Status of mangrove clam (*Anodontia philippiana* Reeve, 1850) in Bagana, Davao Oriental, Philippines

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Abstract. Mangrove clams *Anodontia philippiana*, locally known as imbao, are predominantly found in mangrove ecosystems in the Philippines. Nowadays, these are declining due to habitat disturbances and unregulated harvest. This study was conducted in Baganga, Davao Oriental, with lush mangrove forest in its coastline. Four study sites were identified based on local interviews and with the assistance of the municipal agriculturist, namely barangay Kinablangan, Lucod, Salingcomot and Bobonao. A 1x1 m transect quadrat method was employed during sampling. Density, length and weight of mangrove clams, as well as the physico-chemical parameters were determined. Analysis of variance, Tukeys test and linear regression were used during analysis. Mangrove clams with a higher density were found in Kinablangan, the size ranging from 3.5-4.4 cm in barangay Kinablangan, Lucod and Salingcomot, while Bobonao had clams with a size range between 4.5-5.4 cm. Lighter mangrove clams were found in Kinablangan (10-19.9 g). In Lucod and Salingcomot clams were heavier (20-29.9 g) and Bobonao clams were the heaviest (30-39.9 g). Mature mangrove clams dominated the catch in all study sites. The study revealed no significant differences in the density among stations. However, significant differences were noted for the length and weight of mangrove clams among stations and a positive relationship between length and weight. No presence of overexploitation was perceived, but indiscriminate harvest was observed. It is essential to implement mangrove clam conservation and harvest strategy to sustain the mangrove clam population in the mangrove areas of Baganga, Davao Oriental, Philippines.

Key Words: exploitation, gleaning, invertebrates, mangrove ecosystem, sustainable harvest.

Introduction. Mangrove forests can be found along the coasts of tropical and subtropical regions. These trees provide various ecological and economic benefits. Mangroves provide a variety of ecosystem functions, including buffering the coastline from erosion and storms, providing nursery habitats for fish and crustacean juveniles, and acting as a pollution filtering border. Mangrove resources, such as mangrove woods, fishery products, and mangrove fruits and juice, support coastal communities economically. Macrobenthic creatures such as mollusks (snails, mangrove clams, and oysters), crabs and shrimps as well as phytoplankton, zooplankton and arthropods are also found in the mangrove ecosystem (Lokman & Sulong 2001; Tomlinson 2016; Bahari et al 2021).

Mollusks are the most abundant and well represented taxon of marine organism in mangrove forests, together with decapod crustaceans, and play an important ecological role in the mangrove ecosystem (Kathiresan & Bingham 2001; Nagelkerken et al 2008; Kathiresan 2012). The high density and biomass of mollusks in mangroves is evidence of their ecological importance in converting primary production from the trees into animal tissue, available to higher trophic levels. Bivalves and gastropods are considered the main mollusks in mangrove forests and comprise an important trophic component of detritus-based food webs (Myers et al 2011).

Anodontia philippiana or the mangrove clam belongs to the family Lucinidae. They are widely distributed in the Indo-West Pacific region, being considered a seafood delicacy in the Philippines. Imbao, as it is locally named, has been one of the most valued bivalves in the region because of its flavor, size and demand, as local favorite shellfish in the region (Adan 2000; Lebata 2001). In the Davao region, two species of mangrove clams were identified, namely *A. philippiana* and *Austriella corrugata*, which are locally referred to as imbao baye and imbao laki, respectively (Lumogdang et al 2022). These mangrove clam species accommodate bacterial symbionts that utilize sulfides for their nourishment. It is very common to have an existing mangrove clam species in a mangrove ecosystem, since this habitat provides plenty of sulfides because of its oxygen deficient environment, necessary for the survival of bacterial symbionts that live in the gills of the mangrove clams (Taylor et al 2010; Lumogdang et al 2022).

Imbao collection supports the livelihood of coastal communities where these resources are present (Furkon et al 2019). The study of Bacaltos et al (2010) found that there have been reports of overexploitation, manifested as a decline in density and size of imbao for the past years, resulting in a declined supply of this commodity that may affect the economic condition of imbao collectors or gleaners in the region, if not given attention. This paper aims to provide baseline information on the density, length and weight parameters and maturity of mangrove clam resources in Baganga, Davao Oriental, as this municipality is one of the major exporters of mangrove clams in the local markets and in Davao City (Bangkerohan and Agdao Public Markets).

Material and Method. The study was conducted in Baganga, Davao Oriental (7°34'29.77"N; 126°33'41.38"E). Baganga is a 1st class municipality in the province of Davao Oriental, Philippines. According to the 2020 census, it has a population of 58714 people, making it the third largest town in province. The majority of the locals are preoccupied with farming, fishing and gleaning. The established study sites in the area were identified by the help of the local gleaners and through the assistance of the municipal agriculturist. Barangay Kinablangan, Lucod, Salingcomot, and Bobonao were selected as the study sites, with daily reports of substantial volumes of mangrove clam catches. Based on the information given by the municipal agriculturist, mangrove clam is an important commodity and resource for the people in Baganga, Davao Oriental, especially for those directly benefiting from clam harvest (gleaners). For some, the gleaning harvest represents the main source of livelihood, with an estimated 50 kg of harvest daily, depending on weather. They claim that considerable amounts of mangrove clam are harvested daily to be exported to the city markets. One local gleaner said that he spent his entire day in the mangrove areas to collect clams from 7:00 in the morning to 3:00 in the afternoon, generating from 6 to 10 USD daily. Invertebrates like mud crabs and mangrove clams live in abundance in these locations, in the lush mangrove forests (Figure 1).

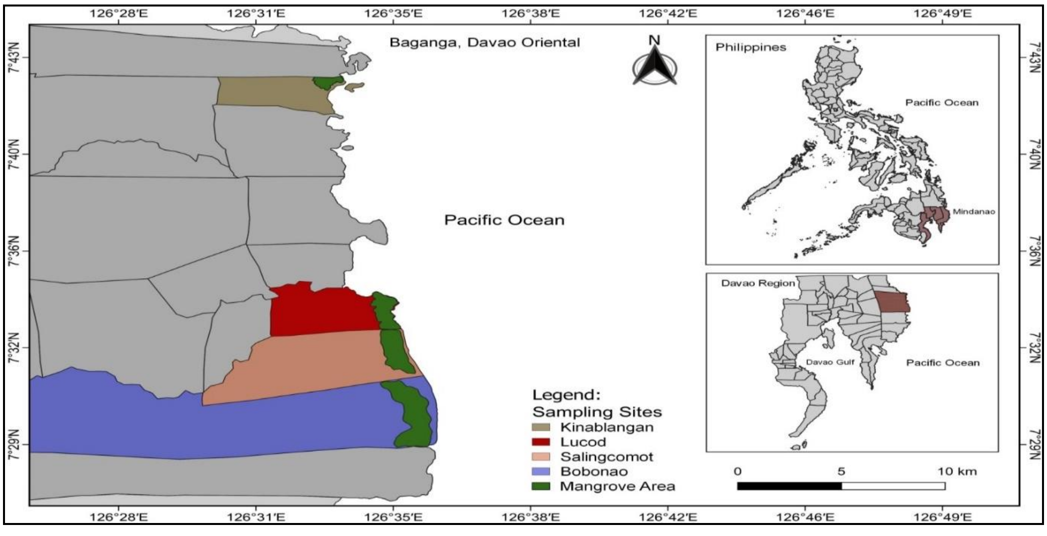

Figure 1. Map of the study sites in Baganga, Davao Oriental, Philippines.

Sample collection. Sampling was conducted in the selected barangay of Baganga, Davao Oriental, on May 2-7, 2022, with the help of hired local gleaners to speed up the sampling and collection. Sampling was done during high tide and daytime to facilitate easy maneuver by the gleaners since they used their feet to collect clams that burrow from 0.6 to 1 m in the muddy substrate of the mangroves. The gleaners prefer to collect clams during high tide because the presence of sea water in the mangroves allows them to move freely and used their feet to make a rhythmic movement, locally known as "hinol-hinol".

Mangrove clam samples were collected in all four study sites: the barangay Kinablangan, Lucod, Salingcomot and Bobonao, using a 1x1 m transect quadrat method, in which a 50 m transect tape was set within the mangrove forest perpendicular to the shoreline. The identified sites were the only barangays that were observed to have an existing resource of mangrove clams according to the information given by the municipal agriculturist and supported by the local gleaners. There were three stations in each sampling site with three transects laid in each station at 50 m intervals. Stations 1 and 3 were in two adjacent boundaries and station 2 was in the middle of the site, to ensure that mangrove clams are extracted across the sampling site. In each transect, five quadrats were established at 10 m intervals. 45 m^2 were assessed during sampling in each station and an over-all 135 m^2 per sampling site were assessed during the conduct of the study. Individual clams were counted and the density was computed using the formula of Mendoza et al (2019):

Density = number of individual clams/area (m^2)

The length and weight of mangrove clams were obtained *in situ*. For length, a vernier caliper (0.1 mm) was used, the length being measured from umbo to pallial line (Figure 2) and the measurement was converted to centimeters. For weight measurement, a digital weighing scales (0.2 g) was used *in situ*. A few minutes were allowed for draining the clam to minimize the water that could influence its weight (Figure 3). A mangrove clam measuring 3.5 cm and above was considered sexually mature in the current study. Based on the research published by Araneta (2016), a clam size of 30 to 50 mm is already an adult, sexually mature.

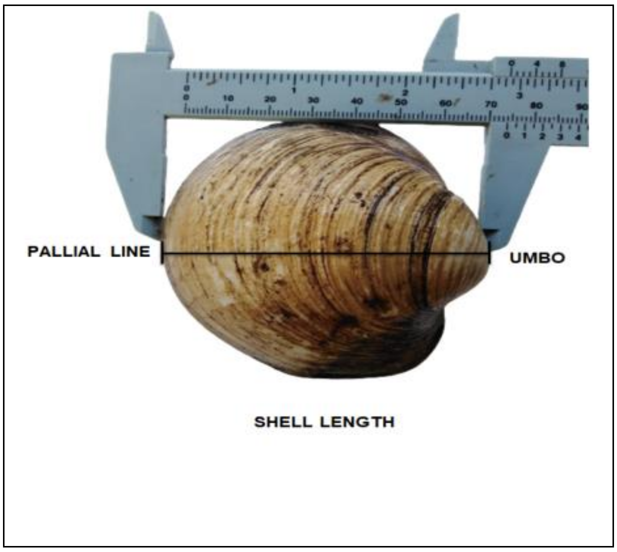

Figure 2. The shell length of mangrove clam.

Physico-chemical parameters were obtained *in situ*. Temperature was obtained using a mercury thermometer. The lower half of the thermometer was immersed into the upper few cm of the sea surface water for 1 minute and the measurements were recorded. Salinity of water was measured with the use of the ATAGO refractometer; a few drops of sea water were placed in the prism and the salinity reading was obtained by directly looking at the scale through the eyepiece. Dissolved oxygen was measured using a DO meter connected to a probe; the probe was submerged in a liquid solution for calibration and, after a few minutes, the probe was submerged under a few cm of sea water for 1 mine. Direct observations were used to identify the type of substrate in the area (mud or sand), and substrates at higher depths (between 0.3-0.7 m) were sampled for identification.

Figure 3. Sampling of mangrove clams in the study sites.

Data analyses. Data analyses on density, length and weight were done by the use of the Analysis of Variance (ANOVA) at 0.05 level of significance. Tukey's test was further used to establish significant differences between sampling sites. Moreover, correlation's test was used to determine the type (positive/negative) and magnitude (strong/weak/absence) of relationships between length and weight of mangrove clams across the four sampling sites. Analyses were carried out through IBM SPSS V.20 and Microsoft Excel 2010.

Results and Discussion

Mangrove clam density. The density of mangrove clams found in four study sites is presented in Table 1. More mangrove clam were found in barangay Kinablangan, with 251 individuals, with a density of 6 ind m^{-2}, followed by Lucod (with 222 individuals at 5 ind m^{-2}), Bobonao (176 individuals at 4 m^{-2}) and Salingcomot (120 individuals at 3 ind m^{-2}). Barangay Kinablangan obtained the highest density of mangrove clams, while barangay Salingcomot had the lowest density. However, no significant difference was found based between sampling sites ($p>0.05$), due to the fact that all sites were densely forested. During sampling, it was also noted that the substrate type was identical (mud).

Previous reports state that mangrove clams usually inhabit dense mangrove forests with muddy substrates (Primavera et al 2002; Primavera et al 2005). Another study of Mendoza et al (2019) states that mangrove clam population does not vary across mangrove forests that have dense cover. Sulphides are abundant in hypoxic environments like mangrove ecosystems. Mangrove clams host an endosymbiotic bacterium that utilizes sulphides. This gives the clam the ability to survive even if its body is submerge into the mud (Clemente et al 2013). The sulphides in the mangrove substrate will be utilized by mangrove clams, with the use of their foot, transported to the gills, where they are made available to bacteria existing in the gills. The bacteria provide organic compounds that nourish mangrove clams through chemosysnthesis and anaerobic oxidation of sulphides (Lebata 2001).

Table 1

Density of mangrove clams in the study sites

Stations	*Number of clams per site*	*Density (ind m^{-2})*
Kinablangan	251	6
Lucod	222	5
Salingcomot	120	3
Bobonao	176	4

Mangrove clam length and weight. Clams were counted according to their size range, from smallest (1.5 cm) to longest (7.4 cm), based on shell length and weighted. The length and weight of mangrove clams in all study sites are presented in Table 2. The majority of the mangrove clams collected in Barangay Kinablangan (52.19%), Lucod (46.67%) and Salingcomot (46.67) were within the size range of 3.5-4.4, cm while in barangay Bobonao, mangrove clam range was within 4.5-5.4 cm (40.91%). In terms of weight, most (38.65%) mangrove clams in Kinablangan were between 10-19.9 g. In Lucod (36.04%) and Salingcomot (27.5%) they were between 20-29.9 g and in Bobonao mangrove clams usually weighted between 30-39.9 g (18.75%). Based on the analysis of variance, there were significant differences found in the length and weight of mangrove clams between sampling sites ($p<0.05$). There were no significant differences only between barangay Kinablangan and Lucod, in the mean length and weight of mangrove clams ($p>0.05$).

Table 2

Mangrove clam length and weight in the study sites

Size range (cm)	*Kinablangan*		*Lucod*		*Salingcomot*		*Bobonao*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
1.5-2.4	2	0.80	3	1.35	0	0.00	2	1.14
2.5-3.4	75	29.88	84	37.84	25	20.83	21	11.93
3.5-4.4	131	52.19	101	45.50	56	46.67	69	39.20
4.5-5.4	41	16.33	30	13.51	34	28.33	72	40.91
5.5-6.4	2	0.80	4	1.80	5	4.17	10	5.68
6.5-7.4	0	0.00	0	0.00	0	0.00	2	1.14
Weight range (g)	*Kinablangan*		*Lucod*		*Salingcomot*		*Bobonao*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
1.0-9.9	12	4.78	9	4.05	0	0.00	3	1.70
10-19.9	97	38.65	58	26.13	23	19.17	23	13.07
20-29.9	66	26.29	80	36.04	33	27.50	31	17.61
30-39.9	34	13.55	34	15.32	25	20.83	33	18.75
40-49.9	18	7.17	12	5.41	13	10.83	29	16.48
50-59.9	13	5.18	12	5.41	15	12.50	22	12.50
60-69.9	6	2.39	9	4.05	3	2.50	18	10.23
70-79.9	2	0.80	1	0.45	4	3.33	7	3.98
80-89.9	1	0.40	3	1.35	1	0.83	2	1.14
90-99.9	1	0.40	2	0.90	2	1.67	2	1.14
>100	1	0.40	2	0.90	1	0.83	6	3.41

Note: n - number of clams.

The varying clam length and weight between stations (aside from Kinablangan and Lucod) was an indication that the clams in the study sites experience differences in biological factors, such as availability of food, predation and anthropogenic stressors, like exploitation due to unmanaged harvest, indiscriminate gleaning and pollution (Bacaltos et al 2010; Hamid et al 2020; Newton et al 2020). All study sites have uniform, dense mangrove areas, so high detrital material exists in every site. The availability of food to mangrove clams was not detrimental on their growth, because food was abundant in their ecosystems (Lebata 2001; Primavera et al 2002). Predation might play a role in the growth of mangrove clams. The juvenile clams are reportedly more exposed to predation. Predators like flatworms and annelids (Govan et al 1993), shore crabs (Dethier et al 2019) and mud crabs (Mamun et al 2008) are the common predators of juvenile clams.

Another obvious observation during sampling across the study sites that could impact the growth of mangrove clams was the number of gleaners that gleaned in every study site, and the indiscriminate gleaning practices. Many gleaners came from Lucod and some of them venture farther to Kinablangan to harvest mangrove clams, as these two barangay were open and not strict in the access to their mangrove areas, to collect mangrove clams. Accessibility and unsustainable harvest over time significantly decrease the abundance and negatively affects the growth of mangrove clams in any mangrove area (Aswani et al 2015). However, in Salingcomot and Bobonao, there are strictly implemented local ordinances that prohibit gleaners to enter the mangrove areas to protect the mangroves and the mud crab (*Scylla serrata*), which is more economically valuable than clams. The local policy that Salingcomot and Bobonao apply to their mangrove areas positively influences the status of mangrove clams in terms of growth. This is also the main reason why the gleaners from Lucod are not able to exploit the resources from the adjacent barangay Salingcomot. In consonance with this statement, a report of Kilatong & Bruckner (2010) states that sustainable gleaning through the implementation of rotational harvesting strategy must be employed to increase the productivity of mangrove clams. The same strategy has not always equated to positive results, since it was sometimes implemented for shorter periods of time for species that are slow in replenishing their populations in the wild (Purcell et al 2015). A rotational harvesting scheme with extended time periods for periodic prohibitions will allow ample time to mangrove clams for developing, maturing and reproducing, and lessen the economic impact towards the gleaners, unlike the implementation of a sanctuary with complete gleaning prohibition (Caddy 1993; Dolorosa & Dangan-Galon 2014; Aswani et al 2015; Purcell et al 2015).

Another anthropogenic component that could impact the growth of mangrove clams is the harvesting of immature clams, measuring less than 3.4 cm. Reports of indiscriminate harvesting in Davao region have existed since 2010 according to the study of Bacaltos et al (2010). Gleaners believe that if small clams are disturbed, they eventually die within a few days, this being one of the reasons for harvesting immature clams. The high market value and their taste is the main reason for exhaustive harvesting (Primavera et al 2002).

In terms of pollution, especially microplastic ingestion, there are reports that clams are highly exposed to microplastic because of their feeding mechanism (Baechler et al 2020; Sathish et al 2020). However, we cannot strongly take into account the impact of microplastic ingestion on the growth of mangrove clams because all sampling sites in this study were located in less urbanized and industrialized areas, anthropogenic activities being one of the factors that influence microplastic contamination in a certain location (Cho et al 2021).

Based on Spearman's correlation test, a strong positive relationship (0.8553) was observed between the length and weight of mangrove clam in the study sites as reflected in the scatter plot in Figure 4. This result suggests that shell length may be used to predict the weight of a mangrove clam. The length and weight of mangrove clams were directly proportional in the sampling areas: as the length of the clam increases, the weight also increases proportionally. Some studies also had similar results, where length was the ideal weight estimator for green mussels (Aban et al 2017; Sajol-Degamon & Fernandez-Gamalinda 2021), and mangrove clams in Surigao City (Sajol-Degamon & Fernandez-Gamalinda 2021).

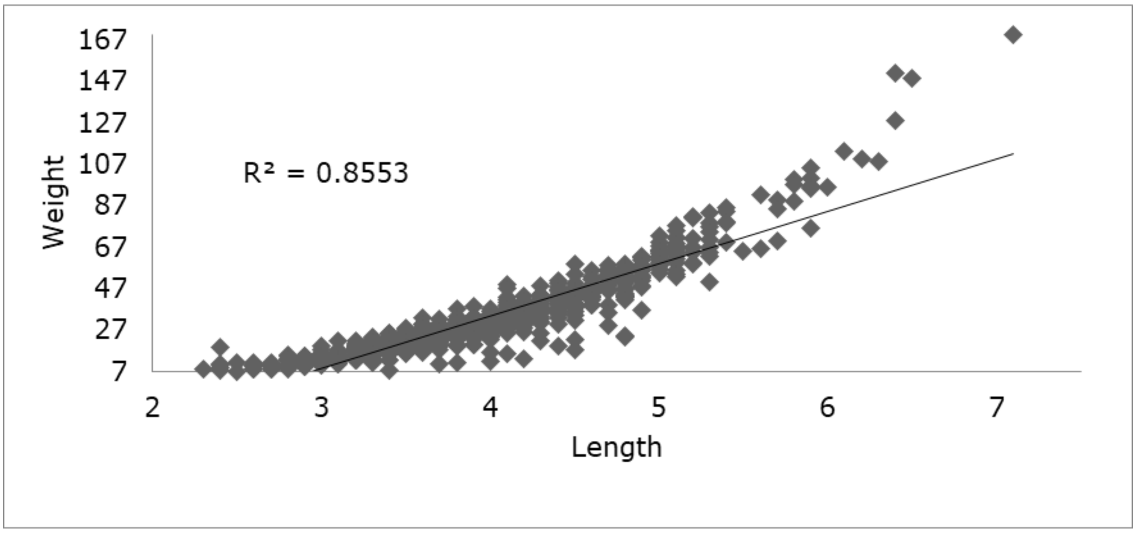

Figure 4. Length and weight of mangrove clams scatter plot.

Mangrove clam maturity. The maturity of mangrove clams is an indication showing if the area is overexploited. In the studied area, there was a dominance of smaller mangrove clams. Mangrove clams measuring at least 3.5 cm shell length were considered sexually mature (Araneta 2016). The maturity of mangrove clams in the study sites is presented in Figure 5, in which Kinablangan, Lucod, Salingcomot and Bobonao were dominated by mature clams with proportions of 69.32%, 60.81%, 79.17% and 86.93%, respectively. This means that the population of the mangrove clams across study sites was in good condition. This result was in congruence with the report of Elvira & Jumawan (2017), in which the majority of mud clams observed in the mangrove areas of Butuan Bay, Philippines, was sexually mature. Mangrove clams might be hermaphrodites in nature, meaning that a single clam can have the ability to reproduce, increasing the density of mangrove clams in the study sites (Geduspan et al 2008). The idea of protection and conservation was also observed among the gleaners across the study sites, as they were very much aware of the importance of sustaining the wild population of imbao, as well as the importance of mangroves economically and ecologically (So et al 2021).

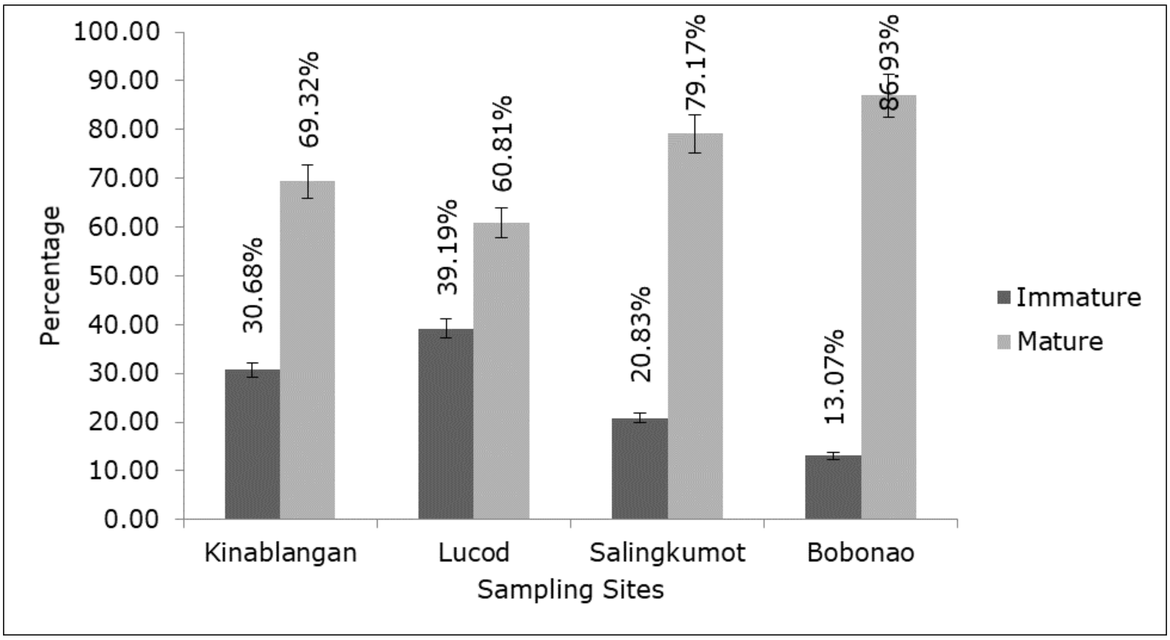

Figure 5. Sexual maturity of mangrove clams in the study sites.

Physico-chemical parameters in the study sites. The physico-chemical study is important when investigating the growth of a certain organism, as it directly or indirectly affects its biological processes like reproduction, metabolism and distribution (Thirunavukkarasu et al 2011). The physico-chemical parameters observed in the study sites are presented in Table 3. Temperature readings across all study sites ranged from 28.7 to 30.5^{O}C, salinity ranged from 27.2 to 29.1 ppt, dissolved oxygen from 4.02 to 4.83 mg L^{-1} and the substrate type was muddy in all study sites. The temperature, salinity and dissolved oxygen readings were comparable to the results of Thirunavukkarasu et al (2011) and Imamsyah et al (2020), while the substrate type was similar to the observations of Primavera et al (2002) in the mangrove ecosystem of Panay.

Tropical countries have higher temperatures compared to temperate regions. This element plays an essential role in the decomposition of dead mangroves and animals in a mangrove ecosystem, as colder temperatures will decrease the decomposition rate of organic matter. According to the results of Bhatkar et al (2021) in a controlled environment, temperature and salinity influence the spawning of mangrove clams and the development of the clam oocyte, which were faster in a salinity of 35 ppt and a temperature of 32^{O}C. However, we cannot compare both studies, since the parameters obtained in the current study vary with time and season, the parameters easily fluctuating in the wild (Saravanakumar et al 2008; Manikannan et al 2011). Low dissolved oxygen in mangrove areas are common, with a mean dissolved oxygen value of 5.99 mg L^{-1} (Dattatreya et al 2018). The low dissolved oxygen in the study sites was the product of the breakdown of organic matter via biochemical decomposition of detritus (Okus et al 2008). As we know, mangrove areas accumulates high organic matter (Raheman et al 2020) due to high detrital composition secondary to mangrove litter (Nagelkerken et al 2008). Moreover, published articles related to the effects of low dissolved oxygen concentrations on mangrove clams showed lower survival rates during the early life stages of the clam (Tomasetti & Gobler 2020). Mangrove clams prefer a muddy or sandy muddy substrate, so that they can easily burry at depths of 25-50 cm (Primavera et al 2002). The type of substrate has a big impact on the distribution of mangrove clams. Substrates that allow for aerial respiration will have more clams than those that do not (Clemente & Ingole 2011). The most common type of substrate of a mangrove ecosystem is muddy or sandy muddy (Wu et al 2020; Auni et al 2020; Chang et al 2020; Primavera et al 2002).

Table 3

Physico-chemical parameters of sea water in the study sites

Stations	*Temperature (°C)*	*Salinity (ppt)*	*Dissolved oxygen (mg L^{-1})*	*Substrate type*
Kinablangan	29.3	28.3	4.83	Mud
Lucod	30.5	27.2	4.58	Mud
Salingcomot	30.1	28.5	4.02	Mud
Bobonao	28.7	29.1	4.61	Mud

Conclusions. Mangrove clam *Anodontia philippiana*, locally known as imbao, is commonly found in the mangrove ecosystem of the Philippines, especially in Baganga, Davao Oriental. Kinablangan, Lucod, Salingcomot and Bobonao were the study sites identified with high volumes of reported catch. Mangrove clam density was higher in Kinablangan, followed by Lucod, Bobonao and Salingomot. The majority of the clams in Kinablangan, Lucod and Salingcomot were within the size range of 3.5-4.4 cm, while Bobonao recorded larger clams, at 4.5-5.4 cm. Lighter clams were observed in Kinablanga (10-19.9 g) while Lucod and Salingcomot clams weighted 20-29.9 g. Bobonao recorded the heavier clams, at 30-39.9 g. Length and weight have a positive relationship, which means that when the length increases, a proportional increase in weight is also recorded. Mangrove clams collected during sampling were dominated by sexually mature mangrove clams, which means that overexploitation was absent. Physico-chemical parameters were comparable to those of several other published articles. Although overexploitation was not observed in the study, as more mature clams were observed during sampling, mangrove clam conservation and harvesting management strategy must be implemented, because there are reports of the decline of catch and observed indiscriminate harvest.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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