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# CONSERVATION STATUS REASSESSMENT OF GIANT CLAMS (MOLLUSCA: BIVALVIA: TRIDACNINAE) IN SINGAPORE

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***ABSTRACT.*** — Throughout their range, giant clams (family Cardiidae, subfamily Tridacninae) are increasingly threatened by anthropogenic impacts and natural disasters. While almost all tridacnid species are protected under Appendix II of CITES and included in the IUCN Red Data List, these classifications are outdated and may not accurately reflect the situation in individual countries. Recent extensive surveys and a literature review established that the coral reefs in Singapore host two genera and five species of giant clams. Their present conservation status is herein evaluated, and we propose that all are highly threatened in Singapore: *Tridacna maxima* and *Tridacna squamosa* are "critically endangered", and *Tridacna crocea* is "endangered", while *Hippopus hippopus* and *Tridacna gigas* are "presumed nationally extinct". Species assessments at finer geographical scales provide a more nuanced status and are therefore of greater value when planning local conservation strategies. As Singapore's reefs continue to undergo coastal modifications, active management of the remaining giant clam species is necessary to prevent their extirpation.

***KEY WORDS***. — Red Data List status, *Hippopus*, *Tridacna*, distribution, abundance, Singapore

## INTRODUCTION

Giant clams (family Cardiidae, subfamily Tridacninae) are a group of marine bivalve molluscs consisting of two genera: *Hippopus* and *Tridacna*, with 10 extant species (bin Othman et al., 2010). These charismatic bivalves are often cited as important ecological components of coral reefs, especially as contributors to overall productivity and providers of substrate, i.e., their shells, for epibionts (Hardy & Hardy, 1969; Mingoa-Licuanan & Gomez, 2002). Unfortunately, populations of wild giant clams are declining in various countries including Australia (Braley, 1987), Indonesia (Pringgenies et al., 1995), Malaysia (Tan & Yasin, 2003), the Philippines (Alcala, 1986), and Singapore (Neo & Todd, 2012a), as they face threats of coral reef degradation (Chou, 1999; Guest et al., 2008), subsistence harvesting by coastal and island communities (Munro, 1989; Kinch, 2002), and the sale and export of wild specimens for the aquarium trade (Wells, 1997; Wabnitz et al., 2003). Giant clams are highly vulnerable to stock depletion because of their late sexual maturity and sessile adult phase (Munro, 1989). Fertilisation of tridacnid eggs is maximised by synchronised spawning (Lucas, 1988; Gilbert et al., 2006), which is induced by the release of eggs from an individual stimulating spawning of surrounding clams (Munro et al., 1983). If densities of mature clams decrease, breeding is disrupted (Lucas, 1988) and populations become reproductively dysfunctional. This can result in reduced recruitment and eventual population collapse.

Table 1. Conservation status categories of nine giant clam species listed by the IUCN Red List of Threatened Species (Molluscs Specialist Group, 1996; Wells, 1996).

| Species Name | Common Names | Global Conservation Status |
|---|---|---|
| *Hippopus hippopus* (Linnaeus, 1758) | bear paw clam; horse's hoof clam; strawberry clam | Lower Risk/conservation dependent |
| *Hippopus porcellanus* Rosewater, 1982 | China clam | Lower Risk/conservation dependent |
| *Tridacna crocea* Lamarck, 1819 | boring clam; crocus clam; saffron-coloured clam | Lower Risk/least concern |
| *Tridacna derasa* (Röding, 1798) | southern giant clam | Vulnerable A2cd |
| *Tridacna gigas* (Linnaeus, 1758) | giant clam; bénitier géant | Vulnerable A2cd |
| *Tridacna maxima* (Röding, 1798) | small giant clam | Lower Risk/conservation dependent |
| *Tridacna rosewateri* Sirenko & Scarlato, 1991 | bénitier de rosewater | Vulnerable A2cd |
| *Tridacna squamosa* Lamarck, 1819 | fluted clam; fluted giant clam; scaly clam | Lower Risk/conservation dependent |
| *Tridacna terovoa* Lucas, Ledua & Braley, 1990 | tevoro clam; bénitier de tevoro | Vulnerable B1+2c |

To date, nine giant clam species (i.e., all except the newly described *Tridacna costata*) are protected under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Table 1 summarises their global conservation statuses as assessed by the International Union for Conservation of Nature (IUCN).

The listed species can be categorised into two main global status groups: "vulnerable" for *Tridacna derasa*, *Tridacna gigas*, *Tridacna rosewateri*, and *Tridacna tevoroa* and "lower risk/conservation dependent" for *Hippopus hippopus*, *Hippopus porcellanus*, *Tridacna crocea*, *Tridacna maxima*, and *Tridacna squamosa*. The IUCN Red List of Threatened Species highlights species at risk of extinction and promotes their conservation (Collar, 1996). The list is frequently used to guide management of resources (Rodrigues et al., 2006), such as by CITES that help prevent species from becoming threatened through international trade (Wells & Barzdo, 1991). Hence, both the IUCN and CITES serve to complement the development of effective conservation strategies and measures for protecting species. However, it is important to note that 1) the assessed global status might be outdated (as is the case for giant clams, as they were reviewed mostly by Wells [1996]) and 2) their reported status may not accurately reflect the situation in individual countries. Without accurate assessments at finer geographical scales, CITES and IUCN data may become misleading for conservation managers. For instance, it is quite possible for a species to be classified by the IUCN as "lower risk/conservation dependent" but extinct or near extinct at country level.

Singapore's coral reefs once hosted five giant clam species: *Hippopus hippopus*, *Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, and *Tridacna squamosa* (Neo & Todd, 2012b), and records of their presence in Singapore can be dated back to the 1800s (Traill, 1847). Giant clams were mostly threatened by exploitation during Singapore's early years (harvesting as food for example [Daily Telegraph, 1914]), which persisted well into the 1960s and possibly beyond (Harrison & Tham, 1973; Chou, 1984). Intensive coastal development beginning in the late 1960s led to extensive loss of coral reefs and their associated fauna (Chou, 1999), including giant clams (Guest et al., 2008), and has probably overtaken exploitation as the greatest threat to reef animals. Increased sea surface temperatures in Singapore (Guest et al., 2012) may also lead to giant clams bleaching, i.e., the expulsion of their symbiotic zooxanthellae (Ishikura et al., 1999). It is likely that, together, these impacts have significantly altered giant clam populations on Singapore reefs. While the presence of giant clams in Singapore has traditionally been quite well documented (e.g., Traill, 1847; Chuang, 1973; Purchon & Purchon, 1981), data on their abundance and distribution has generally been absent. The two editions of the Singapore Red Data Book list selected giant clam species (see Ng & Wee, 1994; Davison et al., 2008) but, based on the findings from extensive recent surveys (Guest et al., 2008; Neo & Todd, 2012a), it is apparent that these entries require updating. This paper revises the list of giant clam species present in Singapore and re-evaluates their conservation status.

## STATUS OF GIANT CLAMS IN SINGAPORE'S RED DATA BOOKS

In the 1st Edition of the Singapore Red Data Book (eds. Ng & Wee, 1994), three species—*Hippopus hippopus*, *Tridacna crocea*, and *Tridacna squamosa* were all assigned the national status of "endangered". *Tridacna squamosa* was "unprotected in Singapore waters and large specimens have virtually disappeared. Young specimens are occasionally but infrequently seen" (Chou et al., 1994: 87). Habitat degradation, collection for food, and the marine curio trade were listed as threats. The authors did not elaborate further on the other two species. In the 2nd Edition of Singapore Red Data Book (eds. Davison et al., 2008), *Tridacna squamosa* was listed as "endangered", i.e., "fewer than 250 mature individuals and no other evidence of decline or fragmentation" (Davison, 2008: 3), but *Hippopus hippopus* and *Tridacna crocea* were unmentioned. For *Tridacna squamosa*, Chou & Tan (2008: 59) also noted "translocation has been used as a technique to avoid loss of specimens from coastal development projects and collectors."

## UPDATED CONSERVATION STATUSES OF GIANT CLAMS IN SINGAPORE

In Singapore, the occurrence of *Hippopus hippopus*, *Tridacna crocea*, *Tridacna maxima*, and *Tridacna squamosa* has been emphasised in numerous publications (e.g., Chuang, 1961, 1973; Johnson, 1964; Rosewater, 1965; Purchon & Purchon, 1981; Henrey, 1982; Lim et al., 1994; Ng et al., 1995; Wells, 1997). A recent review by Neo & Todd (2012b) produced new evidence suggesting a fifth species, *Tridacna gigas*, was once present in Singapore (Traill, 1847; Whymper, 1883), bringing the number of giant clam species to five. Giant clam sightings from early surveys mostly indicated their presence or absence in Singapore's waters (e.g., Purchon & Enoch, 1954; Purchon & Purchon, 1981; Chou & Wong, 1986), with little additional information. The first quantitative clam survey was conducted at seven reefs in 2003 (Guest et al., 2008), and determined an overall clam density of 0.24 per 100 $m^2$. A more extensive survey of 29 reefs in 2009/2010, however, revealed a much lower density of 0.067 per 100 $m^2$ (Neo & Todd, 2012a). Species composition also differed between the two surveys, with *Tridacna maxima*, *Tridacna crocea*, and *Tridacna squamosa* listed in 2003, but only the latter two species were encountered in 2009/2010 (Table 2). *Hippopus hippopus* and *Tridacna gigas* were not found in either of the surveys. Based on evidence from these two surveys, plus additional

observations made by the authors, we present below updated conservation statuses for the five species recorded in Singapore.

***Tridacna gigas*.** — To the best of our knowledge, the presence of *Tridacna gigas* in Singapore has only been mentioned in three early sources: William Traill's table entitled "Catalogue of the shells of Singapore and its vicinity" (Traill, 1847), the "Great Oyster from Singapore (*Tridacna gigas*)" presented at a fisheries exhibition in London, England

Table 2. A comparison of survey data from 2003 (Guest et al., 2008) and from 2009/2010 (Neo & Todd, 2012a).

| **Period of Surveys** | **2003 Survey** | **2009/2010 Survey** |
|---|---|---|
| Number of sites | 7 | 29 |
| Total area | 9,760 $m^2$ | 87,515 $m^2$ |
| Clam density (per 100 $m^2$) | 0.24 | 0.067 |
| **Species Encountered** | | **Number of Individuals** |
| *Hippopus hippopus* | 0 | 0 |
| *Tridacna crocea* | 7 | 31 |
| *Tridacna gigas* | 0 | 0 |
| *Tridacna maxima* | 1 | 0 |
| *Tridacna squamosa* | 14 | 28 |

(Whymper, 1883, Fig. 1), and a newspaper article in the UK's Daily Telegraph (1914). These findings are noteworthy, as *Tridacna gigas* is not listed as native to Singapore by the IUCN (Wells, 1996). In 2007, *Tridacna gigas* shell valves were excavated from a pre-1932 site at Tyrwhitt Road, Singapore, and these may have been harvested from local reefs (Neo & Todd, 2012b). No signs of either live or dead *Tridacna gigas* individuals were found during surveys by Guest et al. (2008) or Neo & Todd (2012a). As *Tridacna gigas* can grow up to over 1 m long (Lucas, 1988), it would be difficult to miss them on Singapore's narrow and compacted reef crest and slopes which are monitored for various purposes by local marine biologists (e.g., Tun, 2012). As the last known record is from 1866 (Daily Telegraph, 1914), *Tridacna gigas* can be assigned the national status of "presumed nationally extinct" (i.e., not having been found alive for more than 50 years in Singapore)(Davison, 2008: 3).

***Hippopus hippopus*.** — *Hippopus hippopus* (Fig. 2) was documented by various authors between 1847 and 1963 (Neo & Todd, 2012b), with the last sightings of live individuals in 1963 at Tanjong Teritip (Lee, 1966). However, Tanjong Teritip (in the west of Singapore Island) has since been reclaimed, built on, and is now Tuas. Purchon & Enoch (1954), Lee (1966), and Dawson & Philipson (1989) mentioned that *Hippopus hippopus* individuals were generally rare on local reefs but provided no actual numbers. Known to the local Malay fishers as '*Siput lupat*' (Chuang, 1961), *Hippopus hippopus* was traditionally harvested as food (Harrison & Tham, 1973; Chou, 1984). Recent surveys (Guest et al., 2008; Neo & Todd, 2012a) found no live individuals. Similarly, none were seen outside of survey areas and there

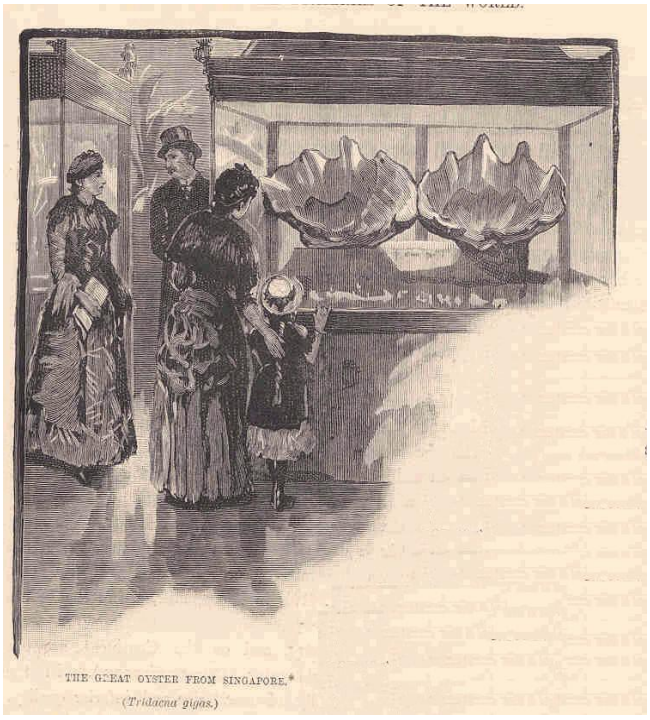


Fig. 1. An image from Whymper (1883) with the captions—"The Great Oyster from Singapore (*Tridacna gigas*)." "This is the finest known specimen, and to it the Jury awarded a diploma at the Fisheries Exhibition. Its weight is 3 cwt. 3 qrs. 14 lbs.; its length 3 ft. 4 in.; and its breadth 2 ft.; 2 in." (Source of this public domain image: Freshwater and Marine Image Bank).

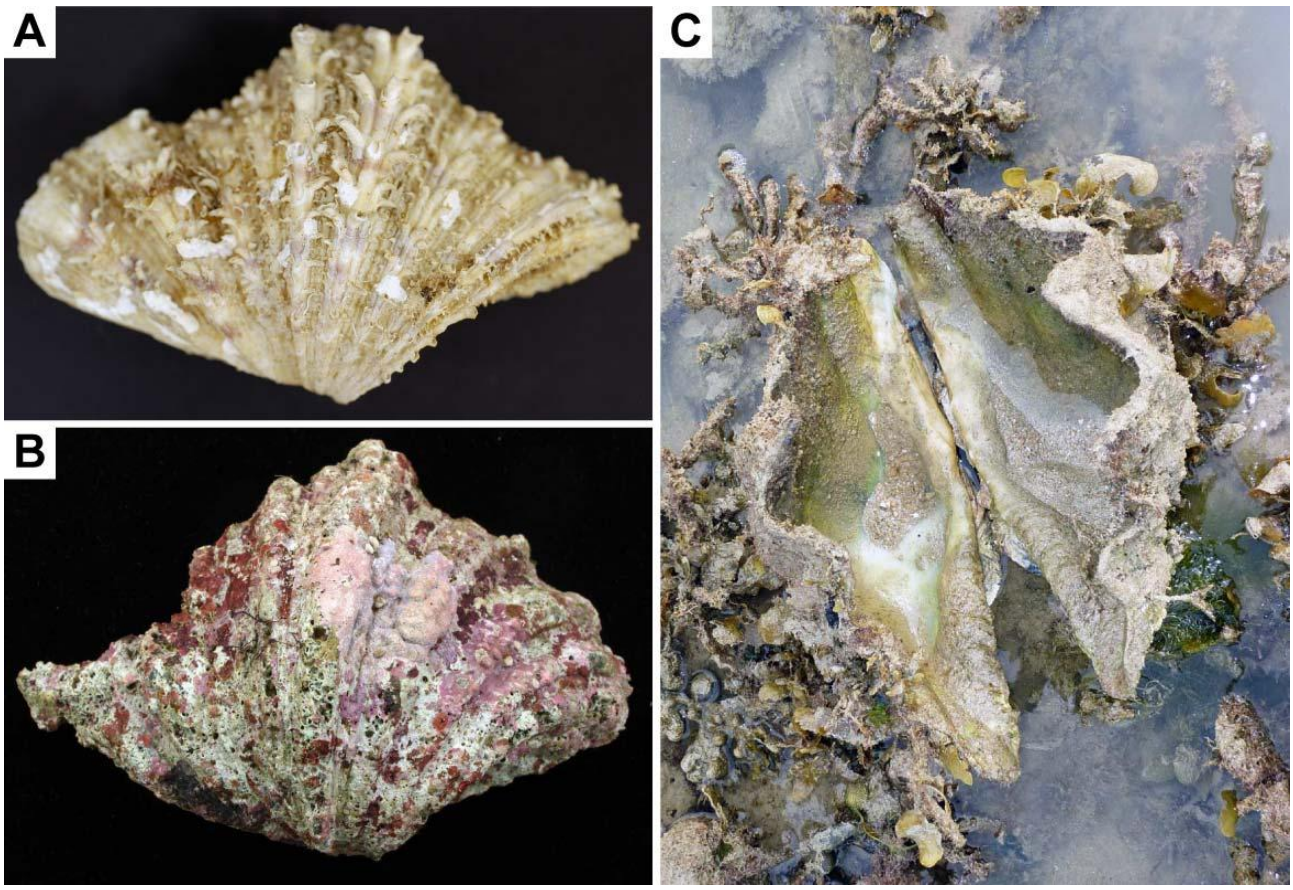


Fig. 2. *Hippopus hippopus* specimens, Singapore. A, Shell length (SL) = 7.5 cm, collected from Pulau Pawai in 1933 (ZRC1975.8.1.1, Raffles Museum of Biodiversity Research); B, SL = 15.2 cm, collected from Cyrene reefs on 18 Nov.2009; C, SL = 32.1 cm, photographed on 2 May 2010 at Terumbu Raya. (Photographs by: Neo Mei Lin [A, B] and Loh Kok Sheng [C])

have been no anecdotal reports. Dead specimens, however, can still be found on Singapore's reef flats (Neo & Todd, 2012a, 2012b). The natural rarity of *Hippopus hippopus* on local reefs, coupled with harvesting activities, has probably resulted in their extirpation (Neo & Todd, 2012b). In 2013, *Hippopus hippopus* reached the 50-year no-sighting criterion for the category of national extinction (Davison, 2008: 3). Hence, the status of *Hippopus hippopus* in Singapore should be reclassified from "endangered" (Davison et al., 2008) to "presumed nationally extinct".

***Tridacna maxima*.** — Even though present in Singapore from at least the 14$^{th}$ century (Neo & Todd, 2012b), there is no mention of *Tridacna maxima* in either edition of the Singapore Red Data Book. Exploitation of *Tridacna maxima* in Singapore is not discussed in any of the published literature. Despite the extensiveness of the surveys by Guest et al. (2008) and Neo & Todd (2012a), only a single *Tridacna maxima* individual was found (at Raffles Lighthouse; Guest et al., 2008). Another live specimen (Fig. 3), a mature adult with a shell length of 25 cm, was

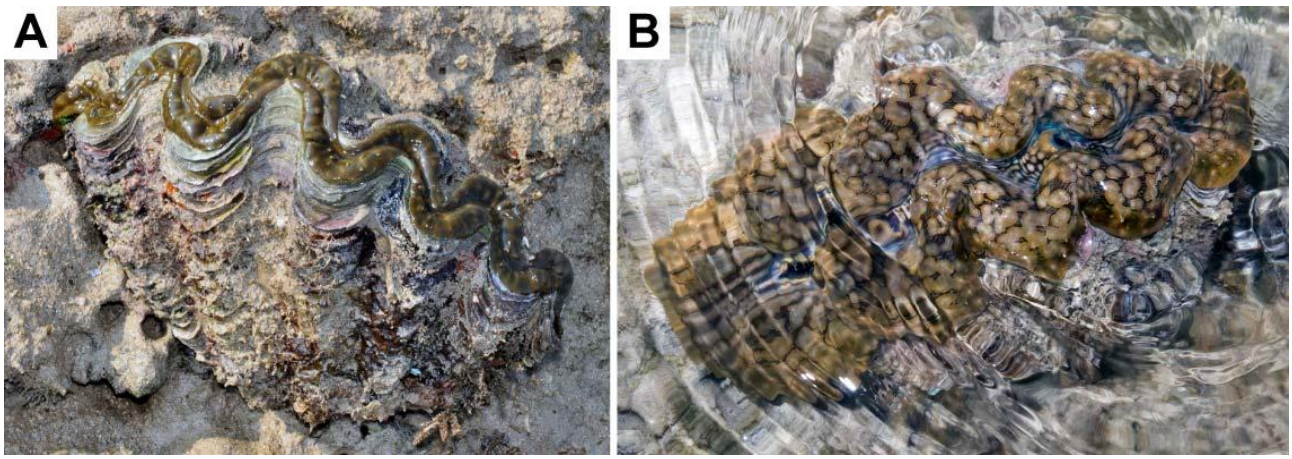


Fig. 3. The recently discovered *Tridacna maxima* individual on Terumbu Bemban. SL = 25.0 cm. (Photographs by: Toh Chay Hoon on 23 Apr.2011 [A] and Ria Tan on 12 Apr.2012 [B])

later discovered on the patch reefs of Terumbu Bemban in Apr.2011 (pers. obs.). The poorly consolidated substratum on Singapore's reefs (Tun, 2012) may explain the lack of *Tridacna maxima*, as they partially burrow into coral heads for anchorage (Rosewater, 1965). As Singapore's seascape has changed considerably over the decades, with many reef flats reclaimed in their entirety (Neo & Todd, 2012b; Tun, 2012), *Tridacna maxima* is threatened by the lack of suitably large surfaces to accommodate its burrowing behaviour. This species was not previously included in the two Singapore Red Data Book editions, but it clearly should be. Given that live specimens can only be found locally in extremely low numbers, we propose the Singapore national status for *Tridacna maxima* to be listed as "critically endangered (Category D)".

***Tridacna crocea*.** — Based on archaeological finds, the smallest giant clam species, *Tridacna crocea* (Fig. 4) has been in Singapore from at least the 14th century to the present day (Neo & Todd, 2012b). Similar to *Tridacna maxima*, *Tridacna crocea* harvesting has never been documented, possibly because they are generally completely embedded in the substratum (Hamner & Jones, 1976). Contemporary reefs in Singapore are characterised by loose and soft substrates (Tun, 2012) that are not well suited to *Tridacna crocea*'s burrowing behaviour and renders them vulnerable to wave and tide action (Hamner, 1978). Surveys in 2009/2010 put their density at a low 0.035 per 100 $m^2$ (Neo & Todd, 2012a) compared to 0.07 per 100 $m^2$ in 2003 (Guest et al., 2008). These numbers may be conservative as its burrowing behaviour (Hamner & Jones, 1976) and cryptic colouration (Todd et al., 2009) can lead to underestimates of abundance. Nevertheless, even if missed individuals doubled the density, the population size would still be very small (Guest et al., 2008; Neo & Todd, 2012a). We therefore suggest that the status of *Tridacna crocea* in Singapore remains as "endangered (Category D)".

***Tridacna squamosa*.** — The largest extant giant clam species in Singapore is *Tridacna squamosa* (Fig. 5). Historical records have shown its presence from the 14th century (Neo & Todd, 2012b) and it is the most studied of the local species (e.g., Huang et al., 2007; Ling et al., 2008; Neo & Todd, 2011). Chou et al. (1994) considered habitat degradation as well as exploitation for food and curios as threats to *Tridacna squamosa* populations in Singapore. *Tridacna squamosa* was traditionally known to Malay fishers as '*Siput kima*' (Chuang, 1961; Purchon & Purchon, 1981) and specimens were frequently harvested as food (Harrison & Tham, 1973). Unlike the burrowing

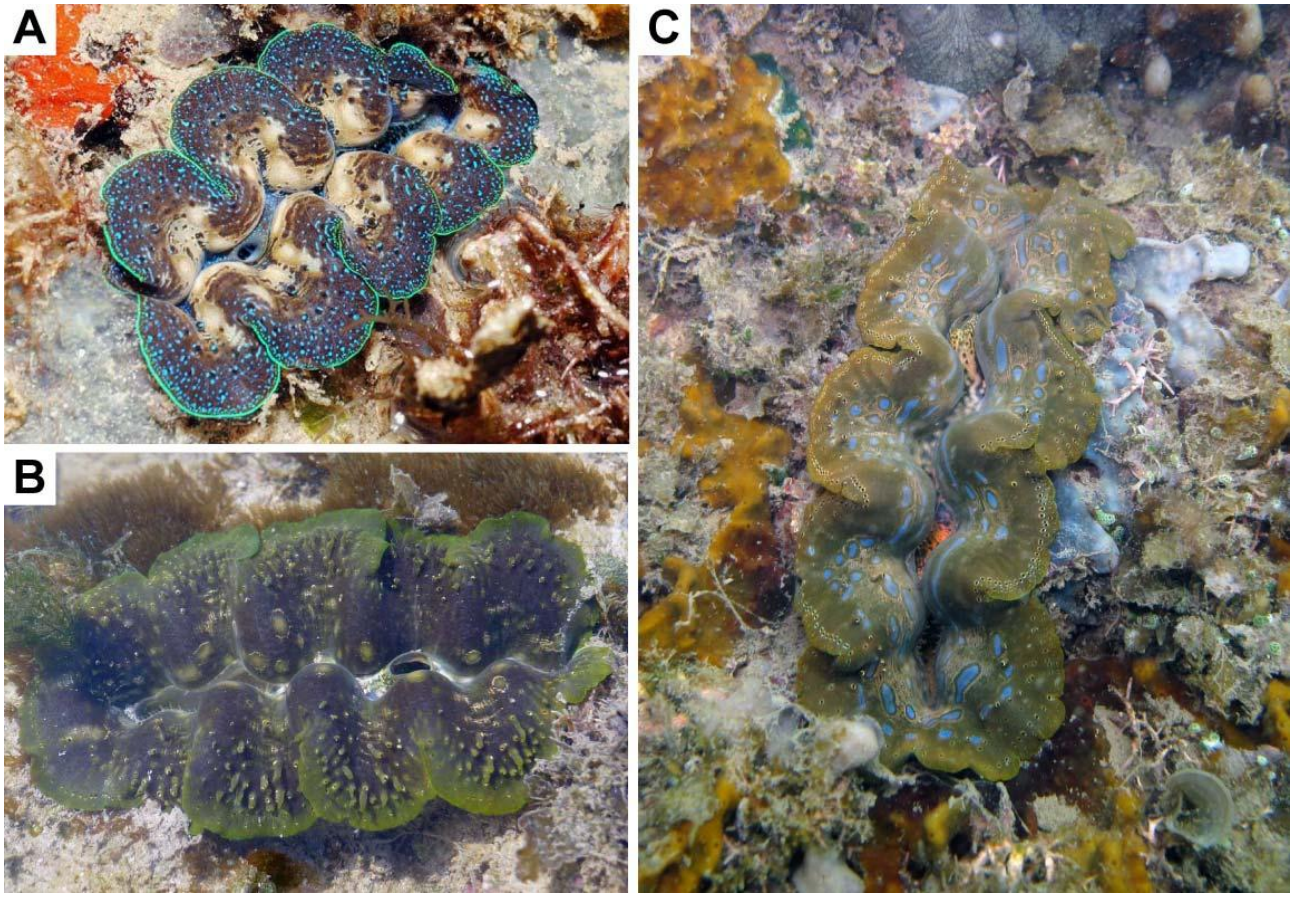


Fig. 4. *Tridacna crocea* specimens, Singapore. A, SL = 15.0 cm, photographed on 13 Nov.2012 at Pulau Semakau; B, SL = 14.0 cm, photographed on 11 May 2012 at Terumbu Pempang Laut; C, SL = 15.0 cm, photographed on 10 Nov.2009 at Raffles Lighthouse. (Photographs by: Loh Kok Sheng [A] and Neo Mei Lin [B, C])

*Tridacna crocea*, the larger and free-living *Tridacna squamosa* are easier to remove from the reef (Neo & Todd, 2012a). With the reduction in subsistence fishing in the late 1960s, coastal development became the next major threat, depleting natural habitats for all giant clam species in Singapore (Lee, 1966; Chou, 1999). Bleaching due to elevated temperatures can also negatively impact giant clams (Leggat et al., 2003; Sangmanee et al., 2010) and during the high sea surface temperature event in Jun.2010, local bleaching of *Tridacna squamosa* was observed (per. obs.). The most recent survey (Neo & Todd, 2012a) estimates *Tridacna squamosa* density to be 0.032 per 100 $m^2$, i.e., five times lower than the 0.16 per 100 $m^2$ measured in 2003 (Guest et al., 2008). Owing to their low numbers and scattered distribution, the population of *Tridacna squamosa* in Singapore is quite possibly functionally extinct (Guest et al., 2008). Hence, the national status for *Tridacna squamosa* should be changed from "endangered" to "critically endangered (Category C.1.)".

## CONCLUSIONS

The two editions of the Singapore Red Data Book (Ng & Wee, 1994; Davison et al., 2008) serve as a foundation for understanding local biodiversity and have been cited in numerous research papers and technical reports. Accurately assessing a species' status, however, becomes difficult when there is a paucity of population and ecological data. The present paper revises the classifications for giant clam species in Singapore (Table 3) using past literature and, critically, the results of two major surveys conducted over the last 10 years. It is important to note that the global statuses (see Table 1) of giant clams differs from those of Singapore's, demonstrating how the IUCN global status does not necessarily reflect the local situation. For example, while *Tridacna gigas* is "vulnerable" in general, they were extirpated from Singapore many decades ago. Localised classifications, such as those in the Singapore Red Data Book editions, provide a more nuanced status and are therefore of greater value when planning conservation strategies.

Table 3. Proposed revised classifications for Singapore's giant clam species. [1]Ng & Wee (1994) Singapore Red Data Book 1st Edition. [2]Davison et al. (2008) Singapore Red Data Book 2nd Edition.

| Species | Last Recorded in Singapore | Previous Classification | Current Suggested Classification |
|---|---|---|---|
| *Tridacna gigas* | 1866 | — | Presumed Nationally Extinct |
| *Hippopus hippopus* | 1963 | Endangered[1] | Presumed Nationally Extinct |
| *Tridacna maxima* | Extant | — | Critically Endangered (Category D) |
| *Tridacna crocea* | Extant | Endangered[1] | Endangered (Category D) |
| *Tridacna squamosa* | Extant | Endangered[1,2] | Critically Endangered (Category C.1.) |

Our reassessment shows all giant clam species are highly threatened on Singapore's reefs, with *Tridacna gigas* and *Hippopus hippopus* locally extinct and *Tridacna maxima*, *Tridacna crocea*, and *Tridacna squamosa* only present in very low numbers. The latter three species are probably already functionally extinct as they are reproductively isolated and unlikely to fertilise conspecifics. While the results of recent surveys and studies present a rather bleak picture of giant clam numbers and the potential to recover naturally, ongoing restocking efforts aim to repopulate Singapore's reefs with cultured individuals of *Tridacna squamosa*. Supporting research efforts have examined larval biology of *Tridacna squamosa* to enhance survivorship (Neo et al., 2011) and modelled connectivity patterns to identify transplant sites (Neo & Todd, 2012a; Neo et al., 2013). As Singapore's reef environments continue to change as a result of

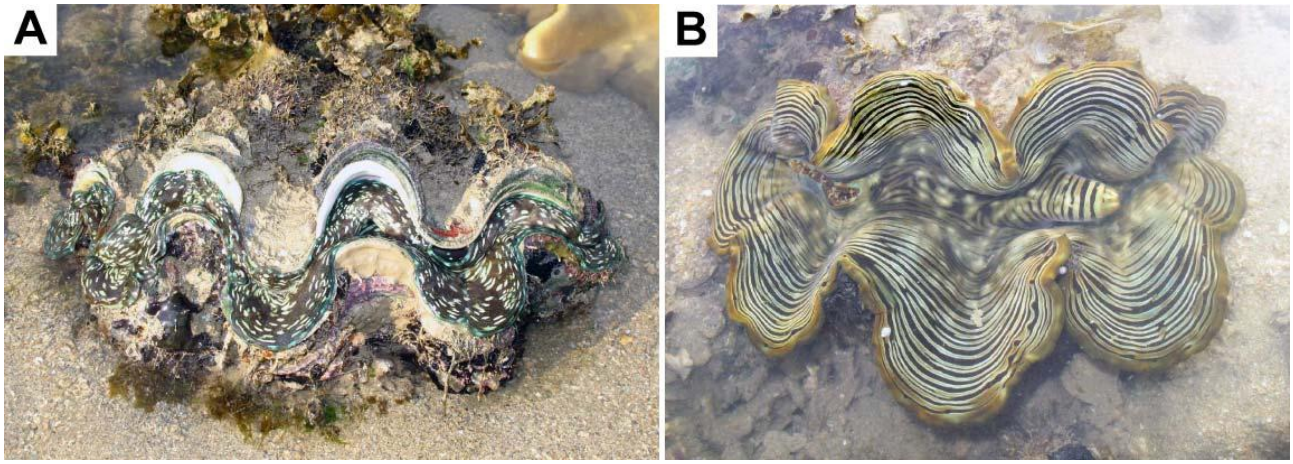


Fig. 5. *Tridacna squamosa* specimens, Singapore. A, SL = 36.0 cm, photographed on 30 May 2010 at Pulau Berkas; B, SL = 24.3 cm, photographed on 2 May 2010 at Terumbu Raya. (Photographs by: Neo Mei Lin)

economic development, active management of the remaining giant clam species is necessary to prevent their extirpation. With commitment (and some luck), they might yet have a chance to thrive again.

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