 between adjacent spiral cords. Body whorl with 4 spiral cords on shoulder slope, a 5th one marking shoulder, followed by 5 cords on shell base.

Siphonal canal distinct, sculptured with strong spiral cords similar to those on shell base. Siphonal canal notably recurved backward; fasciole indistinct.

Aperture reversed drop-shaped, outer lip rounded, slightly thickened and turned inwards. Inside outer lip with 4–6 fine spiral lirae. Inner lip reflected, arched, extending downwards to form a margin on siphonal canal, brown. Columella with 3–4 folds. Adapical side of aperture wide, at conjunction of outer lip and body whorl with a strong denticle which delimits a wide and relatively deep rounded anal sinus, present in adults at growth termination.

Background colour brown, with crests of axial ribs and spiral cords off-white. Tip of siphonal canal white.

Operculum corneous, elongated with terminal nucleus shifted adaxially. Background colour red-brown with vague longitudinal lighter strips.

Soft body off-white in live animals with light orange narrow line fringing ventral part of foot at border with sole and irregular marks on remaining part of foot, head and tentacles orange. Distinctive black eyes at the midlength of head tentacles (Fig. 2 A, B).

Radula of holotype (Fig 2, C, D) proportionally very long, consists of more than 150 transversal rows, length around 3 mm (0.7 of aperture length), width *ca* 40 µm (0.9% of aperture length). Each transversal row consists of a narrow central tooth with long base and three short stout cusps, flanked by two massive laterals. Each lateral tooth bears six strong and relatively short cusps, of which the innermost is smallest.

The anatomy was studied in an adult female (SL 9.1 mm, BWL 5.6 mm, AL 4.3 mm, SB 4.2 mm). Body in alcohol completely lacking pigmentation, light yellow. Body of 3.5 whorls, mantle spanning about one whorl. Columellar muscle forming 1.5 whorls, thick, not split into branches. Head contracted, very short with medium long tentacles and distinct eyes. Nephridium short with transparent walls, nephridial gland narrow (Fig. 3 B – ng). Digestive gland occupies ventral part of upper whorls of visceral mass, border line between digestive gland and ovary slightly wavy (Fig. 3 A–B).

Foot thick, short when contracted, rounded posteriorly. Propodium (Fig. 3 B – prp) very narrow, hardly separated from metapodium by very narrow and shallow propodial cleft.

Mantle cavity: Mantle cavity long (Fig. 3 C), its length about 2 times width, mantle edge even except for a shallow but distinct notch (Fig. 3 C – mn) corresponding to the anal notch of shell, mantle edge slightly thickened. Siphon with thick walls, medium long, extending beyond mantle edge. Ctenidium very long, spans nearly entire mantle length, narrow, consisting of tall triangular lamellae, tallest in central part of ctenidium where lamellae bear short flagellae. Osphradium twice as wide as ctenidium and about 0.5 of its length, slightly assymmetrical, with broad axis, light brown. Its lamellae on right side are wider than on left side. Hypobranchial gland indistinct, narrow, lacking folds, covered with mucus layer. Rectum narrow, short, less then half of mantle length, thin-walled. Rectal gland absent.

Alimentary system (Figs. 3 D–G): Proboscis very long and narrow in contracted state (about 4 mm, or 0.93 AL), with smooth walls, occupying most of rhynchocoel length, rhynchodaeum thin, semitransparent. Proboscis length about 10 times its diameter. Mouth opening broad compared to proboscis diameter, with shape of dorso-ventrally compressed narrow slit. Proboscis retractor large (Figs. 3 – prr), unpaired, attached to rhynchodaeum ventrally at its mid-length and to columellar muscle at end of very long body haemocoel that spans about one whorl.

Oesophagus leaving proboscis posteriorly, narrow, dorso-ventrally compressed and forming very long loop (Fig. 3 E). Valve of Leiblein (Fig. 3 F – vL) large compared to oesophagus diameter, pyriform, situated anterior to tip of retracted proboscis, mucous circular pad visible through transparency of valve walls. Circumoesophageal nerve ring not large (Fig. 3 D–E – nr), concentrated and covered with thick connective tissue layer, which is obscuring borders between ganglia. Mid-oesophagus, after passing through nerve ring, and posterior oesophagus of same diameter as anterior oesophagus. Gland of Leiblein very long (Figs. 3 D–E – gL), broad-tubular, uncoiled, tapering posteriorly, in posterior part and dorsally in medial part very light brown, anteriorly creamy.

Salivary glands medium-sized, situated on both sides of anterior part of rhynchodaeum, adjoining on its dorsal side, and covering circumoesophageal nerve ring and most of valve of Leiblein (Figs. 3 – rsg, lsg). Glands white, acinous judging from external view. Salivary ducts thin leaving glands to fuse with walls of oesophagus immediately anterior to valve of Leiblein,. Accessory salivary glands absent. Stomach small (Fig. 3 G – st), broadly U-shaped, without posterior mixing area. Outer stomach wall covered by thin but distinct transverse folds visible by transparency. Posterior oesophagus opening ventro-posteriorly into stomach (Fig. 3 G – poe).

Remarks: *Angulofusus nedae* n. sp. conchologically resembles members of conoidean family Clathurellidae in general outline, shape of outer lip and presence of distinct anal sinus of a similar shape. However, Clathurellidae usually have rounded whorls outline and spiral sculpture dominating over axial. Apart from that Clathurellidae have different protoconchs, lack operculum and never have a reflected inner lip. An inner lip similar to that in *Angulofusus nedae* n. sp. is common in members of the family Muri-

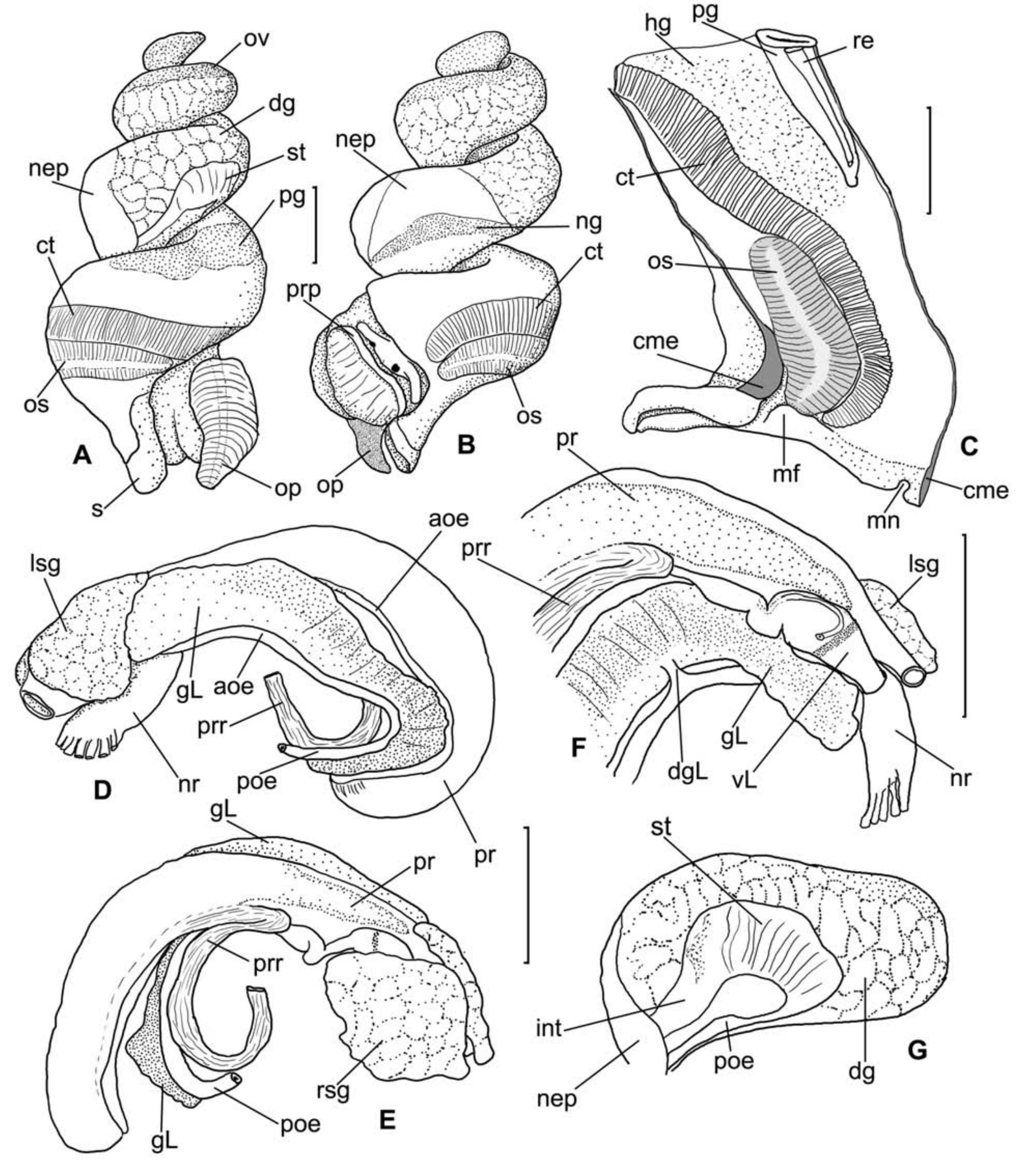

Figure 3. Anatomy of *Angulofusus nedae* n. sp. A, B – general morphology of the soft body; C – mantle; D–F – foregut anatomy; G – stomach. Abbreviations: aoe – anterior oesophagus; cme – cut mantle edge ; ct – ctenidium; dg – digestive gland; dgL – duct of gland of Leblein; gL – gland of Leblein; hg – hypobrancheal gland; int – intestine; lsg – left salivary gland; mf – mantle fold; mn – notch of mantle; nep – nephridium; ng – nephridial gland; nr – circumoesophageal nerve ring; op – operculum; os – osphradium; ov – ovary; pg – pallial gonoduct; poe – posterior oesophagus; pr – proboscis; prp – propodium; prr – proboscis retractor; re – rectum; rsg – right salivary gland; s – siphon; st – stomach; vL – valve of Leblein. Scale bars: 1 mm.

cidae, which, however, always have an elliptical aperture with no anal sinus and a nearly enclosed siphonal canal.

Within the family Fasciolariidae *Angulofusus nedae* n. sp. somewhat resembles *Fusinus wallacei* HADORN & FRAUSSEN 2006 in having angulated whorls and in general shell sculpture; however *A. nedae* n. sp. has a distinctive anal sinus, wider interspaced axial ribs and a shorter siphonal canal.

Discussion

One of the intriguing characters of the new species is the well formed anal sinus of the shell, in all respects similar to that of some Conoidea. Judging from the growth lines of the shell, the anal sinus is formed at the end of the shell growth and therefore is absent in specimens with not completely formed outer aperture lip (including holotype). The function of the notch remains unclear. Although *Angulofusus nedae* n. sp. looks misleadingly similar to some members of Clathurellidae (for example, the genera *Lienardia* Jousseaume 1884 or *Clathurella* Carpenter 1857), its anatomy and radular morphology undoubtedly place it in the Fasciolariidae.

The subfamilial assignment of the genus *Angulofusus* is not apparent, however we would suggest it to belong to the subfamily Fusininae, basing on following evidence:

Radular structure: Both the narrow central tooth and massive laterals with relatively few strong cusps agree well with the radulae of studied species of the subfamily Fusininae. Radulae with very similar morphology were found in the genus *Amiantofusus* Fraussen, Kantor & Hadorn 2007 (Fraussen & al. 2007) (especially, *Amiantofusus amiantus* (Dall 1889)), and species of the genera *Fusinus* Rafinesque 1815 and *Granulifusus* Kuroda & Habe 1954 (Bouchet & Warén 1985; Hadorn & Fraussen 2005; Hadorn & Fraussen 2006). Species of the subfamily Fasciolariinae studied to date (for example, *Fasciolaria tulipa* (Linnaeus 1758), *Pleuroploca trapezium* (Linnaeus 1758)) possess characteristic multicuspidate laterals, bearing 15 to more than 35 cusps each (Bandel 1984; Wells 1969), which differ strikingly from the radula of *Angulofusus nedae* n. sp. The subfamily Peristerniinae shows great variability in radular morphology. In most genera, such as *Latirolagena* Harris 1897 or *Peristernia* Mörch 1852, radulae have wide lateral teeth with numerous cusps, more or less similar to radulae of Fasciolariinae (Taylor & Lewis 1995). However, some species of the genera *Turrilatirus*, Vermeij & Snyder 2006 (*T. turritus* (Gmelin 1791)) or *Leucozonia* Gray 1847 (*L. ocellata* (Gmelin 1791)) (Bandel 1984) have radulae with rather narrow central base and laterals with fewer cusps, that generally resemble radula of *Angulofusus nedae* n. sp., although with more cusps on the lateral teeth.

Coloration of the soft body: Members of the fasciolariid subfamilies Fasciolariinae and Peristerniinae are notable because of intensive red coloration of their head–foot that makes them easily recognizable at a glance. On the contrary, members of the subfamily Fusininae have bodies of white colour as is the case with *Angulofusus nedae* n. sp.

Apart from these evidences, the protoconch of *Angulofusus nedae* n. sp. – of 3 whorls with axial ribs sculpturing last 1/3 whorl – strongly resembles the protoconchs found in some species of the genus *Fusinus* (*F. alcyoneum* Hadorn & Fraussen 2006) and *Amiantofusus* (*A. amiantus*) (Bouchet & Warén 1985; Hadorn & Fraussen 2006; Fraussen & al. 2007).

We used BLAST search to compare the available CO1 sequence of *Angulofusus nedae* n. sp. (658 nucleotides, GenBank number ***) with other CO1 sequences in the GenBank. No high similarity of this sequence to any other accessible in NCBI database was found. Nevertheless, the highest of all sequences BLAST scores, 702 to 743 (query coverage 94–99%; max. ind. 86–87%), were displayed by 10 CO1 sequences obtained from specimens of undescribed species of the genus *Granulifusus* (Fasciolariidae, Fusininae). Unexpectedly the next fasciolariid sequence in the list of most similar to query (*Turrilatirus turritus*) was in 37th position with the BLAST score of 651. None of accessible CO1 sequences of *Fusinus* spp. fell within the 100 most similar results. Molecular data indicate that *Angulofusus nedae* n. sp. is most close to *Granulifusus* species, thus confirming our proposed subfamily assignment. The poor similarity with other Fasciolariidae is probably due to the low representation of the family in the NCBI database.

Anatomically the new genus is also very similar to *Amiantofusus*, both in digestive system anatomy and mantle complex. Fasciolariidae remains anatomically relatively poorly studied so far. Besides the description of the anatomy of *Leucozonia nassa* (Gmelin 1791) (Marcus & Marcus 1962) and *Microfulgur carinatus* (Ponder 1970), two species of *Amiantofusus* (Fraussen, Kantor & Hadorn 2007) and 7 other species (Kosyan & al. 2009) were recently examined. With the addition of more species, it is becoming obvious that Fasciolariidae anatomically is a rather heterogeneous group, although at least two characters are shared by all studied species – the presence of only one or two proboscis retractors and the absence of posterior mixing area of the stomach. In the presumably closely related Buccinidae, the proboscis retractors are numerous, arranged in symmetrical bundles at both sides of the rhynchodaeum (Kosyan & al. 2009), while the posterior mixing area of the stomach is present in most studied species (Kantor 2003).

The relationships of subfamilies within Fasciolariidae and their status remain unclear (Snyder 2003). None of molecular studies published to date (Hayashi 2005; Kosyan & al. 2009; Zou & al. 2011) had enough resolution and coverage in the family Fasciolariidae to clarify its relationships or confirm its monophyly. Being large and morphologically heterogeneous, the family Fasciolariidae could potentially comprise paraphyletic groups and requires further morphological and molecular studies.

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