Status Review Report

of

7 Giant Clam Species Petitioned Under the U.S. Endangered Species Act: *Hippopus hippopus*, *H. porcellanus*, *Tridacna derasa*, *T. gigas*, *T. mbalavuana*, *T. squamosa*, and *T. squamosina*

Peer Reviewer Comments

We solicited review of the Status Review Report for 7 Giant Clam Species Petitioned Under the U.S. Endangered Species Act. We received an initial round of peer review on this Status Review Report from three subject matter experts in 2019. After substantial revision to the previous version of this report, we received a second round of peer review from one of the previous subject matter experts and one additional subject matter expert. Reviewer comments are compiled below from comments on drafts of the manuscript and are not in the order of the reviewer identification list below. Comments are not associated with the order of the reviewers as listed below.

Reviewers (listed alphabetically):

Dr. Eric Armstrong
Université de Perpignan Via Domitia
Clichy, France

Dr. Richard D. Braley
Aquasearch
Magnetic Island, Australia

Dr. Jeffrey Kinch*
Food and Agriculture Organisation of the United Nations (FAO)
Apia, Samoa

Dr. Mei Lin Neo
Tropical Marine Science Institute,
National University of Singapore

* Dr. Kinch provided two separate reviews for the original (2019) and revised (2023) versions of the Status Review Report.

Specific Responses to Terms of Reference Questions (not associated with order of names as they appear above)**:**

First round of review (2019):

Reviewer 1:

Evaluate the adequacy, appropriateness and application of data used in the Status Review document.

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, its biology, stock structure, habitats, threats, and risks of extinction?

Yes.

2. Are the scientific conclusions factually supported, sound, and logical?
   Yes.

3. Where available, are opposing scientific studies or theories acknowledged and discussed?
   Yes.

4. Are uncertainties assessed and clearly stated?
   Yes.

Evaluate the findings made in the "Individual Species Extinction Risk Assessments" section of the Status Review

1. Are the methods used for the Extinction Risk Analysis valid and appropriate?
   Yes.

2. Are the results and conclusions of the Extinction Risk Analysis supported by the information presented?
   Yes.

Reviewer 2:

Evaluate the adequacy, appropriateness and application of data used in the Status Review document.

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, its biology, stock structure, habitats, threats, and risks of extinction?
   Yes

2. Are the scientific conclusions factually supported, sound, and logical?
   Yes

3. Where available, are opposing scientific studies or theories acknowledged and discussed?
   Yes

4. Are uncertainties assessed and clearly stated?
   Yes

Evaluate the findings made in the "Individual Species Extinction Risk Assessments" section of the Status Review

1. Are the methods used for the Extinction Risk Analysis valid and appropriate?
   Yes, Food and Agriculture Organization (FAO) uses the methodology cited in Musick (1999)

2. Are the results and conclusions of the Extinction Risk Analysis supported by the information presented?
   Yes

Reviewer 3:

Evaluate the adequacy, appropriateness and application of data used in the Status Review document.

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, its biology, stock structure, habitats, threats, and risks of extinction?

This status review covers all relevant issues for the 7 species of giant clams. In general, scientific, commercial, habitats, threats, risks of extinction were excellent. I do have a comment about the biology and aquaculture in particular. In the mid 1980s to early 1990s several large projects (Palau, ACIAR / JCU Australia and Pacific countries, and ICLARM, Solomons) on the biology and aquaculture of giant clams. Many papers were published in that time. You have cited many of these but also much of your citing has come from other 'recent' papers. Original research papers should be cited in these cases.

2. Are the scientific conclusions factually supported, sound, and logical?
   Given the facts presented for the 7 species, I believe the authors have made sound and logical conclusions. Overharvest is perhaps the most serious of threats and risk of extinction for most of the giant clams. I have worked in many Pacific Island countries, Philippines and SE Asia with giant clams and pearl oysters and noted the demise of reefs over time. Along the Great Barrier Reef there are serious problems for coral reefs, however, there is essentially no harvest of giant clams here. This did happen in the 1960s and 1970s with the Taiwanese boats, and one case several years ago of a boat caught in the Northern Territory (Darwin) but I disagree with comments in the tables that there still is some significant poaching on the GBR.

3. Where available, are opposing scientific studies or theories acknowledged and discussed?
   I believe the authors have covered the science fairly.

4. Are uncertainties assessed and clearly stated?
   The uncertainties are stated clearly. Given the scope of this review there will be uncertainties as to the effect of the various factors putting pressure on the extinction of these species. This was expected.

Evaluate the findings made in the "Individual Species Extinction Risk Assessments" section of the Status Review

1. Are the methods used for the Extinction Risk Analysis valid and appropriate?
   The factors being assessed are valid. However, using factors like ocean acidification to assess the effect upon the 7 giant clam species has resulted in virtually the same assessment for all species. Sedimentation and nutrients are other factors that are not appropriate for many reef locations where these giant clams species live. So, perhaps some factors may not hold as much weight in the assessment as factors such as over exploitation.

2. Are the results and conclusions of the Extinction Risk Analysis supported by the information presented?
   I basically agree with the results and conclusions, but for populations of T. gigas on the GBR it does not fit the Extinction Risk Analysis assessed for other countries in the range of this species.

<u>Second round of review (2023):</u>

Reviewer 4:

Evaluate the adequacy, appropriateness and application of data used in the Status Review document.

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, its biology, stock structure, habitats, threats, and risks of extinction?

In general, yes, the Status Review Report cites and includes the most recent and best scientific information available on giant clam species.

However, I have identified two areas in which recent studies have expanded our understanding of giant clam biology that were not previously mentioned in the report – 1) the role of the giant clam host in actively promoting photosynthesis in its zooxanthellae symbionts through supply of inorganic carbon, and 2) the ecological significance of coral-boring species such as Tridacna crocea and T. maxima for reef bioerosion and the recently described biological mechanism permitting this burrowing behavior. I have suggested edits to the text describing these two biological features in sections 2.4 and 2.5 of the Report, respectively. I believe the inclusion of these two recent findings helps to ensure the fullest possible picture of our current understanding of giant clam biology within the Status Review Report.

I found the examples regarding exploitation of giant clams to be heavily biased towards locations/population from southeast Asia. I have attempted to include additional references to populations from other oceanic regions (most notably, French Polynesia) to supplement these examples. For example, I have suggested edits to the Subsistence Fisheries section (3.2.1) highlighting the traditional harvest of giant clams in Polynesia for their meat and shells for use in religious traditions and woodworking as well as in Melanesia as fishing hooks. I have also cited a second concrete example highlighting success of local regulations in restoring giant clam stocks within French Polynesia in the Local Regulations section (3.4.1).

2. Are the scientific conclusions factually supported, sound, and logical?
   Yes, the scientific conclusions of the Status Review Report appear to be sound based on all provided evidence for each of the species.
3. Where available, are opposing scientific studies or theories acknowledged and discussed?
   Yes, the Report acknowledges and discusses the existing discrepancies in our understanding of tridacnid biology, particularly regarding the effects of climate change drivers on giant clam growth, reproduction, and mineralization.
4. Are uncertainties assessed and clearly stated?
   Yes, uncertainties are clearly stated and sufficiently addressed in several sections of the Status Review Report. For example, the Report authors clearly highlight the uncertainty surrounding the effects of ocean warming and acidification on habitat rugosity and our lack of understanding of the relative importance of this habitat characteristic for continued survival and reproductive success among the various giant clam species.

Evaluate the findings made in the "Individual Species Extinction Risk Assessments" section of the Status Review

1. Are the methods used for the Extinction Risk Analysis valid and appropriate?
   Yes, the methods used for the extinction risk analysis are thorough, incorporating multiple aspects of giant clam ecology and specific threat assessments. Where data is not available (e.g., population genetics of H. hippopus) the Report makes this clear and attempts to draw conclusions based on appropriate studies in alternative, but ecologically similar, species.

2. Are the results and conclusions of the Extinction Risk Analysis supported by the information presented?
   Yes, it is my opinion that the conclusions regarding the extinction risk are supported by the information presented in the Report.

Reviewer 5:

Evaluate the adequacy, appropriateness and application of data used in the Status Review document.

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, its biology, stock structure, habitats, threats, and risks of extinction?
   I feel that the Authors have done a very good job with the literature review. I provide additional source below and in an accompanying email.

2. Are the scientific conclusions factually supported, sound, and logical?
   Again, I feel that the Authors have done a very good job with the literature review and used that information to make their assessment.

3. Where available, are opposing scientific studies or theories acknowledged and discussed?
   Again, I feel that the Authors have done a very good job with the literature review and used that information to assess status and risk.

4. Are uncertainties assessed and clearly stated?
   Yes, and these are noted by the Authors throughout the report.

Evaluate the findings made in the "Individual Species Extinction Risk Assessments" section of the Status Review

1. Are the methods used for the Extinction Risk Analysis valid and appropriate?
   Yes, though see attached for some documents that may be useful.

2. Are the results and conclusions of the Extinction Risk Analysis supported by the information presented?
   Again, I feel that the Authors have done a very good job with the literature review and used that information to make their assessment.

General Comments (not associated with order of names as they appear above)**:**

<u>First round of review (2019):</u>

Reviewer 2:

I think largely it is all there; I do note that you indicate that no information is available for *T. gigas, H. hippopus, T. squamosa* prevalence/abundance in PNG; information on these three species is available for New Ireland Province and Milne Bay Province which shows all three species are relatively rare across a diversity of habitats; see attached references. Additionally, in the section on international management you could add something on the Convention on Biological Diversity (CBD) and the Aichi Targets, plus sustainable development goal (SDG) 14 of the MDGs.

For Extreme weather, events see: Andrefouet et al. 2018. Adaptive management for the sustainable exploitation of lagoon resources in remote islands: lessons from a massive El Niño-induced giant clam-bleaching event in the Tuamotu atolls (French Polynesia). Environmental Conservation. 45 (1): 30-40.

Second round of review (2023):

Reviewer 4:

Overall, I found the Report to be exceptionally thorough and the conclusions regarding updates to protection status for the listed giant clam species to be scientifically sound. I had only a few, minor suggestions to the text. These were mostly in regards to updating some aspects of giant clam biology and subsistence use that I felt could be expanded upon.

Reviewer 5:

I would contact Jamie Whitford [jamiew@spc.int], SPC's Aquaculture Advisor for an update on giant clam production in the Pacific Islands region.

I would also contact Ariella D'Andrea [Ariellad@spc.int], SPC's Coastal Fisheries Legal Advisor for status of giant clam legislation [https://www.spc.int/CoastalFisheries/Legislation/main].

Editorial Comments (by section of the report, reviewer numbers are not associated with order of names as they appear above):

First round of review (2019):

1.0 Introduction

Reviewer 1: RE: (*or T. tevoroa*) – Do not italicize "or"

Reviewer 1: RE: *T. Lorenzi* should be *T. lorenzi*

Reviewer 1: RE: The second, third, and fourth sections of the report will discuss information that is general to all giant clam species in the family Tridacninae,

Should be "subfamily"

2.1 Giant Clam Taxonomy and Distinctive Characteristics

Reviewer 1: RE: *Tridacna noae* was recently resurrected from synonymy with the small giant clam, *T. maxima*, after additional molecular and morphological evidence provided support for the taxonomic separation of the two species (Su et al. 2014); however, neither of these species are included in this review.

It will be good to explain in a few sentences why *T. maxima* and *T. noae* are omitted.

I do have concerns of excluding *T. maxima*, given that this species is widely available in the aquarium trade. Hence, the management of this species is equally critical.

Reviewer 1: RE: Figure 2

Italicize species names

Reviewer 3: RE: "Tridacna spp. exhibit a byssal gape."

Though this gape closes with age in the two largest species, *T. gigas* and *T. derasa*.

2.2 Range, Distribution, and Habitat Use

Reviewer 1: RE: Additionally, three species of giant clam (i.e., *T. maxima*, *T. squamosa* and *T. squamosina*) are found as far west as East Africa and the Red Sea (Soo and Todd 2014).

Not the appropriate study to cite. Suggest to use this citation:

https://www.cell.com/current-biology/supplemental/S0960-9822(08)00969-X

Reviewer 1: RE: Gilbert et al. (2007) documented the first observation of *T. squamosa* in French Polynesia, extending the species' range farther east, and *T. mbalavuana* was recently observed in the Loyalty Islands of New Caledonia (Kinch and Teitelbaum 2010), on the northeast coast of mainland New Caledonia (Tiavouane and Fauvelot 2016), and Lihou Reef in the Coral Sea (Ceccarelli et al. 2009). *Tridacna mbalavuana* was previously thought to be restricted to Tonga and Fiji.

Revise: Gilbert et al. (2007) documented the first observation of *T. squamosa* in French Polynesia, extending the species' range farther east. Previously thought to be restricted to Tonga and Fiji, *T. mbalavuana* was recently observed in the Loyalty Islands of New Caledonia (Kinch and Teitelbaum 2010), on the northeast coast of mainland New Caledonia (Tiavouane and Fauvelot 2016), and Lihou Reef in the Coral Sea (Ceccarelli et al. 2009).

Reviewer 1: RE: have been introduced in Hawaii (bin Othman et al. 2010; Neo et al. 2015; Neo et al. 2017).

Remove: Neo et al. 2015 reference

Reviewer 1: RE: In terms of habitat, giant clams are markedly stenothermal (i.e., they can tolerate only a small range of temperatures) and are thus restricted to warm waters (Soo and Todd 2014),

Suggest to use this citation instead:

https://www.tandfonline.com/doi/abs/10.1080/10641269409388557

Reviewer 1: RE: similar to many species of coral.

Change to: similar to many species of stony corals.

Reviewer 1: RE: However, the extent of benefits these abilities provide to giant clams has yet to be determined.

There is a new study that experimentally demonstrates the pros and cons for clumping together.

See: https://link.springer.com/article/10.1007%2Fs00227-018-3363-6

Reviewer 1: RE: and their shells and mantle cavities provide substratum and shelter for a variety of organisms (Neo et al. 2015).

Change to: and their shells and mantle cavities provide substratum and shelter, respectively, for a variety of organisms (Neo et al. 2015).

Reviewer 1: Change "Symbiodinium spp." to "family Symbiodiniaceae"

Due to recent changes in the taxonomy of symbionts, we now refer to them using family.

Reviewer 1: RE: However, it has been suggested that the link between giant clams and coral reefs is two-fold: coral reefs provide a complex physical structure that enables giant clam juveniles to be both cryptic and exposed to intense light levels (Lucas et al. 1989).

I don’t understand how it is two-fold here, nor its connection to the earlier sentence.

Reviewer 1: RE: Some species of giants clams not included in this review (e.g., *T. maxima* and *T. crocea*) likely enjoy some level of protection by burrowing into reef structures (Hernawan 2010; Ramah et al. 2017). Additionally, while specific substrates and other environmental characteristics (e.g., presence of CCA; presence of conspecifics, etc.) may be preferred for certain species of giant clam, it is unclear how critical these are for giant clam survival.

I’m not following the narrative here. How are these information relevant to how giant clams play ecological roles on reefs?

Reviewer 3: RE: (Ledua et al. 1993)

Should be 1992

Reviewer 4: RE: “the the” – remove second “the”

2.3 Reproduction and Growth

Reviewer 1: Change “Once an egg is fertilized, a succession of larval stages occurs, which is similar for all tridacnid species” to “Once an egg is fertilized, a succession of larval stages occurs, which is similar for all tridacnine species”

Reviewer 1: RE: Successful fertilization in giant clams occurs when chemical cues from the eggs trigger spawning in conspecific clams, which then produces sperm for fertilization (Munro 1993).

Use this citation instead:

https://www.sciencedirect.com/science/article/pii/0742841383901779

Reviewer 1: Italicize “in situ”

Reviewer 1: RE: Overall, giant clams appear to be long-lived, with relatively late sexual maturity, a sessile, exposed adult phase, and a broadcast spawning reproductive strategy (Neo et al. 2015).

Suggest using this citation instead: Neo ML (2019). Conservation of Giant Clams (Bivalvia: Cardiidae). In: Reference Module in Earth Systems and Environmental Sciences, Elsevier. ISBN 978-0-12-4095489. DOI: 10.1016/b978-0-12-409548-9.11780-4

Reviewer 1: Change “mutualistic relationship with dinoflagellate algae Symbodinium” to “mutualistic relationship with dinoflagellate algae Symbiodiniaceae”

Reviewer 3: Add “However, there have been cases of unusually high survival such as the 1,950,000 juvenile *T. derasa* at 3 mo. age in Sulawesi, Indonesia (Braley and Rachman, 1996).”

Reviewer 4: Correct “recuits” to “recruits”

Reviewer 4: RE: Figure 2 below – Current location of Figure 2 is above this text.

2.4 Feeding and Nutrition

Reviewer 1: change “At the same time, the giant clam is provided essential metabolites (Leggat et al. 2003)” to “At the same time, the giant clam is provided with essential metabolites (Leggat et al. 2003)”

Reviewer 1: change “and can therefore function without needing particulate or dissolved organic matter” to “and can therefore survive without needing particulate or dissolved organic matter”

Reviewer 1: RE: The presence of zooxanthellae in the mantle is also responsible for the vivid colors often seen in giant clams (Junchompoo et al. 2013).

I disagree with this statement, as zooxanthellae cells are mostly brown, which explains the brown colors. The vivid colors have to do with the structural components within the mantle, and how they reflect light.

Here's a study that explains: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4223897/

Reviewer 1: RE: Information regarding nutrition of giant clams

There is a major review that looked at the factors affecting larval nutrition.

Link: https://onlinelibrary.wiley.com/doi/abs/10.1111/raq.12069

Reviewer 1: RE: Of the nine clades of zooxanthellae, five are associated with giant clams (Stat et al. 2006). Clades A, C and D seem to be particularly dominant (Carlos et al. 2000; Rowan et al. 1996; DeBoer et al. 2012) and can differ based on local environmental conditions (DeBoer et al. 2012). Depending on what clade of zooxanthellae a clam hosts can have implications for how an individual responds to threats, such as ocean warming. For example, clades C and D may be more heat-tolerant than clade A (DeBoer et al. 2012).

As there has been major changes to the symbionts' taxonomy, I suggest updating this section using the following references as guide:

- https://link.springer.com/article/10.1007/s13199-019-00615-5

- https://www.cell.com/current-biology/pdf/S0960-9822(18)30907-2.pdf

Reviewer 3: Re: The presence of zooxanthellae in the mantle is also responsible for the vivid colors often seen in giant clams (Junchompoo et al. 2013).

This statement is incorrect; I challenge it because the zooxanthellae are only variations of a brown to yellowish brown color. The iridocytes (cells of the giant clam) are the ones producing the vivid greens, blues, etc.

Reviewer 3: Add "The ultra-structure of the pillars of zooxanthellae spaced approximately 200 um from adjacent pillars and the iridocytes that direct useful blue and red light to the zooxanthellae whilst green light is reflected outward have been brilliantly described by Holt et al., 2014. The surface area of the zooxanthellae pillars is 10 x the surface area of the mantle itself. The authors describe the reflective nature of the iridocytes by green and yellow light being like a Bragg mirror."

Reviewer 4: Add "They also actively enhance inorganic carbon supply to their zooxanthellae symbionts using a carbon-concentrating mechanism consisting of host-derived vacuolar-type H+-ATPases (VHAs) and Carbonic Anhydrase 2-like proteins localized within the apical membrane of epithelial cells in the tubular gut system of the siphonal mantle (Ip et al., 2017, 2018; Armstrong et al., 2018). These proteins have been similarly convergently exapted in reef-building corals and significantly enhance zooxanthellae photosynthesis within their hosts (Armstrong et al., 2018; Barott et al., 2022)."

Inorganic nutrient supply is important, but is only half of the picture as a supply of carbon is also necessary for zooxanthellae photosynthesis. Several recent studies have expanded our understanding of carbon supply in giant clams. Some of these studies are already discussed in the section regarding growth (as the same proteins play a role in calcification), but they and other studies should be discussed here as well alongside the nitrogen/phosphorous supply mechanisms listed.

Recent analyses in several species of giant clams have demonstrated the existence of a carbon-concentrating mechanism which actively promotes zooxanthellae photosynthesis. The primary mechanism is by active acidification of the zoxanthellae-containing tubules (Z-tubes) which facilitates the conversion of bicarbonate (HCO3, the primary form of carbon present in seawater) to carbon dioxide (CO2, the carbon substrate for zooxanthellae photosynthesis). This acidification is carried out by clam-derived vacuolar-type H+-ATPase proteins (VHAs) which have been convergently exapted for this purpose in several marine photosymbiotic species, including scleractinian corals (Barott et al. (2022) and Armstrong et al. (2018)). Additionally, clam Carbonic anhydrase 2-like proteins are likely also involved in inorganic carbon supply from the clam host to the zooxanthellae (see Ip et al. (2017)).

For example, Ip et al. (2018) and Armstrong et al. (2018) both demonstrated expression and localization of clam-derived VHA within the siphonal mantles of T. squamosa and T. maxima clams, respectively, and discuss the role of these proteins in carbon supply to the zooxanthellae. Additionally, Armstrong et al. (2018) show that inhibition of VHA within giant clam siphonal mantle tissue reduces zooxanthellae photosynthetic productivity by as much as 40% indicating the critical role these proteins play in maintaining the photosymbiosis in giant clams.

Citations:

Barott, K. L.; Thies, A. B.; Tresguerres, M. V-Type H + -ATPase in the Symbiosome Membrane Is a Conserved Mechanism for Host Control of Photosynthesis in Anthozoan Photosymbioses. R. Soc. Open Sci. 2022, 9 (1). https://doi.org/10.1098/rsos.211449.

Armstrong EJ, Roa JN, Stillman JH, Tresguerres M. (2018) Symbiont photosynthesis in giant clams is promoted by V-type H+-ATPase from host cells. Journal of Experimental Biology 221: jeb.177220. https://doi.org/10.1242/jeb.177220

Ip, Y. K., Koh, C. Z. Y., Hiong, K. C., Choo, C. Y. L., Boo, M. V.,Wong,W. P., Neo, M. L. and Chew, S. F. (2017). Carbonic anhydrase 2-like in the giant clam, Tridacna squamosa: characterization, localization, response to light, and possible role in the transport of inorganic carbon from the host to its symbionts. Physiol. Rep. 5, 1-15. (already cited in the growth section)

Ip, Y. K., Hiong, K. C., Lim, L. J. Y., Choo, C. Y. L., Boo, M. V., Wong, W. P., Neo, M. L. and Chew, S. F. (2018). Molecular characterization, light-dependent expression, and cellular localization of a host vacuolar-type H+-ATPase (VHA) subunit A in the giant clam, Tridacna squamosa, indicate the involvement of the host VHA in the uptake of inorganic carbon and its supply to the symbiotic zooxanthellae. Gene 659, 137-148. (already cited in the growth section)

2.5 Genetics and Population Structure

Reviewer 1: change “Cook Islands, Kiribati, and the Marshall Islands.” to “Cook Islands, Republic of Kiribati, and the Marshall Islands.”

Reviewer 5: Add “to” for grammar

Reviewer 5: RE: *T. maxima* and *T. crocea* can often be found boring into live bouldering corals – The mechanism behind this boring behavior has recently been elucidated in T. maxima. Citation: Hill RW, Armstrong EJ, Inaba K, Morita M, Tresguerres M, Stillman JH, Roa JN, Kwan GT. (2018) Acid secretion by the boring organ of the burrowing giant clam, Tridacna crocea. Biology Letters 14. https://doi.org/10.1098/rsbl.2018.0047

Add ", a behavior facilitated by the secretion of concentrated acid from the pedal mantle (Hill et al. 2018)."

Reviewer 5: RE: incorporated into the reef framework – Giant clams also play significant roles in reef bioerosion which should be highlighted here alongside their contributions to reef accretion. Citation: Hamner WM, Jones MS. 1976. Distribution, burrowing, and growth rates of the clam Tridacna crocea on interior reef flats. Oecologia 24, 207–227. https://doi.org/10.1007/BF00345474

Add "Additionally, boring species such as T. crocea and T. maxima rank among the largest animals known to live fully ensconced within live bouldering corals and their abundance and size make them key contributors to reef bioerosion (Hamner & Jones 1976)."

3.0 Global Giant Clam Status and Trends

Reviewer 1: 10-10,000 ha-1, superscript the -1

Reviewer 3: RE: "Population density is spatially variable, but giant clams as a group generally range from 10-4 to 10-5 individuals per m-2 in most surveyed areas, with exceptionally high densities observed in some atolls of French Polynesia (Neo et al. 2017)."

of *T. maxima* only

Reviewer 3: Add "The Great Barrier Reef of Australia is the exception with some high-density natural populations of *T. gigas* and *T. derasa* (Braley, 1987a, 1987b). This is due to virtually no pressure on clam populations being take for food except during the 1960s and 1970s when Tawanese poachers frequented the Great Barrier Reef."

4.1 Destruction, Modification or Curtailment of Habitat or Range

Reviewer 1: Re: In fact, it may be that coral reefs depend more heavily on giant clams than giant clams depend on coral reefs.

Not sure what this means.

4.1.1 Climate Change Impacts to Coral Reefs

Reviewer 1: pCO2 Italicize the *p*

4.1.2 Degradation and Destruction of Coral Reefs

Reviewer 1: Thus, giant clams residing in deeper waters (e.g. *T. squamosa*) may be less affected by the trickle-down effects of overfishing.

Change to *T. mbalavuana* the only species that truly lives in deep waters. The record for *T. squamosa* is one-off.

4.1.3 Conclusion

Reviewer 3: RE: Adult giant clams have been observed in a wide variety of habitats, several of which are not pristine coral reef habitat (e.g., sand, rock, dead coral rubble, boulders, seagrass beds, macroalgae zones).

Please note that giant clams will never settle on sand, but what has happened when we see them on sand is that the area once had fast growing corals (mainly Acropora spp.) which gave the juvenile clams protection until a storm broke up the coral, leaving clams on sand.

4.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Reviewer 1: change "Consequently, almost all Tridacnid species" to "Consequently, almost all Tridacninaed species"

4.2.1 Subsistence Fisheries

Reviewer 1: Add: "e.g." before Neo and Loh 2014

Reviewer 1: change: "Gomez and Acala 1988" to "Gomez and Alcala 1988"

Reviewer 1: RE: For instance, some giant clam populations in southern Japan were likely fished into extinction before recorded history (Lucas 1994).

What does 'before recorded history' mean here? In terms of time-scale?

4.2.2 Illegal Poaching and Commercial Harvest

Reviewer 1: Remove "has" from following sentence: Taiwan has consistently had the largest market and demand for giant clams.

Reviewer 1: change "Between 2003 and 2009, Vietnam consistently exported the largest number of Tridacnids (Craig et al. 2011)." To "Between 2003 and 2009, Vietnam consistently exported the largest number of Tridacnines (Craig et al. 2011)."

Reviewer 3: RE: Consequently, they are now thought to only occur in a few locations due to overexploitation (Hernawan 2010).

Primarily in eastern Indonesia, Braley pers. Comm.

Reviewer 3: Add: The Chinese Institute of Oceanology began a giant clam aquaculture project in Sanya, southernmost Hainan Island in 2016 and were advised on improved culture methods (RD Braley, pers. Comm.). The species they had available for broodstock included *T. derasa*, *T. squamosa*, *T. maxima*, *T. noae*, and *H. hippopus*.

Reviewer 3: RE: Additionally, the vast majority of giant clams exported are the smaller, more colorful *T. crocea* and *T. maxima* to western countries; as such, it is likely that the international trade in giant clams is largely for the aquarium industry (Mies et al. 2017b).

This will include *T. noae*, which was formerly called teardrop maxima.

Reviewer 3: RE: However, Mies et al. (2017b) notes that without temporal data and official statistics, a thorough assessment of shifts and trends in giant clam aquaculture is difficult.

The huge success of fish and mollusk aquaculture is the example to follow for giant clams. Protocols for the hatchery and nursery are relatively easy for bivalve molluscs. Marine parks in the Philippines have been stocked with aquacultured *T. gigas* which were produced from Great Barrier Reef seed stock. While no clam farm currently is culturing clams for human food, this may be where the financial investment will be most needed.

4.2.3 Scientific and Educational Use

Reviewer 1: RE: We also note that in many scientific publications on giant clams involve cultured giant clams as opposed to wild sourced.

This is generally dependent on the questions asked, whether cultured source or wild source should be used.

Change "involve" to "involved"

Reviewer 3: RE: Although uncertain, we do not have substantial information to indicate that overutilization for scientific and/or educational purposes currently represents a major threat to giant clams.

Research on giant clam populations that makes observations on population densities and spatial distribution do not kill Giant clams for the research and the data obtained is a baseline to compare with changes caused by anthropogenic culling over time.

4.3.2 Predation

Reviewer 1: RE: "squirting water from siphons (Neo and Todd 2010)." Change to "2011"

4.4.2 Local Regulations

Reviewer 1: Should be 66 locations

Reviewer 3: Add "Likewise, giant clam reserves or closed areas were advised in Tuvalu and Tokelau atolls (Braley, 1988, 1989)."

4.4.3 Conclusion

Reviewer 1: Should be 66 locations

4.5 Other Natural or Manmade Factors

Reviewer 1: remove Lough 2012

4.5.1 Ocean Warming

Reviewer 1: Change "genus Symbiodinium" to "family Symbiodiniaceae"

Reviewer 3: RE: "For example, increased temperatures can cause issues in giant clam hatcheries, such as algal overgrowth, poor shell precipitation (Schwartzmann et al. 2011),"

However, the use of suiable polyculture with herbivores can mitigate the effects of algal overgrowth.

Reviewer 3: RE: "and possibly premature spawning patterns (Neo et al. 2017)."

I do not believe there is good evidence for this.

4.5.4 Stochastic Events

Reviewer 3: RE: Despite early hypotheses that these mass mortalities were caused by a protozoan parasite (Perkinsus sp.; Alder and Braley 1989), this was never confirmed (Gervis 1992).

However, the mass mortality occurred in austral winter at Lizard Island. Evidence of poorer survival of cultured *T. gigas* juvneniles in winter months was found at the Orpheus Island research station (Braley, pers. Comm.).

5.1.2.2 Range, Distribution, and Habitat Use

Reviewer 3: Add: A rare citing of *H. hippopus* in seagrass beds in Tongatapu Is. In the early 1970s would be one of the last natural citings for Tonga until Great Barrier Reef genetic stock were brought to Tonga in the late 1980s during the ACIAR / JCU giant clam project (Braley, pers. comm.)

5.1.3 Abundance, Density, and population Status

Reviewer 1: Change "*H. hippops*" to "*H. hippopus*"

5.1.4.4 Inadequacy of Existing Regulatory Mechanisms

Reviewer 1: Make the "A" in Approximately lowercase

5.2.3 Abundance, Density, and population Status

Reviewer 3: RE: In Indonesia reports show that populations of *H. porcellanus* are considered to be extremely rare if not locally extinct in some areas (Firdasy and Tisdell in Tisdell 1992).

In mid-1990s Hassanuddin University's hatchery for giant clams was operating on Barrong Lompo Island, near to Makassar city. Broodstock of *H. porcellanus, H. hippopus, T. derasa, and T. squamosa* were collected from adjacent islands and used in spawning and larval rearing (RD Braley pers. Comm.)

5.2.4.4 Inadequacy of Existing Regulatory Mechanisms

Reviewer 1: Add a space between the H. and p in "*H. porcellanus*" and add a "," after Additionally

5.2.5 Demographic Risk Assessment

Reviewer 3: RE: Therefore, we conclude that the species' low abundance and likely low densities throughout its relatively restricted range is likely contributing to an elevated extinction risk for this species, particularly with the ongoing utilization of *H. porcellanus* in the shell trade and for subsistence use.

This should be a wakeup call to urgently support the aquaculture of this species.

Reviewer 3: RE: Additionally, evidence suggests giant clams may undertake physical movement in order to aggregate into groups or "clumps" (Huang et al. 2007).

Note that in the wild, if there is aggregation of adults it is due to very high numbers of larvae that settled together in one place. Metamorphosed larvae and small juveniles are not able to move very far from where they have settled (RD Braley, pers. Comm.)

5.2.6 Overall Extinction Risk Assessment

Reviewer 1: change "contributes" to "contribute"

5.3.2.1 Taxonomy and Distinctive Characteristics

Reviewer 1: do not italicize "et al."

5.3.2.5 Genetics and Population Structure

Reviewer 1: RE: nine polymorphic loci.

Elaborate what these loci were?

Reviewer 1: RE: We conclude that the species is made up of at least three reproductively isolated populations: Great Barrier Reef, Philippines, and Fiji.

Based on what evidence?

5.3.3 Abundance, Density, and Population Status

Reviewer 1: Add a space between the T. and d in "*T.derasa*"

Reviewer 3: Add: Braley (1987a) reported on the distribution and abundance of *T. derasa* and *T. gigas* at 57 reefs on the Great Barrier Reef. *T. derasa* was mainly found on outer barrier reefs and the highest abundance found was 92 individuals per hectare.

Reviewer 3: RE: A small population of *T. derasa* (n=44 individuals) showed an annual mortality of 4.4% at Michaelmas Cay on the Great Barrier Reef between 1978 and 1985 (Pearson and Munro 1991).

and annual mortalities of *T. derasa* at four sites on the Great Barrier Reef varied from 1.4 % - 6.25% (Braley, 1988).

5.3.4 Threats to *Tridacna derasa*

Reviewer 1: Italicize *Tridacna derasa*

5.3.4.3 Disease or Predation

Reviewer 3: RE: The only clues they reported were the presence of Perkinsus sp. (reported by previous studies in the same area), and an unidentified unicellular organism found in the tissue of some of the dead specimens.

It was also noted that the mass mortality began in austral winter and observations on aquacultured *T. gigas* (in particular) found higher mortality in the lower winter water temperature.

5.4.2.1 Taxonomy and Distinctive Characteristics

Reviewer 3: RE: All *T. gigas* specimens lack scales except near the byssal orifice where small scales may be present.

T. gigas juveniles up to 10+ cm do have scales but they disappear, as the clam grows larger.

5.4.2.2 Range, Distribution, and Habitat Use

Reviewer 3: RE: *T. gigas* has been introduced in American Samoa, the Cook Islands,

Add: (from the ACIAR / JCU giant clam project, Australia in the late 1980s)

5.4.3 Abundance, Density, and Population Status

Reviewer 3: RE: In Australia, the *T. gigas* population from the Great Barrier Reef, the species' last stronghold, consists primarily of large adult clams. The absence of younger, faster-growing *T. gigas* results in a low annual production of new biomass (Neo et al. 2015).

Re-surveys of RD Braley's PhD field sites (eg Lizard Island, Michaelmas Cay and others) now cover over 3 decades and recruitment of juvenile *T. gigas* continues (Braley, pers. Comm.)

5.4.4.5 Other Natural or Manmade Factors

Reviewer 3: RE: In a recent study by Enricuso (2018), elevated water temperatures lead to increased abnormal embryonic development and a decrease in post-settlement survival of *T. gigas* larvae.

However, on the Great Barrier Reef increase in temperature may actually increase the range toward the southern Great Barrier Reef where current winter water temperature is too low for T. gigas survival (RD Braley, pers. Comm.).

5.4.5 Demographic Risk Assessment

Reviewer 3: RE: Abundance

Cite Braley 1987a and 1987b in Micronesica.

Reviewer 3: RE: Therefore, as natural populations of *T. gigas* will likely experience population declines in the foreseeable future due to ongoing threats of harvest and climate change,

Excluding the Great Barrier Reef where harvest is minimal

5.5 *Tridacna mbalavuana*

Reviewer 3: Correct spelling, should be mbalavuana

5.5.2.2 Range, Distribution, and Habitat Use

Reviewer 1: RE: Most recently, Wakum et al. (2017) report one observed individual (during surveys completed in 2014) at Teluk Sauros in the Raja Ampat Islands of West Papua Indonesia,

Great finding! Thank you!

5.5.4.1 Destruction, Modification or Curtailment of Habitat or Range

Reviewer 3: RE: Because *T. mbalavuana* juveniles also require settlement space, we assume they are vulnerable to these same effects, although this remains uncertain.

I was one of the authors Ledua et al. 1993 and I can say that all *T. mbalavuana* found were in very clear water (where you could see them at 30m from the surface. We believe they would only settle on reef that has very clear water and not with sediment.

5.5.5 Demographic Risk Assessment

Reviewer 3: RE: As noted, the results of that experiment are unreliable in terms of representing productivity in the wild for a variety of reasons including low sample size, high probability of self-fertilization due to experimental design, and the lack of any follow up or repetitive experiments.

I believe there were follow-up spawnings. I was involved with training the Tonga fisheries and Fiji fisheries staff involved with the ACIAR / JCU giant clam project. They continued to produce *T. derasa* and other species so I believe they would have carried on with more spawnings of this species as well. I do not have that information but it should be with Tonga and Fiji fisheries.

5.5.6 Overall Extinction Risk Assessment

Reviewer 3: RE: Most of the available information for this species is over 30 years old, however the most recent limited survey efforts within Tonga in 2014 and 2017 did not record any observations of *T. mbalavuana*.

However, that survey did not go to the areas of Haápai where the work published in Ledua et al. was conducted.

5.6.2.1 Taxonomy and Distinctive Characteristics

Reviewer 1: RE: figure 21.

The picture is of another species (*T. noae).* It is not *T. squamosa*.

5.6.2.2 Range, Distribution, and Habitat Use

Reviewer 3: RE: Tridacna squamosa is one of the most widely distributed giant clam species, with a broad geographical range that extends from the Red Sea and eastern Africa in the west to the Pitcairn Islands and Queensland, Australia in the east (Neo et al. 2017).

In Tonga also

5.6.4 Threats to *Tridacna squamosa*

Reviewer 1: Italicizes *Tridacna squamosa*

Reviewer 1: Neo and Todd (2010) should be Neo and Todd (2011)

5.6.4.3 Disease or Predation

Reviewer 1: Han et al. should be Ling et al.

5.6.6 Overall Extinction Risk Assessment

Reviewer 1: *T. sqaumosa's* should be *T. squamosa's*

5.7.2.1 Taxonomy and Distinctive Characteristics

Reviewer 1: change "*Tridacna squamosina* grows to be 32 cm" to "*Tridacna squamosina* could grow to be 32 cm"

5.7.3 Abundance, Density, and Population Status

Reviewer 3: RE: Table 16

This should say *Tridacna squamosina*

5.7.4 Threats to *Tridacna squamosina*

Reviewer 1: Italicizes *Tridacna squamosina*

5.7.4.4 Inadequacy of Existing Regulatory Mechanisms

Reviewer 1: Re: likely due to its rarity

Another possible reason is the difficulty in identifying them correctly.

6.0 Conservation Efforts

Reviewer 1: change "E.D. Gomez, pers. Obs. in Neo et al. 2017" to "E.D. Gomez, pers. obs. in Neo et al. 2017"

Reviewer 1: RE: success stories are generally limited

New papers for your further reading on issues of conservation.

Teitelbaum, A. & Friedman, K. 2008. Successes and failures in reintroducting giant clams in the Indo-Pacific region. SPC Trochus Information Bulletin 14, 19–26.

https://www.tandfonline.com/doi/full/10.1080/09614524.2018.1467378

Reviewer 3: Add: Followed by the ACIAR / JCU giant clam project from 1985-1992 that initiated hatchery and nurseries in Queensland, Australia, Tonga, Fiji, Cook Islands and at two universities in the Philippines.

Reviewer 3: My comment here is that attempting to develop proactive management of giant clam resources has a much poorer chance of making a difference for giant clams than aquaculture of giant clams. The effort and funds are needed for more aquaculture of these tridacnines to mitigate extinction.

Second round of review (2023):

Executive Summary

Reviewer 4: RE: filter feed – Suspension feed is the preferred terminology as the mechanism of prey capture is not entirely clear.

2.1 Taxonomy and Phylogeny

Reviewer 5: RE: Su et al. 2014 – See also Militz, T.; Kinch, J. and Southgate, P. 2015. Population demographics of *Tridacna noae* (Röding 1798) in New Ireland, Papua New Guinea. *Journal of Shellfish Research.* 34 (2): 329-335.

2.2 Geographic Distribution

Reviewer 4 & 5: RE: "the the" – remove second "the"

2.3 Reproduction and Growth

Reviewer 4: Correct "recuits" to "recruits"

Reviewer 4: RE: Figure 2 below – Current location of Figure 2 is above this text.

Reviewer 5: Add "scholars"

Reviewer 5: Add "(Allee, 1949)" – Allee, W., Emerson, A., Park, O., Park, T. & Schmidt, K. 1949. *Principles of Animal Ecology.* W.B. Saunders, Philadelphia.

2.4 Feeding and Nutrition

Reviewer 4: Add "They also actively enhance inorganic carbon supply to their zooxanthellae symbionts using a carbon-concentrating mechanism consisting of host-derived vacuolar-type H+-ATPases (VHAs) and Carbonic Anhydrase 2-like proteins localized within the apical membrane of epithelial cells in the tubular gut system of the siphonal mantle (Ip et al., 2017, 2018; Armstrong et al., 2018). These proteins have been similarly convergently exapted in reef-building corals and significantly enhance zooxanthellae photosynthesis within their hosts (Armstrong et al., 2018; Barott et al., 2022)."

Inorganic nutrient supply is important, but is only half of the picture as a supply of carbon is also necessary for zooxanthellae photosynthesis. Several recent studies have expanded our understanding of carbon supply in giant clams. Some of these studies are already discussed in the section regarding growth (as the same proteins play a role in calcification), but they and other studies should be discussed here as well alongside the nitrogen/phosphorous supply mechanisms listed.

Recent analyses in several species of giant clams have demonstrated the existence of a carbon-concentrating mechanism which actively promotes zooxanthellae photosynthesis. The primary mechanism is by active acidification of the zoxanthellae-containing tubules (Z-tubes) which facilitates the conversion of bicarbonate (HCO3, the primary form of carbon present in seawater) to carbon dioxide (CO2, the carbon substrate for zooxanthellae photosynthesis). This acidification is carried out by clam-derived vacuolar-type H+-ATPase proteins (VHAs) which have been convergently exapted for this purpose in several marine photosymbiotic species, including scleractinian corals (Barott et al. (2022) and Armstrong et al. (2018)). Additionally, clam Carbonic anhydrase 2-like proteins are likely also involved in inorganic carbon supply from the clam host to the zooxanthellae (see Ip et al. (2017)).

For example, Ip et al. (2018) and Armstrong et al. (2018) both demonstrated expression and localization of clam-derived VHA within the siphonal mantles of T. squamosa and T. maxima clams, respectively, and discuss the role of these proteins in carbon supply to the zooxanthellae. Additionally, Armstrong et al. (2018) show that inhibition of VHA within giant clam siphonal mantle tissue reduces zooxanthellae photosynthetic productivity by as much as 40% indicating the critical role these proteins play in maintaining the photosymbiosis in giant clams.

Citations:

Barott, K. L.; Thies, A. B.; Tresguerres, M. V-Type H + -ATPase in the Symbiosome Membrane Is a Conserved Mechanism for Host Control of Photosynthesis in Anthozoan Photosymbioses. R. Soc. Open Sci. 2022, 9 (1). https://doi.org/10.1098/rsos.211449.

Armstrong EJ, Roa JN, Stillman JH, Tresguerres M. (2018) Symbiont photosynthesis in giant clams is promoted by V-type H+-ATPase from host cells. Journal of Experimental Biology 221: jeb.177220. https://doi.org/10.1242/jeb.177220

Ip, Y. K., Koh, C. Z. Y., Hiong, K. C., Choo, C. Y. L., Boo, M. V.,Wong,W. P., Neo, M. L. and Chew, S. F. (2017). Carbonic anhydrase 2-like in the giant clam, Tridacna squamosa: characterization, localization, response to light, and possible role in the transport of inorganic carbon from the host to its symbionts. Physiol. Rep. 5, 1-15. (already cited in the growth section)

Ip, Y. K., Hiong, K. C., Lim, L. J. Y., Choo, C. Y. L., Boo, M. V., Wong, W. P., Neo, M. L. and Chew, S. F. (2018). Molecular characterization, light-dependent expression, and cellular localization of a host vacuolar-type H+-ATPase (VHA) subunit A in the giant clam, Tridacna squamosa, indicate the involvement of the host VHA in the uptake of inorganic carbon and its supply to the symbiotic zooxanthellae. Gene 659, 137-148. (already cited in the growth section)

2.5 Genetics and Population Structure

Reviewer 4: Add “to”

Reviewer 4: RE: *T. maxima* and *T. crocea* can often be found boring into live bouldering corals – The mechanism behind this boring behavior has recently been elucidated in T. maxima. Citation: Hill RW, Armstrong EJ, Inaba K, Morita M, Tresguerres M, Stillman JH, Roa JN, Kwan GT. (2018) Acid secretion by the boring organ of the burrowing giant clam, Tridacna crocea. Biology Letters 14. https://doi.org/10.1098/rsbl.2018.0047

Add “, a behavior facilitated by the secretion of concentrated acid from the pedal mantle (Hill et al. 2018).”

Reviewer 4: RE: incorporated into the reef framework – Giant clams also play significant roles in reef bioerosion which should be highlighted here alongside their contributions to reef accretion. Citation: Hamner WM, Jones MS. 1976. Distribution, burrowing, and growth rates of the clam Tridacna crocea on interior reef flats. Oecologia 24, 207–227. https://doi.org/10.1007/BF00345474

Add “Additionally, boring species such as T. crocea and T. maxima rank among the largest animals known to live fully ensconced within live bouldering corals and their abundance and size make them key contributors to reef bioerosion (Hamner & Jones 1976).”

3.1.1 Climate Change Impacts to Coral Reefs

Reviewer 4: Correct “severly” to “severely”

3.1.2 Coastal Development

Reviewer 4: Add “of” to correct grammar

3.2.1 Subsistence Fisheries

Reviewer 4: Correct "Archaelogical" to "Archaeological"

Reviewer 4: Add "Similarly in French Polynesia, giant clams have historically been harvested for their meat as well as for their shells which had uses as receptacles in religious ceremonies (Babadzan 1992) and as adze blades for woodworking on low-elevation atolls where stones suitable for this use were otherwise unavailable (Radclyffe 2015)."

Babadzan A. 1992. La Dépouille des dieux. Essai sur la religion polynésienne à l'arrivée des Européens. L'aube des peoples, Gallimard. 344 p

Radclyffe, C. (2015, December 9). Archaeology and Shell Adzes in Prehistoric Oceania: A Revised Methodological Approach to the Descriptive Analysis of a Solomon Islands Collection (Dissertation, Bachelor of Arts Honours). Retrieved from http://hdl.handle.net/10523/6745

Reviewer 4: Change "closeby" to "close by"

Reviewer 5: RE: "Where shells have value, sticks and crowbars may be used to pry clams from the reef" – This is mainly for subsistence, to access the meat.

3.2.2 Commercial Harvest and Illegal Poaching

Reviewer 4: Add "In French Polynesia, consumption of T. maxima clams by tourists in Bora Bora as part of seafood-tasting cruises resulted in decreases in the average size of clams and shells remaining within the lagoon (Planes et al., 1993)."

Citation:

Planes, S., Chauvet, C., Baldwin, J., Bonvallot, J., Gabrie, C., Holthus, P., Payri, C. & Galzin, R. (1993). Impact of tourism-related fishing on Tridacna maxima (Mollusca, Bivalvia) stocks in Bora-Bora lagoon (French Polynesia). Atoll Res. Bull., 385, 1–13.

Reviewer 5: Add Kinch (2020) [Citation: Kinch, J. 2020. *Changing Lives and Livelihoods: Culture, Capitalism and Contestation over Marine Resources in Island Melanesia.* Unpublished PhD Thesis, Australian National University, Canberra, Australian Capital District, Australia.]

Reviewer 5: RE: […] ***Taiwanese Poaching*** – More recently Vietnamese Blue Boats, but the main target was black and white teatfish sea cucumber species, though giant clams would have been harvested also for food.

Blaha, F. 2016. Illegal fishing in the central and South Pacific. *SPC Fisheries Newsletter.* 151: 21-23.

Song, A.; Hoang, V.; Cohen, P.; Aqorau, T. and Morrison, T. 2019. Blue boats' and 'reef robbers': a new maritime security threat for the Asia-Pacific? *Asia Pacific Viewpoint.* doi: 10.1111/apv.12240.

Reviewer 5: RE: "In most cases, countries have limited their reporting to the family or genus level, and outside of a few instances of trade reported for *T. derasa*, *T. gigas*, and *T. squamosa*, no other species were identified specifically." – see also Kinch, J. 2021. Giant clams - Tridacnidae species. In: Pavitt, A.; Malsch, K.; King, E.; Chevalier, A.; Kachelriess, D.; Vannuccini, S. and Friedman, K. (eds.). *CITES and the sea: Trade in commercially exploited CITES-listed marine species*. pp: 50-54. FAO Fisheries and Aquaculture Technical Paper, No.: 666. Rome: FAO.

Reviewer 5: RE: "This includes 3615 kg and 472 kg of *T. gigas* and *T. derasa* meat, respectively, exported from Solomon Islands in the 1990s" – Solomon Islands is very problematic. Aquarium Arts was exporting wild harvest giant clams. More recently, dead shells have been exported in considerable volumes following the earthquake in Western Province.

Kinch, J. 2004. *The Marine Aquarium Trade in the Solomon Islands, with Specific Notes on the Marau Sound, Guadalcanal*. A Report prepared for the Marine Aquarium Council and the Foundation of the Peoples of the South Pacific-International, Suva, Fiji.

Reviewer 5: RE: "Kinch (2002) also reports several more instances of commercial export of giant clam meat from Papua New Guinea that are not included in the CITES trade database" – There have been several aquarium operations in PNG since 2008, EcoEZE, Eco-Aquariums and more recently Golden Ocean. Golden Ocean was trying to export giant clams that were farmed at the Nago Island Mariculture and Research Facility. This never eventuated however.

Reviewer 5: RE: "At the higher end, Tonga has exported an average of 1210 kg giant clam meat per year since 2005, and at the lower end, the Federated States of Micronesia has averaged 58 kg per year during the same period." – Kosrae has the National Aquaculture Centre that has been doing giant clam production for years.

Reviewer 5: RE: "Businesses carved the shells into decorative sculptures, jewelry, and other handicraft, and sold them at one of the many retail shops in the province or online on the major Chinese e-commerce sites, such as Taobao.com, Alibaba.com, and Aliexpress.com" – Add Kinch (2021).

Reviewer 5: RE: "In fact, according to CITES reports, over 99% of the recorded *T. squamosa* exports from Cambodia were imported by Vietnam, implying a close trade connection between the two nations." – Vietnam has become the new entreport for imports to China as tarriffs are now imposed in Hong Kong. There is alleged wide-scale smuggling across the Vietnamese border to China.

3.3.1 Disease and Parasites

Reviewer 4: Change "Perkinosis" to "Perkinsosis"

3.4.1 Local Regulations

Reviewer 4: Change "Wildife" to "Wildlife"

Reviewer 4: Add "In addition, there is evidence of population recovery and maintenance of higher phenotypic diversity in T. maxima clams following ca. 12 years of protection within a series of small, unenforced, no-take marine protected areas on the island of Moorea in French Polynesia (Armstrong 2017)."

Armstrong, E. J. (2017). Ion-regulatory and developmental physiology of giant clams (Genus Tridacna) and their conservation status on the island of Mo'orea, French Polynesia. (Doctor of Science). Doctoral dissertation. University of California, Berkeley, CA, USA. https://escholarship.org/uc/item/74f4p4jg

Reviewer 4: RE: "consistently report declining populations" – This is not the case for the above mentioned report. However this finding for Moorea is an exception, rather than the norm, so suggest modifying the word 'consistently' to 'largely'.

Reviewer 5: RE: "Without more recent data, we cannot determine whether the regulatory actions have had any effect on this trajectory." – There are still regulations from the National Fisheries Authority. There was a large stock assessment conducted for sedentary resources including giant clams in 2001.

Skewes, T.; Kinch, J.; Polon, P.; Dennis, D.; Seeto, P.; Taranto, T.; Lokani, P.; Wassenberg, T.; Koutsoukos, A. and Sarke, J. 2003. *Distribution and Abundance of Reef Resources in the Milne Bay Province, Papua New Guinea: Giant Clams and other Species*. Report prepared for the National Fisheries Authority, Port Moresby, Papua New Guinea; and the Australian Centre for International Agricultural Research, Sydney, New South Wales, Australia.

3.5.1 Ocean Warming

Reviewer 5: See Andrefouet et al. (2017) for bleaching in French Polynesia.

3.5.3 Land-Based Sources of Pollution

Reviewer 4: Change “synergestic” to “synergistic”

4.1.2 Abundance, Density and Population Status (*H. hippopus*)

Reviewer 5: RE: ***Papua New Guinea*** – See https://png-data.sprep.org/system/files/Rapid_Ecological_Assessment_Northern_Bismarch%20Sea%20Papua%20New%20Guinea.pdf

Reviewer 5: RE: “…further intensification of giant clam mariculture is in most cases considered economically unviable” – See Hambrey et al., 2011 [https://spccfpstore1.blob.core.windows.net/digitallibrary-docs/files/c7/c735b4a1a8fcdc4ce03cca0d88b1836e.pdf]

Lindsay, S. and Lindley, B. 2022. [https://spccfpstore1.blob.core.windows.net/digitallibrary-docs/files/77/77e6d71c80ed72e4c8c7362199c368df.pdf?sv=2015-12-11&sr=b&sig=p30ZmqmM0fP9i0K367zz3b4BguP7hOdCBvYYkogsIbo%3D&se=2023-06-17T10%3A11%3A28Z&sp=r&rscc=public%2C%20max-age%3D864000%2C%20max-stale%3D86400&rsct=application%2Fpdf&rscd=inline%3B%20filename%3D%22HoF14_IP12.pdf%22]

4.1.5 Overall Extinction Risk Assessment (*H. hippopus*)

Reviewer 4: Change “determing” to “determining”

4.2.1.2 Range, Distribution, and Habitat Use (*H. porcellanus*)

Reviewer 4: RE: “…it has also been reported in Palau, the Milne Bay Province (Papua New Guinea)…” – It was not observed in the 1997 and 2001 Marine Biodiversity Surveys, but could have been misidentified.

Allen, G.; Kinch, J.; McKenna, S. and Seeto, P. (eds.). 2003. A Rapid Biodiversity Assessment of the Coral Reefs of Milne Bay Province, Papua New Guinea - Survey II (2000). RAP Bulletin of Biological Assessment No.: 29. Washington, D.C.: Conservation International.

Or in the Bismarck Sea survey.

Hamilton, R., A. Green and J. Almany (eds.) 2009. Rapid Ecological Assessment: Northern Bismarck Sea, Papua New Guinea. Technical report of survey conducted August 13 to September 7, 2006. TNC Pacific Island Countries Report No. 1/09.

4.2.2 Abundance, Density and Population Status (*H. porcellanus*)

Reviewer 5: RE: “The only available survey data from this region are from a giant clam stock assessment conducted in the Engineer and Conflict Islands in 1996, which estimated a population density of 0.3 ind ha^{-1} (Kinch, 2002)” – This is possibly a misidentification.

4.2.3.1 Destruction, Modification or Curtailment of Habitat or Range (*H. porcellanus*)

Reviewer 5: RE: "…Burke et al. (2012) identified major proportions of coral reefs in Indonesia (20%), Malaysia (35%), Papua New Guinea (25%)…" – More recent references? I'm not sure how this figure was obtained as that suggests that one quarter of PNG's coast line is degrading. The only areas will be around urban centres and areas of coastal logging, coastal plantation agriculture and close to coastal mines.

4.5.5 Overall Extinction Risk Assessment (*T. mbalavuana*)

Reviewer 4: Change "comprehesive" to "comprehensive"

4.6.3.5 Other Natural and Manmade Factors (*T. squamosa*)

Reviewer 4: Change "synergestic" to "synergistic"

Additional References provided by Reviewers:

Allen, G.; Kinch, J.; McKenna, S. and Seeto, P. (eds.). 2003. *A Rapid Biodiversity Assessment of the Coral Reefs of Milne Bay Province, Papua New Guinea - Survey II (2000).* RAP Bulletin of Biological Assessment No.: 29. Washington, D.C.: Conservation International. pp: 172.

Andréfouët, S., Van Wynsberge, S., Kabbadj, L., Wabnitz, C. C., Menkès, C., Tamata, T., Pahuatini, M., Tetairekie, I., Teaka, I., Scha, T.A., Teaka, T., and Remoissenet, G. 2018. Adaptive management for the sustainable exploitation of lagoon resources in remote islands: lessons from a massive El Niño-induced giant clam bleaching event in the Tuamotu atolls (French Polynesia). Environmental Conservation, 45(1), 30-40.

Braley, R.D. 1984. Reproduction in the giant clams Tridacna gigas and T. derasa in situ on the North-Central Great Barrier Reef, Australia, and Papua New Guinea. Coral Reefs 3:221-227.

Braley, R.D. 1986. Reproduction and Recruitment of Giant Clams and some Aspects of their Larval and Juvenile Biology. PhD Thesis, University of New South Wales, 297p incl. tables, figs., and appendices.

Braley, R.D. 1987a. Distribution and Abundance of the Giant Clams Tridacna gigas and T. derasa on the Great Barrier Reef. Micronesica 20:215-223.

Braley, R.D. 1987b. Spatial Distribution and Population Parameters of Tridacna gigas and T. derasa. Micronesica 20:225-246.

Braley, R.D. 1988. Recruitment of the Giant Clams Tridacna gigas and T. derasa at four sites on the Great Barrier Reef. pp. 73-77 In, Copland, J.W. and J.S. Lucas (eds.), Giant Clams in Asia and the Pacific. ACIAR Monograph no. 9, Australian Centre for International Agricultural Research, Canberra. 274p.

Braley, R.D. 1988. The Status of Giant Clam Stock and Potential for Clam Mariculture in Tuvalu. Rept. for FAO South Pacific Aquaculture Development Project and Tuvalu Fisheries Division, 41p + 55p tables, figs., and appendices.

Braley, R.D. 1989. A giant clam stock survey and preliminary investigation of pearl oyster resources in the Tokelau Islands. Prepared for the Dept. of Agriculture and Fisheries, Tokelau Affairs Office

(Apia, W. Samoa) and the FAO South Pacific Aquaculture Development Project (Suva, Fiji). 52p + 65p figs. and appendices.

Braley, R.D. and Rachman, A. 1996. Technical Note: A successful protocol for the hatchery and land nursery culture of giant clams (Fam. Tridacnidae). Perairan Maluku dan Sekitarnya (LIPI journal), vol. 10:81-85.

Crawford, CM, Nash, WJ, and Lucas, JS. 1986 Spawning induction, and larval and juvenile rearing of the giant clam, *Tridacna gigas*. Aquaculture, 58, 281-295.

Eldredge, L. G. 1994. Perspectives in aquatic exotic species management in the Pacific Islands. Introductions of commercially significant aquatic organisms to the Pacific islands, 17, 1.

Gillett, R., McCoy, M. A., Bertram, I., Kinch, J., Desurmont, A., and Halford, A. 2020. Aquarium products in the Pacific Islands: a review of the fisheries, management and trade. Noumea, New Caledonia: Secretariat of the Pacific Community (SPC).

Hambrey Counsulting and Nautilus Consultants Ltd. 2011. Opportunities for the Development of the Pacific Islands' Mariculture Sector. Report to the Secretariat of the Pacific Community. Noumea, New Caldonia: Secretariat of the Pacific Community.

Heslinga, G. A., Peron, F. E., and Orak, O. 1984. Mass culture of giant clams (F. Tridacnidae) in Palau. Aquaculture, 39, 197-215.

Heslinga, G. A. 1996. Clams to cash: how to make and sell giant clam shell products (Vol. 125). Waimanalo, Hawaii: Center for Tropical and Subtropical Aquaculture.

Holt, A. L., Vahidinia, S., Gagnon, Y. L., Morse, D. E., & Sweeney, A. M. (2014). Photosymbiotic giant clams are transformers of solar flux. Journal of the Royal Society, Interface, 11(101), 20140678. https://doi.org/10.1098/rsif.2014.0678

Jonasson, J., Harkonen, T., Sundqvist, L., Edwards, S. V., & Harding, K. C. 2022. A unifying framework for estimating generation time in age-structured populations: implications for phylogenetics and conservation biology. The American Naturalist, 200(1), 48-62.

Kinch, J. 2004. The marine aquarium trade in the Solomon Islands, with specific notes on Marau Sound, Guadalcanal. *Suva, Marine Aquarium Council, Foundation of the Peoples of the South Pacific International*.

Kinch, J. 2008. From Prehistoric to Present: Giant Clam (Tridacnidae) use in Papua New Guinea. In: Antczak, A. and Caprini, R. (eds.). Early Human Impact on Megamolluscs. *Bri_sh Archaeological Reports Interna_onal Series.* 1865: 179-188.

Kinch, J. 2011. Marine invertebrates species of commercial value. Contribution to the biological inventory and resource assessment of the Chesterfield reefs. Ch. 3: 103-107.

Kinch, J. 2021. Giant clams - Tridacnidae species. In: Pavitt, A.; Malsch, K.; King, E.; Chevalier, A.; Kachelriess, D.; Vannuccini, S. and Friedman, K. (eds.). CITES and the sea: Trade in commercially exploited CITES-listed marine species. pp: 50-54. FAO Fisheries and Aquaculture Technical Paper, No.: 666. Rome: FAO.

LaJeunesse, T.C., Parkinson, J.E., Gabrielson, P.W., Jeong, H.J., Reimer, J.D., Voolstra, C.R., & Santos, S.R. (2018). Systematic Revision of Symbiodiniaceae Highlights the Antiquity and Diversity of Coral Endosymbionts. Current Biology: CB, 28 16, 2570-2580.e6 .

Ledua, E., N. Manu, and R. Braley. 1992. Distribution, habitat and culture of the recently described giant clam Tridacna tevoroa in Fiji and Tonga. pp. 147-153, In, Fitt, W.K. (ed.), The biology and mariculture of giant clams: a workshop held in conjunction with the 7th International Coral Reef Symposium 21-26 June 1992, Guam, U.S.A. ACIAR Proceedings no. 47, 154p.

Lim, S.S.Q., Huang, D., Soong, K. et al. Diversity of endosymbiotic Symbiodiniaceae in giant clams at Dongsha Atoll, northern South China Sea. Symbiosis 78, 251–262 (2019). https://doi.org/10.1007/s13199-019-00615-5

Militz, T.; Kinch, J. and Southgate, P.C., 2015. Popula_on demographics of Tridacna noae (Roding, 1798) in New Ireland, Papua New Guinea. *Journal of Shellfish Research.* 34 (2): 329-335. doi: 10.2983/035.034.0215.

Munro, P.E. & Bearu, J.H. & Lacanienta, E.. (1983). Investigations on the substance which causes sperm release in tridacnid clams. Comparative Biochemistry and Physiology Part C: Comparative Pharmacology. 74. 219–223. 10.1016/0742-8413(83)90177-9.

Musick, J. A. 1999. Criteria to define extinction risk in marine fishes: the American Fisheries Society initiative. Fisheries, 24(12), 6-14.

Neo ML (2019). Conservation of Giant Clams (Bivalvia: Cardiidae). In: Reference Module in Earth Systems and Environmental Sciences, Elsevier. ISBN 978-0-12-4095489. DOI: 10.1016/b978-0-12-409548-9.11780-4.

Rees, M., et al. (2003). Survey of trochus, holothuria, giant clams and the coral communities at Ashmore, Cartier Reef and Mermaid Reef, northwestern Australia. Townsville, Queensland: Australian Institute of Marine Science, Unpublished report.

Richter, Claudio & Roa-Quiaoit, Hilly & Jantzen, Carin & Al-Zibdah, Mohammad & Kochzius, Marc. (2008). Collapse of a New Living Species of Giant Clam in the Red Sea. Current Biology. 18. 1349–1354. 10.1016/j.cub.2008.07.060.

Selch, M. 2020. The return of the true giant clam to Kosrae. SPC Fisheries Newsletter. Noumea, New Caledonia: Secretariat of the Pacific Community. 162.

Sim, D.Z.H., Neo, M.L., Ang, A.C.F. et al. Trade-offs between defence and competition in gregarious juvenile fluted giant clams (Tridacna squamosa L.). Mar Biol 165, 103 (2018). https://doi.org/10.1007/s00227-018-3363-6

Skewes, T., Kinch, J., Polon, P., Dennis, D., Seeto, P., Taranto, T., Lokani, P., Wassenberg, T., Koutsoukos, A, and Sarke, J. 2003. Distribution and abundance of reef resources in Milne Bay Province, Papua New Guinea: giant calms and other species. CSIRO Division of Marine Research Final Report, Cleveland Australia.

Teitelbaum, A. & Friedman, K. 2008. Successes and failures in reintroducting giant clams in the Indo-Pacific region. SPC Trochus Information Bulletin 14, 19–26.

Turak, E., L. DeVan_er and J.E.N. Veron. 2009. Coral Communi_es and Reef Health. In: Hamilton, R., A. Green and J. Almany (eds.) 2009. Rapid Ecological Assessment: Northern Bismarck Sea, Papua New Guinea. Technical report of survey conducted August 13 to September 7, 2006. pp: 101-151. TNC Pacific Island Countries Report No. 1/09.

Waters, C.G., Lindsay, S. and Costello, M.J. (2016), Factors relevant to pre-veliger nutrition of Tridacnidae giant clams. Rev Aquacult, 8: 3-17. doi:10.1111/raq.12069

Watson, Sue-Ann & Southgate, Paul & Miller, Gabrielle & Moorhead, Jonathan & Knauer, Jens. (2012). Ocean acidification and warming reduce juvenile survival of the fluted giant clam,Tridacna squamosa. Molluscan Research. 32. 177-180.

Watson S-A (2015) Giant Clams and Rising CO2: Light May Ameliorate Effects of Ocean Acidification on a Solar-Powered Animal. PLoS ONE 10(6): e0128405. https://doi.org/10.1371/journal.pone.0128405