Study of giant clam resources for potential marine tourism in Morella Waters, Central Maluku

I Rabiyanti1,*, F Yulianda2 and Z Imran2

1Graduate Program in Marine and Coastal Resources Management, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Bogor, 16680, Indonesia
2Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Bogor, 16680, Indonesia

*Corresponding author: irabiyanti@yahoo.co.id

Abstract. The giant clam is a marine mollusk that lives in the coral reef ecosystem and is protected by CITES Appendix II. This study aimed to analyze the potential of clams, which are part of the coral reef ecosystem, for the use of diving and snorkeling ecotourism with clams as the main object in Morella. The parameters used for the analysis of the clam population are 1) density of clams, 2) diversity index, and Tourism Suitability Index. There were five species of clams in Morella, such as Tridacna maxima, T. squamosa, T. gigas, T. crocea, and Hippopus hippopus. The widest distribution was shown by T. maxima. The highest population of clam in Lettang Beach was T. squamosa. The highest percentage of coral reef coverage was found at Lubang Buaya Beach at 81.10%, and the lowest was at Hallasy Beach at 55.53%. The highest diversity of reef fish species was found in Lettang Beach, with 197 species. All areas were suitable to be used as tourist attractions for snorkeling activities of clams and reefs. Whereas, Hallasy Beach, Lubang Buaya Beach, and Lettang Beach were suitable to be used for clam and coral attractive object of diving activities.

1. Introduction
The giant clam is mollusks that live in the coral substrates and sand. There are seven species found in Indonesian waters, which are Tridacna maxima, T. squamosa, T. gigas, T. crocea, T. derasa, Hippopus hippopus, and H. porcelanus. The giant clam is a biota that is protected by CITES Appendix II since 1985 and Government Regulation No.7 of 1999 on preserving plants and animals, which includes seven species of giant clams that live in Indonesian waters, because of the utilization of giant clam is very exploitative like capturing and trafficking.

Morella Waters is one of the territorial waters in eastern Indonesia, which is a giant clam’s habitat. The local communities utilized the Morella Waters as a place of tourism and fishing, including giant clam to make the traditional food. Giant clam populations in the waters of Kei Island, Southeast Maluku, are still found [1], and clams are used as traditional food, construction materials, and the interests of traditional events [2]. Besides, giant clamshells are used for decoration material [3]. This animal is increasingly rare, Morella waters once had the largest clam population among all the waters of Central Maluku, but it is overexploited [4].

*Corresponding author: irabiyanti@yahoo.co.id

Abstract. The giant clam is a marine mollusk that lives in the coral reef ecosystem and is protected by CITES Appendix II. This study aimed to analyze the potential of clams, which are part of the coral reef ecosystem, for the use of diving and snorkeling ecotourism with clams as the main object in Morella. The parameters used for the analysis of the clam population are 1) density of clams, 2) diversity index, and Tourism Suitability Index. There were five species of clams in Morella, such as Tridacna maxima, T. squamosa, T. gigas, T. crocea, and Hippopus hippopus. The widest distribution was shown by T. maxima. The highest population of clam in Lettang Beach was T. squamosa. The highest percentage of coral reef coverage was found at Lubang Buaya Beach at 81.10%, and the lowest was at Hallasy Beach at 55.53%. The highest diversity of reef fish species was found in Lettang Beach, with 197 species. All areas were suitable to be used as tourist attractions for snorkeling activities of clams and reefs. Whereas, Hallasy Beach, Lubang Buaya Beach, and Lettang Beach were suitable to be used for clam and coral attractive object of diving activities.

1. Introduction
The giant clam is mollusks that live in the coral substrates and sand. There are seven species found in Indonesian waters, which are Tridacna maxima, T. squamosa, T. gigas, T. crocea, T. derasa, Hippopus hippopus, and H. porcelanus. The giant clam is a biota that is protected by CITES Appendix II since 1985 and Government Regulation No.7 of 1999 on preserving plants and animals, which includes seven species of giant clams that live in Indonesian waters, because of the utilization of giant clam is very exploitative like capturing and trafficking.
Based on an interview with the local community of Morella, the giant clams are utilized as food and are caught because they do not know the giant clam status as protected biota. The existence of giant clams must be preserved. Efforts to prevent the extinction of giant clam in Morella need to be carried out by conservation to protect giant clam.

The potential development of giant clams that there is a need to improve the management of water areas and can also be linked to fisheries management in Indonesia. Fisheries management in Indonesia is based on the Law of the Republic of Indonesia No. 45/2009 and Law No. 1/2014; as a step to manage coastal and small islands and the management of fish resources, it is necessary to carry out efforts to conserve ecosystems, fish species conservation, and fish genetic conservation. The law was passed down through Government Regulation (PP) No. 60/2007 and the Regulation of the Minister of Maritime Affairs and Fisheries (PER.02/MEN/2009) regarding the rules for the determination of water conservation areas.

Ecological and socio-economic studies are needed in the process of identifying and inventorying potential conservation areas. The reserve plan is through the issuance of Maluku Province Regional Regulation No. 1/2018 concerning Zoning Plans for the Peisisir Area and Small Islands (RZWP3K) of Maluku Province. The research on the optimal potential of clams is needed as an alternative to the giant clam management that is part of the coral reef ecosystem as an object of ecotourism. The analysis is needed to determine the core zone and utilization zone that will be determined suitability for giant clam ecotourism by using a scoring system that is based on the suitability matrix of giant clam and coral reef ecosystem tourism for marine ecotourism zoning.

2. Research method

2.1. Time and Location of Research
The study was conducted in 3 months (October–December 2018) in Morella Village, Central Maluku. This was done at four sampling sites (Figure 1).

![Figure 1. Research location in Morella, Central Maluku.](image-url)
2.2. Data collection
The data was collected in qualitative and quantitative ways. Data on clams and coral reefs potential was carried out directly in the research location. A sampling of giant clam was collected using the Manta Tow technique then continued with the UVC (Underwater Visual Census) method. The UVC method uses belt transects. Coral reef observations were used Line Intercept Transect (LIT) method. The LIT method is a method that is developed to monitoring the condition of the living corals’ ecosystem [5].

2.3. Data analysis
1) Clams density
The density for each type of clams was analyzed by comparing the individuals, which are found at the research location. The formulation used is [6]:

\[
D_i = \frac{n_i}{A}
\]

Explanation:
\(D_i\) = \(i\) density
\(n_i\) = \(i\) number of individuals
\(A\) = research area

2) Size of clams
The size of the clam is measured using a rod and caliper. Clams which found are measured by its shell.

3) Coral reefs cover
The formula used to analyze the coral reefs cover is [7]:

\[
L_i = \frac{n_i}{L} + 100\%
\]

Explanation:
\(L_i\) = \(i\) coral cover percentage
\(n_i\) = \(i\) total length of coral groups
\(L\) = total length of line transect

4) Reef fish diversity
Species of reef fish were analyzed descriptively.

5) Zonation Suitability Index
The suitability index of zonation refers to the modification of [8] as follow:

\[
ZSI = \left[ \frac{N_i}{N_{max}} \right] \times 100\%
\]

Explanation:
\(ZSI\) = Zonation Suitability Index
\(N_i\) = \(i\) parameter value (weight x score)
\(N_{max}\) = maximum value of a tourism category

6) Tourism Suitability Index
The suitability index of marine tourism refers to [8] as follow:

\[
TSI = \left[ \frac{N_i}{N_{max}} \right] \times 100\%
\]
Explanation:

- **TSI** = Tourism Suitability Index
- **Ni** = i parameter value (weight x score)
- **Nmax** = maximum value of a tourism category

The suitability analysis of marine ecotourism zoning potential considering eight supporting parameters, such as clam density, clams size, clams diversity, percentage of coral cover, coral life form, current velocity, and water brightness. Two kinds of the matrix used for analysis with each parameter, which are eight parameters for snorkeling and seven parameters for diving.

3. Result and discussions

Morella waters have considerable coastal resource potential. Clam is one of the unique biotas found, which is part of the coral reef ecosystem. Thus, this potential can be used as a tourist attraction to trigger the economic growth of local people who act as managers of these tourist areas.

3.1. Density of clams

The sampling of clams is carried out at for areas with each station divided into two depths, which are less than or equal to two meters and more than two meters by identifying snorkeling and diving for clams and corals. All of the research areas were found five species of clams which are *Tridacna squamosa*, *T. maxima*, *T. gigas*, *T. crocea*, and *Hippopus hippopus*. The highest number of clam density means in Lettang Beach on *Tridacna squamosa* and Morella Beach on the lowest (Table 1).

| No | Clams type   | Hallasy Beach | L. Buaya Beach | Lettang Beach | Morella Beach |
|----|--------------|---------------|----------------|---------------|--------------|
|    |              | ≤2 m          | >2 m           | ≤2 m          | >2 m         | ≤2 m | >2 m |
| 1  | *T. squamosa*| 9             | 13             | 8             | 12           | 19   | 0    |
| 2  | *T. maxima*  | 4             | 5              | 7             | 9            | 9    | 13   | 6    |
| 3  | *T. gigas*   | 0             | 5              | 0             | 8            | 5    | 0    | 0    |
| 4  | *T. crocea*  | 3             | 6              | 0             | 6            | 5    | 0    | 0    |
| 5  | *H. hippopus*| 0             | 0              | 0             | 1            | 0    | 2    | 0    |
| Total |           | 16            | 29             | 13            | 26           | 31   | 38   | 15   | 6    |

The total of clams found in Morella with a total area of research about 4000 m$^2$ was 174 individuals from five species of clams. *Tridacna squamosa* was found as the highest density in all research areas, such as 70 individuals or 40.2% of the total clams found. Whereas the clams which have the lowest are *Hippopus hippopus* or sand clams which only found three individuals or 1.72% of the total clams found. According to [9], in her research in the Spermonde Islands of South Sulawesi; the highest distribution of clams found was *T. maxima*.

3.2. Distribution of clams

The distribution of clams based on species found in two depths in each area. The presentation of clam distribution is shown in Figure 2, and the distribution of giant clam is shown in Figure 3. The diversity index an illustration of the community structure of an organism that can share information about the density of organisms to verify the ideal location of the core zone. The density of biota in an area, which means the higher the diversity is suitable to be used as a core zone that analyzed [10]. The highest diversity was found in Lettang Beach, which is 1.47, and the lowest was found in Lettang Beach, which was 0 because only *Tridacna squamosa* was found.
Figure 2. Map of clams distribution.

Figure 3. Map of giant clams distribution.
3.3. Percent of coral community coverage
In all research, areas found that coral community cover conditions ranged from good to very good categories, between 51.17-81.10% (Figure 4). This condition has a high prospect for developing marine ecotourism.

![Circle chart showing coral community cover percentages for Hallasy, Lubang Buaya, Lettang, and Morella beaches.]

**Figure 4.** Percentage of coral community cover.

The percentage of coral community cover for marine ecotourism according to the conditional ranges from 25-50%, quite suitable is 50-75%, and very suitable is 75%. The percentage of coral community cover in all research areas is presented in Figure 5. The hard corals are most commonly found in the slope [11].

![Pie charts showing coral reef cover percentages for Hallasy, Lubang Buaya, Lettang, and Morella beaches.]

**Figure 5.** Percentage of coral reef cover in Morella waters.

3.4. Reef fish diversity
The highest number of reef fish species was found in Lettang Beach about 197 species per 1000 m² and the lowest potential in Morella Beach, about 102 species per 1000 m².
The factor is the highest percentage of coral cover in the area is possible to be the fish habitat. According to [12], one of the causes of the high diversity of species in the coral reefs is variation in habitat because coral reefs are not only composed of corals, but there are sandy, rocky and diverse forms of the base. The differences in fish density are also caused by different conditions of coral reefs, which is the availability of food sources [13]. Coral reefs are the habitat of clams. Therefore, clams are part of the coral reef ecosystem. The relationship between clams and coral reefs is 1. as a contributor to calcium carbonate [14], 2. clams as bio-eroders [15], 3. increase topography [16], 4. source of zooxanthella [17], and 5. eutrophication prevention [18]. The relation between the density of clams and the percentage of coral cover in Morella waters shows that there is a relation of coral as the habitat of *Tridacna*. The process of taking clams in nature will not only reduce the population of clams in nature but also damage the coral ecosystem and also when the coral damaged, and then the clams will lose its habitat. Therefore, both must be maintained integrative. The picture of the relationship between clams and coral populations is shown in Figure 6.

![Figure 6](image-url)

**Figure 6.** The relation between coral cover percentage and clam population in Morella waters.

### 3.5. Suitability areas of clams as diving and snorkeling object

The Hallasy Beach at a depth of fewer than 2 meters for snorkeling activity is suitable with a TSI value of 83.33%. Lettang Beach 81.48%, and both Lubang Buaya Beach and Morella Beach has TSI value of 64.81. The areas such as Hallasy Beach, Lubang Buaya Beach, and Lettang Beach are suitable for the diving activity. The map for clam tourism is shown in Figure 7.

### 3.6. Suitability of snorkeling and diving tourism

Suitability analysis considers six parameters, such as water brightness, coral cover, coral life form, reef fish diversity, current velocity, and depth of coral reefs. Based on the results, all of the research areas are very suitable. There are TSI at Hallasy Beach is 81.48%, Lubang Buaya Beach is 90.74%, Lettang Beach is 88.89%, while Morella Beach is an inappropriate location for diving activities with grades TSI is 44.44%, this is allegedly due to the sloping water base profile. The highest percentage of coral cover was found at Lubang Buaya Beach, which was 81.1%, and the lowest was at Hallasy Beach, which was 55.53%. The highest coral fish was found in Lettang Beach, which was 197 species, and the lowest was in Morella Beach, which was 102 species. The lowest current velocity at Lubang Buaya Beach is 6.7 cm/sec, and the highest at Morella Beach is 19.4 cm/sec. Current flow in Morella ranges from 2.5 - 41.8 cm/sec [19]. The results show that all research areas are in the very suitability of snorkeling activities. The TSI in Hallasy Beach, the IKW value was 91.23%, Lubang Buaya Beach
was 89.47%, Lettang Beach was 87.72%, and Morella Beach was 89.47%. The snorkeling and diving tourism suitability map is presented in Figure 8.

### 3.7. Suitability of marine ecotourism areas

Based on the results, Lettang Beach has the potential as a core zone while the other areas function as a utilization zone of use for activities such as diving, snorkeling, and giant clam tourism. The suitability map of the potential zoning area is presented in Figure 9. The zoning area is designed with the outer boundary line to facilitate the determination of zone boundaries. According to [20], structuring of the maritime eco-tourism area paying attention to conservation principles to maintain the natural balance. The zoning systems that consist of core zones and utilization zones are the effort to protect natural resources and facilitate management. After overlaying the tourism suitability and zoning suitability maps, that was found utilization map for general marine tourism and tourism giant clam of snorkeling and diving (Figure 10).

![Figure 7. Map of clam tourism.](image-url)
Figure 8. Map of snorkeling and diving suitability areas.

Figure 9. Map of zoning area in Morella waters.
4. Conclusion

1) There were five species of clams such as *Tridacna maxima*, *T. squamosa*, *T. crocea*, *T. gigas* and *Hippopus hippopus* in Morella waters. The widest distribution was found in *T. maxima* species in Lettang Beach, and the highest density was found in *T. squamosa* species in Morella Beach. The highest percentage of coral communities was found in Lubang Buaya Beach waters.

2) Lettang Beach has the potential to be a core zone and other areas, potentially as a utilization zone. The whole area is suitable for snorkeling and coral species activities, and only Morella Beach is not suitable for diving activities.

Acknowledgment

The authors would like to thank LPDP Indonesia, P2LP LIPI Ambon, PSPL Sorong, and Morella local community who had supported this research, especially to Mr. Radjab, Ms. Wiwit, Mr. Dominggus, Mr. Barends, Mr. Pay, and Mr. Alik. Suggestions from Reviewers for the refinement of this article are greatly appreciated.

References

[1] Hernawan U E, Triandiza T and Kusnadi A 2010 Survey of giant clams species (Tridacnidae) in coral reef of Baer Island, Southeast Mollucas, Indonesia *Journal of Neritic* 2 1-6

[2] Kusnadi A, Triandiza T and Hernawan U E 2008 The inventory of mollusk species and its potent on seagrass bed in Kei Kecil Island, Southeast Moluccas *Biodiversitas* 9 30-34

[3] Mohammad S, Widyasari F, Arafat G, Robiandi, Setiadi D, Rahmat S, Latulananit M N, Fahlevi A R and Arisandy K R 2017 Distribution, density and identification of giant clams in coastal...
area of Negeri Morella, the district of Leihtu, Central Maluku Regency, Indonesia Journal of RJOAS 9 315-322

[4] Radjab A W 2013 Potential conservation of clams (Tridacnidae) and the quality of the waters of Central Maluku, Maluku Semnaskan UGM (Yogyakarta) (in Bahasa)

[5] Wilson J R and Green A L. 2009. Biological Monitoring Methods for Assessing Coral Reef Health and Management Effectiveness of Marine Protected Areas in Indonesia (TNC Indonesia Marine Program Report)

[6] Krebs C J 1978 Ecology. The Experimental Analysis of Distribution and Abundance (New York: Happer and Prow Inc. Publisher)

[7] English S, Wilkinson C and Baker V 1997 Survey Manual for Tropical Marine Resources (Townsville: Australian Institute of Marine Science)

[8] Yulianda F, Fahrudin A, Hutabarat A A, Harteti S, Kusharjani and Kang H S 2010 Integrated Coastal and Marine Management (Bogor: Pusdiklat Kehutanan – Departemen Kehutanan RI and SECEM Korea International Cooperation Agency) (in Bahasa)

[9] Susiana, Niartiningsih A and Amran M A 2017 Relationship between Conformity of Water Quality and Abundance of Clams (Tridacnidae) in the Spermonde Islands (Makassar: Hasanuddin University) (in Bahasa)

[10] Maguran A E 2014 Measuring Biological Diversity (USA: Blackwell Science Ltd)

[11] Waskita A M A 2016 The Basic Complexity of Coral Reef Waters With Benthic Terrain Modeler and In Situ Rugosity on Coconut Island and Harapan, Kepulauan Seribu, Jakarta [Undergraduate Thesis] (Bogor: Bogor Agricultural University) (in Bahasa)

[12] Nybakken J W 1993 Marine Biology: An Ecological Approach (Jakarta: PT. Gramedia) (in Bahasa)

[13] Nasir M, Zuhal M and Ulfah M 2017 The structure of the reef fish community in the waters of the Island of Bate, Peukan Bada District, Aceh Regency Bioleuser Journal 176-85 (in Bahasa)

[14] Romanek C S and Grossman E L 1989 The isotope profile of Tridacna maxima as environmental indicators. Palaios 4 402-413

[15] Morton B 1990 Corals and their bivalve borers-the evolution of a symbiosis (The Bivalvia) ed Morton B Proceedings of a Memorial Symposium in Honour of Sir Charles Maurice Yonge, Edinburgh (Hongkong: Hongkong University Press) pp 11-46

[16] Gutierrez J L, Jones C G, Strayer D L and Iribarne O O 2003 Mollusks as ecosystem engineers: the role of shell production in aquatic habitats Oikos 101 79-90

[17] Baillie B K, Belda-Baillie C A and Maruyama T 2000 Conspecificity and Indo-Pacific distribution of Symbiodinium genotypes (Dinophyceae) from giant clams J. Phycol. 36 1153-1161

[18] Neo M L, Erfemeijer P L A, van Beek J K L, van Maren D S, Teo S L M and Todd P A 2013 Conservation status reassessment of giant clams (Mollusca: Bivalvia: Tridacninae) in Singapore Nat. Singapore 6 125-133

[19] Nugroho S 2013 Geomorphological conditions, surface sediments and human activities in the tourist area on the maritime village of Morella and Negeri Lima, Ambon Indonesian Journal of Oceanology and Limnology 39 263-276

[20] Yulianda F 2007 Marine Ecotourism as an Alternative Use of Conservation-Based Coastal Resources (Bogor: Bogor Agricultural University) (in Bahasa)