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FULL PAPER

Searching the Virtually Extinct *Tridacna gigas* (Linnaeus, 1758) in the Reefs of Palawan, Philippines

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ABSTRACT

Tridacna gigas (Cardiidae: Tridacninae) is the largest extant reef-associated bivalves that occur abundantly in the Indo-West Pacific Region. However, unregulated exploitation had caused localized extinction in many parts of its distribution range. In Palawan, the species was considered virtually extinct in the 1980s, and since then, no study has been done to monitor their status in the wild. In the absence of updated studies about *T. gigas*, we gathered information through field reports, key informants, and field visits. Within five months of data gathering, we recorded 97 empty shells (14 in pairs and 83 single shells) with 65.86 cm (range: 42-112 cm) average shell length, which were estimated to be from 5 to >76 years old. Most (78.36%) of the empty shells were used for decoration and landscaping. On the other hand, 29 live individuals with 73.69 cm (range: 42-109 cm) average shell length were estimated to be 5 to >76 years old. Tubbataha Reefs Natural Park and some island resorts harbored the highest number of live *T. gigas*. The presence of live *T. gigas* in these areas reflects years of effective management and the resorts' essential contribution to resource conservation. These remaining live individuals could be used in breeding and restocking programs to restore their lost populations.

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1. INTRODUCTION

Tridacna gigas, the largest among the eight known giant clam species in the Philippines (Neo et al. 2017; Viray-Mendoza 2018) can attain a maximum shell length of 140 cm (Lucas 2014; Rosewater 1965; Simon 2000; Wabnitz et al. 2003) and weigh up to 500 kg (Lucas 2014). They become sexually mature in four to five years (Surtida and Buendia 2000) and can live for almost 40-100 years in the wild (NGS 2011), and 34 years under mariculture conditions (Carlson 2012; Heslinga 2013). They are found in sandy substrates in coral reefs (Teitelbaum and Friedman 2008), from water depths of a few feet up to 15 m (Newman and Gomez 200). They are of varied ecological importance, which includes the provision of food and shelter to various marine organisms (Cabaitan et al. 2008; Neo et al. 2015).

The global wild populations of *T. gigas* are widely distributed from Northern Australia and East Thailand extending towards the South Pacific (bin Othman et al. 2010; Neo et al. 2017), however international poaching during the 1960s until 1980s (Lucas 1994) have caused localized extinction in some areas (Alcala 1986; Juinio et al. 1989; Neo et al. 2017).

In the Philippines, giant clams are harvested for both meats and shells (Gomez and Mingoa-Licuanan 2006; Lebata-Ramos et al. 2010; Miguelmies and Sumida 2012; Wabnitz et al. 2003), but the shells have the greatest economic importance (Juinio et al. 1987) especially for international trade (Lucas 1994). The Bureau of Fisheries and Aquatic Resources reported an export of about 243 to 11,930 tons of giant

clams between 1976 and 1980 (BFAR 1980); however, the volume of trade sharply declined at about 39 to 66 tons due to unregulated harvest (Wells 1997). In Palawan, *T. gigas* was considered virtually extinct (Alcala 1986; Juinio et al. 1989) although the province was regarded as the Philippines' last stronghold of native *T. gigas* (Neo et al. 2017).

T. gigas and other giant clam species have been listed as Vulnerable (VU - A2cd) in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Wells 1996) to regulate harvesting and protect the species from extinction. *Tridacna gigas* are listed in Appendix II of Convention on International Trade in Endangered Species (CITES) Flora and Fauna (Neo et al. 2017; Teitelbaum and Friedman 2008; Wabnitz et al. 2003; Wells 1996) which means that the species are not necessarily threatened with extinction but in which trade must be controlled in order to avoid utilization incompatible with their survival. In the Philippines, the Fisheries Administrative Order (FAO) 168, series of 1990 (DA 1990), regulates the culture and exportation of all shelled mollusks especially, the subfamily Tridacninae. While FAO No. 208, series of 2001 (DA 2001) prohibits the collection of all wild giant clams in the country. The ban on exportation had resulted in reduced CITES export records (1983 to 2015) of 805 to only 149 giant clam individuals from the Philippines (Davila et al. 2017).

T. gigas breeders from Australia and Solomon Islands were used for hatchery propagation and restocking project (Gomez and Mingoa-Licuanan 2006) to hasten the revival of giant clam populations in the Philippines when researchers failed to find the local broodstocks in Palawan (Alcala 1986; Juinio et al. 1989). After more than 20 years of restocking initiatives, Gomez and Mingoa-Licuanan (2006) reported that more than 45,000 individuals had been distributed in various parts of the country with some success stories (Mingoa-Licuanan and Gomez 2007). Gomez and Mingoa-Licuanan (2006) emphasized the importance of strong community involvement in promoting a successful restocking project, but this was not the case for the restocked clams in Palawan. Hence, the possibility for those clams to survive is low.

The recent observation on the presence of live *T. gigas* in some localities in the mainland Palawan and Tubbataha Reefs Natural Park (TRNP) in the municipality of Cagayancillo (Dolorosa et al. 2015; Neo et al. 2017), suggest that the clams may have recovered after several decades of protection. This study aimed to inventory the live *T. gigas* and its relics in the province to document the status of *T. gigas* in Palawan. Specifically, we obtained data about the distribution, numbers, sizes, age, and usage of both empty shells and live *T. gigas*. Information derived from this study could be used to support local conservation initiatives such as aggregation of wild populations and breeding of locally available broodstocks.

2. MATERIALS AND METHODS

2.1. Study Site

The province of Palawan, composed of 1,768 islands, is found in the southwest of the Philippines (9° 30'N and 118° 30'E), lying between the West Philippines and Sulu Seas (Figure 1). It was designated as a biosphere reserve by the UNESCO - Man and Biosphere Programme (MAB) in 1990 because of its relatively intact ecosystems and its potential to showcase the co-existence of sustainable development and protection of the environment (Sandalo and Baltazar 1997).

2.2. Data Collection

Information about *T. gigas* was compiled from various field activities, key informants (KIs), and previous studies (Figure 1). Other sources of information included blogs, online news, and articles. We reviewed a total of 24 unpublished/published papers and reports dealing with coral reefs and marine invertebrate assessments, which were conducted within Palawan (Table 1) from 2003 and 2016. With the aid of a guide questionnaire, 93 KIs from different localities (Table 2) were either personally interviewed or corresponded via social media. Information such as numbers of shells or live individuals and sizes of *T. gigas* were solicited to all KIs. Only 25 or 25.77% of KIs have provided 75 photos: empty shells (62) and live (13) *T. gigas*. The KIs were affiliated to government agencies (28), non-government organizations (8), private sectors (7), academe (17), students (20), resident (5), bloggers (4), resort personnel (2), and others (2). Site visits in different resorts, residences, restaurants, churches, museums, and many other places were conducted to verify the reports from KIs.

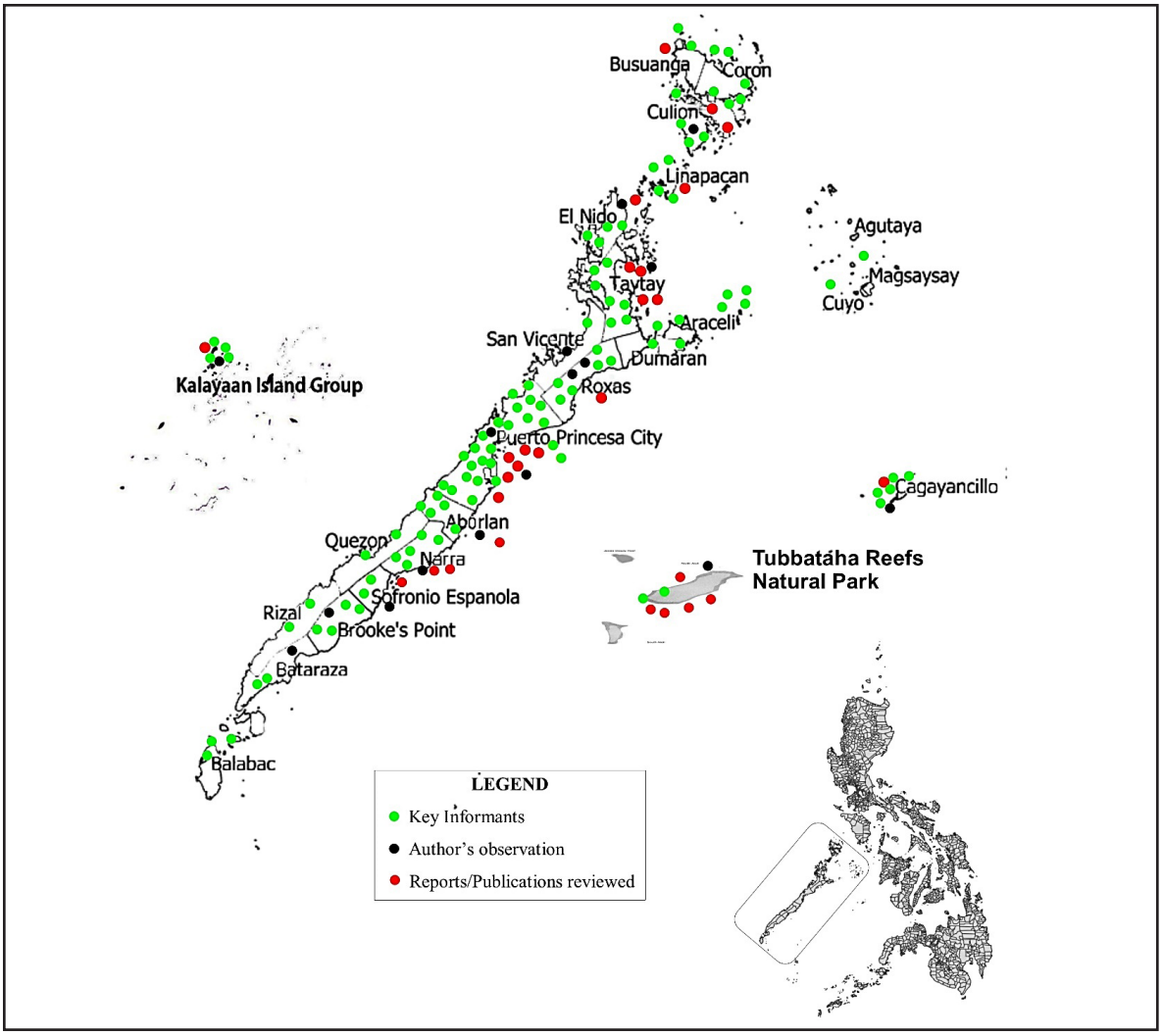

Figure 1. Map of Palawan showing the different sources of information for live and empty shells of *Tridacna gigas*.

Table 1. Reviewed papers and reports (published and unpublished) about coral reefs and marine invertebrates assessment conducted within Palawan. Under the column "number of papers and reports" letters (a,b,c) were of the same sources and counted as one publication. The single asterisk (*) is for unsupported with photos and double asterisk (**) means supported with photos. The single plus sign (+) indicates unpublished papers and the double plus sign (++) for articles published in peer-reviewed journals.

Localities	No. of papers and reports	No. of papers and reports that has *T. gigas* reported		Reviewed papers and reports
		live	empty shell/s	
Aborlan	1	-	-	(Balisco et al. 2015+)
Busuanga	1(a)	-	-	(White et al. 2006++)
Cagayancillo	6	1	2	(Conales et al. 2015++; Dolorosa and Schoppe 2005++; Dolorosa et al. 2014++; Dolorosa et al. 2015a*+; Dolorosa et al. 2015b**++; Dolorosa and Jontila 2012*++)
Coron	1(b)	-	-	(White et al. 2006++)
Culion	1(c)	-	-	(White et al. 2006++)

Localities	No. of papers and reports	No. of papers and reports that has *T. gigas* reported		Reviewed papers and reports
		live	empty shell/s	
El Nido	1	1	-	(Gonzales et al. 2013*+)
Kalayaan Island	1	-	-	(Gonzales et al. 2008+)
Linapacan	1	-	-	(PCSDS 2006+)
Narra	2	-	-	(Dolorosa et al. 2015+; Dolorosa 2016+)
Puerto Princesa	5	1	-	(Becira et al. 2012++; Bolen 2005+; Dolorosa and Schoppe 2010++; Gonzales et al. 2014*++; Picardal and Dolorosa 2014++)
Roxas	1	-	-	(Condesa 2005+)
Sofronio Espanola	1	-	-	(Balisco et al. 2016+)
Taytay	4	-	-	(Dolorosa 2014+; Dolorosa and Matillano 2015+; Gonzales et al. 2014++; Sayson 2003+)

Table 2. Code number of the Key Informants and information provided about *Tridacna gigas*. Under the column "number of *T. gigas* encountered," the number of shells followed with a letter in parenthesis means the same *T. gigas* recorded for that locality. The authors encountered other samples. Key Informants who provided photos of *T. gigas* are indicated by an asterisk (*).

Localities	Code number of Key Informants	No. of *T. gigas* encountered			Photos		Sizes		Date *T. gigas* observed
		Live	Empty shells						
			Single	Paired	with	w/out	with	w/out	
Aborlan	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5*	-	4	-	√	-	√	-	1990-2018
Araceli	6*	-	1	-	√	-	√	-	2004-2018
	7*	-	-	1	√	-	√	-	2018
	8*	-	1	-	√	-	√	-	2018
	9*	-	-	-	-	-	-	-	-
Agutaya		-	-	-	-	-	-	-	-
Balabac	10*	-	1	-	√	-	-	-	2018
	11	1	-	-	-	√	√	-	2018
	12*	1	-	-	√	-	√	-	2010
Bataraza	13	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-
Brooke's Point	15	-	1	-	-	√	√	-	2017
	16	-	-	-	-	-	-	-	-
	17*	-	1	-	√	-	√	-	2012
	18	-	-	-	-	-	-	-	-
Busuanga	19*	-	1	-	√	-	√	-	2018
	20	-	-	-	-	-		-	-

Localities	Code number of Key Informants	No. of *T. gigas* encountered			Photos		Sizes		Date *T. gigas* observed
		Live	Empty shells						
			Single	Paired	with	w/out	with	w/out	
Cagayancillo	21	-	1	-	-	√	√	-	2018
	22	-	-	1	-	√	√	-	2018
	23*	8	-	-	√(7)	√(1)	√	-	2010-2018
	24*	-	2	-	√	-	√	-	2018
	25*	-	38(a)	-	√	-	√	-	2018
	26	-	1	-	-	√	-	√	2015
	27	-	36(b)	-	-	√	-	√	1970-2018
Coron	28	-	-	-	-	-	-	-	-
	29*	-	1	-	√	-	√	-	2018
	30*	5	-	-	√(1)	-	√(1)	-	2018
	31*	1	-	-	-	√	-	√	2016
	32*	-	-	1	√	-	√	-	2016
	33*	-	2	-	√	-	√	-	2018
Culion	34*	-	1	-	√	-	√	-	2018
	35	-	-	-	-	-	-	-	-
	36	1	-	-	-	-	√	-	2018
	37*	-	1	-	√	-	√	-	2018
Cuyo	38	-	-	-	-	-	-	-	-
Dumaran	39	2(a)	-	-	-	√	√	-	2016
	38	2(b)	-	-	-	√	√	-	2016
	6*	-	1	-	√	-	√	-	2018
	40	-	-	-	-	-	-	-	-
El Nido	41	-	-	-	-	-	-	-	-
	42	-	-	-	-	-	-	-	-
	23	-	-	-	-	-	-	-	-
	43	-	-	-	-	-	-	-	-
Kalayaan Island	44	-	5	-		√	-	√	2015
	38	-	-	-	-	-	-	-	-
	45	-	-	-	-	-	-	-	-
	42	-	-	-	-	-	-	-	-
Linapacan	46	-	-	-	-	-	-	-	-
	47	-	-	-	-	-	-	-	-
	48	-	-	-	-	-	-	-	-
	49	-	-	-	-	-	-	-	-
Magsaysay	25	-	-	-	-	-	-	-	-
Narra	50	-	-	-	-	-	-	-	-
	51	-	-	-	-	-	-	-	-
	52	-	-	-	-	-	-	-	-
	53	-	-	-	-	-	-	-	-
	54	-	-	-	-	-	-	-	-

Localities	Code number of Key Informants	No. of *T. gigas* encountered			Photos		Sizes		Date *T. gigas* observed
		Live	Empty shells						
			Single	Paired	with	w/out	with	w/out	
Puerto Princesa	55*	-	1	1	√	-	√	-	2018
	56*	-	1	-	√	-	√	-	2018
	57	-	-	-	-	-	-	-	-
	58	-	-	1	√	-	√	-	2013
	59	-	-	-	-	-	-	-	-
	60	4(a)	-	-	-	√	-	√	2018
	61	-	-	-	-	-	-	-	-
	62*	4(b)	-	-	√	-	√	-	2018
	63	-	-	-	-	-	-	-	-
	64	4(c)	-	-	-	√	-	√	2018
	65	4(d)	-	-	-	√	-	√	2018
	66*	-	4	-	√	-	√	-	2018
	67*	-	-	2	√	-	√	-	2018
	68	-	-	-	-	-	-	-	-
	69	-	-	-	-	-	-	-	-
	70	-	-	-	-	-	-	-	-
	71	-	-	-	-	-	-	-	-
	72	-	-	-	-	-	-	-	-
	73	3	-	-	-	√	√	-	2018
	74	-	-	-	-	-	-	-	-
	38*	-	1	-	√	-	√	-	2018
	75	-	-	-	-	-	-	-	-
	5*	-	-	1	√	-	√	-	2018
	76	-	-	-	-	-	-	-	-
	77	-	1	1	√	-	√	-	2010-2018
	78	-	-	-	-	-	-	-	-
Quezon	79	-	-	-	-	-	-	-	-
	80	-	-	-	-	-	-	-	-
Rizal	81	-	1	-	-	√	-	√	2018
	82	-	-	-	-	-	-	-	-
Roxas	83	-	-	-	-	-	-	-	-
	56*	-	1	-	√	-	√	-	2018
	15	-	1	-	-	√	√	-	2018
	7	-	-	-	-	-	-	-	-
	84*	-	1	-	√	-	√	-	2018
	85	-	-	-	-	-	-	-	-
San Vicente	86	-	-	-	-	-	-	-	-
Sofronio Espanola	45	-	-	-	-	-	-	-	-
	87	-	2	-	-	√	-	√	2018
Taytay	88	-	-	-	-	-	-	-	-
	89*	-	3	-	√	-	√	-	2018
	90	-	-	2	-	√	-	√	-

Localities	Code number of Key Informants	No. of *T. gigas* encountered			Photos		Sizes		Date *T. gigas* observed
		Live	Empty shells						
			Single	Paired	with	w/out	with	w/out	
	91	-	-	-	-	-	-	-	-
	92	-	-	-	-	-	-	-	-
	93	-	-	-	-	-	-	-	-
Total		**26**	**80**	**11**					

2.3. Data Analysis

The distribution and numbers of live individuals and empty shells were grouped per municipality or city and were plotted in a bar graph. Photos of live and empty shells with size reference were measured for shell length using CPCE4.1 software (Kohler and Gill 2006). Photos of *T. gigas* embedded in the church of Cagayancillo were all treated as single shells.

The sizes were calculated to obtain the mean shell length per locality, and these were visualized in a bar graph.

To generate the size at age, we substituted the growth parameter estimates ($L\infty$ = 93; K=0.13) of Villanoy et al. (1988) for *T. gigas* from Sulu Archipelago and southern Palawan to the von Bertalanffy growth formula $L_t = L\infty - (L\infty - L_0)e^{-Kt}$ (where: L_t = length at time t, $L\infty$- mean asymptotic length or mean length of the clams, K- growth coefficients, determines how fast the clams approaches its $L\infty$ and t- the age of clams) (Cailliet et al. 2006; Ogle 2016). The size data were plotted on a graph along with the predicted size at age. In the von Bertalanffy growth curve, the L∞ = 93 was reached in 76 years.

3. RESULTS

3.1. Empty shells of *T. gigas*

A total of 97 empty shells (14 pairs and 83 single shells) were recorded and documented in 14 localities in Palawan (Figure 2). Out of 14 paired shells, 10 have photos, while for 83 single shells, 76 have photos. The highest number of shells (40.21% of 97 shells) were found embedded in the walls of a church in Cagayancillo while only one single shell was recorded in Balabac, Busuanga, Dumaran, and Narra (Figure 2).

The shells were used for outdoor (30.39%) and indoor decorations (7.22%). Those found in the coastal areas comprised 6.19% (Figure 3 and 4).

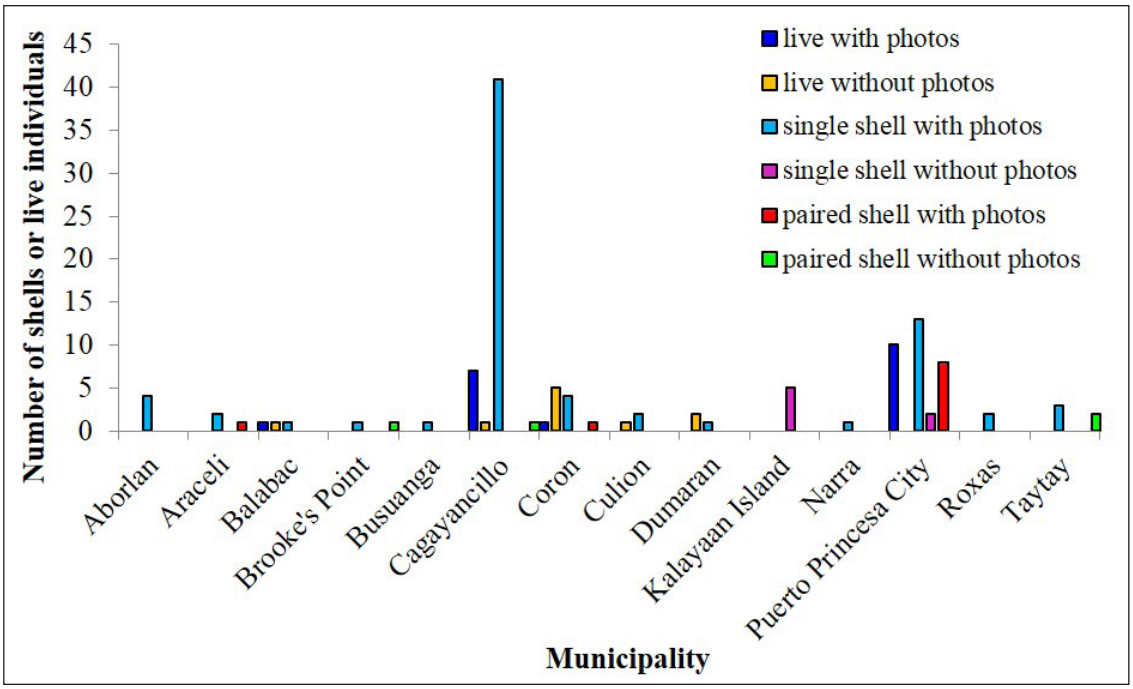

Figure 2. Distribution and numbers of empty shells and live *Tridacna gigas* in various localities within Palawan.

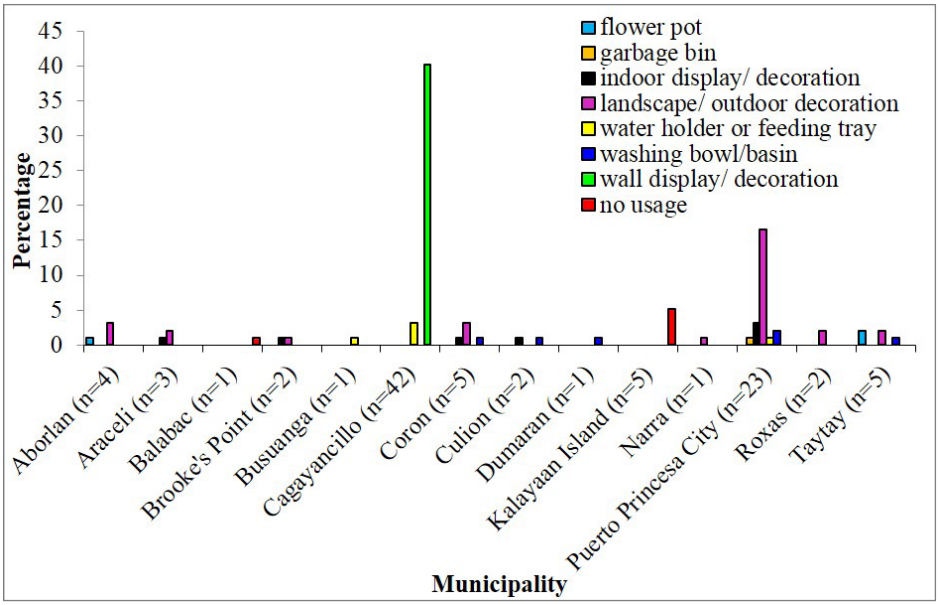

Figure 3. Percent usage of *Tridacna gigas* empty shells per locality.

Figure 4. Images of *Tridacna gigas* empty shells in different localities in Palawan portraying different usage: (a-c) wall decoration in Cagayancillo church, (d) hand wash basin in Taytay, (e-f) garbage bin and garden ornament in Puerto Princesa City, (g) water holder in Safari Park, Calauit, Busuanga, (h) indoor display in Araceli, (i) water basin in Coron, (j) landscape decoration in Dos Palmas Island Resort and Spa in Puerto Princesa City, and (k) flowering pot in a private residence in Aborlan. Unmarked photos were taken by the authors. Scale bar=15 cm.

3.2. Live *T. gigas*

A total of 29 live specimens were documented (the KIs reported 26 of these) in six localities. However, only 19 individuals were supported by photographs (Figures 5 and 6). The highest numbers (10 individuals) were reported in the mainland Palawan (Puerto Princesa City), followed by TRNP, Cagayancillo, with eight individuals. Six individuals were recorded in a resort in Coron, while only one to three individuals were reported in other sites (Figure 2). Some of these clams are being promoted as tourists' destination (Figure 5).

Figure 5. Photos of live *Tridacna gigas* found in various island resorts in Palawan: (**a-d**) Dos Palmas Island Resort and Spa, Puerto Princesa City, (**e**) Onok Island Resort, Balabac, (f) Dimakya Island Resort, Coron, and (**g-l**) Rita Island Resort, Puerto Princesa City. Unmarked photos were taken by the authors. Scale bar =15 cm.

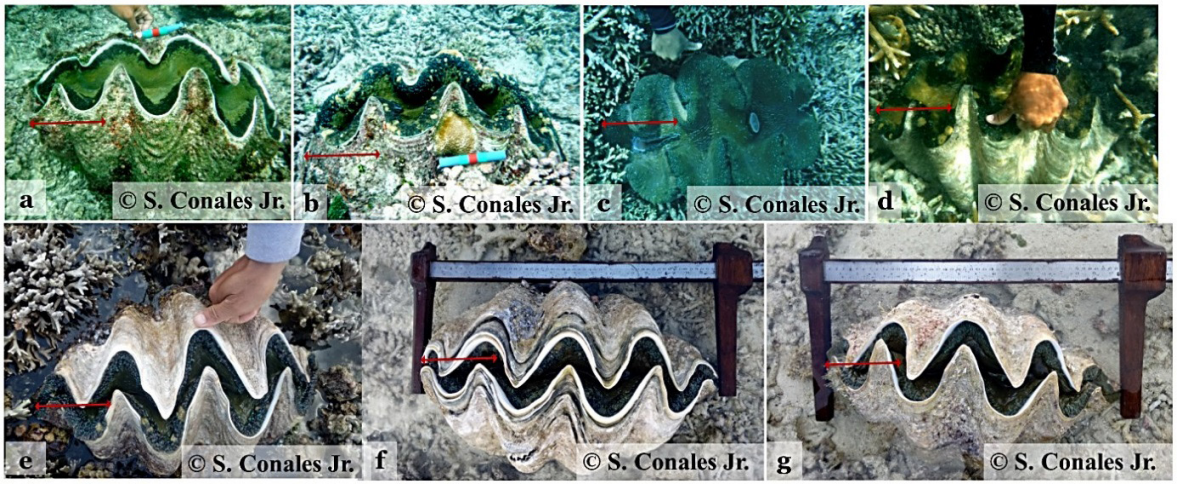

Figure 6. The seven of the eight live *Tridacna gigas* encountered and photographed by a KI in Tubbataha Reefs Natural Park in the municipality of Cagayancillo. Scale bar = 15 cm.

3.3. Age estimation and sizes of empty shells and live *T. gigas*

The sizes of empty shells ranged between 42.0 and 112 cm (mean = 65.86 cm). The municipality of Taytay holds the largest single shell with 112 cm shell length. The largest paired shell with a shell length of 100 cm was encountered in Puerto Princesa City (Figure 7). The live clams had shell length ranging between 42 and 109 cm (mean = 73.69 cm; Figure 7). The largest individuals with photos measuring 77-109 cm were encountered in Puerto Princesa City (Figure 5), while the smallest (42 cm) was found in TRNP, which is under the jurisdiction of Cagayancillo (Figure 6). The recently documented *T. gigas* in Rita Island, Ulugan Bay, Puerto Princesa City measured about 79-109 cm shell length (Figure 5g-l). When fitted to the von Bertalanffy growth curve, both empty shells and live *T. gigas* were between 5 and >76 years old (Figure 8).

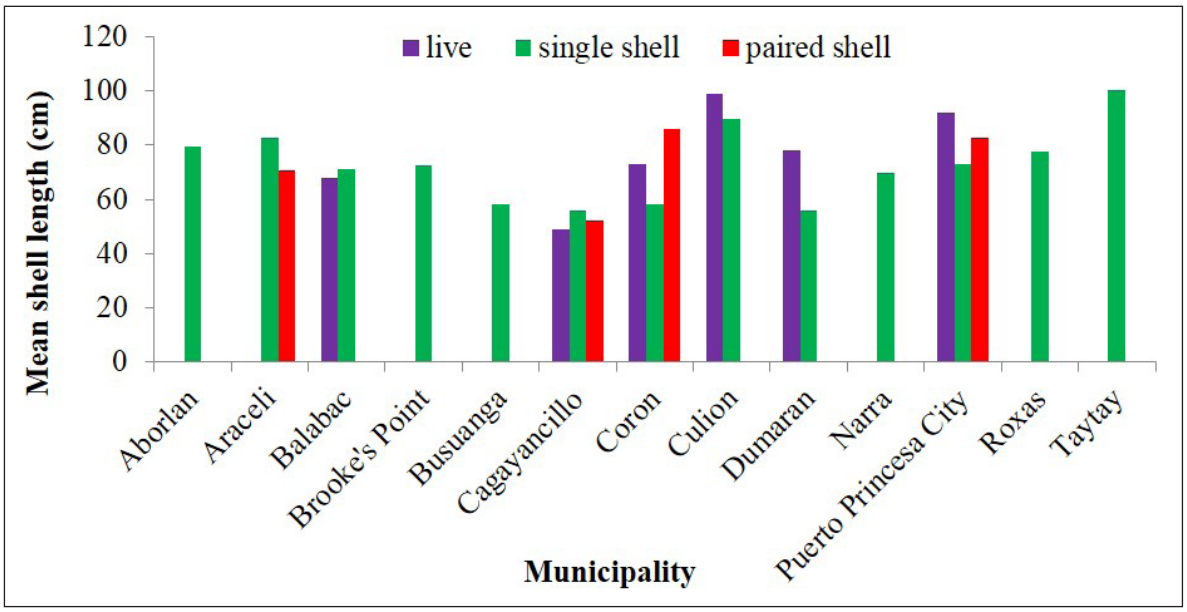

Figure 7. Mean shell lengths of empty shells and live *Tridacna gigas* per locality within Palawan.

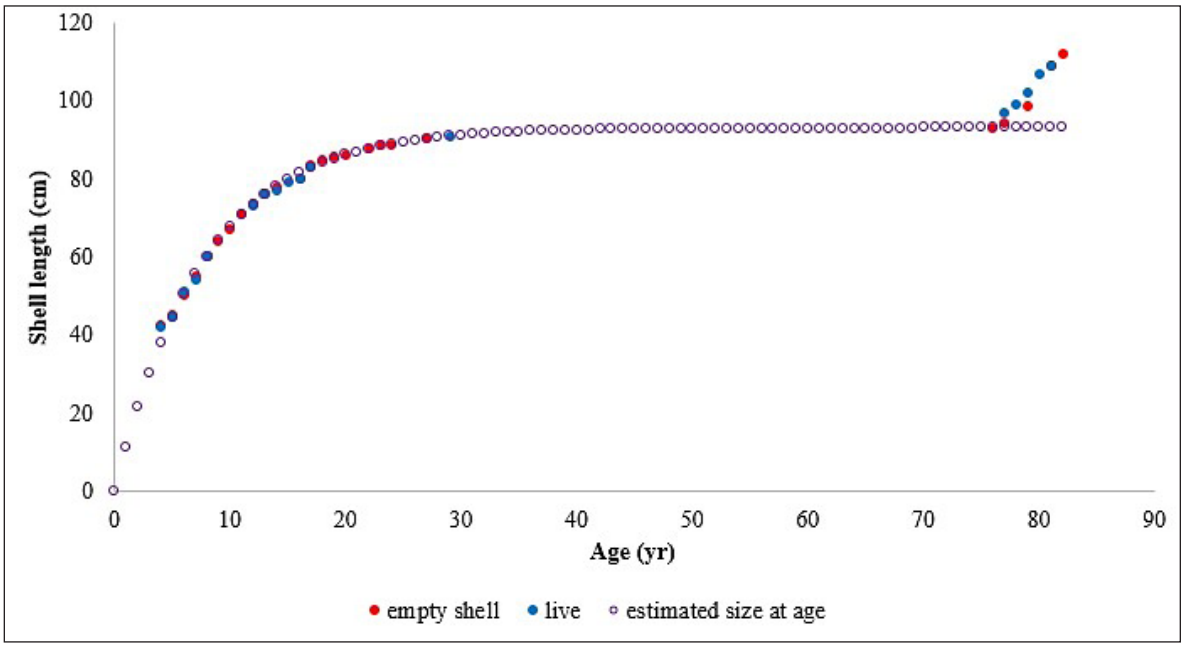

Figure 8. Estimated size at age of live *Tridacna gigas* and its empty shells when fitted to the von Bertalanffy growth curve derived using the parameter estimates of Villanoy et al. (1988).

4. DISCUSSION

4.1. Empty shells of *T. gigas*

The most significant findings of *T. gigas* empty shells were in the walls of Cagayancillo church. A KI claimed that these empty shells from the reefs of Cagayancillo were installed during the construction of the church in the 18th century. Another KI also added that in the 1980's giant clams in the reefs of Cagayancillo were abundant and heavily exploited by most of the residents and were traded to nearby provinces. Trading also occurred within Palawan as some of the encountered shells in Puerto Princesa City were transported from the islands or municipalities for various local uses such as landscaping and interior design, while some are used as flowering pot and washing bowl. The report of a KI on newly harvested *T. gigas* and of other giant clam species suggest that harvesting of these protected species remained a problem. Effective law enforcement, along with a continuous awareness campaign, is needed to help save these species.

The trade of *T. gigas* shells has been rampant in the Philippines way back in the 19th century (Lucas 1994). The Australians have a yearly market of 100,000 to 120,000 clam shells been imported from the Philippines, but supplies became scarce when CITES takes effect and natural stocks become exhausted (Tisdell 1994). Davila et al. (2017) also mentioned that the export of *T. gigas* entered in CITES from the Philippines fall from 197 individuals from 1985 to 85 individuals in 2014. Also adding to the pressure is the recent increase in demand for *T. gigas* shells as a substitute for elephant tusks in the lucrative carving industry for jewelry and religious icons (Larson 2016; Lee 2016; Lyons et al. 2018; Neo 2017). The increasing demand had been reported to cause severe destruction to the reefs and other living flora and fauna by illegal fishers in the West Philippines Sea (WPS), the epicenter for giant clam shells (Bale 2016; Lee 2016). Associated with this ecological damage is the loss of its economic sustenance (around $57 billion a year) to all individuals who are dependent on the resources of the area (Bale 2016). In some municipalities of Palawan like Taytay and Roxas, the shells of *T. gigas* were stripped of the outer thicker parts to expose the pearly portions, which are then polished to look like giant clam pearl (Krzemnicki and Cartier 2017).

One KI claimed that several fossilized *T. gigas* shells have scattered in a forest several kilometers from the shore of Bugsuk Island, municipality of Balabac, but only a piece of shell was photographed. This island in the southern tip of Palawan is home to some threatened species no longer found in the mainland (Manalo 2003). The presence of the pearl farm and its remoteness may have also helped protect the island from severe exploitation as manifested by the presence

of saltwater crocodiles (*Crocodylus porosus*), wild boar, deer in the wild and much other wildlife (Cruz pers. comm.). Areas that form part of pearl farms serve the dual purpose of production and fish sanctuaries. These sites have very good to excellent coral conditions and moderate to very high fish density (Baltazar and Dalusung-Rodriguez 2016) and may as well harbor some remaining local *T. gigas* populations.

4.2. Live *Tridacna gigas*

The presence of 12 live *T. gigas* (supported with photos) in four resorts in Palawan (Figure 6) reflects the essential contributions of these sectors in giant clam conservation. When properly maintained over time, these resorts can function as natural marine protected areas (MPAs) by providing safe places for marine life to breed and recover from severe fishing. The importance of island resorts in biodiversity conservation has been observed in Dos Palmas Island Resort and Spa in Honda Bay, Puerto Princesa City, where Jontila et al. (2017) found a higher abundance of sea cucumbers in this well-managed island resort than in other open accessed areas. Cowburn et al. (2018) also reported that tourist development appeared to have less impact on reef conditions in the Maldives, maintaining moderately high coral cover and features of a resilient ecosystem.

The live *T. gigas* in well-managed marine protected areas like the TRNP in Cagayancillo and some private resorts in Palawan provide hope for the possible restoration of lost local populations. However, natural re-establishment of stock in isolated areas may take hundreds of years (Kinch 2002). For example, in Silaqui Island and Hundred Islands National Park, Pangasinan, the two sites with the largest restock population of giant clams in northwestern Philippines (Gomez and Mingoa-Licuanan 2006), only two recruits measuring about 29 cm were reported in 2017 (Cabaitan and Conaco 2017). The TRNP as part of Cagayancillo have been severely exploited in the 1980s (Arquiza and White 1999; Dolorosa et al. 2010; Dygico 2006; White and Palaganas 1991), and only after 30 years of protection, that eight individuals *T. gigas* were encountered between 2014 and 2018. While other small giant clam species have recovered from overharvesting, other medium-sized species such as *Tridacna derasa* and *Tridacna squamosa* also remained rare at TRNP (Dolorosa and Jontila 2012; Dolorosa and Schoppe 2005; Dolorosa et al. 2015). In other fish sanctuaries like the 18 MPAs in the city of Puerto Princesa, only small species of giant clams were found (Delgado pers. comm.), making these as potential sites for *T. gigas* restocking.

The lengthy natural recovery period of *T. gigas* population in the wild could be shortened by restocking hatchery-produced juveniles. Gomez and Mingoa-Licuanan (2006) restocked more than 45,000 hatchery-produced non-native *T. gigas* in various sites in the Philippines with success stories in some sites. Some of these giant clams were restocked in Palawan, specifically in El Nido Island (15 adults/sub-adults), Puerto Princesa City (18 adults/sub-adults), and Pag-asa Island (271 adults/sub-adults and 2,314 juvenile) (Mingoa-Licuanan and Gomez 2007). However, it is assumed that these clams did not survive due to the absence of management interventions.

4.3. Age estimation and sizes of empty shells and live *T. gigas*

While there is no published information on the long term growth of restocked giant clams in the Philippines (Lebata-Ramos et al. 2010), the use of von Bertalanffy growth formula is the simplest possible way to estimate the ages of live *T. gigas* and its empty shell. The use of other methods such as growth increment is impossible as most of the samples were only solicited and obtained from the KIs. Lack of materials and equipment in using other advanced methods also hinders in obtaining the exact ages of the giant clams. Besides, many studies used this method in estimating the size at the age of giant clams in different countries and localities (Dolorosa et al. 2014; Lucas 1994; Munro 1993; Pearson and Munro 1991).

The estimated ages of *T. gigas* empty shells embedded in the walls of Cagayancillo church were between 5 to 14 years old at the time of capture. In other areas, some large shells (112 cm) were higher than the $L\infty$ (93 cm) of Villanoy et al. (1988), suggesting that the samples used in the previous study did not involve the largest individuals. The study of Villanoy et al. (1988) was done when *T. gigas* were considered virtually extinct in Palawan (Alcala 1986), so it is possible that the samples were of smaller sizes than during the beginning of the fishery. The exploitation of high value and large individuals are the usual targets at the start of the fishery, followed by a shift on small-sized individuals as for the case of sea cucumbers (Anderson et al. 2011).

The live *T. gigas* in Puerto Princesa City, having 109 cm shell length, is much larger compared to the largest (98.3 cm) 35 years old live giant clam in

Bolinao Marine Laboratory, which originates from the Solomon Islands (Cabigao 2018). If the growth rates in Puerto Princesa are similar to those in Bolinao, Pangasinan, the one we found could be one of the last local stocks in the country; however, genetic analysis is needed to ascertain the origin or genetic make-up of these clams.

For those restocked *T. gigas* in Palawan between 1990 and 2007 (Mingoa-Licuanan and Gomez 2007), any surviving individuals could be about 28 years old and be more or less 91 cm when fitted to the von Bertalanffy growth curve. If the clams reproduce ten years after restocking, an 18 years old recruit could measure 84 cm (Figure 8) and could be easily spotted on the reefs. However, one of the KIs, a dive instructor in El Nido, claimed that there are no more *T. gigas* in the area. Also, the second author did not find any *T. gigas* in El Nido after doing several reef assessment activities. In addition, the assessment done by Gonzales et al. (2008) in Pag-asa Island did not report any live *T. gigas*. It is, therefore, possible that the restocked clam did not survive due to the absence of management intervention. Gomez and Mingoa-Licuanan (2006) reiterated that the key to a successful restocking project requires the cooperation of the locals, which were not been reported for the restocking projects in Palawan.

The encountered *T. gigas* in TRNP have shell lengths ranging between 42 cm to 57 cm and could be between 5 to 7 years old when fitted to the VB growth curve. Unlike the other reefs in Cagayancillo, TRNP had been effectively protected for 30 years, and only in recent years that *T. gigas* were spotted. The absence of much older *T. gigas* in TRNP suggests that these recruits came from other areas within the Sulu Sea or other localities. The hydrographic flow within Palawan are interconnected from different areas within the West Philippines Sea (WPS) and Sulu Sea (Juinio-Meñez et al. 2003; Tangunan and Peleo-Alampay 2018), and we do not discount the possibility of recruits coming from the different successfully managed restocking sites in the country. A genetic study could help verify the origin of these recruits.

The distantly scattered *T. gigas* in TRNP could be aggregated in a suitable site to increase the chances of natural fertilization and recruitment. Keeping the clams proximate at each other could also help ease the procedure in extracting the gametes for hatchery propagation programs involving local populations. Other live *T. gigas* reported by KIs especially those unsupported with photos needs further verification and assessment to maximize their full potential in ecological restoration. Giant clams like *T. gigas*, when restored, can both help improve reef ecosystems (Cabaitan and Conaco 2017; Cabaitan et al. 2008; Neo et al. 2015), and generate revenues from ecotourism (Davila et al. 2017).

5. CONCLUSION

The presence of few *T. gigas* empty shells in various localities in Palawan suggests that the species were once abundant but were heavily exploited and eventually exterminated. *Tridacna gigas* are now very rare considering that out of the 24 reviewed reports/publications, only three have reported the species. One paper showed photos of the clam, and the other two reports have no picture nor size data for further verification. The species were only reported to occur in well-managed protected areas and resorts, suggesting that it is unlikely to encounter them in open-accessed areas. The use of Key Informants in searching for virtually extinct species like *T. gigas* appeared effective.

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