

# First report of two ark shells, *Anadara consociata* (E.A. Smith, 1885) and *A. troscheli* (Dunker, 1882) (Arcidae: Anadarinae) from Indian waters with notes on morpho-taxonomy of some related species from east coast of India

Prasad Chandra Tudu<sup>1\*</sup>, Prasanna Yennawar<sup>2</sup> and Anil Mohapatra<sup>1,3</sup>

<sup>1</sup>Marine Aquarium and Regional Centre, Zoological Survey of India, Digha - 721428, West Bengal, India; tuduprasad.c@zsi.gov.in

<sup>2</sup>Freshwater Biology Regional Centre, Zoological Survey of India, Hyderabad - 500048, Telengana, India

<sup>3</sup>Estuarine Biology Regional Centre, Zoological Survey of India, Gopalpur-on-Sea - 761002, Odisha, India

## Abstract

Two species of ark shells i.e., *Anadara consociata* (E.A. Smith, 1885) and *Anadara troscheli* (Dunker, 1882) reported for the first time from Indian waters. These two species were identified based on the collections from different surveys along east coast of India and specimens of National Zoological Collections of Marine Aquarium and Regional Centre, Zoological Survey of India, Digha. Overall eleven species of subfamily Anadarinae of family Arcidae are presented in the current paper. The taxonomic compilation of the eleven species is done with specimens available in the study localities. A key of the eleven species is presented here for future references. These two species are overlooked with related species during the earlier studies from this region.

**Keywords:** Anadarinae, *Anadara*, East Coast of India, First report, *Mosambicarca*, *Tegillarca*

## Introduction

The ark shells are the bivalve molluscs of subfamily Anadarinae, family Arcidae and order Arcoidea (Bieler *et al.*, 2010). These bivalves are widely distributed in tropical and subtropical regions of the World oceans, although the highest diversity in the Indian and Pacific oceans (Evseev and Lutaenko, 1998); and the subfamily comprises 60 valid species, of which 38 species are known to date from Indo-Pacific region (Lutaenko, 2011). Several earlier studies on inventorisation of mollusc along the Indian coast has been done by Nevill (1880), Annandale (1907,1922), Preston (1915), Hornell (1917), Satyamurti (1956), Kundu (1965), Choudhury *et al.* (1984), Subba Rao *et al.* (1983, 1991, 1992, 1995a, b), Subba Rao (1977, 2017), Janaki Ram and Radhakrishna (1984), Goswami (1992), Rama Rao *et al.* (1992), Edward and Ayyakkannu (1992), Nagabhushanam and Krishnan (1993), Hameed and

Samasundaram (1998), Apte (1998), Surya Rao and Maitra (1998), Subba Rao and Dey (2000), Mahapatra (2001), Hylleberg and Kilburn (2002), Khan (2003), Ramakrishna *et al.* (2003), Dey *et al.* (2005), Dey and Mitra (2005), Dey (2006), Lutaenko (2006), Dey and Ramakrishna (2007), Mitra *et al.* (2010), Ramakrishna and Dey (2010), Pati and Sharma (2012), Yennawar and Tudu (2014), Souji and Radhakrishnan (2015) and Tudu *et al.* (2018a,b). Till date there are twenty-three species, including three freshwater species of ark shells of subfamily Anadarinae are reported from Indian waters i.e. *Anadara antiquata* (Linnaeus, 1758), *A. compacta* (Reeve, 1844), *A. cornea* (Reeve, 1844), *A. craticulata* (Nyst, 1848) [= *A. (Scapharca) clathrata*, (Reeve, 1844) (Subba Rao *et al.*, 1991)], *A. deshayesi* (Hanely, 1856), *A. ehrenbergi* (Dunker, 1868), *A. ferruginea* (Reeve, 1844), *A. gubernaculum* (Reeve, 1844), *A. inaequalvis* (Bruguière, 1789), *A. indica* (Gmelin,

\* Author for correspondence

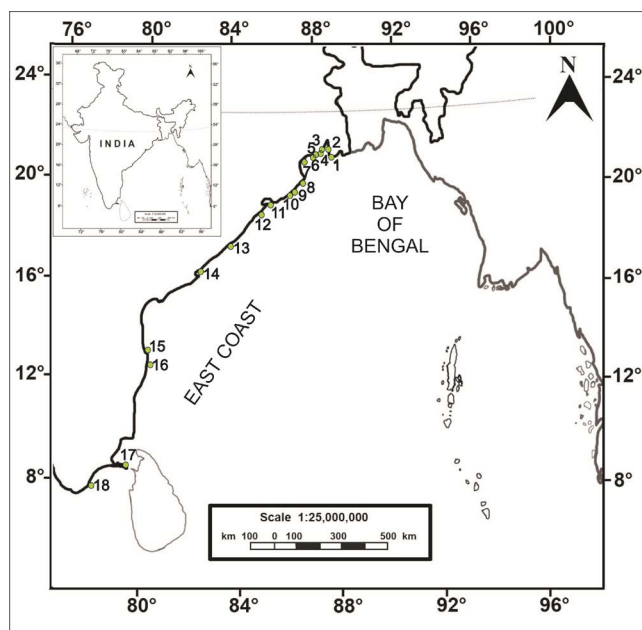
1791) [= *A. (Scapharca) deyrollei*; *A. (Scapharca) japonica* (Reeve, 1844) (Subba Rao, 2017)], *A. natalensis* (Krauss, 1848), *A. pilula* (Reeve, 1843), *A. pumila* (Dunker, 1868), *A. trapezia* [= *A. (Scapharca) lischkei* (Dunker, 1868) (Mollusca Base, 2018)], *A. uropigimelana* (Bory de Saint-Vincent, 1827) [= *Anadara holocerica* (Reeve, 1843) (Subba Rao, 2017)], *Mosambicarca erythraeonensis* (Jonas in Philippi, 1851), *Tegillarca aequilatera* (Dunker, 1868), *T. granosa* (Linnaeus, 1758), *T. nodifera* (Martens, 1860), *T. rhombea* (Born, 1778) and three freshwater species sometimes inhabiting brackish water are i.e., *Scaphula celox* Benson, 1836, *S. deltae* Blanford, 1867 and *S. nagarjunai* Janaki Ram and Radhakrishna, 1984. Present report consist of eleven species belongs to the subfamily Anadarinae of which two species *Anadara consociata* (E.A. Smith, 1885) and *A. troscheli* (Dunker, 1882) are first ever report from Indian waters. These two species are overlooked with similar species like *A. ehrenbergi* (Dunker, 1868) and *T. rhombea* (Born, 1778) respectively.

## Material and Methods

Specimens of National Zoological Collections (NZC) present at Marine Aquarium and Regional Centre (MARC), Zoological Survey of India (ZSI), Digha and recent collections are accessed and identified. All the shells are collected randomly from intertidal zone; either live or as disjointed shells. All the collection localities are along the East coast of India (Figure 1). Classification follows Bieler *et al.* (2010) and descriptions are adopted from Narasimham (1988), Poutiers (1998), Evseev and Lutaenko (1998) and Subba Rao (2017). The specimens were photographed using Olympus PEN E-PL1 (Olympus Corporation, China), Sony Cyber shot W510 and Sony DSC hx400v digital camera (Sony Corporation, Tokyo, Japan) and morpho-metric measurements (length=L and height=H) were taken using vernier calliper (Mitutoyo, Japan). Geographical coordinates are obtained by Garmin GPS (Model No. GPS 72H and OREGON 550) and Sony DSC hx400v digital camera with GPS.

## Results

Altogether eleven species belonging to three genera of subfamily Anadarinae under family Arcidae are identified and presented in this study. Out of which two species are



**Figure 1.** Collection localities, 1-Bokhali, 2-Sagar Island, 3-Junput, 4-Jalda (Tajpur), 5-Digha, 6-Udaypur & Talsari, 7-Chandipur, 8-Paradip, 9-Chandrabhaga, 10-Puri, 11-Chilka New Mouth, 12-Gopalpur, 13-Vishakhapatnam, 14-Kakinada, 15-Pulicat lake, 16-Chennai, 17-Rameswaram, 18-Tuticorin.

new records to Indian waters and a concise morpho-taxonomic compilation (with figure) of all the eleven species is done with available examples. A brief taxonomic description is given below:

## Systematic accounts

Order ARCOIDA Gray, 1854

Superfamily ARCOIDEA Lamarck, 1809

Family ARCIDAE Lamarck, 1809

Subfamily ANADARINAE Reinhart, 1935

Genus *Anadara* Gray, 1847

Type species *Arca antiquata* Linnaeus, 1758

### 1. *Anadara antiquata* (Linnaeus, 1758) (Fig. 2; a & b)

1758. *Arca antiquata* Linnaeus, 694

1844. *Arca creanata* Reeve, sp. 51

1844. *Arca hankeyana* Reeve, sp. 68

1844. *Arca maculosa* Reeve, sp. 24

1998. *Anadara (Anadara) antiquata*: Evseev & Lutaenko, 8. pl. 1, fig. J

1998. *Anadara antiquata*: Poutiers, 146

2010. *Anadara antiquata*: Ramakrishna & Dey, 62

2017. *Anadara antiquata*: Subba Rao, 58

**Material examined:** 1ex, Gopalpur (19°15.449'N and 084°54.559'E), 3-II-2008, coll. P. Yennawar, (Reg. No. MARC/ZSI M3556); 1ex, Rameswaram (09°16.867'N and 079°18.879'E), 7-IX-2014, coll. P.C. Tudu, (MARC/ZSI M4143); 2ex, Tuticorin (08°47.575'N and 078°09.636'E), 9-IX-2014, coll. P.C. Tudu, (MARC/ZSI M4145).

**Description:** Shell medium in size (L up to 51mm & H up to 45mm), equivalve, solid, equilateral, obliquely ovate and elongate in outline, posterior margin nearly straight, extending along the postero-ventral corner; anterior margin convex, smoothly rounded ventrally, ventral margin nearly straight. Umbones much inflated, situated rather forwards, cardinal area narrow and elongate. Radial ribs 34-44 in number, ribs twice as wide as their interspaces, arcuated in cross section and ornamented with regular ridges. Ligamental area triangular, without ligamental grooves, its maximal wide situated posterior of the beaks. Beak prosogyre and medium in height; slightly depressed in their middle part, hinge plate thickened, hinge series equal to each other, with the centre posterior of the beaks. No byssal gape. Periostracum of the radial ribs brown in colour, squamated, long cilia in the space between ribs, coarse and velvety. Outside of shell white in colour covered with periostracum, inner side white and light yellow in the umbonal cavity.

**Distribution:** In India: Andaman and Nicobar Islands, Andhra Pradesh, Goa, Gujarat, Kerala, Maharashtra, Odisha, Tamil Nadu (Ramakrishna and Dey, 2010); Elsewhere: Australia and New Caledonia, East coast of Africa, Japan, Hawaii, Red Sea (Evseev and Lutaenko, 1998; Poutiers, 1998), Singapore (Tan and Woo, 2010), China, Philippines, Vietnam (Evseev and Lutaenko, 1998), Madagascar (Poutiers, 1998), Indonesia, Myanmar, Mauritius, Sri Lanka, Zanzibar (Ramakrishna and Dey, 2010), East Africa to Central Pacific (Tebano and Paulay, 2000).

**Remarks:** According to Evseev and Lutaenko (1998), Tebano and Paulay (2001) and Poutiers (1998), the range of radial ribs for this species is 35-40; 35-39 and up to 44 respectively. Here, our specimen has range from 34 to 35, hence, it is considered that numbers of radial ribs for this species is 34-44.

## 2. *Anadara consociata* (E.A. Smith, 1885) (Fig. 2; c - e)

1885. *Arca consociata* E.A. Smith, 19

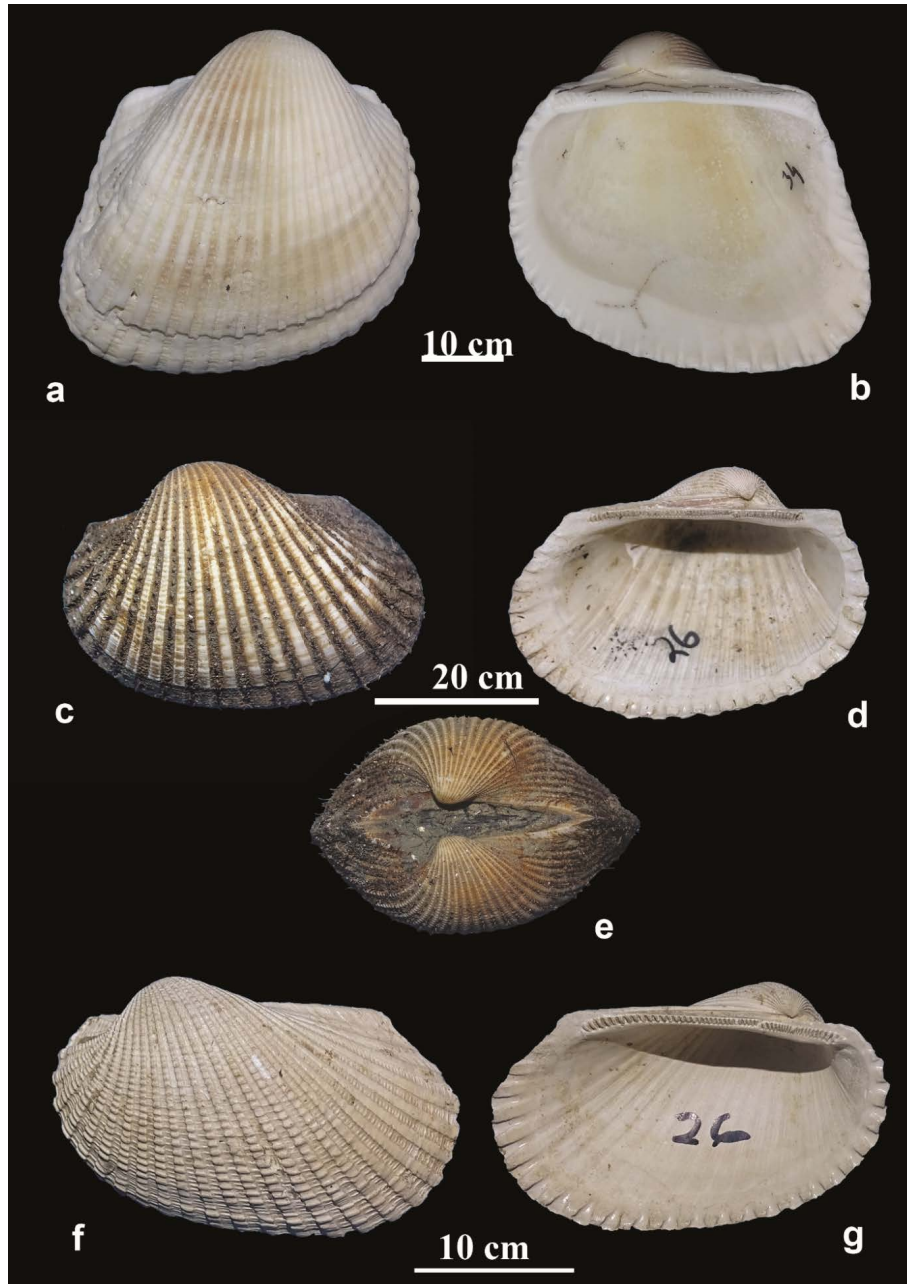
1998. *Anadara (Mabellarca) consociata*: Evseev and Lutaenko, 8

**Material Examined:** 38ex, Rameswaram (09°16.867'N and 079°18.879'E), 7-IX-2014, coll. P.C. Tudu, (MARC/ZSI M4140).

**Description:** Shell medium in size (L up to 34mm and H up to 23.4mm), equivalve, elongate ovate; ventral margin smoothly arcuated and widely rounded towards the anterior and posterior sides. Umbones somewhat inflated, situated rather forwards, cardinal area narrow and elongate. Radial ribs not wide, flattened, squarish or somewhat concave in cross-section in adults, and narrow, triangular in cross section, ornamented in top with closely situated and well-rounded nodules in both juvenile and adults; number of ribs 21-27; there are fine regular ridges in interspaces of the ribs and width of interspaces smaller than width of ribs. Ligamental area narrow, with shorter and wider anterior side compared to posterior side; ligament opisthodetic, however its narrow strip continues anteriorly before area border, with 1-2 chevron grooves. Beak prosogyrate, shifted anteriorly; tooth plate divided in two series a little posterior in beak, the anterior series twice as short as posterior series. Periostracum brown or dark brown, finely rugulated on the interspaces of ribs at certain interval which is visible under microscope only. Outside of shell grey white or cheesy white in colour and inner with whitish colour.

**Distribution:** In India: Tamil Nadu (present report); Elsewhere: Arafura Sea (Northern Australia) (Smith, 1885), China Sea, widely distributed in Vietnam (Evseev and Lutaenko, 1998).

**Remarks:** This species is the first ever report from Indian waters, from Tamil Nadu (Rameswaram). This species is quite similar with *A. ehrenbergi* (Dunker, 1868) in general appearance and in number of radial ribs but radial ribs of *A. consociata* contains rounded nodules and ribs are triangular in cross section; in compared to the radial ribs of *A. ehrenbergi* having regular ridges and squarish in cross section of ribs.



**Figure 2.** a-b, *Anadara antiquata* (Linnaeus, 1758); a- exterior of right valve, b- interior of right valve; c-e, *A. consociata* (E.A. Smith, 1885), c- exterior of left valve, d- interior of left valve & e- dorsal view of umbo; f-g, *A. ehrenbergi* (Dunker, 1868), f- exterior of left valve, g- interior of left valve.

**3. *Anadara ehrenbergi*** (Dunker, 1868) (Fig. 2; f & g)

1868. *Anomalocardia ehrenbergi* Dunker

1997. *Anadra ehrenbergi*: Al-Khayat, 486

2006. *Anadara* (?*Imparilarca*) *ehrenbergi*: Luatenco, pl.5, fig.A-H

2010. *Anadra ehrenbergi*: Ramakrishna and Dey, 62

*Material examined*: 1ex, Vishakhapatnam (17° 42.452'N and 083° 18.823'E), 23-VI-2013, coll. A. Mohapatra and P.C. Tudu, (MARC/ZSI M4156).

*Description*: Shell medium in size (L up to 25.7mm & H up to 16.3mm), equivalve, elongate ovate; ventral margin

smoothly arcuated and somewhat more or less curve; anterior margin rounded, and posterior margin widely rounded. Umbones much inflated, situated at anterior part, cardinal area quit narrow and elongate. Radial ribs not wide, flattened, squarish in cross-section, ornamented in top with fine regular ridges; number of ribs 26; there are fine regular ridges in interspaces of the ribs; width of interspaces is as wide as radial ribs. Ligamental area narrow, with shorter and narrower anterior side compared to posterior side; ligament opisthodontic, with chevron grooves. Beak prosogyrate, shifted anteriorly; tooth plate divided in two series a little posterior in beak, the anterior series twice as short as posterior series. Periostracum not found in this specimen as it is adequately old. Outside of shell greyish white or cheesy white in colour and inner with white in colour.

*Distribution:* In India: Andhra Pradesh (present report), Gujarat and Tamil Nadu (Ramakrishna and Dey, 2010); *Elsewhere:* Qatar (Al-Khayat, 1997), throughout Indo-Pacific (Ramakrishna and Dey, 2010).

*Remarks:* Details mentioned in the *A. consociata*.

#### 4. *Anadara ferruginea* (Reeve, 1844) (Fig. 3; a & b)

1844. *Arca ferruginea* Reeve, sp. 39  
 1844. *Arca radiata* Reeve, sp. 40  
 1998. *Anadara (Diluvarca) ferruginea*: Evseev & Lutaenko, 8  
 1998. *Anadara ferruginea*: Poutiers, 154  
 2006. *Anadara (Mabellarca) ferruginea*: Lutaenko, 115  
 2010. *Anadara ferruginea*: Ramakrishna & Dey, 62

*Material examined:* 10ex, Rameswaram (09°16.867'N and 079°18.879'E), 7-IX-2014, coll. P.C. Tudu, (Reg. No. MARC/ZSI M4142).

*Description:* Shell medium in size (L up to 53 and H up to 38mm), elongated, equivalve; anterior margin slightly convex, ventral side smoothly and broadly rounded, posterior side convex in the middle part and wider than the anterior part, without a postero-ventral fold. Umbones less flattened and concave, situated backwardly at slight anterior to the middle of shell. Radial ribs narrowed, rectangular in section, granulated with close and crossed crests that are rather strong in the anterior and central fields of the left valve and in the anterior field of the right valve; interspaces of radial ribs equal to the width of the ribs of the right valve and covered by low ridges

continuing into the rib crest; the number radial ribs are 25-27. Ligamental area subtriangular in shape, shorter and wider in the anterior part than in the posterior part, with four chevron grooves posteriorly and two anteriorly. Hinge plate narrow, the boundary between the anterior and the posterior series unclear. Periostracum brown and film-like on the ribs tops and ciliated along the rib interspaces.

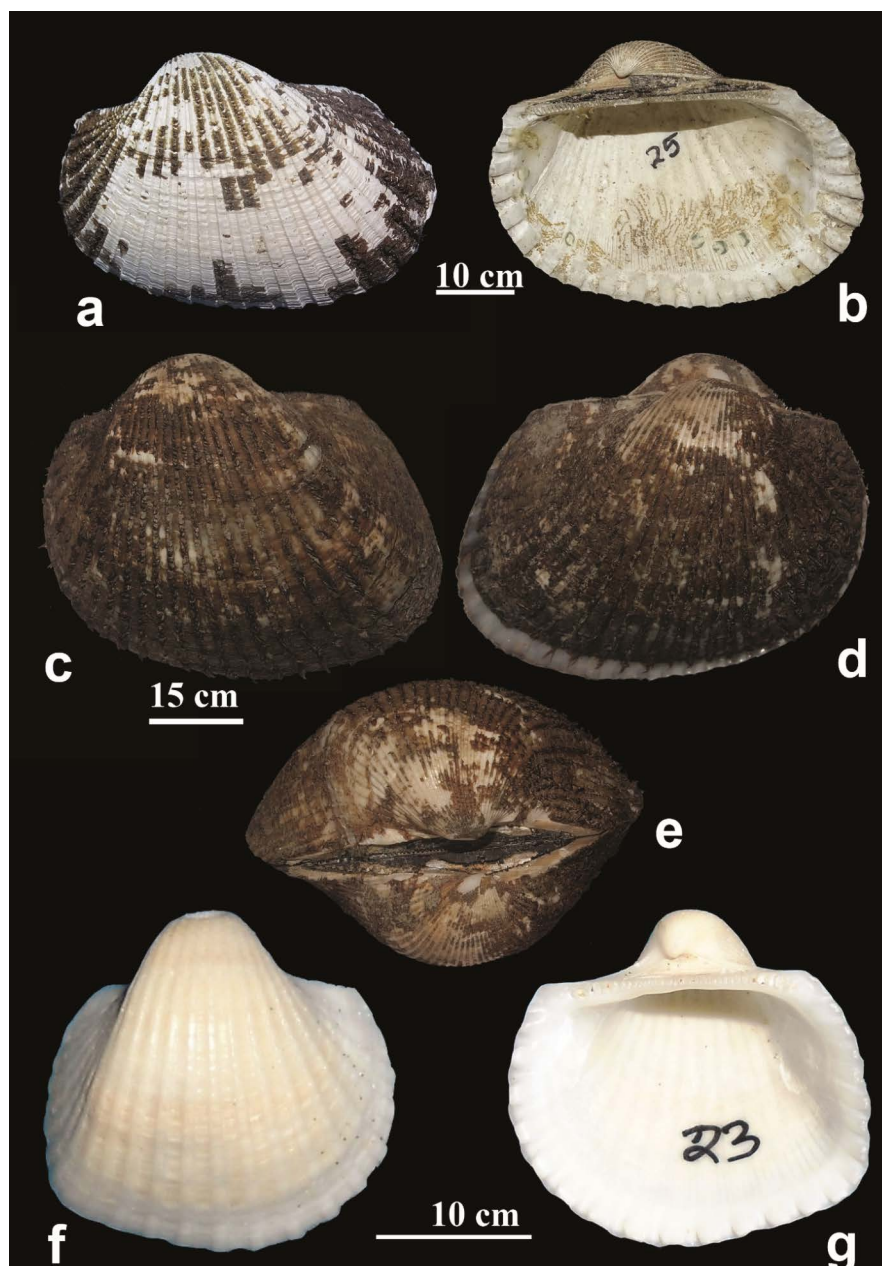
*Distribution:* In India: Tamil Nadu (Ramakrishna and Dey, 2010), *Elsewhere:* East and South China Sea, Japan, Philippines, Taiwan, Vietnam (Evseev and Lutaenko, 1998), Indo-Pacific (Ramakrishna and Dey, 2010).

*Remarks:* This species shows resemblance with *A. craticulata* (Nyst, 1848) in the characteristics of the radial ribs, but that species is distinct in having a more squarish shell covered by ribs with deep intervals (Evseev and Lutaenko 1998).

#### 5. *Anadara inaequivalvis* (Bruguière, 1789) (Fig. 3; c - e)

1789. *Arca inaequivalvis* Bruguière;  
 1965. *Arca inaequivalvis*: Kundu, 40  
 1998. *Scapharca inaequivalvis*: Poutiers, 152  
 2010. *Anadara (Scapharca) inaequivalvis*: Ramakrishna & Dey, 66  
 2017. *Scapharca inaequivalvis*: Subba Rao, 59

*Material examined:* 1ex, Puri (19°47.416'N and 085°49.346'E), 26-III-2007, coll. P. Yennawar, (MARC/ZSI M3554); 3ex, Chandrabhaga (19°51.576'N and 084°06.409'E), 31-I-2008, coll. P. Yennawar, (MARC/ZSI M3553); 2ex, Bokhali (21° 33.302'N and 088° 33.301'E), 06-II-2008, coll. P. Yennawar (MARC/ZSI M469); 1ex, Gopalpur (19°15.449'N and 084°54.559'E), 3-II-2008, coll. P. Yennawar, (MARC/ZSI M3074); 1ex, Digha (21°37.294'N and 087°31.338'E), 12-VII-2009, coll. P.C. Tudu (MARC/ZSI M4153); 1ex, Udaypur (21°36.327'N and 087°28.529'E), 25-XI-2008, coll. P.C. Tudu (MARC/ZSI M549); 1ex, Chandipur (21°27'07.066" N and 087°02'46.444" E), 1-X-2012, coll. P.C. Tudu (MARC/ZSI M4152); 1ex, Paradip (20°15.115'N and 086°39.283'E), 20-III-2013, coll. A. Mohapatra (MARC/ZSI M2992); 2ex, Chilka New Mouth (19° 39.486'N and 085° 31.050'E), 19-III-2013, coll. A. Mohapatra (MARC/ZSI/M3646); 2 ex, Junput (21°43.143'N and 087°49.118'E), 13-VI-2013, coll. P.C. Tudu (MARC/ZSI M3555); 13ex, Rameswaram (09°16.867'N and 079°18.879'E) 7-IX-2014, coll. P.C.



**Figure 3.** a-b, *A. ferriginea* (Reeve, 1844), a- exterior of left valve, b- exterior of right valve; c-e, *A. inaequivalvis* (Bruguière, 1789); c- exterior of left valve, d- exterior of left valve & left valve overlapping the right valve along postero-ventral region, e- umbo; f-g, *A. pilula* (Reeve, 1843); f- exterior of right valve, g- interior of right valve.

Tudu (MARC/ZSI M4141); 3ex, Tuticorin (08°47.575'N and 078°09.636'E) 9-IX-2014, coll. P.C. Tudu (MARC/ZSI M4144); 8ex, Chennai (13°07'25" N and 80°17'50" E) 17-XII-2014, coll. P.C. Tudu (MARC/ZSI M4139).

**Description:** Shell of medium size (L up to 64.5mm & H up to 51mm), roughly quadrate in shape, inflated, inequilateral; with a broad and nearly straight margin;

anterior margin slightly convex, arcuated ventrally and obliquely truncate posterior margin, with a postero-ventral fold; left valve distinctly overlapping the right valve ventrally and posteriorly (Fig. 3, d). Cardinal area rather long and narrow. Radial ribs low, flat and smooth; in the anterior filed of the left valve they are sometimes ornamented with crossings ridges; number of ribs 33-37; interspaces of the ribs smooth or covered by low cross

ridges on the bottom; width of interspaces as wide as the ribs, granulated on left valve. Beak somewhat broad, low, situated anteriorly from the middle of the shell. Ligamental area narrow. Hinge plate narrow, centre of series under the beak, the posterior series nearly twice as long as the anterior series. Periostracum well developed. Internal margin with strong crenulations corresponding with the external radial ribs; no byssal gape. Outside of shell white in colour covered with blackish brown periostracum, inner side also white.

**Distribution:** In India: all maritime states including Andaman and Nicobar Island (Ramakrishna and Dey, 2010); *Elsewhere:* Australia, Japan, Malaysia, Sri Lanka (Poutiers, 1998), Singapore (Tan & Woo, 2010), Vietnam (Evseev and Lutaenko, 1998), Indo-Pacific (Subba Rao *et al.*, 1992), Central India Ocean, Western Pacific Ocean, Mediterranean and Black Sea (Poutiers, 1998).

**Remarks:** Number radial ribs of this species is 30-36 (Poutiers, 1998) and 32-35 (Subba Rao *et al.*, 1992), one of our specimens has total numbers ribs are 37 and other characters are similar with this species; so, we considered that, range of radial ribs of this species is 30-37.

## 6. *Anadara pilula* (Reeve, 1843) (Fig. 3; f & g)

1843. *Arca pilula* Reeve, sp. 8

1998. *Scapharca pilula*: Poutiers, 156

2010. *Anadara (Scapharca) pilula*: Ramakrishna & Dey, 68

2017. *Anadara pilula*: Subba Rao, 61

**Material examined:** 1ex, Puri (19°47.416'N and 85°49.346'E), 24-III-2007, coll. P. Yennawar (MARC/ZSI M3570); 1ex, Gopalpur (19°15.450'N and 84°54.557'E), 27-III-2007, coll. P. Yennawar (MARC/ZSI M3568); 3ex, Chandrabhaga (19°51.576'N and 84°06.409'E), 31-I-2008, coll. P. Yennawar (MARC/ZSI M3569); 2ex, Paradip (20°15.115'N and 86°39.283'E), 28-II-2008, coll. P. Yennawar (MARC/ZSI M4154); 2ex, Paradip (20°17.322'N and 86°42.596'E), 28-VI-2012, coll. P.C. Tudu (MARC/ZSI M4151); 2ex, Paradip (20°17.500'N and 86°42.720'E), 27-IX-2012, coll. P.C. Tudu (Reg. No. MARC/ZSI M3666); 2ex, Chilka New Mouth (19°39.486'N and 85°31.050'E), 19-III-2013, coll. A. Mohapatra (MARC/ZSI/M3647).

**Description:** Shell of medium in size (L up to 22.9mm and H up to 21.9mm), strongly inflated, sub-rounded,

inequivalve; anterior margin short and slightly convex, ventral side narrowly arcuated, posterior margin nearly straight, with the postero-ventral side somewhat elongated in adults. Radial ribs narrow, ornamented with small nodules which look like crosses and with closely situated ridges that slope to the beak more steeply than to the ventral margin; nodules absent in the middle field of the right valve; number of ribs 23-24. Interspaces of ribs wide, beak prosogyrate and high, narrow, nearly touching the hinge line. No byssal gape. Ligamental area wide, trigonal, ligament ampidetic and equilateral, without chevron grooves. Hinge plate narrow, teeth small, transversal in the middle part and inclined near the edges of the plate, border of teeth series shifted somewhat posteriorly from the beak. Periostracum thin and brown.

**Distribution:** In India; Andaman and Nicobar Islands, Tamil Nadu (Ramakrishna and Dey, 2010), *Elsewhere:* East and South China Seas, Indonesia, Thailand, Pacific Coast of Australia, Malaysia, Vietnam (Evseev and Lutaenko, 1998), Philippines, Sri Lanka, Papua New Guinea (Evseev and Lutaenko, 1998; Poutiers, 1998), Taiwan, Queensland, Central India Ocean, Western Pacific (Poutiers, 1998).

**Remarks:** This species is often confused with *Tegillarca rhombea* (Born, 1778) as both the species having equal range of radial ribs, but differs with having thin, strongly inflated shell, no nodules on radial ribs, interspaces wider than ribs.

## 7. *Anadara troscheli* (Dunker, 1882) (Fig. 4; a-g)

1882. *Scapharca troscheli* Dunker.

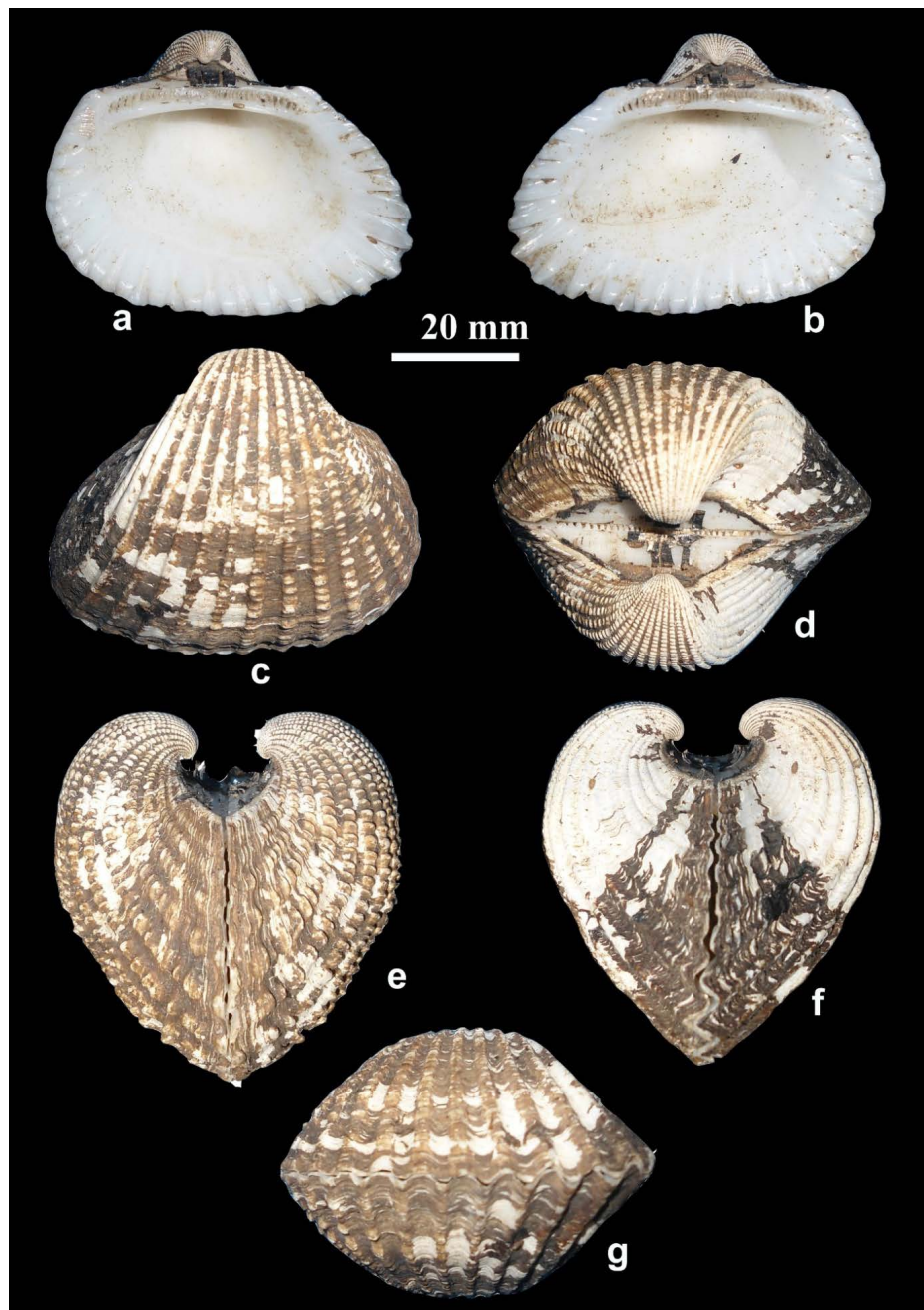
1998. *Anadara (Scapharca) troscheli*: Evseev & Lutaenko, 31

**Material examined:** 1ex, Gopalpur (19°15.450'N and 84°54.557'E), 27-III-2007, coll. P. Yennawar (MARC/ZSI M3550); 1ex, Gopalpur (19°15.449'N and 84°54.559'E), 2-I-2008, coll. P. Yennawar (MARC/ZSI M3551); 2ex, Kakinada (16°54.492'N and 82°14.370'E), 25-VI-2013, coll. A. Mohapatra & P.C. Tudu, (MARC/ZSI M3552); 2ex, Pulicat Lake (13°25'27" N and 80°19'26" E), 12-XII-2014, coll. P.C. Tudu, (MARC/ZSI/M4088).

**Description:** Shell medium in size (L up to 69.8mm and H up to 57.9mm), stout, subtrigonal in shape and high, with an elongated posterior margin and a prominent posterior-ventral fold; anterior margin narrow, smoothly joined to the slightly convex ventral

margin; posterior margin broad, nearly straight. Radial ribs narrow, rectangulate in cross-section, bear coarse growth lines or irregular knobs on flat tops in the right valve, and are rounded, with crossing ridges in the left valve, especially well exposed on the anterior and central field of the valve; number of ribs 22-25; interspaces between ribs wider than ribs. Ligamental

area concentric, its maximal width situated under the beak, chevron grooves regular and strong in the posterior part, and short, uneven with posterior grooves in the anterior part. Beak prosogyre, narrow and high, with a prominent postero-ventral fold. Hinge plate wide, the posterior teeth series somewhat longer than the anterior series; the border between the anterior



**Figure 4.** a-g, *A. troscheli* (Dunker, 1882); a-b, interior right & left valve, c- exterior right valve, d- umbo, e- anterior, f- posterior & g- ventral view of shell.



and posterior series is situated slightly posterior to the beak. Periostracum brownish and ciliated.

*Distribution:* In India: Andhra Pradesh, Odisha and Tamil Nadu (present report); *Elsewhere:* Japan, South China Sea, Vietnam (Evseev and Lutaenko, 1998), Thailand (Meyer *et al.*, 2008).

*Remarks:* Present report is the first ever report of *A. troscheli* (Dunker, 1882) from Indian waters, from Andhra Pradesh, Odisha and Tamil Nadu state. This species may be overlooked with morphologically similar species, *Tegillarca rhombea* (Born, 1778), but this species having wider interspaces between ribs or same as in ribs width and lesser number of radial ribs (22-25) compared to narrower interspaces than ribs in later and more number of radial ribs (24-27).

Genus *Mosambicarca* Lutaenko, 1994

Type species *Mosambicarca mosambicana* (Bianconi, 1850) (= *Arca mosambicana*)

**8. *Mosambicarca erythraeonensis*** (Jonas in Philippi, 1851) (Fig. 5; a & b)

1997. *Anadara erythraeonensis*: Al-Khayat, 486

2010. *Anadara erythraeonensis*: Ramakrishna & Dey, 62

2006. *Anadara (Mosambicarca) erythraeonensis*: Lutaenko, pl.2, fig.D-E, pl.3, fig.A-D

*Material examined:* 2ex, Tuticorin (08°47.575'N and 078°09.636'E), 9-IX-2014 (MARC/ZSI M4146).

*Description:* Shell medium size (L up to 63mm and H up to 42mm), equivalve, solid, equilateral, obliquely ovate and elongate in outline at posteriorly, posterior margin less rounded; anterior margin convex, smoothly rounded ventrally, ventral margin narrower towards posterior. Umbones inflated, situated rather anteriorly, cardinal area narrow and elongate. Radial ribs 38-39 in number, ribs twice as wide as their interspaces, at least half of the anterior ribs are bisected with narrow and light groove, this groove is less deep than interspaces, arcuated in cross section and ornamented with irregular smaller ridges. Ligamental area less triangular, without ligamental grooves, its maximal wide situated posterior of the beaks. Beak prosogyrate and medium in height; slightly depressed in their middle part, hinge plate thickened,

hinge series equal to each other, with the centre posterior of the beaks. No byssal gape. Periostracum brown in colour squamated, long cilia in the ventral side with coarse and velvety structure. Outside of shell white in colour covered with periostracum, inner side white and light yellow or whitish yellow in the umbonal cavity.

*Distribution:* In India: Tamil Nadu state (Ramakrishna and Dey, 2010); *Elsewhere:* Qatar (Al-Khayat, 1997), throughout Indo-Pacific (Ramakrishna and Dey, 2010).

*Remarks:* This species shows resemblance with *A. antiquata* (Linnaeus, 1758) but outline structure at posterior margin nearly straight, extending along the postero-ventral corner and radial ribs is solid as compared to less straight and rounded and radial ribs narrowly grooved in *M. erythraeonensis* (Jonas in Philippi, 1851).

Genus: *Tegillarca* Iredale, 1939

Type species: *Tegillarca (granosa) bessalis* Iredale (= *Arca granosa* Linnaeus).

**9. *Tegillarca granosa*** (Linnaeus, 1758) (Fig. 5; c & d)

1758. *Arca granosa* Linnaeus, 694

1844. *Arca granosa* Reeve, sp. 15

1844. *Arca cuneata* Reeve, sp. 37

1965. *Arca granosa*: Kundu, 40, pl.II, fig. 3a&b

1998. *Arca granosa*: Apte, 90

1988. *Anadara (Tegillarca) granosa*: Narasimham, 200-205

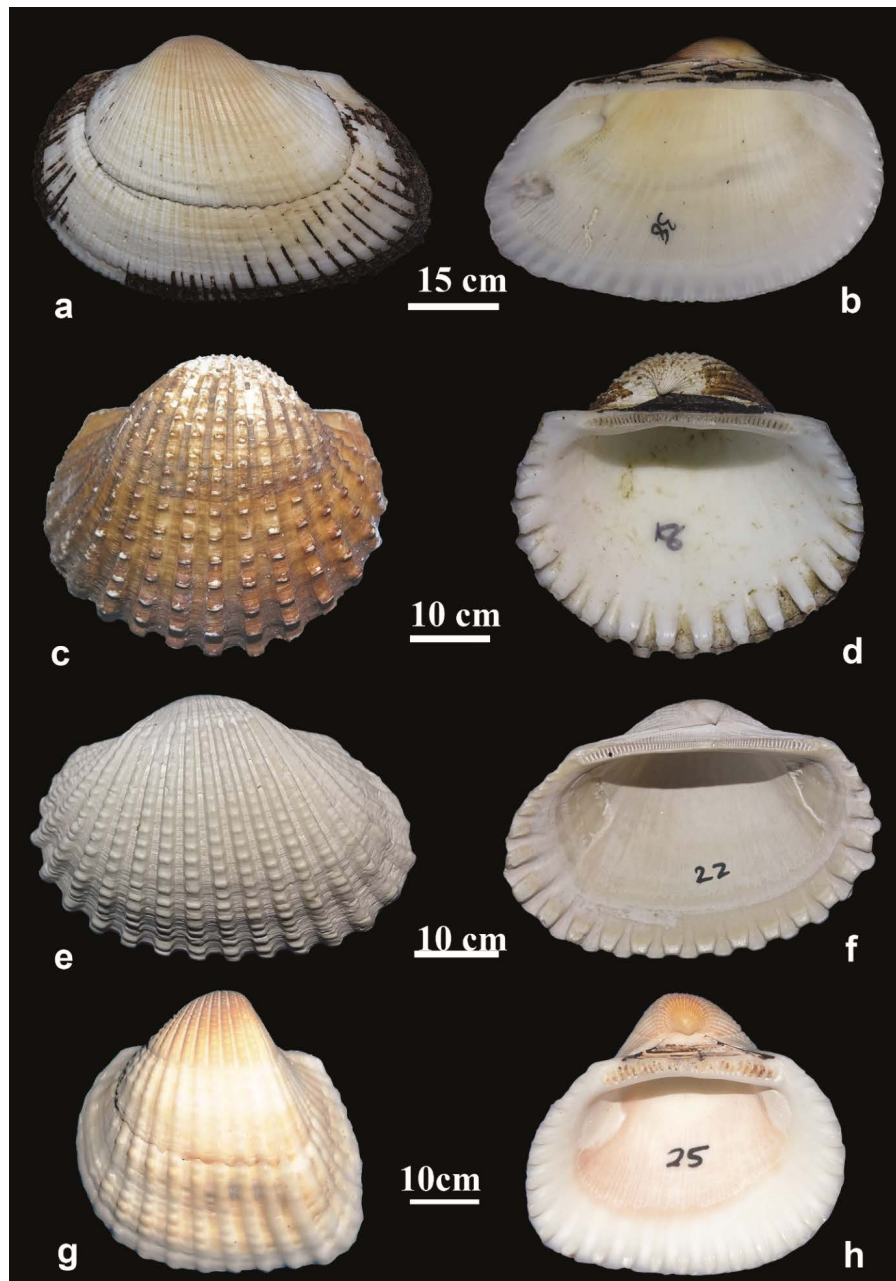
1998. *Anadara granosa*: Poutiers, 147

1998. *Anadara (Tegillarca) granosa*: Evseev & Lutaenko, 22

2010. *Anadara granosa*: Ramakrishna & Dey, 63

2017. *Tegillarca granosa*: Subba Rao, 62

*Material examined:* 1ex, Gopalpur (19°15.450'N and 084°54.557'E), 26-III-2007, coll. P. Yennawar (MARC/ZSI M3566); 1ex, Gopalpur (19°15.259'N and 084°54.343'E), 27-III-2007, coll. P. Yennawar (MARC/ZSI M3564); 1ex, Chandrabhaga (19°51.576'N and 084°06.409'E), 31-I-2008, coll. P. Yennawar (MARC/ZSI M3565); 1ex, Jalda (Tajpur) (21°38.882'N and 087°38.094'E), 25-I-2008, coll. P. Yennawar (MARC/ZSI M388); 6ex, Gopalpur (19°15.259'N and 084°54.343'E), 2-II-2008, coll. P. Yennawar (MARC/ZSI M423); 1ex, Sagar Island (21°37.508'N and 088°04.405'E), 25-XII-2012, coll. P.C. Tudu (MARC/ZSI M2840); 3ex, Chilka New Mouth (19°39.486'N and 085°31.050'E), 19-III-2013, coll.



**Figure 5.** a-b, *Mosambicarca erythraneonensis* (Jonas in Philippi, 1851), a- exterior of left valve, b- interior of left valve, c-d, *Tegillarca granosa* (Linnaeus, 1758); c- exterior of right valve, d- internal view of right valve; e-f, *T. nodifera* (Martens, 1860); e- exterior of left valve, f- interior of left valve; g-h, *T. rhombea* (Born, 1778); g- exterior of left valve, h- interior of left valve.

A. Mohapatra (MARC/ZSI/M3644); 6ex, Kakinada (16° 54.492'N and 082° 14.370'E), 25-VI-2013, coll. A. Mohapatra & P.C. Tudu (MARC/ZSI M3563); 1ex, Pulicat Lake (13° 25' 27" N and 80° 19' 26" E), 12-XII-2014, coll. P.C. Tudu (MARC/ZSI/M4098).

**Description:** Shell medium in size (L up to 50mm and H up to 41.3mm), equivalve, thick and solid. The shape of shell subtrigonal to globose, strongly inflated, to some extent length is more than high; antero-ventral margins widely arcuate, posterior margin slightly convex and

rather elongated along the postero-ventral fold. Umbones strongly protruding, cardinal teeth area rather large. Radial ribs high, number of ribs 15-21; squarish in cross-section, roofed with unequal cross ridges of different height and widths, or with round or more or less squarish nodules; interspaces of ribs are U-shape and wider than ribs near the postero-ventral fold. Internal margin with strong crenulations; corresponding with the external radial ribs. Ligamental area trigonal in shape, with its maximum width under the beak, posterior part rather longer than the anterior part, chevron grooves unequal. Beak prosogyrate and tall. Hinge plate narrow and anterior series of teeth are shorter than the posterior series. No byssal gape. Periostracum greenish-pale to brownish in colour; thin and smooth. Outside of shell white in colour under periostracum, inner side white often tinged light yellow towards the umbonal cavity.

**Distribution:** In India; all maritime states including Andaman and Nicobar Island (Ramakrishna and Dey 2010), *Elsewhere:* Japan, Indonesia, East Africa, Vietnam (Evseev and Lutaenko, 1998), China, Malaysia, Philippines, (Evseev and Lutaenko, 1998; Poutiers, 1998), Singapore (Tan & Woo, 2010), Indo-Pacific (Subba Rao *et al.*, 1992), Eastern Indian Ocean to tropical West Pacific (Poutiers, 1998).

**Remarks.** According to Narasimham (1988), the number of radial ribs are 18-21, (21<sup>st</sup> ribs is very faint); later Poutiers (1998) mentioned that ribs count is 15-20 and Evseev and Lutaenko (1998) stated that, number of radial ribs are 16-18, but in our specimens the range of ribs is 18-21, so, here we come to a conclusion, that the range of radial ribs is 15-21. This species is confused with another similar species *T. nodifera* (Martens, 1860), but having less number ribs, less number of nodules on ribs and less elongated shell compared to more ribs (19-23), more nodules and more elongated shell, in later one.

**10. *Tegillarca nodifera*** (Martens, 1860) (Fig. 5; e & f)

1860. *Arca nodifera* Martens, p. 17

1988. *Anadara (Tegillarca) nodifera*: Narasimham, pp. 200-205

1998. *Anadara (Tegillarca) nodifera*: Evseev & Lutaenko, 23. Pl. 3, fig. B, F.

1998. *Anadara nodifera*: Poutiers, 148

**Material examined:** 2ex, Chandrabhaga (19°51.576'N and 084°06.409'E), 27-III-2007, coll. P. Yennawar, (MARC/ZSI M258); 1ex, Gopalpur (19°15.449'N and 084°54.559'E), 2-II-2008, coll. P. Yennawar (MARC/ZSI M3567); 1ex, Gopalpur (19°15.450'N and 084°54.557'E), 21-IX-2012, coll. P.C. Tudu (MARC/ZSI M4155); 1ex, Bokhali (21° 33.302'N and 088° 33.301'E), 23-XII-2012, coll. P.C. Tudu (MARC/ZSI M2835); 2ex, Pulicat Lake (13° 25' 27" N and 80° 19' 26" E), 12-XII-2014, coll. P.C. Tudu (MARC/ZSI/M4149); 2ex, Talsari (21° 36' 1.74" N and 87° 27' 12.86" E) 1-III-2015, coll. P.C. Tudu (MARC/ZSI M4147).

**Description:** Shell of medium size (L up to 22.6mm and H up to 17.2mm), ovately elongated, thick, equivalve, moderately inflated and solid; anterior margin smoothly arcuated, ventral margin convex and broadly transformed into the posterior margin and distinctly longer than high. Umbones moderately protruding, cardinal area rather narrow. Radial ribs elevated, trapezoidal in cross-section, with well-expressed nodules which looks like crosses and with regular ridges; number of the shell ribs 19-21; interspaces between the ribs U-shaped in crass section, smooth at their bottoms, somewhat wider than the ribs. Internal margins with strong crenulations corresponding with the external radial ribs. Ligamental area narrow, subtrigonal, with 2-3 chevron grooves, its maximal width anterior of the beak, the posterior part is longer than anterior one. Beak low and prosogyre, hinge plate wide, anterior teeth series 1.5-1.8 times shorter than posterior series, boundary point between series situated posterior tom beak. Periostracum rather thin brownish and smooth.

**Distribution:** In India: Odisha and West Bengal (present report), Tamil Nadu (Souji and Radhakrishnan, 2015); *Elsewhere:* Burma (Evseev and Lutaenko, 1998), East and South China Seas, Malaysia, Philippines, (Evseev and Lutaenko, 1998; Poutiers, 1998), Myanmar (Poutiers, 1998), Taiwan, Vietnam (Evseev and Lutaenko, 1998), Singapore (Tan and Woo, 2010), Eastern Indian Ocean to tropical East Pacific (Poutiers, 1998).

**Remarks:** A commonly available similar species *Tegillarca granosa* (Linnaeus, 1758) is always confused with this species, which varies in having more elongated shell, narrower radial ribs count (15-21) as compared to *T. nodifera* (19-23) and nodule pattern.

## 11. *Tegillarca rhombea* (Born, 1778) (Fig. 5; g & h)

1780. *Arca rhombea* Born,  
 1843. *Arca rhombea* Reeve, sp. 12  
 1965. *Arca rhombea*: Kundu, 40  
 1988. *Anadara (Tegillarca) rhombea*: Narasimham, 203  
 2010. *Anadara rhombea*: Ramakrishna & Dey, 64  
 2017. *Tegillarca rhombea*: Subba Rao, 64

**Material examined:** 3ex, Chandrabhaga (19°51.576'N and 084°06.409'E), 25-III-2007, coll. P. Yennawar (MARC/ZSI M3560); 1ex, Gopalpur (19°15.450'N and 084°54.557'E), 26-III-2007, coll. P. Yennawar (MARC/ZSI M3561); 4ex, Gopalpur (19°15.259'N and 084°54.343'E), 27-III-2007, coll. P. Yennawar (MARC/ZSI M3557); 3ex, Chandrabhaga (19°51.576'N and 084°06.409'E), 31-I-2008, coll. P. Yennawar (MARC/ZSI M3559); 11ex, Gopalpur (19°15.449'N and 084°54.559'E), 2-II-2008, coll. P. Yennawar (MARC/ZSI M3562), 10ex, Gopalpur (19°15.338'N and 084°54.434'E), 3-II-2008, coll. P. Yennawar (MARC/ZSI M3558); 1ex, Talsari (21°36' 1.74" N and 87°27' 12.86" E), 21-VIII-2008, coll. P.C. Tudu (MARC/ZSI 4150); 33ex, Chilka New Mouth (19° 39.486'N and 085° 31.050'E), 19-III-2013, coll. A. Mohapatra (MARC/ZSI/M3645); 4ex, Pulicat Lake (13°25' 27" N and 80°19' 26" E), 12-XII-2014, coll. P.C. Tudu (MARC/ZSI/M4087).

**Description:** Shell medium in size (L up to 40.4mm & H up to 37.3mm), equivalve, thick and solid; somewhat heart shaped, convex, much inflated and distinctly equilateral; dorsal margin straight, anterior end rounded sloping ventrally, posterior end rounded and obliquely produced in the ventral side; ventral margin concave. Ligamental area rather wide, rhomboidal and with brownish black chevron markings; consisting one complete marginal chevron, with numerous vertical markings. Hinge long, slightly concave with taxodont dentition in single straight series. Tooth 35-52 become slightly longer at the extremes; the anterior and posterior ones slightly curved forward and backwards respectively; remaining teeth perpendicular to the hinge line. Beaks prosogyrate; umbones widely separated. Radial ribs 21-27 in number, high and squarish solid; sculptured with closely set transverse flat nodules; posterior 9-10 ribs without nodules, interspaces of the nodules much smaller than nodules; interspaces of the ribs smaller than ribs. Periostracum dark brown, smooth for major part except

for the posterior part where it is hairy. Inner shell white in colour. Ventral, anterior and posterior margins of the valves with strong crenulations corresponding to the external ribs. Impressions of the external ribs not visible in inner side of the valves. Pallial line without siphonal indentation, palial sinus absent. Posterior adductor scar elongately squarish and anterior scar similar but smaller.

**Distribution:** India: All maritime states including Andaman and Nicobar Island (Ramakrishna and Dey, 2010); *Elsewhere:* Chinese Seas (Reeve, 1843; Evseev and Lutaenko, 1998), Indonesia, Java, Pakistan (Subba Rao *et al.*, 1991), Sri Lanka (Reeve, 1843; Subba Rao *et al.*, 1991), Philippines, Pleistocene deposits of Taiwan (Evseev and Lutaenko, 1998), Indian Ocean (Narasimham, 1988).

**Remarks.** This species is morphologically similar with, *A. troscheli* (Dunker, 1882) but having narrower interspaces and more number of radial ribs (24-27) compared to wide interspaces and lesser number of radial ribs (22-25) in later.

## Discussion

Among the twenty-one species reported in Indian region; the *Anadara gubernaculum* (Reeve, 1844) is reported by Kundu (1965) from Gulf of Kutch only; and three species i.e. *A. pumila* (Dunker, 1868), *T. aequilatera* (Dunker, 1868) and *T. nodifera* (Martens, 1860) are reported by Souji and Radhakrishnan (2015) from southern coast of India but further confirmation is required for the distribution of *A. pumila* (Dunker, 1868) and *T. aequilatera* (Dunker, 1868) in India. Similarly, another three species i.e. *A. compacta* (Reeve, 1844), *A. deshayesi* (Hanely, 1856) and *A. natalensis* (Krauss, 1848) are reported by the Hylleberg and Kilburn (2002) from the Gulf of Mannar but further confirmation of validity of species is required for *A. deshayesi* (Hanely, 1856). In this study there are eleven species of subfamily Anadarinae are conveyed from collections of east coast of India. Taxonomy of subfamily Anadarinae is confusing because of intra species morphological variation. As per the molecular presentation of Feng *et al.* (2015), the Anadarinae is a valid subfamily. The genus *Mosambicarca* proposed by Lutaenko (1994) also considered as valid genus to preserve the validity of subfamily Anadarinae. Here we have presented only one species belongs to genus *Mosambicarca* which is available in the Indian region. The *Tegillarca* was recovered as a valid group by Feng *et al.* (2015). This is a small attempt

to solve the taxonomy of this subfamily, hence the species are taxonomically compiled with related species available in the Indian region. Out of eleven species two species *Anadara consociata* (E.A. Smith, 1885) and *A. troscheli* (Dunker, 1882) are reported first time from Indian waters. *A. consociata* (E.A. Smith, 1885) is identified based on the 38 examples collected from Rameswaram and *A. troscheli* (Dunker, 1882) on the basis of 6 examples collected from Gopalpur, Kakinada and Pulicate Lake.

### Key to species

1. Anterior half of radial ribs are bisected with narrow groove ..... 2  
Anterior half of radial ribs are not bisected with narrow groove ..... 3
2. Shell equivalve, equilateral, umbones inflated, radial ribs 38-39, twice as interspaces, interspaces ornamented with irregular nodules.....  
.....*Mosambicarca erythraeonensis*
3. Shell equivalve and inflated, sculpture contains few moderately narrow, radial ribs with nodules, separated by interspaces of equal or greater width... 4  
Shell equivalve or inequivalve, strong radial ribs with smooth or nodules, separated by interspaces of equal or narrow or greater width than ribs..... 7
4. Radial ribs narrower than interspaces..... 5  
Radial ribs wider than interspaces..... 6
5. Shell slightly longer than high, with strongly protruding umbones, radial ribs squarish in cross section, and number 18-21 ..... *Tegillarca granosa*  
Shell markedly longer than high, with moderately protruding umbones, radial ribs trapezoidal in cross section, and number 19-21 .....*Tegillarca nodifera*
6. Shell somewhat longer than high, with very strongly protruding umbones, radial ribs squarish in cross section, and number 21-27 .....*Tegillarca rhombea*
7. Shell equivalve ..... 8  
Shell inequivalve..... 13
8. Radial ribs equal or narrower than interspaces ..... 9  
Each valve equilateral, radial ribs wider or twice than interspaces..... 12

9. Shell longer than high, radial ribs equal than interspaces..... 10  
Radial ribs narrower than interspaces..... 11
10. Umbones much inflated, situated anteriorly, radial ribs squarish in cross section, equal to interspaces with fine regular nodules, number 26 .....  
..... *Anadara ehrenbergi*  
Umbones less flattened, situated near middle of shell, radial ribs rectangular in cross section, equal to interspaces with fine granules, number 25-27 .....  
.....*Anadara ferruginea*
11. Shell longer than high, radial ribs rectangular in cross section, width less than interspaces with coarse growth lines, number 22-25 ..... *Anadara troscheli*
12. Shell less longer than high, umbones much flattened, situated on anterior, radial ribs arcuated in cross section, ribs wider twice than interspaces with regular ridges, number 34-35 ..... *Anadara antiquata*  
Shell more longer than high, umbones inflated, situated rather forward, radial ribs squarish or concave in cross section, wider than interspaces with rounded nodules, number 21-27 .....  
..... *Anadara consociata*
13. Shell strongly inflated, sub-rounded, radial ribs narrow, with small nodules, interspaces wider than ribs, number 23-24 ..... *Anadara pilula*  
Shell roughly quadrate, left valve distinctly overlapping the right valve, radial ribs low and smooth or ornamented with crossing ridges, equal to interspaces, number 33-37..... *Anadara inequivalvis*

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