*Phuket mar. biol. Cent. Res. Bull.***78:** 59–68 (2021)

Anadara subrubra (Dunker, 1866) (BIVALVIA: ARCIDAE) IN SOUTH-EAST ASIA, RE-DESCRIPTION AND TAXONOMIC COMMENTS

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ABSTRACT: *Anadara* (*Anadara*) *subrubra* (Dunker, 1866), a little-known anadarine species, has been recently reinstated as a valid species distributed in the Philippines, South China Sea to southern Japan. Its re-description, illustrations of type material, synonymy and comparison with allied species are presented. *A. subrubra* was often misidentified as *Anadara antiquata* (Linnaeus, 1758); a synonym of the former species is *Anadara dekkeri* Thach, 2015 described from Vietnam. Comments on taxonomy and identities of taxa included into the *A. antiquata* species complex are given.

Keywords: Arcidae, Anadarinae, *Anadara antiquata* (Linnaeus, 1758) complex, *Anadara subrubra* (Dunker, 1866) identity, taxonomy, type material, re-description

INTRODUCTION

Taxonomy and faunal compositions of the widespread tropical and subtropical bivalves - anadarines (blood cockles) (Bivalvia: Arcidae: Anadarinae) are still poorly studied in many parts of the Indo-West Pacific. Although only between 40 and 50 species are known from this area (for review see Huber (2010) and Lutaenko (2011)), much disagreement exists about status of many anadarines. The species richness of the anadarines is the highest in the eastern portion of the Indo-West Pacific (up to 24 in Chinese waters) and decreases to 7–8 species in the Red Sea and Southern Africa.

The *Anadara* (*Anadara*) *antiquata* (Linnaeus, 1758) complex, the type species of the genus *Anadara* Gray, 1847, is one of the most complicated among anadarines and has been so since the original description. While various treatments by earlier workers and then the classic revision by Lamy (1907) attempted to improve understanding of the group, it did not because of high morphological variability. This species is widely distributed in the Indo-West Pacific extending from the Red Sea, eastern and southern Africa, the Persian Gulf, the Seychelles and India to north-eastern Australia, the Philippines, the South China Sea, Thailand and northern Borneo, and, perhaps, southern Japan (Lamy 1907 (part.); Kilburn 1983; Vongpanich 1996; Evseev and Lutaenko 1998; Huber 2010). According to Huber (2010), there are only three synonyms of this variable species: *Arca scapha* Gmelin, 1791 (type locality Sri Lanka), *Anomalocardia transversalis* H. Adams, 1872 (type locality: the Red Sea, type specimen is lost), and *Anadara suggesta* Iredale, 1939 (North Queensland, Australia). Many other "forms" (as "var.") of this species were delineated by Lamy (1907) based on previously described species, some overlapping in shell morphology, and no modern revision of this species complex exists. Huber (2010) assigned species status to some of Lamy's (1907) varieties, we do not dispute that the actual species diversity of the *A. antiquata* complex is higher than a majority of authors in the 20th century thought. Moreover, the traditional concept of *A. antiquata*/*A. scapha* relationships might be wrong when the type material (a syntype of *A. scapha* from Chemnitz collection was recently found in the collection of the Zoological Institute, Russian Academy of Sciences in St. Petersburg) has been examined, and a long discussion in literature (Hanley 1855; Lamy 1904; 1907; Iredale 1939; Dodge 1952; Huber 2010) has not resolved this problem. The revision of this species complex is out of the scope of this paper; however, based on available data, it is preferable to recognize both *A. antiquata* and *A. scapha* as valid. Unfortunately, shell morphology is not well studied in this species complex (*e.g.*, sculpture of ribs, periostracum patterns), especially in long series, and no molecular studies based on material from various geographical areas are published, and these shortcomings negate further revision.

A species, which has rarely been illustrated and discussed in literature since the 19th century, is *Anadara subrubra* (Dunker, 1866). This species has been believed to be a synonym of *A. antiquata* (*e.g.*, Oostingh 1923; 1925; Habe 1965; Stevenson 1972; Evseev and Lutaenko 1998) until Huber (2010) considered it valid. An arcid recently found in Vietnam and described as new to science (Thach 2015) is here synonymized with *A. subrubra*, which is re-described and seems to be a widely distributed anadarine in Southeast Asia. The validity, synonymy, and status of allied species are discussed.

Abbreviations used throughout the paper are as follows: **MNHN** – Muséum National d'Histoire Naturelle, Paris, France; **NHMUK** – the Natural History Museum, London UK; **ANSP** – Academy of Natural Sciences of Philadelphia, Philadelphia, USA; **ZMFU** – Zoological Museum, Far Eastern Federal University, Vladivostok, Russia.

RESULTS

TAXONOMY

Anadara (*Anadara*) *subrubra* (Dunker, 1866)

Figs. 1–3, 4A, B

Anomalocardia subrubra Dunker, 1866: 83, Taf. 28, fig. 1–3.
Arca (*Anomalocardia*) *subrubra* - Kobelt 1889: 111, Taf. 29, fig. 4–5.
Arca antiquata var. *subrubra* - Lamy 1907: 200.
Arca (*Anadara*) *subrubra* - Lynge 1909: 119.
Anadara (*Anadara*) *subrubra* - Huber 2010: 137 (photo).
Anadara antiquata - Thach 2005: 242, pl. 75, fig. 9; ?Dharma 2012 (part.): 5, pl. 1, fig. 1a (non Linne, 1758).
Anadara oceanica - Poppe 2010: 474, pl. 928, figs. 7–8 (non Lesson, 1831).
Anadara dekkeri Thach, 2015: 89, figs. 1–12; Thach 2016: 76, pl. 34, figs. 430–432; syn. nov.

Type locality. *Anomalocardia subrubra* Dunker, 1866: "Philippinas insulas" [Philippines]; (Dunker 1866, p. 83); *Anadara dekkeri* Thach, 2015: Vietnam Nam, Khánh Hòa Province, Nha Trang (Thach 2015, p. 89).

Type material. *Anomalocardia subrubra* Dunker, 1866: NHMUK, two **syntypes**, reg. no. 1969177, Philippines, Hugh Cuming collection (Fig. 2); *Anadara dekkeri* Thach, 2015: Naturalis Biodiversity Center, Leiden, The Netherlands, **holotype;** Muséum National d'Histoire Naturelle, Paris, France, **paratype**, mus. no. MNHN-IM-2014-6053, Vietnam, Nhatrang (Fig. 3); Academy of Natural Sciences of Philadelphia, Philadelphia, USA, **paratype**; collection of N.N. Thach, Vietnam, two **paratypes**; all paratypes are from the type locality (Thach 2015).

Material studied. 2 specimens (syntypes), Philippines, NHMUK; 1 specimen, Nhatrang, Vietnam, ZMFU.

Original description. "Testa ovata, parum obliqua, subrubra, intus alba, umbones versus flacenses, valde tumida, epidermide fusca villosa, in sulcis setigera obducta, costis 36–40 subgranosis exceptis posterioribus latioribus sulco mediano bipartitis, instructa; umbones tumidi remotiusculi, subcancellati, paullulum incurvi, antrorsum inclinati; arca ligamenti subcavata magna, impressiones musculares leves, postica paullo major; cardinis denticuli inaequales haud obliqui; linea pallii satis impressa. – Long. 42 mill. Long. alt. crass. Ratio his numeris respondet 100, 60, 60." (Dunker 1866, p. 83).

Description. Shell large (up to 88 mm), elongate-ovate to sub-rectangular, inaequilateral, white with light brownish tone in the outer surface in the middle part, ventral margin gently and widely rounded and in large specimens nearly subparallel to straight dorsal margin, anterior margin well rounded, posterior margin rounded in young and well-rounded in adult specimens. Postero-ventral margin generally drawn down especially in adults. Shell moderately inflated to somewhat flattened in adult stage (over 70 mm in length). Shell relatively thin (2.4 mm in ventral margin in a 59 mm long specimen). Umbos relatively low, beaks often with median depression, ligamental area narrow, inaequilateral, anterior part occupies 1/3 of the total length, no chevrons. Hinge nearly straight, narrow, with numerous small vertical teeth but slightly oblique laterally. Inner surface with clear fine striation above the pallial line and glossy below the line; inner margin deeply crenulated in postero-dorsal part. Sculpture of 38–41 low, closely spaced radial ribs, the interspaces with fine concentric striae or stripes, anterior 23–24 ribs dichotomous, with median groove, grooves also present on posterior ribs, anterior and posterior ribs bear small nodules or beads. Periostracum velvety,

brown, with short bristles and fine hairs. A specimen (single valve) with maximum size in our collection (ZMFU) has length 59.4 mm, height 43.3 mm.

Distribution. According to Huber (2010), this species is distributed in the Philippines, South China Sea, Thailand, Cambodia, Vietnam, southern China (Hainan Isl.), East China Sea (Taiwan), southern Japan (Amami Isl.); perhaps, in Indonesia (Dharma 2012; as *A. antiquata* (part.)). Within Vietnam, *A. subrubra* is known from central part - from Quảng Ngãi Province to Bình Thuận Province (Thach 2015; as *A. dekkeri*). Rare species.

Comparison. *A. subrubra* differs from allied species by shell shape, number of radial ribs, and periostracum patterns: from *A. antiquata* and *A. scapha* (Fig. 4E–H) - by having more radial ribs (36–41 vs. 35), absence of erect bristles of periostracum, narrower ligamental area, thinner shell; from *Anadara hankeyana* (Reeve, 1844) - by presence of simple median groove on ribs (vs. 3–5 times incised ribs); from *Anadara oceanica* (Lesson, 1831) - by having more radial ribs (36–41 vs. 32–35), from *Anadara rugifera* (Dunker, 1866) (38–40 ribs), *Anadara setigericosta* (Nyst, 1848) (35–36 ribs) and *Anadara fultoni* (G.B. Sowerby III, 1907) (42–43 ribs) (Fig. 4C–D) - by elongated shell shape and incision pattern of ribs (Table 1).

Remarks: In addition to the morphological comparison outlined above and in Table 1, the taxonomic status and validity also needs some comments. Lamy (1907), in his worldwide revision of Arcidae, regarded various species associated with the *A. antiquata*-complex and described in the 19th century, as varieties (var.). In total he recognized six varieties, among them *A. antiquata* var. *subrubra*; some other species were synonymized. Later, Lamy (1917) split *A. antiquata* and *A. scapha*, two major species of the complex as distinct species, each with one variety, based on material from the Red Sea. This system, according to some authors (Iredale 1939; Huber 2010) led to chaos whereas a majority of subsequent workers of Arcidae generally followed this synonymy without critical analysis or due in part to the lack of comparative material from other regions. Huber (2010) substantiated that a number of species previously synonymized with *A. antiquata* were valid. He recognized the following: *A.* (*A.*) *hankeyana* (with *Arca amaliae* Kobelt, 1888 as a synonym; widely distributed Indo-Pacific species), *A.* (*A.*) *oceanica* (with the well-known *Arca maculosa* Reeve, 1844 and *Arca novaecaledoniae* Baird in Brenchley, 1873 as synonyms; Australia, New Caledonia, Polynesia, Melanesia), *A.* (*A.*) *rugifera* (eastern Africa and north-western Australia), *A.* (*A.*) *setigericosta* (Philippines) and *A.* (*A.*) *subrubra*. Of course, this distinction requires a molecular confirmation but one should be aware of vast distributional ranges of these Indo-West Pacific species and their high variability, so, a careful conchological identification should be done first, all voucher specimens and their images should be available and duly published.

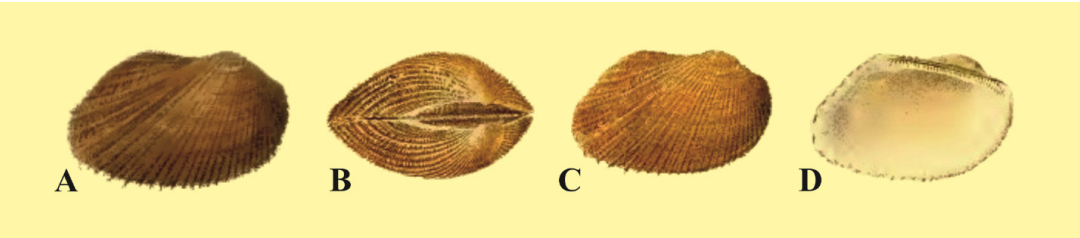

Figure 1. Drawings of *Anadara subrubra* (Dunker, 1866) in the 19th century works: A. Kobelt (1889, Taf. 29, fig. 4; as *Arca* (*Anomalocardia*) *subrubra*); B–D. Dunker (1866, Taf. 28, figs. 1–3; as *Anomalocardia subrubra*).

Table 1. Distinguishing morphological characteristics of species included in the *Anadara antiquata* complex.

Species	Shell shape	Number of ribs	Rib sculpture and periostracum	Illustrations of typical specimens
Anadara antiquata	Ovate	35	Median groove on ribs anteriorly; periostracum of fine lamellae and fine erect bristles	Oliver (1992, pl. 3, fig. 1; as *A. antiquata*); Singer and Mienis (2007, pl. 1; as *A. antiquata*)
Anadara scapha	Ovate-squarish, obliquely truncate posteriorly	33–35	Strong median groove	Huber (2010, p. 135; as *A. antiquata*); Lutaenko (2016, pl. 1, figs. E, F; as *A. antiquata*)
Anadara hankeyana	Ovate-elongate	32–33	Fine secondary grooves; very dense regular periostracum with short bristles	Schenk and Reinhart (1938, pl. 3, fig. 4; as A. *hankeyana*); Huber (2010, p. 136; as *A. hankeyana*)
Anadara rugifera	Ovate-subquadrate	38–40	Ribs often not bifid, with strong nodules on surface	Huber (2010, p. 136; as *A. rugifera*)
Anadara oceanica	Ovate-elongate	32–35	-	Lamprell and Healy (1998; p. 53, fig. 76; as *A. antiquata*)
Anadara setigericosta	Ovate-squarish, obliquely truncate posteriorly; shorter than *A. antiquata* and *A. scapha*	35–36	Ribs bifid mostly anteriorly, rib interspaces finely striated	Huber (2010, p. 136; as *A. setigericosta*)
Anadara fultoni	Ovate, more regular posteriorly	42–47	Ribs clearly bifid on entire surface; interspaces narrow; periostracum densely lamellate	Huber (2010, p. 135; as *A. fultoni*); Evseev and Lutaenko (1998, pl. 4, fig. B; as *A. crebricostata*); Lutaenko (2016, pl. 1, figs, C, D; as *A. fultoni*)
Anadara crebricostata	Ovate-elongate, anterior end broadly rounded	43–44	Anterior ribs bifid; interspaces rather wide; periostracum densely lamellate	Huber (2010, p. 135; as *A. crebricostata*)
Anadara subrubra	Ovate-elongate	36–41	Anterior 23–24 ribs well bifid, also bifid posteriorly, interspaces with fine concentric striae, anterior and posterior ribs with small nodules; periostracum velvety, brown, with short bristles	Huber (2010, p. 137; as *A. subrubra*); this paper

Figure 2. Syntypes of *Anomalocardia subrubra* Dunker, 1866 in the collection of the NHMUK, London, reg. no. 1969177, Philippines, Hugh Cuming collection, two complete shells (upper and lower images). Courtesy of the NHMUK.

A species recently described from Vietnam - *A. dekkeri* (Thach 2015) (Fig. 3), is here synonymized with *A. subrubra*. Another probable earlier synonym of *A. subrubra* is the large *Arca lamarckii* Philippi, 1845 with its 40 radial ribs (Philippi 1845) described from China. The type material of this species has not been examined because although it is present in the Museo Nacional de Historia Natural, Santiago, Chile (Coan and Kabat 2017) it is not available for loan. No original illustrations are known, the description is insufficient to appraise the identity of this species; and it is here considered a *nom. dub.* (Huber 2010). It is noteworthy that Prashad (1932) and Li (1983) did not include *A. subrubra* in the synonymy of *A. antiquata*.

Oostingh (1925) compared the fossil *Anadara fennemai* (Martin, 1910) (40 ribs) and *Anadara junghuhni* (Martin, 1910) (36–38 ribs) described from the Javanese Neogene with *A. antiquata* and *A. subrubra* (as a form of *A. antiquata*) and considered them as synonyms of the former. This was accepted by modern authors (Leloux and Wesselingh 2009); Noda (1979, pl. 38, figs. 5, 8, 13) figured *A. junghuhni* from the Pliocene of Batan Island, the Philippines. Images of syntypes of *A. junghuhni* (Leloux and Wesselingh 2009, pl. 45, figs. 9–12) are similar to *A. subrubra* whereas the holotype of *A. fennemai* (Leloux and Wesselingh 2009, pl. 45, figs. 7–8) is a broken shell with uncertain affinity.

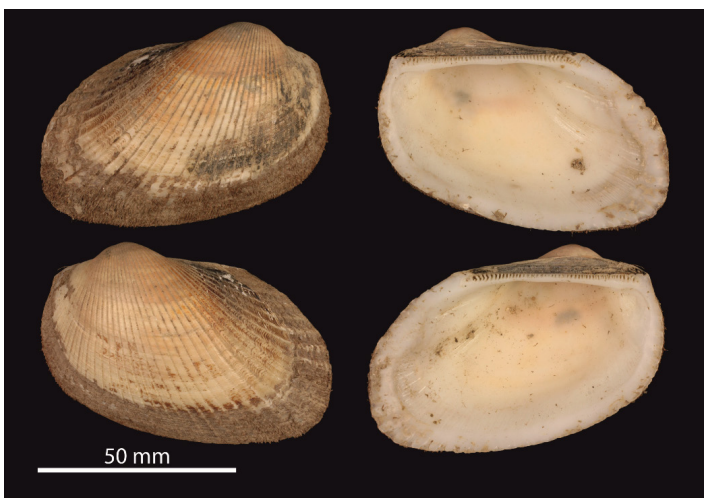

Figure 3. A paratype of *Anadara dekkeri* Thach, 2015 in the collection of the MNHN, Paris, reg. no. MNHN-IM-2014-6053, Vietnam, Nhatrang, complete shell. Courtesy of the MNHN.

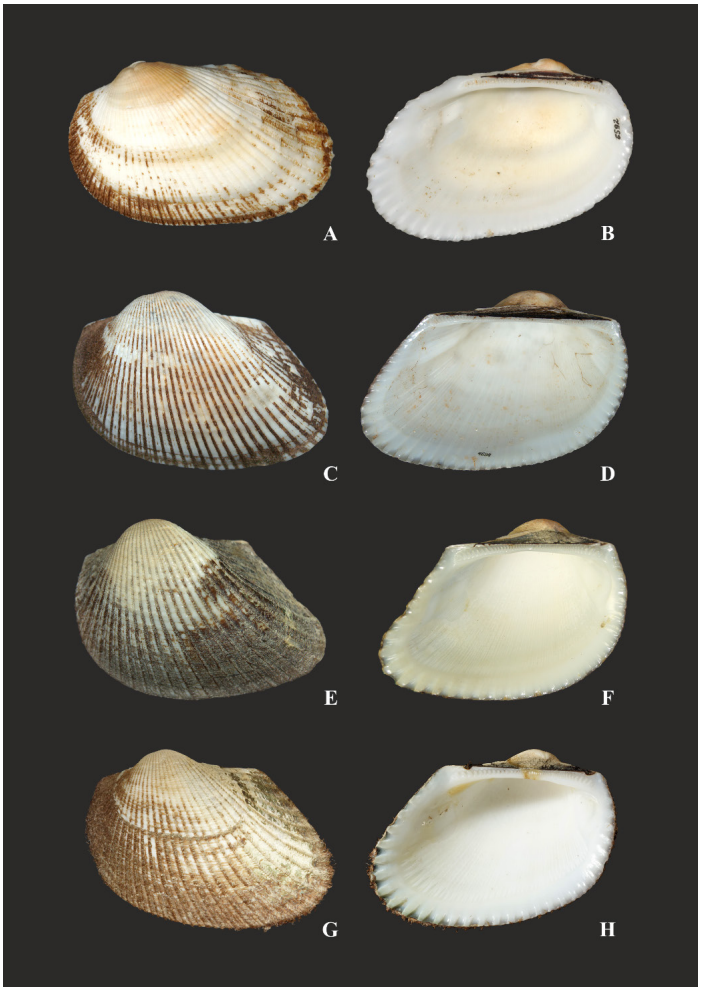

Figure 4. Illustrations of some species belonging to *Anadara antiquata*-complex: A–B. *Anadara subrubra* (Dunker, 1866), South China Sea, Vietnam, Nhatrang, shell length 59.4 mm, ZMFU no. 43356/Bv-6592; C–D. *Anadara fultoni* (G.B. Sowerby III, 1907), South China Sea, Thailand, Prachuab Khirikhan Prov., shell length 70.1 mm, ZMFU no. 27751/Bv-4694; E–F. *Anadara scapha* Gmelin, 1791, South China Sea, China, Hainan Island, shell length 53.4 mm, ZMFU no. 10634/Bv-912; G–H. *Anadara* cf. *antiquata* (Linnaeus, 1758), South China Sea, Vietnam, Nhatrang, shell length 45.5 mm, ZMFU no. 43352/Bv-6588.

Table 2. Interpretation of species identity of the figured specimens of *Anadara antiquata* complex.

Original identification, reference, region	Re-identification, comments
Anadara crebricostata - Evseev and Lutaenko (1998, pl. 4, fig. B); Vietnam.	*Anadara fultoni*
Anadara fultoni - Lutaenko (2016, pl. 1, figs. C, D); Thailand.	*Anadara fultoni*
Scapharca setigericosta - Thach (2005, p. 243, pl. 75, fig. 3); Vietnam.	*Anadara fultoni*

Original identification, reference, region	Re-identification, comments
Anadara fultoni - Thach (2016, pl. 35, fig. 436); Vietnam.	*Anadara fultoni*
Anadara maculosa - Thach (2012, pl. 125, fig. 1458 top); Vietnam.	*Anadara fultoni*
Anadara crebricostata - Wang *et al*. (2016, p. 78, fig. 219); South China Sea, Chinese coast.	*Anadara fultoni*
Anadara antiquata - Poppe (2010, pl. 926, fig. 1); Tulang Island (the Philippines).	*Anadara fultoni*
Anadara subrubra - Lutaenko (2016, pl. 3, figs. A, B); Vietnam.	*Anadara fultoni*, subadult
Anadara oceanica - Thach (2012, pl. 125, fig. 1458 bottom); Vietnam.	? *Anadara hankeyana*
Anadara valentichscotti - Thach (2016, p. 75, pl. 34, figs. 425, 426); Vietnam.	? *Anadara hankeyana*
Anadara antiquata - Okutani (2017, pl. 467, fig. 14 – upper image only); Japan.	Very close to *Anadara rugifera* but this species is known only from eastern Africa to north-western Australia
Anadara trapezia - Poppe (2010, p. 476, pl. 929, fig. 1); Mactan Island (the Philippines).	*Anadara scapha*
Anadara scapha - Noda (1966, pl. 11, fig. 6); Okinawa.	*Anadara scapha*
Anadara cf. *antiquata* - Lozouet and Plaziat (2008, pl. 1, figs. 5, 6).	? *Anadara scapha*
Anadara antiquata - Okutani (2017, pl. 467, fig. 14 – lower image only); Japan.	*Anadara scapha*
Anadara trapezia - Poppe (2010, p. 476, pl. 929, fig. 3); Bohol (Mahanay Island), the Philippines.	similar to *Anadara setigericosta*
Anadara cf. *antiquata* - Lozouet and Plaziat (2008, pl. 1, figs. 1–4); central Philippines.	similar to *Anadara setigericosta*
Anadara trapezia - Poppe (2010, p. 476, pl. 929, fig. 2); Bohol, the Philippines.	? *Anadara antiquata*
Anadara holoserica - Thach (2012, pl. 125, fig. 1459 bottom); Vietnam.	? *Anadara antiquata*
Anadara antiquata - Zuschin and Oliver (2003, pl. 5, fig. 5.2, not fig. 5.1); Red Sea, Egypt.	*Anadara antiquata*
Anadara scapha - Hu and Tao (1994); Taiwan .	*Anadara* (*Scapharca*) sp., no bifid ribs
Anadara antiquata - Wang *et al*. (2016, p. 77, fig. 217); South China Sea, Chinese coast.	*Anadara* (*Scapharca*) sp.
Anadara antiquata - Tudu *et al*. (2019, fig. 2a, b); eastern India.	*Anadara* (*Scapharca*) *inaequivalvis* (Bruguière, 1789); unusual trigonal shape
Anadara antiquata - Jahangir *et al*. (2012, p. 265, fig. 4); Pakistan.	*Anadara* (*Scapharca*) sp.

Notes: true *Anadara crebricostata* is an Australian endemic, whereas *A. fultoni* is a Chinese-Philippine species (Huber 2010); *Anadara trapezia* is an Australian endemic.

ACKNOWLEDGEMENTS

I am very grateful to Dr. Kathe Jensen for inviting me to contribute to this memorial volume dedicated to Prof. J. Hylleberg, founder, leader and spiritual father of the Tropical Marine Mollusc Programme (TMMP, 1990–2004), and for careful editing of the manuscript. Andreia Salvador (The Natural History Museum, London) sent me photographs of the syntypes of *Anomalocardia subrubra*; images were taken by Phil Hurst, NHMUK Photographic Unit. Virginie Héros (Muséum National d'Histoire Naturelle, Paris) kindly permitted to reproduce photographs of a paratype of *Anadara dekkeri* from the online database of the collection in her possesion (credit to Marie Henion, Project RECOLNAT (ANR-11-INBS-0004)). Irina E. Volvenko (V.K. Arseniev Museum of Far East History, Vladivostok) took photographs of anadarines from the collection of the Zoological Museum, Far Eastern Federal University (Vladivostok) and prepared illustrations; Olga N. Pavlyuk (A.V. Zhirmunsky National Scientific Center of Marine Biology FEB RAS, Vladivostok) collected a sample of *Anadara subrubra* in Vietnam and placed at my disposal; Irina A. Barsegova of the same institution checked the English text. I am very thankful to all these people for assistance and support.

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Manuscript received: 4 October 2020
Accepted: 19 December 2020