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THE DISTRIBUTION AND STATUS OF GIANT CLAMS (FAMILY TRIDACNIDAE) – A SHORT REVIEW

Ahmad Syukri bin Othman
Marine Environmental Group, Tropical Marine Science Institute, National University of Singapore, 18 Kent Ridge Road, Singapore 119227, Republic of Singapore

Gideon H. S. Goh and Peter A. Todd
Marine Biology Laboratory, Department of Biological Sciences, National University of Singapore, 14 Science Drive 4, Blk S1 #02-05, Singapore 117543, Republic of Singapore
Email dbspat@nus.edu.sg (PAT)

ABSTRACT. **–** In this review on the distribution, density and status of giant clams (family *Tridacnidae*) we combine reports derived from primary and grey literature with sighting data provided by Reef Check – a non-profit reef-monitoring organisation. Density records from 15 countries typically range from 10^{-3} to 10^{-5} individuals per square meter, however, some populations can achieve numbers in excess of 100 individuals per square meter. *Tridacna maxima* has the most cosmopolitan distribution; almost encompassing the entire geographical range of all the other giant clams species. In contrast, the more recently discovered *T. costata*, *T. rosewateri, T. teveroa* and *H. porcellanus* have the most restricted geographical ranges. Reef Check data includes records of (unidentified to species-level) giant clams beyond previously defined geographical boundaries; extending their known occurrence slightly west to near Cape Agulhas, South Africa. Overfishing, habitat loss, pollution, and increases in sea surface temperatures all contribute to decreases in giant clam populations. Restocking efforts provide an opportunity to redress this decline but, without enhanced protection and enforcement, these efforts may be unsuccessful.

KEY WORDS. **–** Giant clams, distribution, abundance, density.

INTRODUCTION

Giant clams, with their large size, characteristic shell structures and colourful mantles, are iconic coral reef invertebrates that play important ecological roles both as a food source and as a substrate for reef-associated organisms (Alcazar, 1986; Mingoa-Licuanan & Gomez, 2002). There are ten established members of the giant clam family Tridacnidae: *Tridacna gigas* (Linnaeus, 1758), *Hippopus hippopus* (Linnaeus, 1758), *T. maxima* (Roding, 1798), *T. derasa* (Roding, 1798), *T. crocea* (Lamarck, 1819), *T. squamosa* (Lamarck, 1819), *H. porcellanus* (Rosewater, 1982), *T. teveroa* (Lucas, Ledua & Braley, 1991), *T. rosewateri* (Sirenko & Scarlato, 1991) and *T. costata* (Richter, Roa-Quiaoit, Jantzen, Al-Zibdah & Kochzius, 2008). All species host symbiotic photosynthetic zooxanthellae algae, *Gymnodinium microadriaticum*, in their mantles and they are therefore found in relatively shallow and clear waters, such as those associated with coral reefs (Yonge, 1975; Trench et al., 1981; Sutton & Hoegh-Guldberg, 1990). Past research has shown the range of giant clams to span from East Africa to the east Pacific, and from Japan to Australia, but there is presently no review of their current distribution and status.

Giant clams are considered a valuable fishery in many countries, for instance, their adductor, gonads, muscle and mantle are used for food, they are popular aquarium animals (so much so that they were among the top ten of the most traded ornamental invertebrates worldwide; Wabnitz et al., 2003) and their shells are used for ornaments, soap dishes, salad bowls, and floor tiles (Usher, 1984). As is the case for many marine organisms, giant clam numbers have been greatly reduced due to overfishing and loss of habitat (CITES, 2004a,b,c,d). Furthermore, they are susceptible to stress-induced bleaching (expulsion of their symbiotic zooxanthellae) which is often associated with increased sea surface temperatures (Norton et al., 1995; Leggat et al., 2003). According to the 2007 World Conservation Union's Red List of Threatened Species (http://www.iucnredlist.org) eight species of giant clams are listed as either "Lower Risk Conservation Dependent" or "Vulnerable"; with only *T. crocea* classifed as 'Lower Risk Least Concern' (Wells, 1996). *Tridacna crocea* burrows into substrates and is relatively small, making it more difficult, and less economical, to harvest. However, *T. crocea* has also been overfished in areas of Fiji, Japan and Vietnam. Giant clams are also deleteriously affected by increases in sedimentation and pollution (Roberts et al., 2002). One species, *T. costata*, has only very recently been discovered (Richter et al., 2008) and is therefore not yet listed, but Richter et al. (2008) propose “Critically Endangered” as the appropriate category.

Giant clams are under the protection of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), of which 172 countries worldwide are signatories, but illegal trade and poaching continue to be a major problem (Lucas, 1994). The family Tridacnidae are listed under Appendix II, i.e. “not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival” (CITES, 2008) and international trade may only take place upon granting of a permit. Nevertheless, wide disparities in yearly giant clam trade figures (CITES, 2004a,b,c,d) suggest that some countries have failed to exert control on the clam trade. Local extinctions of several species of giant clams have been reported for sites in the Philippines, Indonesia, Micronesia (Lucas, 1994), Malaysia (Tan & Zulfigar, 2003) and Singapore (Guest et al., 2007), while many other countries have only low stocks remaining.

Since Rosewater’s 1965 seminal review paper, many aspects of giant clam biology, from their symbiotic relationship with *Symbiodinium* sp. to their physiology and behaviour have been examined in detail (e.g. Alcazar et al., 1987; Lucas, 1994; Muscatine, 1990; Huang et al., 2007; Han et al., 2008). Yet, even though most giant clam species are considered threatened, there has not been a consolidated update of their global distribution in more than four decades. The aim of this paper is to draw together data on giant clam presence and abundance to provide a resource for workers interested in giant clam ecology and conservation.

MATERIALS AND METHODS

To determine the distribution and, when possible, density of giant clams primary literature was searched for and retrieved using the online resources Web of Science, JSTOR, Science Direct and Google Scholar. In addition, other papers and grey literature were extracted from the National University of Singapore library as well as the World Wide Web. Finally, 75 scientists known to work, or have worked, on giant clams were contacted directly via email. The search was not exhaustive and there exists relatively rare literature, including market surveys and technical reports (often not in English), by organisations such as the Japan International Cooperation Agency and Overseas Fishery Cooperation Foundation of Japan.

We also contacted Reef Check (www.reefcheck.org), an international nongovernmental organisation that surveys and monitors coral reefs worldwide through a network of volunteers, and asked them to provide records of giant clam sightings. Reef Check surveys include the presence/absence of giant clams, but they do not collect species-level or abundance/density data; or survey giant clam communities found in non-reef areas. Raw coordinate data courtesy of Reef Check were converted from sexagesimal to decimal format and saved as *.dbf (version IV) files. The Geographical Information System (GIS) freeware DIVA GIS was then used to make a point shapefile with the *.dbf coordinates superimposed on a continent map with Equal-Area Cylindrical projection centered on longitude150°E. We also extracted the distribution of giant clams from the works of Rosewater, (1965; 1982); Lucas (1988); Sims & Howard (1988); Zann & Ayling (1988); Mingoa-Licuanan & Gomez (2002) and Richter et al. (2008) to obtain species-specific ranges.

RESULTS AND DISCUSSION

Giant clams live along shallow shorelines and on reefs between 30°E and 120°W (South Africa to beyond French Polynesia) and between 36°N and 30°S (Japan to Australia). Distribution is not even, with greater diversity found in the central Indo-Pacific (Spalding et al., 2007). Where records exist, densities typically range from 10^{-3} to 10^{-5} individuals per square meter. Ashmore, Mermaid and Cartier Reefs, located within the Great Barrier Reef, host populations in excess of 100 individuals per square meter and Tatakoto, French Polynesia, has a population density of 90.9 individuals per square meter (Rees et al., 2003, Gilbert et al., 2006). At the other extreme, some sites in the Philippines, Vanuatu, and the Republic of Kiribati have densities of < 10^{-6} individuals per square meter (Table 1). *Tridacna maxima* has the most cosmopolitan distribution; almost encompassing the entire geographical range of all the other giant clam species (Fig. 1). In contrast, the recently discovered species *T. costata*, *T. rosewateri, T. teveroa* and *H. porcellanus* have the most restricted geographical ranges. Reef Check data includes records of (unidentified to species-level) giant clams beyond previously defined geographical boundaries; extending their known occurrence to near Cape Agulhas, South Africa.

Seven species (*T. gigas, T. derasa, T.squamosa, T. crocea, T. maxima, H. hippopus* and *H. porcellanus*) can be found in Southeast Asia (Table 1), but many populations are in sharp decline or, in some cases, functionally extinct. For instance, six species (*T. crocea, T. derasa, T. maxima, T. squamosa, H. hippopus* and *H. porcellanus*) can be found in Malaysia, but only *T. crocea* has a stable population (Tan & Zulfigar, 2003). *Tridacna gigas* is probably extinct in Peninsular Malaysia while *H. porcellanus* and *T. derasa* are restricted to Sabah, Eastern Malaysia (Tan & Zulfigar, 2003). In Singapore, *H. hippopus* is locally extinct, *T. maxima* is functionally extinct and *T. squamosa* and *T. crocea* are present only in very low numbers (Guest et al., 2007). Of the three species of giant clam found in Thailand, *T. squamosa* and *T. maxima* are considered “scarce” (Thamrongnavasawat et al., 2001). Little is known about giant clam distribution in other Southeast Asian countries including Brunei Darussalam, Cambodia, Laos, Myanmar and Vietnam, although anecdotal evidence by SCUBA divers indicate their presence.

To the east and south, giant clams, albeit at lower diversity, can be found throughout Oceania, i.e. Australasia, Melanasia, Micronesia and Polynesia (Table 1). Clam diversity decreases with increasing distance from Australia; from seven species in Near Oceania to only *T. maxima* at the furthest boundary of giant clam distribution in the east Pacific (Fig. 1). Data by Reef Check indicates that there are populations of giant clams beyond the species-specific boundaries described by Rosewater, (1965; 1982); Lucas (1988); Sims & Howard (1988); Zann & Ayling (1988) and Mingoa-Licuanan & Gomez (2002). Wells (1996) noted that *T. derasa, T. gigas* and *T. squamosa* have been introduced during various mariculture efforts in areas including the US (e.g. Hawaii) and the Federated State of Micronesia. The naturally rare *T. tevoroa* is found exclusively in a small locale, mainly on the barrier reefs of Tonga and the Lau islands of Fiji (Klumpp & Lucas, 1994). While the abundance of giant clams in Oceania has generally been declining, there are instances of unusually high numbers; for example Ashmore, Cartier and Mermaid Reefs, Australia, host densities in excess of 100 giant clams per m^2 (Rees et al., 2003).

To the west and north, *T. costata*, *T. maxima*, *T. rosewateri* and *T. squamosa* inhabit coastlines of the Indian Ocean (Fig. 1). *Tridacna maxima* and *T. squamosa* are relatively cosmopolitan in distribution, whereas *T. costata* and *T. rosewateri* are geographically restricted to the northern Red Sea and Mauritius, respectively (Richter et al., 2008; CITES, 2008). *Tridacna costata* is a new discovery; only being described by Richter et al. in 2008. Japan represents the northernmost boundary to the distribution of giant clams (*T. crocea, T. maxima, T. squamosa* and *H. hippopus*). In fact, the southern islands of Okinawa, especially Ishigaki Island, are the main supplier of giant clams for Japan with *T. crocea* making up 90% of total landings (Okada, 1997).

The data presented here indicate that giant clam densities are low in many countries. This is most likely a result of increased fishing pressure and habitat destruction. Lucas (1994) lists four main reasons for giant clam overfishing in recent times: increased human population, improved technology available to subsistence fishermen, expanded international/inter-island trade and poaching of giant clam meat, and expanded international trade in shell specimens and artefacts. In 1987, Heslinga & Fitt suggested local communities could use giant clam culture to supplement subsistence fishing. A number of countries, inluding Tonga, Palau, Fiji, the Soloman Islands and the Cook Islands, have tried to counter the decline of their giant clam populations through local aquaculture and restocking progammes (e.g. Clarke et al., 2003 where young clams are introduced into ocean nurseries in reserves or other protected areas.

Monitoring efforts are limited and measures to protect reintroduced clams are often poorly enforced. Nevertheless, the Marine Science Institute (MSI) at the University of the Philippines has a long and successful record of rearing, having cultured giant clams to restore depleted supplies for the last 20 years. Over 40 sites have received cultured clams and MSI promote giant clam farming as a sustainable livelihood with restocking activities occurring in collaboration with local groups. Overfishing of giant clams in Japan led to a reduction in catch from 578 tonnes in 1975 to just 28 tonnes in 1995 and, as a result, stricter regulations were introduced. Furthermore, the Okinawa Prefectural Fisheries Experimental Station introduced seed production operations (for culture and sea-ranching) to boost giant clam supply (Okada, 1997).

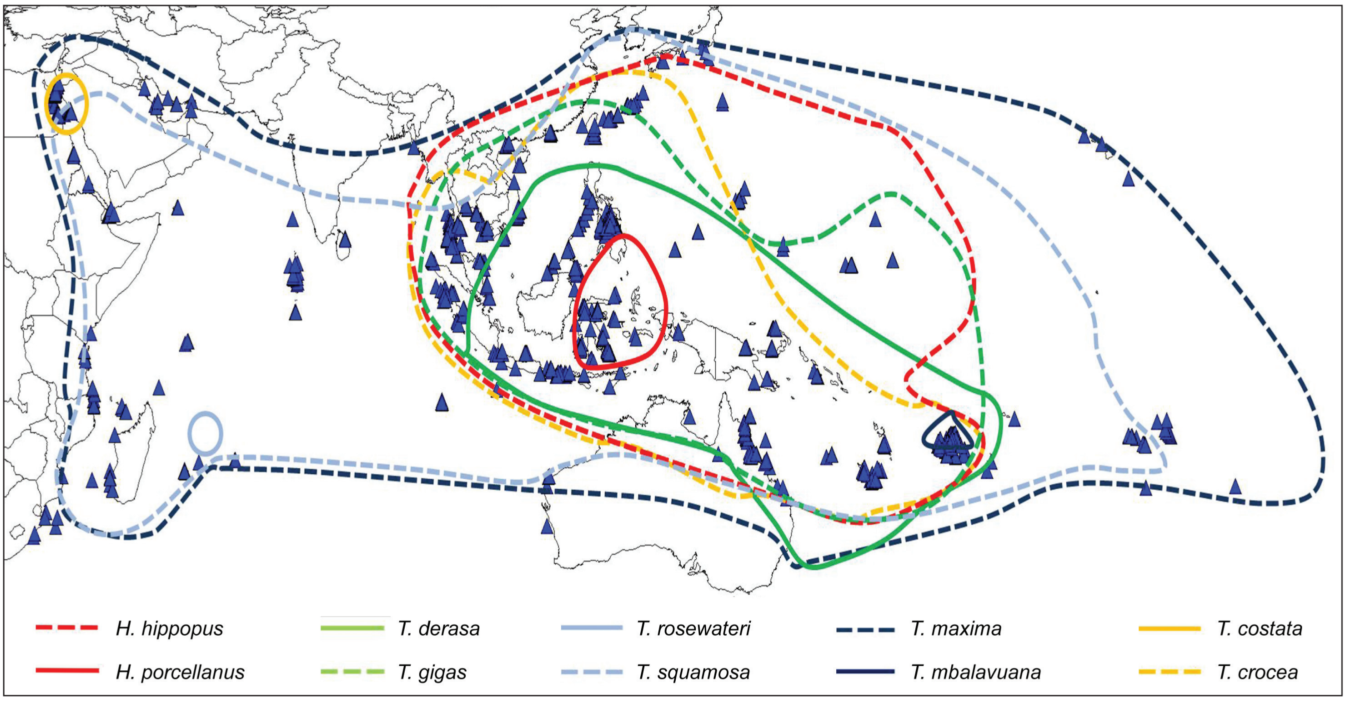

Fig. 1. Distribution of giant clams. Adapted from Rosewater (1965, 1982); Lucas (1988); Howard (1988); Zann & Ayling (1988); Gomez & Mingoa-Licuanan (2002) and Richter et al. (2008). The blue triangles represent Reef Check records and therefore the species are unknown. Abbreviation used for genera: *T.*, *Tridacna*; *H.*, *Hippopus*.

Table 1. Summary of giant clam distribution and density data. Abbreviation used for genera: *T.*, *Tridacna*; *H.*, *Hippopus*.

Sites surveyed	Method of survey	Approx. area surveyed (m^2)	Species	Population density (per m^2)	References (population survey)
Australia					
The Great Barrier Reef	SCUBA diving		*T. derasa*		Braley, 1987
			T. gigas		
The Great Barrier Reef - North	SCUBA diving		*T. derasa*	2.90×10^{-4}	Braley, 1987
			T. gigas	7.80×10^{-4}	
The Great Barrier Reef - South	SCUBA diving		*T. derasa*	5.90×10^{-4}	Braley, 1987
			T. gigas	6.00×10^{-4}.	
Mermaid Reef			*T. maxima*	1.58×10^{2}	Rees et al., 2003
			T. gigas	5.88	
			H. hippopus	4.15	
Cartier Reef			*T. maxima*	2.18×10^{1}	Rees et al., 2003
			H. hippopus	1.51×10^{2}	
Ashmore Reef			*T. maxima*	3.83×10^{1}	Rees et al., 2003
			T. gigas	6.12	
			H. hippopus	1.14×10^{2}	
Caroline Islands					
Palau		1.10×10^{2}	*T. crocea*	1.39×10^{-1}	Hardy & Hardy, 1969
			T. derasa	5.45×10^{-3}	
			T. gigas	1.82×10^{-3}	
			T. maxima	5.45×10^{-3}	
			T. squamosa	6.36×10^{-3}	
			H. hippopus	3.64×10^{-3}	
Cook Islands					
Tongarew Lagoon		6.75×10^{4}	*T. maxima*	4.2×10^{-1}	Chambers, 2007
Aitutaki Lagoon		8.00×10^{1}	*T. maxima*	4.738	Sims & Howard, 1988
Manihiki Lagoon		8.25×10^{2}	*T. maxima*	2.87×10^{-1}	Sims & Howard, 1988
Suwarrow Lagoon		2.24×10^{2}	*T. maxima*	8.75×10^{-2}	Sims & Howard, 1988
Egypt and Jordan					
Gulf of Aqaba			*T. maxima*	4.70×10^{-3}	Roa-Quiaoit, 2005
			T. squamosa	3.10×10^{-3}	
Northern Red Sea and Gulf of Aqaba		1.28 1.1×10^{4}	*T. costata*	9.0×10^{-4}	Richter et al. 2008
Egypt			*T. maxima*	Present	Zuschin & Piller, 1997
French Polynesia					
Fangatau Atoll	Remote Sensing	4.05×10^{6}	*T. maxima*	5.84	Andrefouet et al., 2005
Tatakoto	Remote Sensing	1.15×10^{7}	*T. maxima*	7.71	Gilbert et al., 2006
Tubuai	Remote Sensing	1.63×10^{7}	*T. maxima*	2.91	Gilbert et al., 2006
Malaysia					
Pulau Tioman	SCUBA diving	2.62×10^{3}	*T. crocea*	9.92×10^{-3}	Tan et al., 1998
			T. maxima	5.38×10^{-2}	
			T. squamosa	2.52×10^{-2}	

Table 1. Cont'd.

Sites surveyed	Method of survey	Approx. area surveyed (m^2)	Species	Population density (per m^2)	References (population survey)
New Zealand (Tokelau Islands)					
Fakaofo Atoll			*T. maxima*	1.75×10^{-1}	Braley, 1989
			T. squamosa	8.20×10^{-5}	
Nukunonu Atoll			*T. maxima*	6.86×10^{-1}	Braley, 1989
			T. squamosa	4.10×10^{-5}	
Atafu			*T. maxima*	8.41×10^{-2}	Braley, 1989
Papua New Guinea					
Milne Bay Province			*T. crocea*	1.49×10^{-3}	Kinch, 2002
			T. derasa	3.40×10^{-5}	
			T. gigas	8.20×10^{-5}	
			T. maxima	1.79×10^{-4}	
			T. squamosa	1.37×10^{-4}	
			H. hippopus	4.10×10^{-5}	
The Phillipines					
Central Visayas	Snorkelling & SCUBA diving	5.30×10^5	*T. crocea*	1.63×10^{-4}	Alcala, 1986
			T. maxima	8.00×10^{-5}	
			T. squamosa	6.67×10^{-5}	
Western Visayas	Snorkelling & SCUBA diving	7.00×10^4	*T. crocea*	2.29×10^{-4}	Alcala, 1986
			T. maxima	3.00×10^{-4}	
			T. squamosa	1.31×10^{-3}	
Cagayan, Sulu Sea	Snorkelling & SCUBA diving	5.65×10^4	*T. crocea*	1.81×10^{-3}	Alcala, 1986
			T. maxima	2.55×10^{-3}	
			T. squamosa	1.24×10^{-4}	
Cagayancillo Island	SCUBA diving	6.50×10^4	*T. crocea*	5.16×10^{-4}	Juinio et al., 1989
			T. gigas	1.60×10^{-5}	
			T. maxima	2.61×10^{-3}	
			T. squamosa	4.70×10^{-5}	
			H. hippopus	7.80×10^{-5}	
Palawan Regions	Snorkelling & SCUBA diving	2.10×10^5	*T. crocea*	3.29×10^{-1}	Alcala, 1986
			T. derasa	3.81×10^{-5}	
			T. maxima	2.67×10^{-4}	
			T. squamosa	2.71×10^{-4}	
			H. hippopus	1.38×10^{-4}	
Western Pangasinan	SCUBA diving	5.30×10^5	*T. crocea*	7.40×10^{-5}	Juinio et al., 1989
			T. maxima	1.10×10^{-5}	
			T. squamosa	3.20×10^{-5}	
Polillo	SCUBA diving	2.10×10^5	*T. crocea*	3.40×10^{-2}	Juinio et al., 1989
			T. derasa	2.90×10^{-5}	
			T. gigas	1.00×10^{-5}	
			T. maxima	5.33×10^{-4}	
			T. squamosa	7.00×10^{-4}	
			H. hippopus	2.40×10^{-5}	
Zambales	SCUBA diving	1.04×10^5	*T. crocea*	1.83×10^{-4}	Juinio et al., 1989
			T. maxima	6.70×10^{-5}	
			T. squamosa	1.00×10^{-5}	

Table 1. Cont'd.

Sites surveyed	Method of survey	Approx. area surveyed (m^2)	Species	Population density (per m^2)	References (population survey)
Albay	SCUBA diving	1.45×10^5	*T. crocea*	8.21×10^{-4}	Juinio et al., 1989
			T. maxima	7.03×10^{-4}	
			T. squamosa	4.14×10^{-4}	
Sorsogon	SCUBA diving	1.48×10^5	*T. crocea*	3.11×10^{-4}	Juinio et al., 1989
			T. maxima	8.18×10^{-4}	
			T. squamosa	2.70×10^{-5}	
Calatagan	SCUBA diving	1.11×10^5	*T. crocea*	1.26×10^{-4}	Juinio et al., 1989
			T. maxima	1.08×10^{-4}	
			T. squamosa	2.61×10^{-4}	
Lubang Island	SCUBA diving	1.49×10^5	*T. crocea*	5.64×10^{-4}	Juinio et al., 1989
			T. maxima	1.48×10^{-4}	
			T. squamosa	1.34×10^{-4}	
			H. hippopus	7.00×10^{-6}	
Ambil Island	SCUBA diving	2.50×10^5	*T. crocea*	2.68×10^{-4}	Juinio et al., 1989
			T. derasa	3.60×10^{-5}	
			T. gigas	4.00×10^{-7}	
			T. maxima	4.48×10^{-4}	
			T. squamosa	3.28×10^{-4}	
			H. hippopus	8.00×10^{-6}	
Lubang Island	SCUBA diving	1.49×10^5	*T. crocea*	5.64×10^{-4}	Juinio et al., 1989
			T. maxima	1.48×10^{-4}	
			T. squamosa	1.34×10^{-4}	
			H. hippopus	7.00×10^{-6}	
Apo Reef	SCUBA diving	8.80×10^4	*T. crocea*	2.95×10^{-4}	Juinio et al., 1989
			T. derasa	1.10×10^{-5}	
			T. maxima	9.43×10^{-4}	
			T. squamosa	1.10×10^{-5}	
Puerto Galera	SCUBA diving	1.46×10^5	*T. crocea*	2.70×10^{-5}	Juinio et al., 1989
			T. maxima	9.60×10^{-5}	
			T. squamosa	9.60×10^{-5}	
Northeast Negros	SCUBA diving	2.90×10^4	*T. crocea*	6.90×10^{-5}	Juinio et al., 1989
			T. maxima	3.40×10^{-5}	
			T. squamosa	3.40×10^{-5}	
El Nido	SCUBA diving	2.55×10^5	*T. crocea*	1.10×10^{-3}	Juinio et al., 1989
			T. maxima	9.00×10^{-5}	
			T. squamosa	4.90×10^{-4}	
			H. hippopus	4.70×10^{-5}	
			H. porcellanus	4.00×10^{-6}	
Inagauan-Aborlan	SCUBA diving	4.50×10^4	*T. derasa*	6.90×10^{-5}	Juinio et al., 1989
			T. maxima	2.20×10^{-5}	
			T. squamosa	2.20×10^{-5}	
Camiguin	SCUBA diving	2.13×10^5	*T. crocea*	1.13×10^{-4}	Juinio et al., 1989
			T. maxima	3.10×10^{-4}	
			T. squamosa	1.55×10^{-4}	
Republic of Kiribati					
Abemama Atoll	Tow	2.86×10^7	*T. gigas*	2.30×10^{-4}	Munro, 1988
			T. squamosa	1.15×10^{-5}	
			H. hippopus	3.51×10^{-4}	

Table 1. Cont'd.

Sites surveyed	Method of survey	Approx. area surveyed (m^2)	Species	Population density (per m^2)	References (population survey)
Abiang Atoll	Tow	8.99×10^7	*T. gigas*	5.49×10^{-5}	Munro, 1988
			T. squamosa	5.92×10^{-5}	
			H. hippopus	2.21×10^{-4}	
Maiana Atoll	Tow	2.80×10^7	*T. gigas*	7.68×10^{-5}	Munro, 1988
			T. squamosa	9.21×10^{-5}	
			H. hippopus	5.71×10^{-5}	
Tarawa Atoll	Tow	2.96×10^7	*T. gigas*	1.89×10^{-5}	Munro, 1988
			T. squamosa	2.64×10^{-5}	
			H. hippopus	1.69×10^{-5}	
Samoan Archipelago					
Samoan Archipelago		5.05×10^5	*T. maxima*	5.65×10^{-3}	Green & Craig, 1999
Singapore					
Southern Islands	SCUBA diving	9.76×10^3	*T. crocea*	7.24×10^{-4}	Guest et al., 2007
			T. maxima	1.02×10^{-4}	
			T. squamosa	1.55×10^{-3}	
Thailand					
Lee-Pae Island	Tow	6.40×10^3	*T. crocea*	2.44×10^{-1}	Chantrapornsyl et al., 1996
			T. maxima	6.29×10^{-2}	
Mu Ko Surin National Park	Snorkelling		*T. crocea*	abundant	
			T. squamosa	scarce	
			T. maxima	scarce	
Vanuatu					
Port Anatom	Snorkelling		*T.maxima*	1.60×10^{-3}	Zann & Ayling, 1988
Inyeug Island	Snorkelling		*T.maxima*	5.00×10^{-3}	Zann & Ayling, 1988
			H. hippopus	1.00×10^{-3}	
Port Patrick	Snorkelling		*T.maxima*	1.60×10^{-3}	Zann & Ayling, 1988
Lakariata	Snorkelling		*T.maxima*	5.00×10^{-4}	Zann & Ayling, 1988
Lelepa	Snorkelling		*T. maxima*	3.00×10^{-4}	Zann & Ayling, 1988
			T.crocea	3.00×10^{-4}	
			H. hippopus	3.00×10^{-4}	
Cook's Reef	Snorkelling		*T. maxima*	1.00×10^{-3}	Zann & Ayling, 1988
			H. hippopus	2.50×10^{-3}	
Pentecost	Snorkelling		*T.maxima*	6.00×10^{-4}	Zann & Ayling, 1988
			H. hippopus	9.00×10^{-4}	
Loltong Bay	SCUBA diving		*T.maxima*	2.00×10^{-3}	Zann & Ayling, 1988
Lesalav Bay	SCUBA diving		*T. maxima*	9.00×10^{-4}	Zann & Ayling, 1988
			H. hippopus	1.00×10^{-4}	
Reef Island	Snorkelling & SCUBA diving		*T. maxima*	1.30×10^{-3}	Zann & Ayling, 1988
			H. hippopus	2.30×10^{-3}	
Hog Bay	Snorkelling & SCUBA diving		*T.maxima*	2.00×10^{-4}	Zann & Ayling, 1988
			H. hippopus	2.00×10^{-4}	

The ten species of giant clam identified to date vary greatly in their distribution and abundance, but all are threatened by overexploitation and habitat degradation. Even though they are listed by ICUN and international trade is CITES regulated, giant clam populations continue to decline. Most clam fisheries are relatively small scale and community-based marine resource management has been proposed as the best solution to tackle overharvesting (e.g. Johannes, 1998). Giant clams are suitable for aquaculture and this offers an opportunity to maintain or increase numbers. However, as emphasised by Gomez & Mingoa-Licuanan (2006), community involvement is again vital if restocked clams are to be safeguarded.

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LITERATURE CITED

Alcala, A. C., 1986. Distribution and abundance of giant clams (Family Tridacnidae) in the south-central Philippines. *Silliman Journal*, **33**: 1–9.

Alcazar, S. N., 1986. Observations on predators of giant clams (Bivalvia: Family Tridacnidae). *Silliman Journal*, **33**: 54–57.

Alcazar, S. N., E. P. Solis & A. C. Alcala, 1987. Serotonin-induced spawning and larval rearing of the China clam, *Hippopus porcellanus Rosewater* (Bivalvia: Tridacnidae). *Aquaculture*, **66**: 359–368.

Andrefouet, S., A. Gilbert, L. Yan, G. Remoissenet, C. Payri & Y. Chancerelle, 2005. The remarkable population size of the endangered clam *Tridacna maxima* assessed in Fangatau Atoll (eastern Tuamotu, French Polynesia) using in situ and remote sensing data. *ICES Journal of Marine Science*, **62**: 1037–1048.

Braley, R. D., 1987. Distribution and abundance of the giant clams *Tridacna gigas* and *T. derasa* on the Great Barrier Reef. *Micronesica*, **20**: 215–223.

Braley, R. D., 1989. *A giant clam stock survey and preliminary investigation of pearl oyster resources in the Tokelau Islands.* Department of Agriculture and Fisheries, Tokelau Affairs Office and the FAO South Pacific Aquaculture Development Project. 52 pp.

Chambers, C. N. L., 2007. Pasua (*Tridacna maxima*) size and abundance in Tongareva Lagoon, Cook Islands. *SPC Trochus Information Bulletin*, **13**: 7–12.

Chantrapornsyl, S., K. Kittiwattanawong & K. Adulyanukosol, 1996. Distribution and abundance of giant clam around Lee-Pae Island, the Andaman Sea, Thailand. *Phuket Marine Biological Center Special Publication*, **16**: 195–200.

Clarke, P. J., T. Komatsu, J. D. Bell, F. Lasi, C. P. Oengpepa & J. Leqata, 2003. Combined culture of *Trochus niloticus* and giant clams (Tridacnidae): benefits for restocking and farming. *Aquaculture*, **215**: 123–144.

CITES, 2004a. *Tridacna crocea.* AC22 Doc. 10.2 Annex 8c. URL: http://www.cites.org/eng/com/AC/22/E22-10-2-A8c.pdf.

CITES, 2004b. *Tridacna derasa.* AC22 Doc. 10.2 Annex 8d. URL: http://www.cites.org/eng/com/ac/22/E22-10-2-A8d.pdf.

CITES, 2004c. *Tridacna gigas.* AC22 Doc. 10.2 Annex 8e. URL: http://www.cites.org/eng/com/aC/22/E22-10-2-A8e.pdf.

CITES, 2004d. *Tridacna squamosa.* AC22 Doc. 10.2 Annex 8g. URL: www.cites.org/eng/com/AC/22/E22-10-2-A8g.pdf.

CITES, 2008. Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendices I, II and III. Pp. 32. URL: www.cites.org/eng/app/E-Jul01.pdf.

Gilbert, A., G. Remoissenet, L. Yan & S. Andrefout, 2006. The giant clam *Tridacna maxima* communities of three French Polynesia islands: comparison of their population sizes and structures at early stages of their exploitation. *ICES Journal of Marine Science*, **63**: 1573–1589.

Gomez, E. D. & S. S. Mingoa-Licuanan, 2006. Achievements and lessons learnt in restocking giant clams in the Phillippines. *Fisheries Research*, **80**: 46–52.

Green, A., & P. Craig, 1999. Population size and structure of giant clams at Rose Atoll, an important refuge in the Samoan archipelago. *Coral Reefs*, **18**: 205–211.

Guest. J. R., P. A. Todd, E. Goh, B. S. Sivalonganathan & K. P. Reddy, 2007. Can giant clam (Tridacna squamosa) populations be restored on Singapore's heavily impacted coral reefs? *Aquatic Conservation: Marine and Freshwater Ecosystems*, **18(5):** 570–579.

Han, L., P. A. Todd, L. M. Chou, V. B. Yap & B. Sivalonganathan, 2008. The defensive role of scutes in juvenile fluted giant clams (*Tridacna squamosa*). *Journal of Experimental Marine Biology and Ecology*, **359**: 77–83

Hardy, J. T. & S. A. Hardy, 1969. Ecology of *Tridacna* in Palau. *Pacific Science*, **23**: 467–472.

Heslinga, G. A. & W. K. Fitt, 1987. The domestication of reef-dwelling clams. *Bioscience*, **37**(5): 332–339.

Huang, D., P. A. Todd & J. R. Guest, 2007. Locomotion and aggregation in the fluted giant clam (*Tridacna squamosa* L.). *Journal of Experimental Marine Biology and Ecology*, **342**: 269–281.

Juinio, M., L. Menez & C. L. Villanoy, 1989. Status of giant clam resources of the Philippines. *Journal of Molluscan Studies*, **55**: 431–440.

Johannes, R. E., 1998. Government-supported, village-based management of marine resources in Vanuatu. *Ocean & Coastal Management*, **40**: 165–186.

Kinch, J., 2002. Giant clams: Their status and trade in Milne Bay Province, Papua New Guinea. *Traffic Bulletin*, **19**(2): 67–75.

Klumpp, D. W. & J. S. Lucas, 1994. Nutritional ecology of the giant clams, *Tridacna tevoroa* and *T. derasa* from Tonga: influence of light on filter-feeding and photosynthesis. *Marine Ecology Progress Series*, **107**: 147–156.

Lamarck, J. P. B. A de Monet., 1816. *Histoire naturelle des animaux sans vertèbres, présentant les caractères généraux et particuliers de ces animaux, leur distribution, leurs classes, leurs familles, leurs genres, et la citation des principales espèces qui s'y rapportent; précédée d'une introduction offrant la détermination des caractères essentiels de l'animal, sa distinction du végétal et des autres corps naturels, enfin, l'exposition des principes fondamentaux de la zoologie*. Verdière, Paris, **6**:1–343.

Leggat, W., B. H. Buck, A. M. Grice & D. Yellowlees, 2003. The impact of bleaching on the metabolic contribution of dinoflagellate symbionts to their giant clam host. *Plant Cell and Environment*, **26**: 1951–61.

Linnaeus, C., 1758. *Systema Naturae per Regna tria Naturae, secundum Classes, Ordines, Genera Species, cum Characteribus, Differentiis, Synonymis, Locis*. Tomus I. Editio decima. Holmiae: Laur. Salvius. 824 pp.

Lucas, J. S., 1988. Giant clams: description, distribution and life history. In Copland, J. W. & J. S. Lucas (eds), *Giant clams in Asia and the Pacific*, ACIAR Monograph, No. **9:** 21–32.

Lucas, J. S., E. Ledua & R. D. Braley, 1991. *Tridacna teveroa*: a recently described species of giant clam (Bivalvia; Tridacnidae) from Fiji and Tonga. *Nautilus*, **105**: 93–103.

Lucas, J. S., 1994. The biology, exploitation and mariculture of giant clams (Tridacnidae). *Reviews in Fisheries Science*, **2**:181–223.

Mingoa-Licuanan S.S. & E.D. Gomez, 2002. Giant clam conservation in Southeast Asia. *Tropical Coasts*, **9**: 24–56.

Munro, J. L., 1988. Status of giant clam stocks in the Central Gilbert Islands Group, Republic of Kiribati. *Proceedings of the Workshop on Pacific Inshore Fishery Resources.* Pp. 267–279.

Muscatine, L., 1990. The role of symbiotic algae in carbon and energy flux in reef corals. In: Dubinsky Z., (ed.). *Ecosystems of the World: Coral Reefs.* Elsevier, Amsterdam. Pp. 75–87.

Norton, J. H., H. C. Prior, B. K. Baillie & D. Yellowlees, 1995. Atrophy of the zooxanthellal tubular system in bleached giant clams *Tridacna gigas*. *Journal of Invertebrate Pathology*, **66**: 307–310.

Okada, H., 1997. Market survey of aquarium giant clams in Japan. Access from Food and Agricultural Oragnisation Corporate Document Repository. URL: http://www.fao.org/docrep/005/AC892E/AC892E01.htm.

Rees, M., J. Colquhoun, L. D. Smith & A. J. Heyward, 2003. *Survey of trochus, holothuria, giant clams and the coral communities at Ashmore, Cartier Reef and Mermaid Reef, northwestern Australia. Report to Environment Australia.* Australian Institute of Marine Science. 64 pp.

Richter, C., H. Roa-Quiaoit, C. Jantzen, M. Al-Zibdah & M. Kochzius, 2008. Collapse of a new living species of giant clam in the Red Sea. *Current Biology*, **18**: 1–6.

Roa-Quiaoit, H. A. F., 2005. The ecology and culture of giant clam (Tridacnae) in the Jordanian sector of the Gulf of Aqaba, Red Sea. Ph.D. Thesis, Universitat Bremen. 100 pp.

Roberts, C. M., C. J. McClean, J. E. N. Veron, J. P. Hawkins, G. R. Allen, D. E. McAllister, C. G. Mittermeier, F. W. Schueler, M. Spalding, F. Wells, C. Vynne & T. B. Werner, 2002. Marine conservation hotspots and conservation priorities for tropical reefs. *Science*, **295**: 1280–1284.

Röding, P. F., 1798. *Museum Boltenianum sve catalogus cimeliorum e tribus regnis naturae quae olim collegerat. Joa. Fried. Bolten M.D. p.d. Pars Secunda Contineus conchylis sive testacea univalvia, bi- valvia et multivalvia*. Hamburg, Typis Jhoan. Christi. Trappi. 199 pp.

Rosewater, J., 1965. The family Tridacnidae in the Indo-Pacific. *Indo-Pacific Mollusca*, **1**: 347–394.

Rosewater, J., 1982. A new species of Hippopus (*Bivalvia, Tridacnidae*). *Nautilus*, **96**(1): 3–6.

Sims, N. A. & N. T. Howard, 1988. Indigenous *Tridacnid* clam populations and the introduction of *Tridacna derasa* in the Cooks Islands**.** In: Copland, J. W. & Lucas, J. S. (eds.), *Giant Clams in the Asia and the Pacific*. Australian Centre for International Agricultural Research. Monograph No. **9:** 34–43.

Sirenko, B. I. & O. A. Scarlato, 1991. *Tridacna rosewateri* sp. n. A new species of giant clam from the Indian Ocean. *La Conchiglia*, **22**: 4–9.

Spalding, M. D., H. E. Fox, G. R. Allen, N. Davidson, Z. A. Ferdaña, M. Finlayson, B. S. Halpern, M. A. Jorge, A. Lombana, S. A. Lourie, K. D. Martin, E. Mcmanus, J. Molnar, C. A. Recchia & J. Robertson, 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *BioScience*, **57**(7): 573–583.

Sutton, D. C. & O. Hoegh-Guldberg, 1990. Host-zooxanthella interactions in four temperate marine invertebrate symbioses: assessment of effect of host extracts on symbionts. *Biological Bulletin*, **178**(2): 175–186.

Tan, S., Y. Zulfigar, S. B. Ibrahim & Y. Abdul Aziz, 1998. Status of giant clams in Pulau Tioman, Malaysia. *Malayan Nature Journal*, **52**: 205–216.

Tan, S. & Y. Zulfigar, 2003. Status of giant clams in Malaysia. *SPC Trochus Information Bulletin*, **10**: 9–10.

Thamrongnavasawat, T., A. Saisaeng, N. Sittithaweepat, P. Limviriyakul, S. Worachananant and O. Patimanukasem, 2001. *Survey report in Mu Ko Surin Marine National Park Area presented to UNESCO Project*. URL: www.talaythai.com/English/unesco/index.php3.

Trench, R.K., D.S. Wethey & J.W. Porter, 1981. Observations on the symbiosis with zooxanthellae among the tridacnidae (Mollusca, Bivalvia). *Biological Bulletin*, **161**:180–198.

Usher, G.F., 1984. Coral reef invertebrates in Indonesia: their exploitation and conservation needs. IUCN/WWF Project Report no.1688. 97 pp.

Wabnitz, C., M. Taylor, E. Green & T. Razak, 2003. From ocean to aquarium: the global trade in marine ornamental species. UNEP WCMC, Cambridge, UK.

Wells, S. (1996) In: IUCN 2007. 2007 IUCN Red List of Threatened Species. URL: www.iucnredlist.org.

Yonge, C.M., 1975. Giant clams. *Scientific America*, **232**(4): 96–105.

Zann, L.P. & A.M. Ayling, 1988. Status of giant clams in Vanuatu. In: Copland, J.W. & Lucas, J.S. (eds.). *Giant clams in Asia and the Pacific*. Australian Centre for International Agricultural Research. Monograph No. **9:** 60–63,

Zuschin, M. & W.E. Piller, 1997. Bivalve distribution on coral carpets in the Northern Bay of Safaga (Red Sea, Egypt) and its relation to environmental parameters. *Facies*, **37**: 183–194.