

New Report and Taxonomic Comparison of Anadara and Tegillarca Species of Arcidae (Bivalvia: Arcoidea) from Southern Coast of India

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Abstract: Arcacea family is economically important group of animals. Most of the species in this family are misplaced into invalid subgenera and Indian arcids are wanted a revision in systematic position. In the case of Arcidae family; all of the species are treated under Anadara as main genera, however, some authors considered that the Tegillarca genus is only a sub genus of Arcidae family. Anadara is the commercially important genus of bivalves of Arcidae family. These two genera are confused by many taxonomists and some considered that the morphometric changes of Tegillarca are only the habitual adaptation. But the collected samples from the same habitat from the southern part of India is clearly demarked the distinction between Anadara species and Tegillarca species. In this paper the differences between these two genera are illustrated with the help of specimens from the same habitat and with the help of taxonomic literature of these genera. Species level classification was done based on the morphometric characters like peculiarities of (i) periostracum, (ii) cardinal area, (iii) umbo, (iv) adductor muscle scar and (v) pallial line. The specimens were collected from Neendakara, Vizhinjam and Kovalam along with the south west coast and Thiruchendur in Tamil Nadu, south east coast of India. The new records clearly indicate the abundance and richness of these species of bivalves in the southern part of India. Four species are newly reported and they are Anadara pumila (Dunker, 1868), Anadara trapezia (Deshayes, 1839), Tegillarca nodifera (Martens, 1860) and Tegillarca aequilatera (Dunker, 1868). The newly reported specimens from the southern tip of India were deposited in the Marine Biodiversity Museum, Central Marine Fisheries Research Institute (CMFRI) Kochi, Kerala, India.

Keywords: Anadara pumila, Anadara trapezia, Tegillarca nodifera, Tegillarca aequilatera, Anadara species and Tegillarca species

1. Introduction

Arcidae are thick shelled marine bivalves that are having considerable economic importance. They are widely distributed in shallow tropical and temperate seas. Arcidae species are commercially exploited in several countries. These are the most abundantly occurring species in tropical and subtropical regions of Indo-Pacific region (Broom, 1985; Narasimham, 1988). The Anadara, Scapharca and Tegillarca species have been exploited mainly by several Asian countries (Feng *et al.*, 2011). Broom (1982) reported that over 200 species from the family Arcidae were exploited by man as they are important source of protein for human consumption, so also some of these species are important candidates for aquaculture. Morphologically diverse group of marine bivalves are included in the Anadara genera and under Arcidae family. They have worldwide distribution. Several countries including Japan, Malaysia, China, the Philippines and Borneo are commercially culturing Anadara (Bardach *et al.*, 1972). According to Chan (1985) in the traditional fishery of Malaysia, Anadara species have been reported to be the most important form.

In the Arcidae family, Anadara subfamily was proposed by Reinhart (1935). According to him the taxonomic features of Anadara species are (i) ventral margin closed, (ii) byssal gape lacking (iii) sculpture consisting of large, regular radial ribs, sculptured with grooves or nodes in most species, (vi) (iv) surface of the shell regularly rounded, (v) ligament area narrow to moderately wide, flat to widely 'V' shaped when viewed in cross section (with both valve joined), (vi) hinge straight or gently arched, (vii) teeth regularly diminishing in size from extremities to center, but usually not completely

lacking in the center, (viii) Inner margin of the shell is crenulated, (ix) beaks never opisthogyrate, pointing either inward or forward. Type genus: Anadara Gray based upon *Arca antiquata* Linne, Geologic range: Cretaceous to Recent. The genus is geologically young compared to many other genera of Arcidae. The geologic distribution of Anadara species is Oligocene to Recent and Tegillarca is Miocene to Recent (Schenck and Reinhart, 1938).

The genus, Tegillarca is proposed by Iredale (1939). The important character is the presence of strong nodules or knobs on the radial ribs of both the left and the right shell valves. The subgenus, Tegillarca may possibly have a more limited distribution, namely *Tegillarca cuneata* for East Africa given by Reeve (1844) is rather dubious. Lim (1968) stated that geologically Tegillarca is younger than the Anadara species. The body of Tegillarca is transformed from Anadara. The shell of the Tegillarca is highly variable in shape but the nodule is the invariable character in all the species (Kotaka, 1953). The subgenus Tegillarca may possibly have a more limited distribution, namely *Tegillarca cuneata* for East Africa given by Reeve (1844).

In India, species such as *Anadara granosa* (Linnaeus, 1758) and *Anadara rhombea* (Born, 1780) are fishing along with other bivalves and gastropods (Narasimham, 1988). Rao and Somayajulu (1996) recorded the production of 6 ton in 1993. Besides these three species, Lutaenko (2006) reported six species of *Anadara* (*Tegillarca*) *granosa* (L., 1758), *A. (T.) rhombea* (Born, 1780), *A. (Imparilarca) ehrenbergi* (Dunker, 1868), *A. (Mosambicarpa) erythraeonensis* (Jonasin Philippi, 1851), *A. (Scapharca) inaequalvis*

(Bruguere, 1789), and *Anadara* (? *Mabellarca*) *ferruginea* (Reeve, 1844) from Gulf of Mannar and Palk Bay.

According to Huber (2010) approximately 100 species of Anadaranes are globally known. Some reports included *Anadara tuberculosa*, *Anadara similis* and *Larkinia multicostata* on the Pacific coast of Columbia, *Anadara cornea* in Fiji, *Senilia senlilis* in West Africa (Broom, 1982). *Lunarca ovalis*, *Anadara transversa* and *Noetia ponderosa* in coastal Georgia, USA (Walker, 1998) and *Arcanoea* in the Mediterranean (Hrs- Benko, 1980).

2. Materials and Methods

Live specimens and dead shells were collected from Neendakara, Vizhinjam and Kovalam along the south west and Thiruchendur along the south east coast of India. The live specimens were kept in formalin and dead shells were thoroughly washed and dried by sunlight. Taxonomic identification was done with the help of Huber, (2010) and FAO identification keys. Systematics were done based on online data base especially on *WoRMS*. After identification the identified specimens were deposited in the Marine Biodiversity Museum, Central Marine Fisheries Research Institute (CMFRI) Kochi. The sites of specimen collection are shown in Figs.1. The taxonomic features used for identification are labeled and presented in Figs. 2-7. The accession ID number of specimens is shown in Table 1.



Fig. 1. Collection sites

Table 1: Accession ID numbers of deposited specimens

Sl.No	Name of species	Accession numbers
1	<i>Anadara pumila</i> (Dunker, 1868)	DC.1.1.3
2	<i>Anadara trapezia</i> (Deshayes, 1839)	DC.1.1.4
3	<i>Anadara antiquata</i> (Linnaeus, 1758)	DC.1.1.5
4	<i>Tegillarca granosa</i> (Linnaeus, 1758)	DC.3.1.2
5	<i>Tegillarca nodifera</i> (Martens, 1860).	DC.3.1.12
6	<i>Tegillarca aequilatera</i> (Dunker, 1868)	DC.3.1.13

3. Results and Discussion

Review of literature revealed that Andarine species were reported from Japan (Habe; 1965; Noda, 1968), China (Li, 1983), Russian Far East (Lutaenko, 2006), Western Africa and Mozambique (Kilburn, 1983), Western Africa (Oliver, Cosel, 1992), Thailand (Vongpanich, 1996) and Vietnam (Evseev and Lutaenko, 1998) and Southern India (Lutaenko, 2006). Narasimham *et al.* (1998) gave the description of *Anadara granosa* (Linnaeus, 1758) and *Anadara rhombea* (Born, 1780). In the present paper 3 species are described and included under Anadarine and 3 species are treated under Tegillarca as in Huber (2010). The differences between the species are shown through the magnified image of certain portions of the specimens.

1. *Anadara pumila* (Dunker, 1868)

Parent: *Anadara Gray, 1847*

Class : Bivalvia

Subclass : Pteriomorpha

Order : Arcoida

Superfamily : Arcoidea

Family : Arcidae

Genus : *Anadara*

Locality : Kovalam and Thiruchendur, India

Size : 1.3 cm to 2.0 cm

Habitat : Rocky and sandy sea shore

Synonym : *Scapharca pumila* (Dunker, 1868)

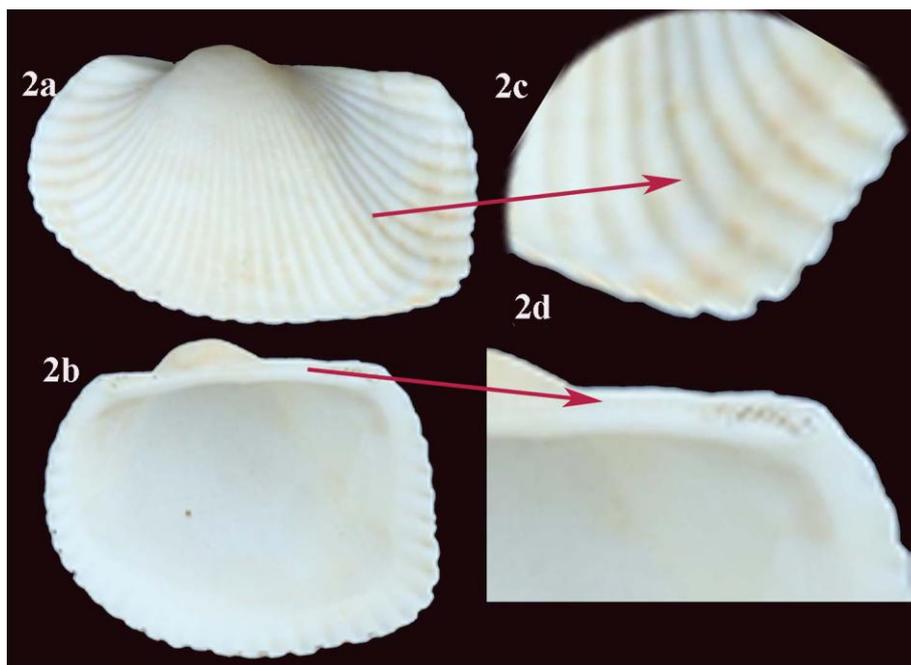


Figure: 2a-2d *Anadara pumila* (Dunker, 1868)

Figure 2a Dorsal view ; 2b inner valve; 2c portion of periostracum; 2d enlarged view of hinge region.

Description

28-29 smooth radial ribs are present. Shell has 1.5 cm length or 2.3 cm width. The periostracum is ivory white and the inner side of the shell is glossy white. Umbo is medium sized, it is placed one third of the shell. Cardinal area is short. Hinge plate composed of very small teeth. It is only visible to extremities. Huber, (2010) reported that the distinguished feature of *Anadara pumila* is the hinge area which is smaller and shorter with a narrower ligament. The taxonomic description and the distributional records of these species are not available in any other literature. It is for the first time that this specimen is described and reported from India.

2. *Anadara antiquata* (Linnaeus, 1758)

Parent : *Anadara Gray, 1847*

Class : Bivalvia

Subclass : Pteriomorphia

Order : Arcoida

Superfamily: Arcoidea

Family : Arcidae

Genus : *Anadara*

Locality : Thiruchendur, Tamil Nadu, India

Size : 2.8 cm to 3.1 cm

Habitat : Rocky sea shore

Synonym: *Anadara scapha* (Gmelin, 1791); *Anadara suggesta* (Iredale, 1939); *Anomalocardia transversalis* (H. Adams, 1872); *Arca antiquata* (Linnaeus, 1758); *Arca scapha* (Gmelin, 1791).

Description

The shell is 2 to 4 cm in length and 1 to 1.50 cm in width. Periostracum is brown in color and several associated fauna is attached on it. The characteristic feature is the two radial ribs which are interspaced. Black coloured hair like projections are present on the margin of the shell. Umbo is short. Small teeth are present on the hinge line. Anterior part of the shell is flattened than the posterior region. The margin of the shell is crenulated.

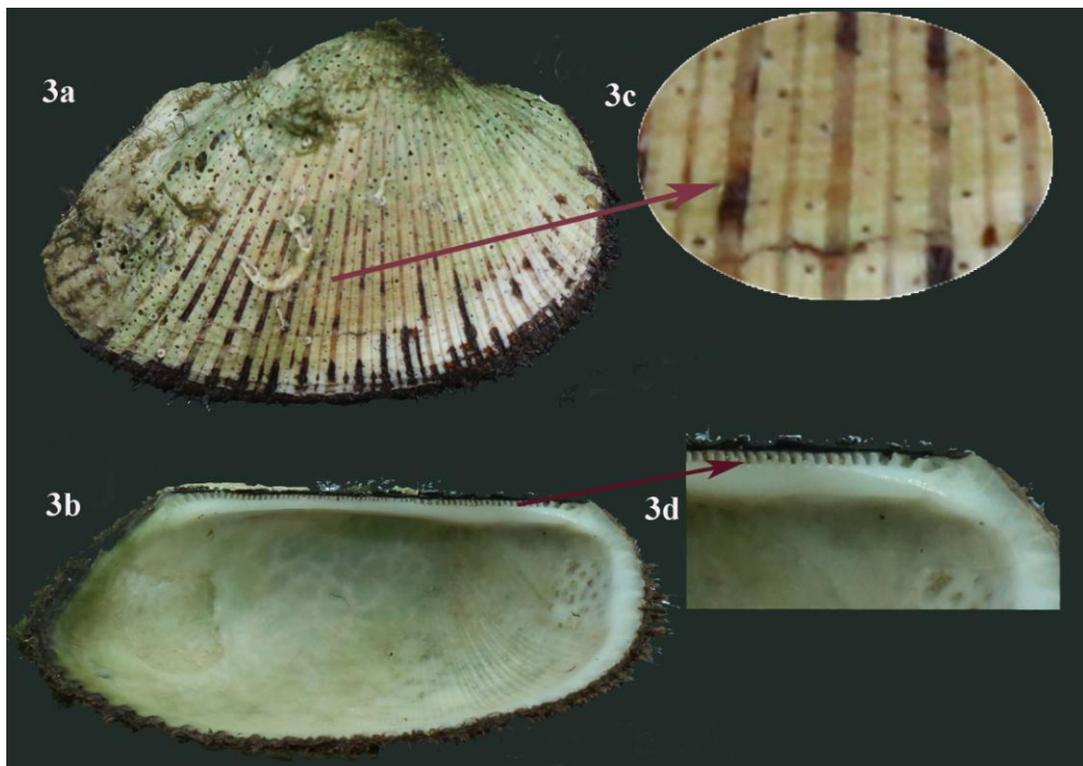


Figure: 3a-3d *Anadara antiquata* (Linnaeus, 1758)

Figure 3a Outer valve; 3b, inner valve; 3c magnified a portion of periostracum; 7d, hinge area.

Evseev, G. A and Lutaenko, K. A, (1998) gave a detailed account of the distribution of *Anadara antiquata* (Linnaeus, 1758). According to them it is distributed in red sea and eastern coast of Africa (Lamy, 1907; Kilbourn, 1983), Australia (Gill, 1972), Indonesia (Altena, 1945), Philippines (Faustino, 1928), China (Chen *et al.*, 1980), Japan (Habe, 1965), Fiji, New Caledonia, Polynesia (Lamy, 1907), Caroline and Marshal Islands and Hawaiian Islands (Dall *et al.*, 1938). It is reported earlier from different parts of India (Subba Rao and Dey, 2000 and Dey and Ramakrishna, 2007).

4. *Anadara trapezia* (Deshayes, 1839)

Parent : *Anadara Gray, 1847*

Class : Bivalvia

Subclass : Pteriomorphia

Order : Arcoida

Superfamily: Arcoidea

Family : Arcidae

Genus : *Anadara*

Size : 1.0 cm to 1.8 cm

Locality : Thiruchendur, Vizhinjam, Neendakara, India

Habitat : Rocky sea shore

Synonym: *Anadara lischkei* (Dunker, 1868); *Anadara nicholsoni* (Iredale, 1927) *Anomalocardia ischkei* (Dunker, 1868); *Arcalobata* (Reeve, 1844); *Anadara trapezia* (Deshayes, 1839).

Description

20 to 25 radial ribs are present. Periostracum is somewhat ash to blackish color. Prominent centrally placed umbo is

present. Cardinal area has 2 to 3 cheverons. Hinge area composed of small teeth. Inner side of the shell is dirty white, composed of lines that corresponding to the radial ribs of the periostracum. The margin of the shell is crenulated. Anterior and posterior adductor muscle scar is clearly marked. Towards the umbo region a cavity like depression is present inside of the shell.

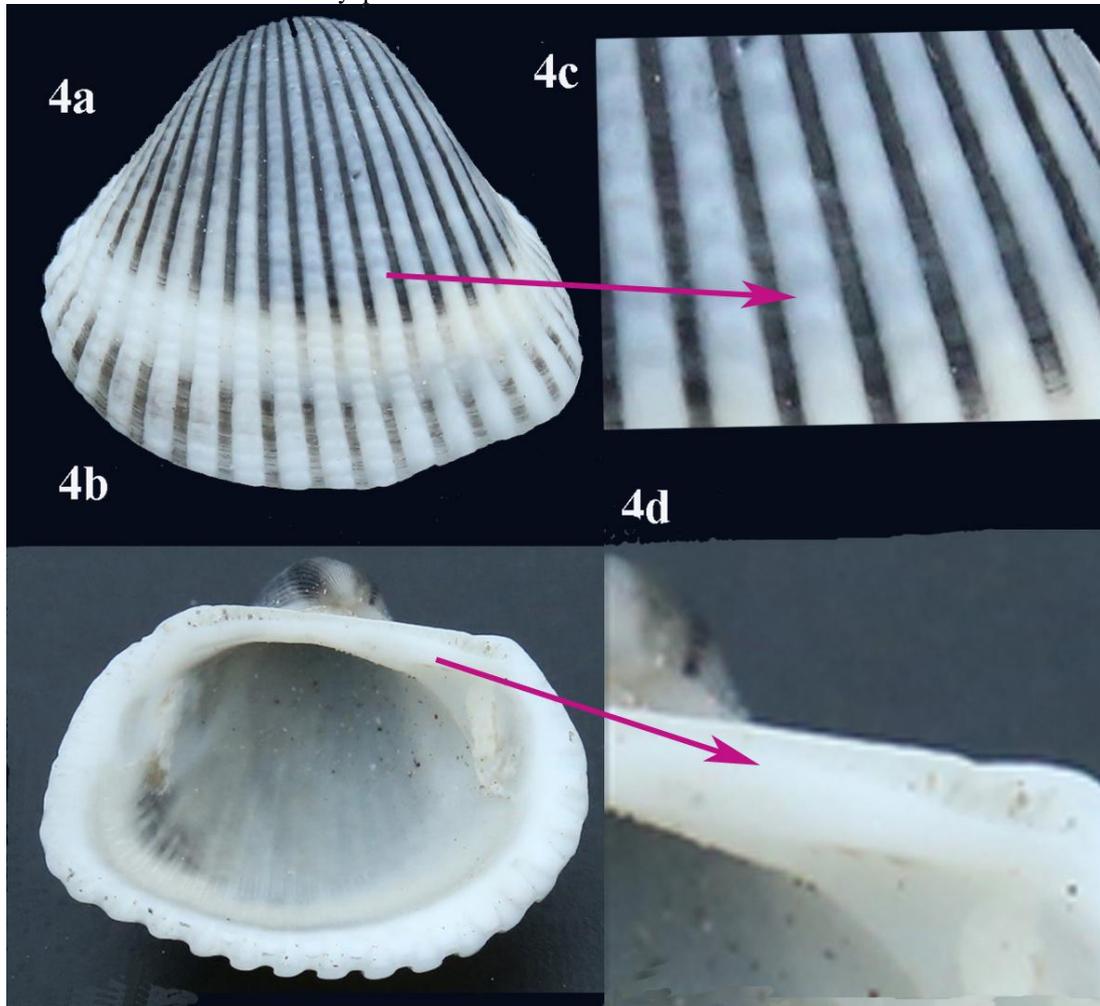


Figure: 4a-4d. *Anadara trapezia* (Deshayes, 1839)

Figure 4a. Dorsal view; 4b inner valve; 4c, magnified portion of periostracum; 4d, hinge region

It is reported from Cairns, northern Queensland (Dixon, 1975) to Port Philip Bay, southern Victoria (Macpherson, 1966; Poore and Rainier, 1974; Smith, Coleman and Watson 1975; Dixon 1975) and in southern western Australia at Oyster Harbour near Albany (Kendrick and Wilson 1959). It is reported from the sea grass beds in South Australia (Cotton 1961; Macpherson and Gabriel 1962; Dixon, 1975). In the present study the shell of the animal was collected from Neendakara, Kovalam in Kerala and Thiruchendur in Tamil Nadu. This is the first report from India.

5. Tegillarca granosa (Linnaeus, 1758)

Parent: Tegillarca (Iredale, 1939)

Class : Bivalvia

Subclass : Pteriomorpha

Order : Arcoida

Superfamily: Arcoidea

Family : Arcidae

Genus : Tegillarca

Locality : Thiruchendur, Tamil Nadu, India

Size : 1.2 to 1.8 cm

Habitat : Rocky sea shore

Synonym: *Anadara bisenensis* (Schrench and Reinhart, 1938); *Anadara granosa* (Linnaeus, 1758); *Anadara thackwayi* (Iredale, 1927); *Anomalocardia pulchella* (Dunker, 1868); *Arca aculeate* (Bruguiere, 1789); *Arca corbicula* (Gmelin, 1791); *Arca corbula* (Dillwyn, 1817); *Arca granosa* (Linnaeus, 1758); *Arca granosa kamakuraensis* (Noda, 1966); *Arca obessa* (Koltaka, 1953); *Tegillarca granosa bessalis* (Iredale, 1939).

Description

16 to 18 radial ribs are present. Periostracum is yellow-white in color. Prominent centrally placed umbo is present. Cardinal area has 2 to 3 cheverons. Hinge area composed of small teeth. Inner side of the shell is glossy white. The radial

ribs of the periostracum are broad and have distinct knobs. The margin of the shell is highly crenulated. Anterior and posterior adductor muscle scar is clearly marked. The umbo region is dorsally narrower as compared to the above described Anadarine species.

It is distributed in Greek part of Aegean Sea (*WoRMS*) also reported from Gulf of Mannar in India (Lutaenko, 2006).

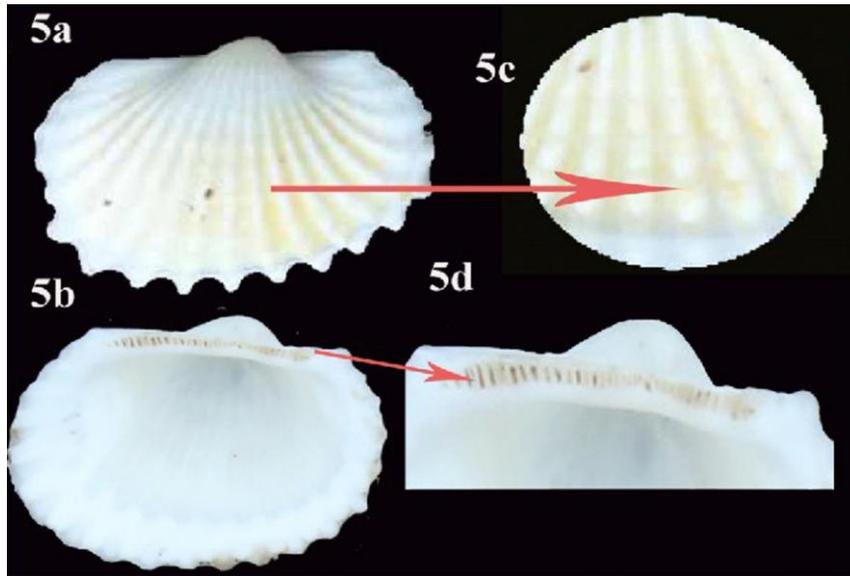


Figure: 5a-5b. *Tegillarca granosa* (Linnaeus, 1758)

Figure 5a. Dorsal view; 5b, inner valve of the shell; 5c, magnified portion of periostracum; 5d, hinge region

6. *Tegillarca nodifera* (Martens, 1860)

Parent: *Tegillarca* (Iredale, 1939)

Class : Bivalvia

Subclass : Pteriomorpha

Order : Arcoida

Superfamily: Arcoidea

Family : Arcidae

Genus : *Tegillarca*

Locality : Thiruchendur, Tamil Nadu, India

Size : 1.1 to 2.0 cm

Habitat : Sandy sea shore

Synonym: *Anomalocardia paucigranosa* (Dunker, 1866); *Arca nodifera* (Martens, 1860); *Arca oblonga* (Philippi, 1849)

Description

Inflated, equivalve shell. 19 to 20 radial ribs are present. Distinct nodules are present on the ribs. Periostracum is orange-white in anterior umbo region posteriorly the color fades and become white. Prominent centrally placed umbo is present. Hinge area composed of small teeth. Inner side of the shell is glossy white. The margin of the shell is highly crenulated. The inner shell colour is corresponding to the outer shell color. Like this the lines are seen corresponding to the outer region. Anterior and posterior adductor muscle scar is clearly marked.

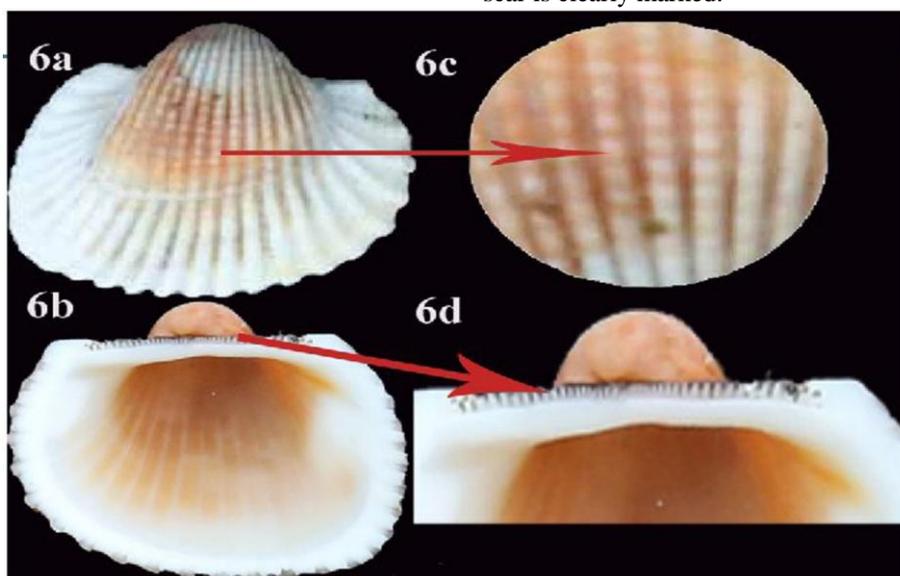


Figure: 6a-6d. *Tegillarca nodifera* (Martens, 1860).

Fig. 6a. Dorsal view of *Tegillarca nodifera*; 6b inner valve; 6c, magnified portion of periostracum; 6d hinge region.

It is distributed in Japan, Hong Kong, China, Indonesia and Thailand (www.gbif.org/species/125186906). It is the first report from India.

7. *Tegillarca aequilatera* (Dunker, 1868)

Parent: *Tegillarca* Iredale, 1939

Class : Bivalvia

Subclass : Pteriomorpha

Order : Arcoidea

Superfamily : Arcoidea

Family : Arcidae

Genus : *Tegillarca*

Locality : Thiruchendur, Tamil Nadu, India

Size : 2.4 to 3.2 cm

Habitat : Rocky sea shore

Synonym: *Anomalocardia aequilatera* (Dunker, 1868);
Arca rhombea var. *pseudogranosa* (Lamy, 1903).

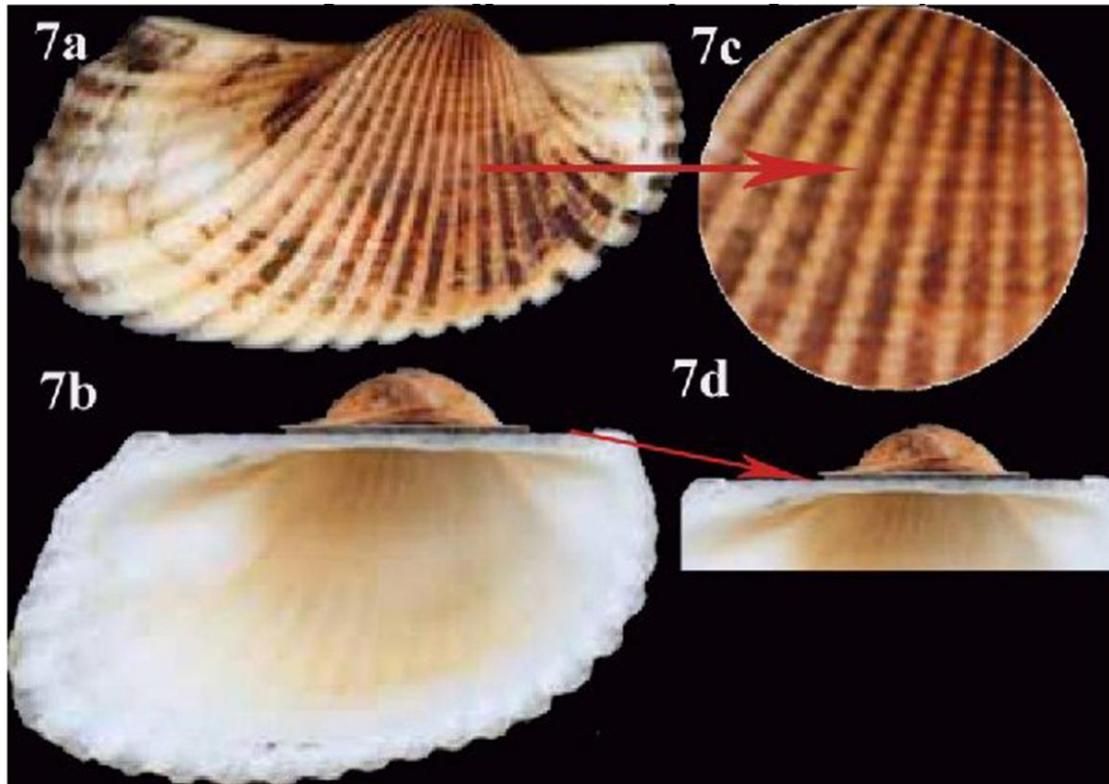


Figure: 7a-7d. *Tegillarca aequilatera* (Dunker, 1868)

Figure 7a Dorsal view; 7b, inner valve; 7c, magnified portion of periostracum; 7d, hinge region.

Description

The posterior part of the shell is flattened, equivalve shell. 23 to 28 radial ribs are present. The ribs are nodulated. Periostracum is orange-yellow turn into dark brown in some portions. Prominent umbo is present. Hinge area composed of small teeth. Inner side of the shell is glossy yellowish white. Crenulated margin is present. Like this, the lines are seen corresponding to the outer region. Anterior and posterior adductor muscle scar is clearly marked. Cardinal area is black, ligamented. It is reported from Thailand and Krabi. It is the first report from India.

Figs. 2c, 3c, 4c, 5c, 6c and 7c show the radial rib portion. In *Anadara* species it is smoother than *Tegillarca*. The hinge region is similar in both genera. All other characters are similar. But Matsumoto (2003) conducted DNA barcoding of some Arcidae and his results showed clear separation of *Tegillarca* from other groups.

4. Conclusion

Arcid bivalves are abundantly distributed in many parts of the coastal region. *Tegillarca rhombea* is one of them seen

abundantly in estuaries and barmouth region. They are the most commercially exploited groups of molluscs. Along the South west and South east coast of Indian Peninsula, there are different habitats such as the mangrove area, rocky area, sandy area, coral reef area, etc. The changing of the habitat/location caused variation in the morphometry of organisms. Thus there is a possibility of evolution in the genera of Anadarine species. However, further molecular studies are needed on Indian arciid bivalves in order to confirm this observation. The arciid groups are showing diversity in morphometry. Thus, there is less chance of evolutionary adaptation in Indian arciid bivalves.

5. Acknowledgement

First author is indebted to Dr. K.K. Joshi, Principal Scientist and Ms. P.M. Geetha of Marine Biodiversity Museum of CMFRI, N. Chandrakumar for the timely help of the work and Kerala University for a JRF during the tenure of this research.

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