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Distribution, habitat characteristics, and conservation status of Noah's clam *Tridacna noae* (Röding, 1798) in the reefs of Palawan, Philippines

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ABSTRACT

This study aimed to provide an updated distribution range of *Tridacna noae* (Röding, 1798) in Palawan with notes on its habitat characteristics and conservation status. Data on the distribution and habitat characteristics were obtained from reef assessments from 2010-2023 and 10 Key Informants (KIs) and plotted using QGIS v3.28 software to illustrate its distribution in a map. A total of 12 reef sites within eight municipalities in Palawan showed the presence of *T. noae*. Majority of these reefs were found in open-access coastal areas facing the West Philippine Sea. The clams were partially buried or settled on the top of dead or live coral in a depth of 1-5 meters from reef flat to reef slope surrounded by macroalgae. *Tridacna noae* remained unlisted in international, national, and local lists of protected species although it was confirmed in 2014 as a distinct species of giant clam, hence; the inclusion of *T. noae* in the lists of protected species in the Philippines is needed. Knowing the distribution, habitat characteristics, and conservation status of a certain threatened species such as the giant clam is an important step in managing and conserving wild population.

Keywords: QGIS, remote sensing, teardrops giant clams, threatened species

INTRODUCTION

Tridacna noae (Röding, 1798) also known as Noah's clam or Teardrop clam is a species of giant clam previously considered as a variant of *Tridacna maxima* (Röding, 1798) because of similarity in morphological features (Rosewater 1965). The validation of *T. noae* as a distinct species from *T. maxima* was through morphological and genetic characteristics (Su et al. 2014). According to Su et al. (2014), the mantle of *T. noae* can be recognized by the presence of its unique ocellate spots or "teardrops" with sparse hyaline organs, while *T. maxima* has only

continuous hyaline organs on the mantle edge. In addition, both species of giant clams are said to have similar maximum shell lengths (i.e. 40 cm), although the largest observed *T. noae* so far was 32 cm (Neo 2023). Both species can be found in shallow reef areas and lagoons with water depths between 1-15 m (Borsa et al. 2015; Militz et al. 2015; Neo 2023) and typically found partially buried either on dead or live coral substrate surrounded by various macroalgae (Su et al. 2014; Neo et al. 2017).

The *T. noae* is widely distributed in the Indo-West Pacific region, extending from the north of the Ryukyu Archipelago in Japan, east of Kiribati,



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southeast of Cook Island, Western Australia, southwest of Christmas Island, west of Vietnam, south of Taiwan, and in the central Philippines (see Borsa et al. 2014; Neo et al. 2017). Over the years, reports of distribution range in some localities within the Indo-West Pacific are still expanding. For example, in 2019 and 2021, the presence of *T. noae* was reported in the west of Palawan, in the Philippines (see Ecube et al. 2019; Mecha 2024). While in 2022 and 2023, a range expansion of *T. noae* was reported in American Samoa (Marra-Biggs et al. 2022) and Cook Island (Morejohn et al. 2023).

All distinct species of giant clams under Tridacninae are listed under the Appendix II of CITES in which the global trade for live, meat, and shell must be regulated due to the declining wild population (CITES 2024; Dolorosa et al. 2024; Lee et al. 2024; Vogel and Hoeksema 2024). These are *Hippopus hippopus* (Linnaeus, 1758); *H. porcellanus* Rosewater, 1982; *T. gigas* (Linnaeus, 1758); *T. derasa* (Röding, 1798); *T. squamosa* Lamarck, 1819; *T. maxima* (Röding, 1798); *T. crocea* Lamarck, 1819; *T. noae* (Röding, 1798); *T. mbalavuana* Ladd, 1934; *T. rosewateri* Sirenko and Scarlato, 1991; *T. squamosina* Sturany, 1899; *T. elongatissima* Bianconi, 1856 (Fauvelot et al. 2020). In the Philippines, the first eight of the 12 species of giant clams mentioned above can also be found on its reefs (Dolorosa et al. 2015; Ecube et al. 2019; Neo et al. 2017), however, only the first seven are formally included in the list of protected species which prohibit the collection of living specimens and byproduct (DA 2001; PCSD 2017).

In Palawan, the presence of *T. noae* was only reported by Ecube et al. (2019) and Mecha (2024), however, the study area was limited to two municipalities. Hence, this study aimed to provide an updated distribution range of *T. noae* in the reefs of Palawan with notes of its habitat characteristics and conservation status which could be used for conservation management of its wild population and hatchery propagation like the case of *T. gigas* (see MFI 2020; Mecha et al. 2020).

METHODS

Study Sites

The study covers the entire province of Palawan in the Philippines (Figure 1), designated as a biosphere reserve by the UNESCO - Man and Biosphere Programme (MAB) in 1990 due to its relatively intact ecosystems and its potential to showcase the co-existence of sustainable development and protection of the environment (Sandalo and Baltazar 1997). It has 1,768 islands and a 2,000 km irregular coastline (UNESCO 2021) that lies between the West Philippine Sea (WPS) and the Sulu Sea known as the apex of marine biodiversity - the Sulu-Sulawesi Marine Ecoregion (SSME) (ADB 2014) and home to eight species of giant clams in the Philippines (Dolorosa et al. 2015; Ecube et al. 2019).

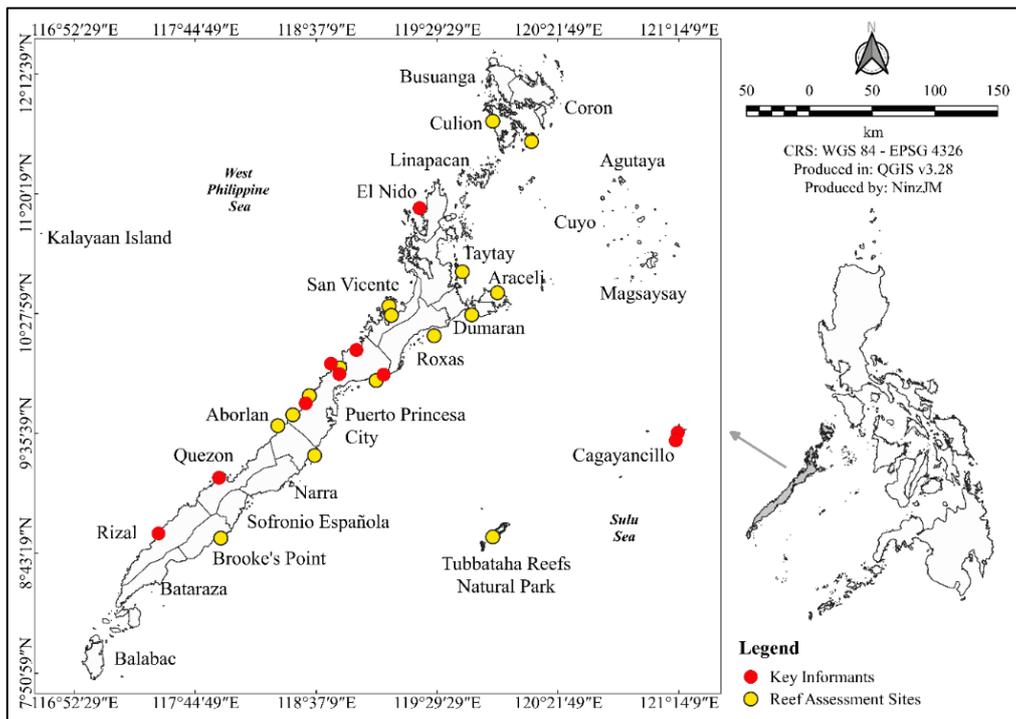


Figure 1. Map of Palawan showing the reef assessment sites (n=16) and location of KIs (n=10) during the virtual interview.

Distribution and Habitat Characteristics

The distribution was based from the compiled photos of individual *T. noae* opportunistically found from various personal reef survey projects in 16 reef sites from 2013-2023 in Palawan. These reef surveys were done using SCUBA gears at reef slope to reef flat with deep ranging from 2 to 15 m. Another source of information was the 10 Key Informants (KIs) employed in different NGOs from Palawan who also accidentally encountered *T. noae* from various reef surveys from 2010-2022. These KIs also responded to the posted information about *T. noae* on social media network between 2021-2023. Only individuals/divers who personally took photos of *T. noae* on the reef were included as KI. Each KI was also asked about the estimated sizes of *T. noae* and the characteristics of the habitat such as the type of substrate, the surrounding environs, and the depth of the reefs. All photos of *T. noae* presented by each KIs were also solicited. The location of reef survey sites and responses of KIs about the distribution of *T. noae* was geographically presented using the QGIS v3.28 software.

Conservation Status

Tridacna noae is not included in regulations, highlighting the need for further assessment. However, the conservation status of the species was evaluated based on the International Union for Conservation of Nature (IUCN 2024) Red List, CITES (2024), Fisheries Administrative Order (FAO) 208 (DA 2001), and Palawan Council for Sustainable Development (PCSD) Resolution 15-521 (PCSD 2017). A thorough review and field survey are needed to determine whether the species is at risk, evaluate existing legal protections, and identify the necessary data for its possible inclusion in conservation policies.

RESULTS

Distribution Range of *Tridacna noae*

A total of 12 reef sites within eight municipalities in Palawan had documentation of *T. noae* (Figure 2). Ten of these reefs are on the west coast of Palawan, while only two reefs in the east coast. Additionally, most of the reefs are open access, except for Puerto Princesa Underground River (PPUR) which is a Marine Protected Area (MPA), and Port Barton, San Vicente which is located in a private resort (Figure 2).

Habitat Characteristics

The majority of *T. noae* were found in the outer reef flat to reef slopes surrounded by macroalgae such as *Padina* spp., *Sargassum* spp., *Halimeda* spp. at a depth of 1-5 m (Table 1; Figures 3 and 4). Most of the clams were partially buried or on top of dead or

live massive corals, while some individuals were found within the base of branching corals.

Conservation Status

Tridacna noae is not listed in FAO 208, and not evaluated in PCSD Resolution 15-521 and IUCN Red List. However, CITES listed all giant clam species including the *T. noae* in Appendix II (Table 2).

DISCUSSION

Distribution Range of *Tridacna noae* in the Reefs of Palawan

The previous distribution range of *T. noae* in Palawan was only reported in the reefs of Port Barton, San Vicente (Ecube et al. 2019), and Malaking Patag, Culion (Mecha 2024). However, this study showed that *T. noae* can also be found in the central to southwest and eastern reefs of Palawan which provides an additional information on its distribution range in the entire province of Palawan and the Philippines (Lizano and Santos 2014). Currently, information on the distribution range of *T. noae* in the Philippines is still limited (Lizano and Santos 2014; Ecube et al. 2019; Mecha 2024; this study) although it is presumed to have a similar distribution range with *T. maxima*. Therefore, revisiting some surveyed sites with reports of *T. maxima* is needed for species revalidation. For example, the revalidation of the *T. maxima* population in various localities has been reported, where 42% of previously identified *T. maxima* was reclassified as *T. noae* in Papua New Guinea (Militz et al. 2015), while in Ningaloo Reef Marine Park, Australia, only *T. noae* are present with no individual *T. maxima* documented after the revisit in the park (Johnson et al. 2016).

On the other hand, a greater number of coastal areas with *T. noae* appeared on the west coast compared to the east despite the latter having more surveyed sites. The lesser degree of exploitation on the west coast compared to the heavily populated east coast of Palawan might be a factor for its absence in some surveyed areas. During bad weather, the majority of the residents living on the Palawan coast depends on the resources in shallow coastal areas for their livelihood and diet, which includes sea shells such as the giant clams (Ardines et al. 2020; Mecha and Dolorosa 2020; Mecha 2024). This is similar to the Kei Islands waters, Southeast of Indonesia within Indian ocean, where *T. noae* was only present in site with less human population than the surveyed sites with more human settlement near coastal areas (Triandiza et al. 2019). Additionally, Dolorosa et al. (2024) reported continuous decline of giant clams in Palawan, although high densities remained in some areas (Conales et al. 2015; Dano et al. 2020; Mecha and Dolorosa 2020). However, further assessments of

giant clams in various coastal areas are needed to understand better their distribution and population abundance, particularly in southern Palawan and other island municipalities. More data on the species

presence and density across the Philippines is also necessary to accurately evaluate its conservation status.

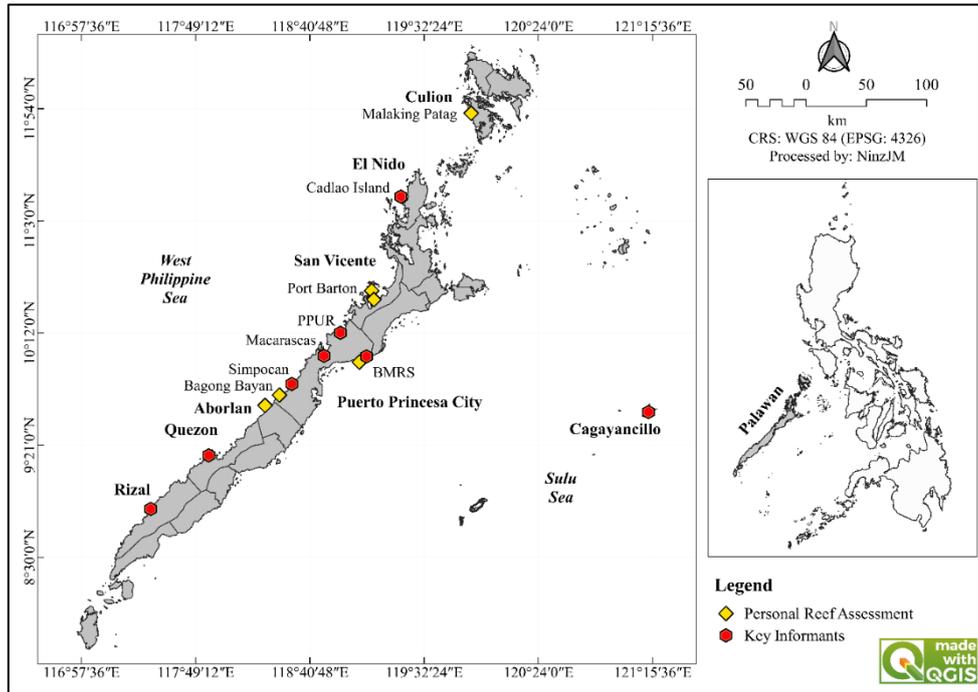


Figure 2. The current distribution range of *Tridacna noae* in Palawan. PPUR – Puerto Princesa Underground River; BMRS – Binduyan Marine Research Station.

Table 1. Habitat characteristics of *Tridacna noae* in different reefs in Palawan.

Localities	Depth (m)	Habitat Characteristics
Malaking Patag, Culion	2	The <i>T. noae</i> were found partially buried in dead coral substrate surrounded by various macroalgae, such as <i>Sargassum</i> spp. and <i>Halimeda</i> spp. at reef flat.
Cadlao Island, El Nido	1	The <i>T. noae</i> was found partially buried in dead coral substrate surrounded by various macroalgae such as <i>Sargassum</i> spp. at reef slope. Some sub-massive live corals are also present in the area.
Cagayancillo	1	The <i>T. noae</i> was found partially buried in dead coral substrate surrounded by a few macroalgae such as <i>Sargassum</i> spp. at reef flat.
Port Barton, San Vicente	1	<i>Tridacna noae</i> were found partially buried in dead coral substrate and crevices of live hard coral surrounded by various macroalgae such as <i>Sargassum</i> spp., <i>Padina</i> spp. and some filamentous green algae near reef crest.
Binduyan Marine Research Station (BMRS), Puerto Princesa City	1	The <i>T. noae</i> were found partially buried in dead coral substrate surrounded by a few macroalgae such as <i>Sargassum</i> spp. at reef slope.
Puerto Princesa Underground River, Puerto Princesa City	2-4	<i>Tridacna noae</i> were found on top of a dead coral substrate next to a live coral near the reef crest.
Macarascas, Puerto Princesa City	3	The <i>T. noae</i> were found partially buried in dead coral substrate surrounded with various macroalgae such as <i>Sargassum</i> spp. at reef flat with nearby sub-massive live corals.
Simpocan, Puerto Princesa City	4	The <i>T. noae</i> were found partially buried in a dead coral substrate with various macroalgae such as <i>Sargassum</i> spp. and <i>Halimeda</i> spp. at reef flat with branching corals at the reef slope.
Bagong Bayan, Puerto Princesa City	3	The clam was found partially buried in dead coral substrate next to a live coral with <i>Sargassum</i> spp. at reef slope.

Localities	Depth (m)	Habitat Characteristics
Apurawan, Aborlan	5	The clam was found on top of dead coral substrate surrounded by <i>Sargassum</i> spp. at reef slope.
Panitian, Quezon	4	The <i>T. noae</i> was found partially buried in dead coral surrounded by live corals and a few macroalgae at reef flat.
Candawaga and Punta Baja, Rizal	5	The <i>T. noae</i> was found partially buried in dead corals surrounded by live corals and a few macroalgae at reef flat.



Figure 3. Images of *Tridacna noae* from various reefs of Palawan. A – Malaking Patag, Culion; B – Cadlao Island, El Nido; C – Cagayancillo; D-E – Port Barton, San Vicente; F – BMRS, PPC; G-L – PPUR, PPC; M-O – Simpocan, PPC.

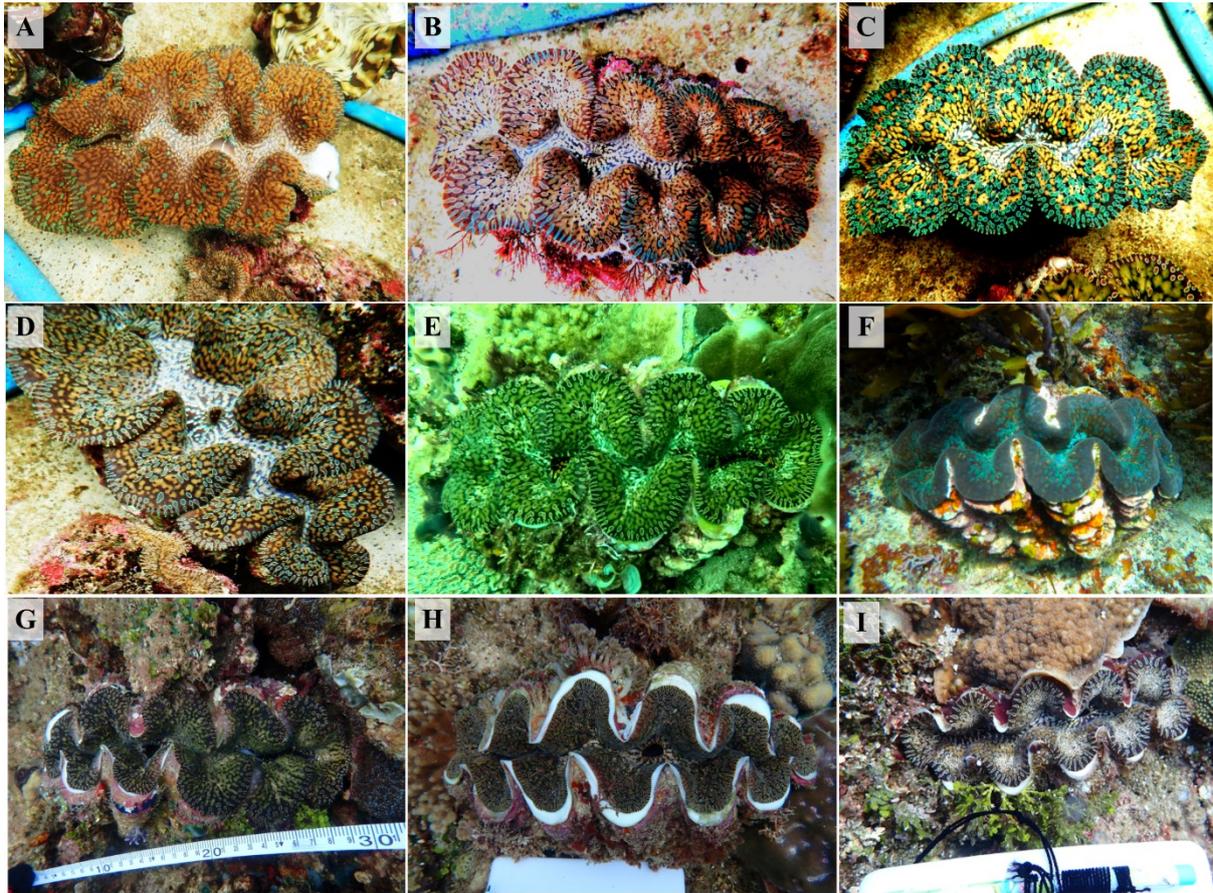


Figure 4. Images of *Tridacna noae* from various reefs of Palawan. A-D – Macarascas, PPC; E – Bagong Bayan, PPC; F – Apurawan, Aborlan; G-H – Panitian, Quezon; I – Punta Baja, Rizal.

Table 2. The conservation status of eight species of giant clams in the Philippines. FAO – Food and Agriculture Organization; PCSD – Palawan Council for Sustainable Development; IUCN – International Union for Conservation of Nature; CITES – Convention on International Trade of Endangered Species.

Species of Giant Clams	FAO 208 (DA 2001)	PCSD Resolution 15-521 (PCSD 2017)	IUCN Red List of Threatened Species (2024)	CITES (2024)
<i>Hippopus porcellanus</i>	Endangered	Endangered	Least Concern	Appendix II
<i>Hippopus hippopus</i>	Endangered	Endangered	Least Concern	Appendix II
<i>Tridacna gigas</i>	Endangered	Endangered	Vulnerable	Appendix II
<i>Tridacna derasa</i>	Endangered	Endangered	Vulnerable	Appendix II
<i>Tridacna squamosa</i>	Endangered	Endangered	Least Concern	Appendix II
<i>Tridacna maxima</i>	Endangered	Endangered	Least Concern	Appendix II
<i>Tridacna noae</i>	Not Listed	Not Evaluated	Not Evaluated	Appendix II
<i>Tridacna crocea</i>	Endangered	Endangered	Least Concern	Appendix II

Habitat Characteristics

The reef flat and reef slope where it encountered in various coastal areas in Palawan are similar to the observations in Kavieng Lagoonal chain, Papua New Guinea (Militz et al. 2015), and Dongsha Atoll, South China Sea (Neo et al. 2018). In addition, the substrate characteristics (e.g. crevices of dead and live corals) and depth (e.g. 1-4 m) of habitat of *T. noae*

encountered in this study are also similar to the reports conducted in Indo-West Pacific region (Borsa et al. 2024; Marra-Biggs et al. 2022; Morejohn et al. 2023; Triandiza et al. 2019; Militz et al. 2015). This implies that *T. noae* are more common in outer reefs exposed to waves actions rather than the inner reef chains and most likely to be found in the abovementioned habitats. According to Dumas et al. (2014) and Millitz et al.

(2015), the larvae and juvenile of *T. noae* has active habitat selection similar to *T. maxima* utilizing chemosensory abilities that allow individuals to distinguish from favorable and unfavorable reef substrates. Majority of *T. noae* documented in this study were also found together with *T. maxima* and *Tridacna crocea* (Lamarck, 1819), suggesting that these giant clam species shared similar habitat selection in the reef (Neo et al. 2018; Mecha 2024). These habitat preferences of *T. noae* could be used as a reference for the conservation of its wild population and protection of the area (Militz et al. 2015; Morejohn et al. 2023). In addition, the presence of macroalgae in major reefs with *T. noae* in this study needs further investigation if it has a connection to the habitat preference of the clams since other studies did not include such information.

Conservation Status

Tridacna noae was initially described as a variant of *T. maxima* by Rosewater (1965), which may explain its absence from the earliest list of protected species in FAO 208 (Table 2; DA 2001). However, the criteria or references used in FAO 208 for listing giant clam species remain unspecified. Regardless of being recognized as a distinct species in 2014 (Su et al. 2014; Neo et al. 2015), it has not been included in key conservation lists due to a lack of updates, particularly for newly recognized species like *T. noae*, which may not yet have been evaluated. As of 2024, the IUCN only recognizes seven giant clam species in the Philippines, with two listed as Vulnerable (VU) and five as Least Concern. Similarly, PCSD Resolution 15-521 (PCSD 2017) lists only these seven species as endangered. (Table 2). Despite this, CITES (2024) includes all species under the family Tridacninae in Appendix II due to the similarity of appearance principle, implying that species are listed because they closely resemble others subject to trade restrictions. This includes *T. noae*, which is not currently threatened with extinction but is listed to ensure that trade regulations prevent potential threats to its wild population.

Although the Philippine government prohibits the harvesting of giant clams, small species such as *T. maxima*, *T. noae*, and *T. crocea* are not only consumed as food (Ardines et al. 2020) but some are also collected for the aquarium industry due to their colorful mantle (Wabnitz et al. 2003; Fartherree 2023; Vogel and Hoeksema 2024). During the collection process, the burrowing species are forcibly extracted from either dead or live coral substrates which pose a threat to the coral reefs (Mecha 2024). In addition, while some reef areas recovered overtime (Abesamis et al. 2023), the general declining trend for coral cover in Palawan (Climaco et al. 2022; Dolorosa et al. 2023; Haworth et al. 2024) is an added threat to the giant clam species. Therefore, there is a need to update the

existing laws and strengthen the enforcement mechanisms to prevent the risk of localized extinction, especially the *T. maxima*, as its density data in the Philippines might be overestimated as this includes the *T. noae* from the previous giant clam assessments. Moreover, there is a need to protect the open access reef areas with *T. noae* in Palawan to conserve its remaining population in the wild. Currently, the hatchery propagation initiative for *T. noae* is ongoing in Palawan through the collaborative efforts of Western Philippines University (WPU) and the Malampaya Foundation Incorporation (MFI). This initiative would help conserve and protect the wild population of *T. noae* in the reefs of Palawan like the case of *T. gigas* (MFI 2020; Mecha and Dolorosa 2020).

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ETHICAL CONSIDERATIONS

All Key Informants voluntarily shared the needed information and photos used in this study. No animals were captured or harmed during the conduct of this study.

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