Asian Journal of Fisheries and Aquatic Research

Volume 25, Issue 4, Page 117-126, 2023; Article no.AJFAR.107689
ISSN: 2582-3760

Biodiversity and Distribution Patterns of Clams (*Tridacninae)* on Coral Reefs in Kayu Angin Bira Island, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2023/v25i4689

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/107689

Original Research Article

Received: 20/08/2023
Accepted: 26/10/2023
Published: 01/11/2023

ABSTRACT

This research aims to find out the biodiversity and distribution patterns of clams and the relationship between clam abundance and coral reef conditions in the Waters of Kayu Angin Bira Island, Kepulauan Seribu. The research was conducted between April and July 2022, with field data collection taking place in September 2022 at four chosen stations. These stations were selected based on variations in water depth and were situated in the South, West, North, and East regions of the waters surrounding Kayu Angin Bira Island. The data collection was conducted using survey methods. Coral reef data collection using LIT (Line Intercept Transect) method and clam observation using belt transect. The results showed that in the waters of Bira Kayu Angin Island, 25 individuals of 2 species of bivalve class were found, namely *Tridacna squamosa*, *Tridacna crocea*. The highest relative abundance of clams is found at the eastern station which is 20% and the lowest relative abundance is found at the southern, western and northern stations which is only 8%. Low diversity index of Tridacninae Clams was discovered at the four stations, which ranged from 0.451 - 0.662 and the uniformity index at the four stations ranged from 0.650 - 0.954, indicates high

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population uniformity. Based on Morisita distribution index, which ranges from 0.4 - 0.74, the spatial distribution of Tridacninae clams could be assigned as uniform. The relationship between clams and coral reefs is 0.7284, shows that clams have a strong relationship with the condition of coral reefs.

Keywords: Biodiversity; tridacninae; coral reefs; Kayu Angin Bira Island.

1. INTRODUCTION

The presence of benthic fauna in a body of water is important for the aquatic ecosystem. In addition to being an indicator of the health of the aquatic environment [1], benthic fauna also has an important role in supporting capture fisheries activities (Kritzer *et al.*, 2016) and as symbiotic fauna for demersal fauna (Kaiser *et al.*, 1999). One of the benthic fauna is Clams (*Tridacninae sp.*).

“Clams play an important role in coral reef ecosystems to maintain ecosystem balance” [2]. The depth-related distribution of clams (*Tridacninae*) has an impact on their shape and size. In regions with greater water depth, the clams tend to be smaller compared to those residing in shallower waters [3]. “The abundance of clams is influenced by the condition or quality of coral reefs as their habitat” [4].

There are several studies that have been conducted on the abundance of clams in Indonesia, one study conducted by Othman, Goh & Todd, [5] revealed that habitat loss, pollution, and increased sea surface temperatures are the causes of declining clam populations. Van Wynsberge et al. [6] found that human population is closely related to clam abundance. According to Setiyaningsih [7], clams in Pulau Seribu are under threat of population decline due to the culture and habits of the surrounding community who consume clams. In addition to human factors, natural factors also affect the abundance of clams. This study aims to measure biodiversity and observe the distribution pattern of clams in the Waters of Kayu Angin Bira Island, Kepulauan Seribu and analyze the relationship between clam abundance and coral reef conditions in the Waters of Kayu Angin Bira Island, Kepulauan Seribu.

2. METHODS

2.1 Research Time and Location

This research was conducted in September 2022. Then, the data processing was carried out until November 2022. The research was conducted in the waters of Kayu Angin Bira Island, Taman Nasional Laut Kepulauan Seribu, DKI Jakarta. Data collection took place in the waters of Kayu Angin Bira Island at four specific station locations: South, West, North, and East. The research stations were chosen using purposive sampling, a technique that involves specific considerations [8]. In this study, four stations were selected (station 1: 5.608018°S 106.565493°E, station 2: 5.605814°S 106.565275°E, station 3: 5.604606°S 106.567206°E, station 4: 5.607150°S 106.570119°E), each plot at varying depths: 3 meters and 9 meters.

The method used in this research is the Survey Method. A survey method in research involves studying a population as the subject, but it focuses on analyzing data collected from samples taken within that population. This approach helps uncover distributions and relationships between variables [9]. The measurements of water parameters conducted with in situ measurements (directly on the spot) at each station. This data includes water temperature data using a thermometer, brightness using a sechi disk, salinity using a refractometer, and water acidity (pH) using a pH meter. The data studied in this research includes clam biodiversity data, coral reef data and water quality data. The data gathered is both quantitative and qualitative information from each observation station. This information includes metrics such as the percentage of coral reef cover, diversity, uniformity, abundance, and patterns of clam distribution, and the data is analysed to explore the correlation between clam abundance and the condition of the coral reefs.

2.2 Observed Parameters

2.2.1 Percentage of coral reef cover

Data obtained from the field is the data from transects with the LIT method, which is then stored in a computer and processed with the Ms. Excel program. To calculate coral reef cover, the formula was used [10].

$$L = \frac{Li}{N} \text{ x } 100\%$$

Description:

L = Percentage of Coral cover
Li = Amount of each component
N = Total Components (50m)

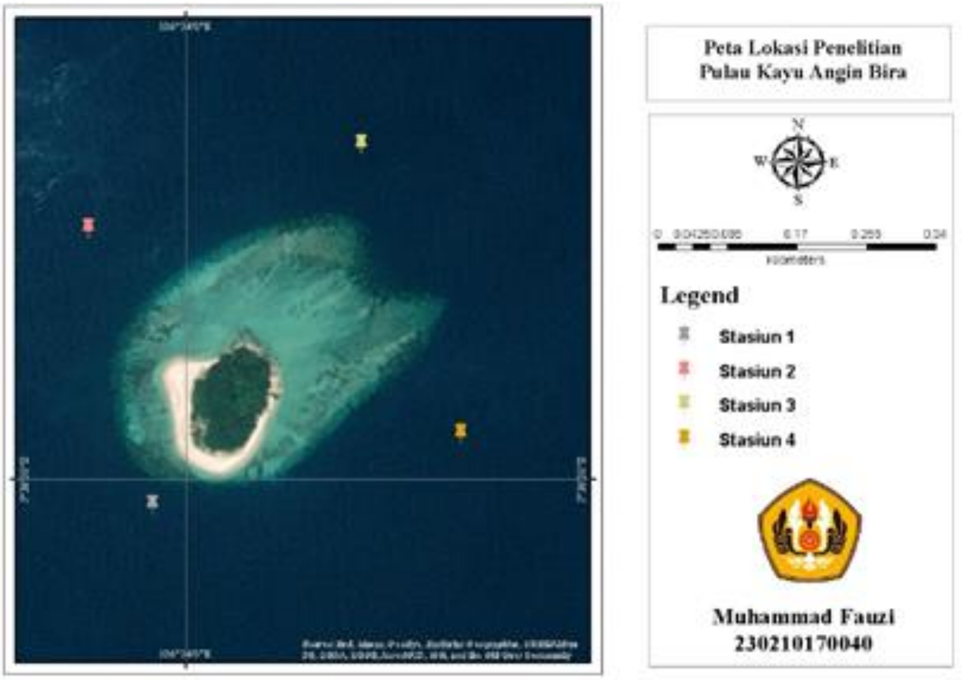

Fig. 1. Map of the research area

The percentage of live coral cover is used to determine the coral reef condition. Coral cover categories based on Gomes and Yap [11] are shown in (Table 1).

Table 1. Coral reef assesment criteria

Category	Live Coral Cover (%)
Bad	0 - 24,9
Moderate	25 - 49,9
Good	50 - 74,9
Very good	75 - 100

2.2.2 Clam abundance

Abundance is the total number of individual clams found during observation. The abundance index provides an overview of the species composition in the community. The relative abundance of clams can be found using the following equation (Van Balen, 1984):

$$KR = \frac{ni}{N} \text{ x } 100\%$$

Description:

KR = Relative Abundance
ni = Number of individuals of species-i
N = Total number of individuals

2.2.3 Clam diversity

The diversity index shows the richness of species in a community and shows the balance in the distribution of numbers per species. The diversity index can be calculated with the Shannon-Wiener index [12] with the equation:

$$H' = -\sum (Pi)\ (\ln Pi)$$

Description:

H' = Diversity Index
Pi = ni/N
ni = Number of Individuals
N = Total number of individuals

Criteria:

$H' < 1$: Low Diversity
$1 < H' < 3$: Medium Diversity
$H' > 3$: High Diversity

2.2.4 Clam uniformity

Clam diversity can be seen from the uniformity index. This index is used to determine the presence of species that dominate the community and to determine the distribution of the number of individuals of each type [13]. This index is obtained by comparing the diversity index with its maximum value as follows:

$$E = \frac{\hat{H}}{Hmax}$$

Description:

E = Uniformity index
Ĥ = Shannon-Wienner diversity index
Hmax = Ln S
S = Number of species

Criteria:

E < 0.4	: Small population uniformity
0.4 < E < 0.6	: Moderate population uniformity
E > 0.6	: High population uniformity

2.2.5 Clam distribution pattern

To determine the distribution pattern of clams in the habitat, the Morisita distribution pattern was used. Morisita distribution index is calculated by the following formula [14]:

$$Id = q \frac{\sum ni\ (ni-1)}{N\ (N-1)}$$

Description:

Id : Morisita Scatter Index
q : number of samples
ni : number of individuals of i sample.
N : Total number of individuals obtained

Criteria:

Id < 1 : The distribution pattern of individual species is uniform
Id = 1 : The distribution pattern of individual species is random
Id > 1 : The distribution pattern of individual species is clustered

2.2.6 Correlation data analysis

Data analysis in this research was carried out using Bivariate Correlation Analysis processed in Microsoft Excel. Bivariate Correlation Analysis is used to measure the level of relationship between two variables.

The formula used is as follows:

$$r_{xy} = \frac{\sum XY - \sum X . \sum Y}{\sqrt{[n. \sum X^2 - (\sum X)^2][n. \sum Y^2 - (\sum Y)^2]}}$$

Description:

r_{xy} = Correlation coefficient of two variables (Clam Abundance and Percentage Coral Reef Cover)
n = Number of transects
X = Number of Clams at each station (x +x_{12} +...)
Y = Coral reef area at each station (y +y_{12} +...)

The results of the bivariate correlation analysis guidelines according to Sugiyono (2007) *in* Miala (2015) can be seen in (Table 2):

Table 2. Criteria for correlation value

Interpretation Number	Correlation
0 - 0,199	Very weak
0,20 - 0,399	Weak
0,40 - 0,599	Moderate
0,60 - 0,799	Strong
0,80 - 1,0	Very strong

3. RESULTS AND DISCUSSION

The measurement results of water quality parameters of Kayu Angin Bira Island.

Based on the observations (Table 3) conducted at four different stations, the data collected were regarding water conditions, coral reef density, and reef cover. The parameters observed included temperature, salinity, brightness, and pH levels. These physical and chemical water parameters were measured with three repetitions conducted simultaneously at each station.

Table 3. Water quality parameters

Station	Temperature (º C)	Salinity (ppt)	pH	Brightness (%)
South	30	35	8	100%
West	30.1	35	8	100%
North	30.2	35	8	100%
East	30	34	8	100%

The water temperature at Kayu Angin Bira Island in (Table 3) at each station has an average of 30.1°C. This temperature range is still in the normal range and is tolerable for aquatic biota. According to Rahman [15], marine biota can tolerate temperatures ranging from 20-35°C. Salinity measurements at the research site show that the salinity levels in the waters of Kayu Angin Bira Island ranged from 34-35 ppt. The salinity levels at all four stations are classified as suitable for the growth of clams, such as the findings of Jameson [16], which states that an optimal salinity range for clams is typically between 25-40 ppt.

The results of brightness level measurements in the waters of Kayu Angin Bira Island are 100%. Brightness is a critical factor that significantly impacts the survival of clams due to their association with clam symbionts, zooxanthella, which rely on sunlight for the photosynthesis process. This is further clarified by Romimohtarto et al. [17], as cited in Niartiningsih [3], regarding the importance of adequate light for zooxanthella's photosynthesis, making clear and shallow waters essential for clams. Furthermore, based on KEPMEN LH No. 51 tahun 2004 concerning marine biota, the brightness levels at Kayu Angin Bira Island satisfy the criteria for supporting a healthy biota population. Lastly, considering the pH requirements for bivalves, Hart and Fuller [18] state that bivalves thrive within a pH range of 5.8 to 8. Thus, water conditions at Kayu Angin Bira Island appear suitable as a habitat for clams.

3.1 Clam Abundance

Referring to KEPMEN LH No. 51 of 2004, the results of observations of the physical and chemical properties of seawater in the waters around Kayu Angin Bira Island indicate favorable conditions for the survival and growth of clams.

The figure below illustrates the relative abundance of clams at four different stations, categorized by variations in depth. The highest total relative abundance was observed at the eastern station, specifically at a depth of 3 meters is 20%. The lowest relative abundance was recorded at the southern, western, and northern stations, with only 8%.

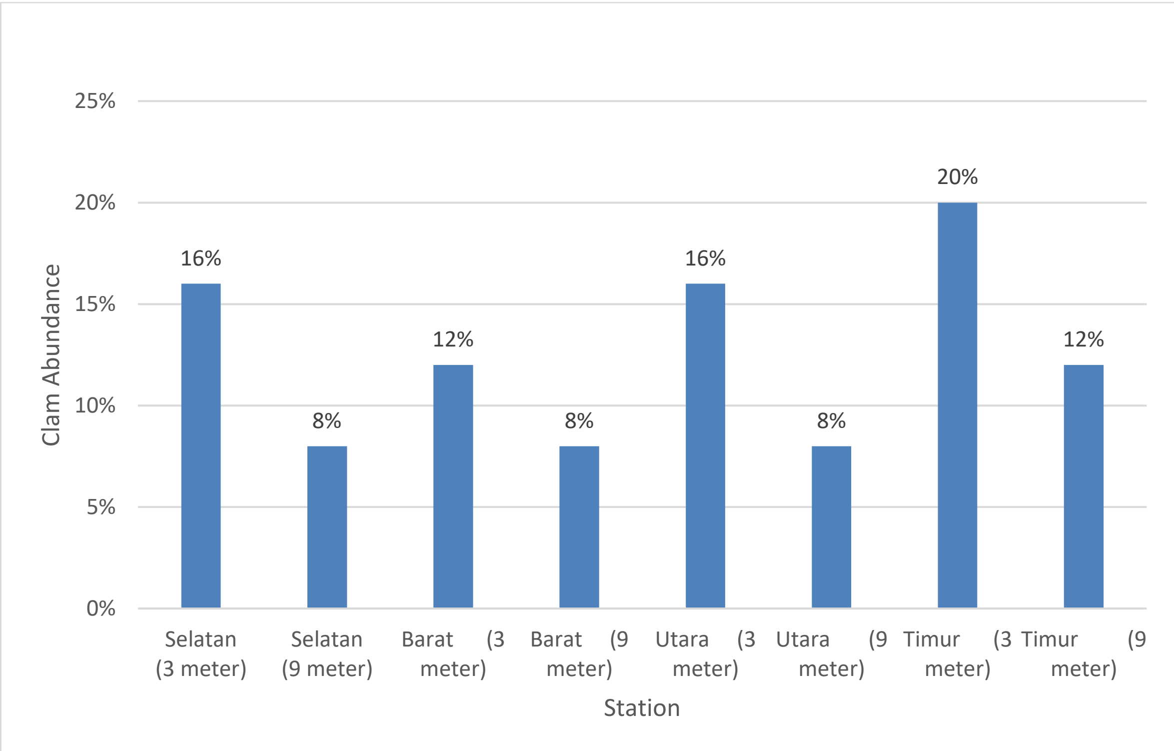

Fig. 2. Relative abundance of Clams in Kayu Angin Bira Island

In general, the clams found in the waters around Kayu Angin Bira Island are typically found on both living and dead massive coral substrates, as well as rocky substrates. Among the four stations, clams were more common at a depth of 3 meters compared to a depth of 9 meters. This phenomenon happens because the sunlight that reaches the seafloor at a depth of 3 meters is more ample, while sunlight diminishes significantly at a depth of 9 meters. This observation aligns with the statement of Rosewater [19], that sunlight plays a crucial role in the photosynthesis of zooxanthellae, which is highly beneficial for clams.

At all four observation stations categorized by depth differences, two types of clams, *T. Crocea* and *T. Squamosa*, were identified. The higher abundance of *T. Crocea* can be attributed to its unique habitat within coral reefs, which makes it challenging for people to harvest this species. *T. Crocea* is typically found attached to hard substrates, fully immersed in the substrate, particularly on massive corals and rocks. This observation aligns with Panggabean [20] description of *T. Crocea* as a small clam that thrives on hard substrates for complete shell immersion. Conversely, *T. Squamosa* was found in fewer observation locations, with only seven individuals recorded.

T. crocea was the most abundant species found at all stations. *T. crocea* species are more abundant than *T. squamosa species* due to the lack of utilization by the community of *T. crocea* species and the tendency of T*. crocea* species to live immersed in the substrate making it difficult to collect.

T. Crocea emerged as the most abundant species across all stations. Its higher abundance can be attributed to the limited use of *T. Crocea* by the local community and the species' tendency to inhabit substrates that are challenging to access.

On the other hand, *T. Squamosa* is the least commonly found clam species in the waters surrounding Kayu Angin Bira Island. This observation aligns with Nugroho and Ambariyanto's [21] statement, which suggests that clam populations in nature are predominantly composed of smaller species like *T. Crocea* and *T. Maxima*, while larger species such as *T. Derasa, T. Squamosa, H. Hippopus,* and *H. Porcellanus* are quite rare.

3.2 Clam Diversity and Uniformity

Based on the research results, the diversity and uniformity indices of clams at the four stations obtained varying results. The diversity and uniformity of clams in the waters of Kayu Angin Bira Island can be seen in Fig. 3.

Based on the data analysis, it's evident that the diversity index in the waters surrounding Kayu Angin Bira Island falls within the low category (H' < 1), while the uniformity index is categorized as high (E > 0.6).

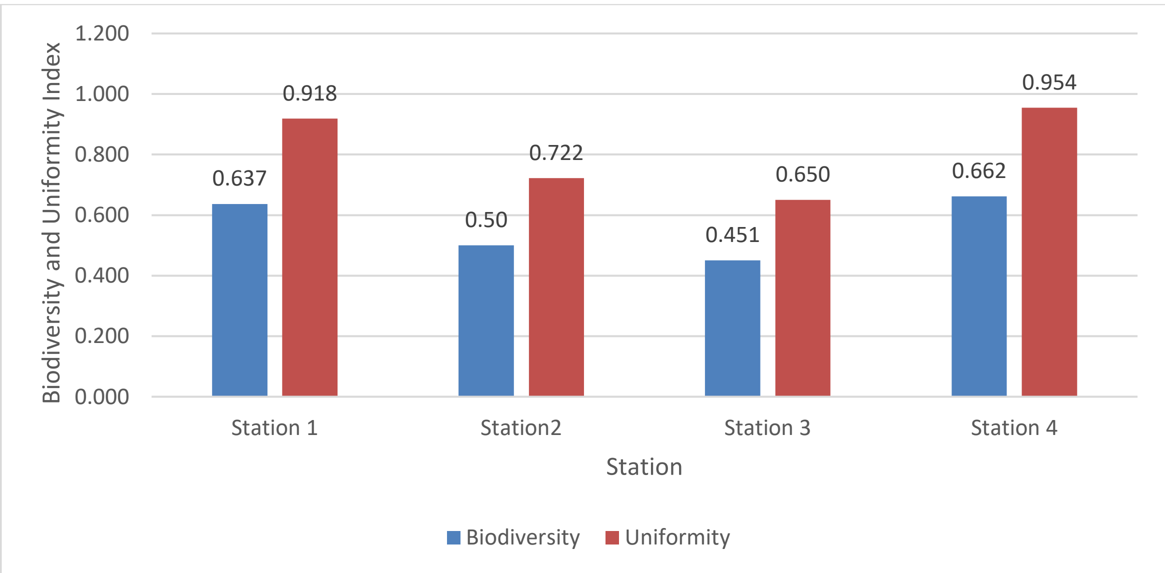

Fig. 3. Diversity and uniformity of Clams in Kayu Angin Bira Island

The diversity index across the four observation stations ranged from 0.451 to 0.662, which means that the diversity level is relatively low. This indicates that while productivity may be low, the ecosystem maintains a balanced state with moderate ecological pressure. The diversity index serves as a systematic representation describing the community's structure and facilitates the analysis of information regarding the types and quantities of organisms present. It's worth noting that the greater the number of species discovered, the higher the diversity index, though this value is influenced by the number of individuals of each species, as pointed out by Wilhm and Doris [22]. Krebs [23] also supports this perspective by indicating that a larger number of evenly distributed individuals will result in a higher diversity index.

While the uniformity index at the four observation stations ranged from 0.650 - 0.954 which means high population uniformity. According to Lind (1979) in Amin [24] "the uniformity index is close to one then the community is stable and the number of individuals between species is the same. In addition, the diversity and uniformity of biota in a body of water is highly dependent on the number of species in the community".

The uniformity index at the four observation stations ranged from 0.650 to 0.954, indicating a high level of population uniformity. As per Lind (1979), as cited in Amin [24], when the uniformity index approaches one, it signifies a stable community with a balanced distribution of individuals among species. Furthermore, it's important to note that the diversity and uniformity of biota in a body of water are strongly influenced by the number of species present within the community.

The results of research conducted in the waters of Kayu Angin Bira Island found 2 types of clams, namely *T. Squamosa* and *T. crocea*. *T. squamosa* found in the waters of Kayu Angin Bira Island has a blackish brown coat with a mixture of white spots. This clam was found at all four stations and totaled 7 individuals. *T. crocea* found a striking and beautiful coat color. *T. crocea was* found in 18 individuals and lived on *coral massive and* rock substrates. This clam has the most abundant population. This is evidenced by the discovery of this type of clam at all four observation stations, namely east, south, west and north.

The research conducted in the waters of Kayu Angin Bira Island identified two types of clams, specifically *T. Squamosa* and *T. Crocea*. *T. Squamosa*, characterized by a blackish-brown shell with white spots, was found at all four stations, totaling seven individuals. On the other hand, *T. Crocea* exhibited a striking and beautiful shell coloration. This species was encountered in 18 individuals and primarily inhabited massive coral and rock substrates. *T. Crocea* demonstrated the most abundant population, as evidenced by its presence at all four observation stations, namely east, south, west, and north.

3.3 Clam Distribution Pattern

To determine the spatial distribution pattern of clams in the waters of Kayu Angin Bira Island, the Morisita index was calculated. Based on the results of calculations using the Morisita Index shows the distribution pattern of clams in Kayu Angin Bira Island is uniform. Clam distribution pattern data can be seen in Table 4.

Table 4. Kima scatter value

Station	Morisita Index	Distribution Pattern
South	0.4	Uniform
West	0.26	Uniform
North	0.4	Uniform
East	0.74	Uniform

Based on the results presented in Table 4, the Morisita Index value varies across the stations, with the highest value observed at the East station (0.74) and the lowest values recorded at the South and North stations (0.4). The calculations of the Morisita Index at each station consistently indicate a uniform distribution pattern of clams. In all four stations, the Morisita Index is less than one, indicating a uniform pattern of clam distribution within these locations. This uniformity can be attributed to the availability of suitable habitat conditions that allow each species to find its own niche and food source. This observation aligns with Odum's [13] assertion that uniform distribution patterns emerge when there is a balanced level of competition among individuals or when there exists a positive antagonistic relationship that supports spatial distribution.

The uniform distribution of clams across the four stations is likely influenced by the substrates they inhabit and the availability of sunlight. As Suin [25] suggests, the physical and chemical factors that are evenly distributed within a habitat, along with the presence of food sources, play a crucial role in determining whether animals live in groups, random patterns, or uniform distributions.

According to Krebs (2003), distribution patterns are a result of various factors, including genetic traits and habitat preferences of individual species. Additionally, other factors such as the spatial and temporal distribution of food resources and competition for habitat resources due to adverse environmental conditions also contribute to the observed distribution patterns.

3.4 Relationship Between Clams and Coral Reefs

The correlation analysis reveals a strong and positive relationship between clam abundance and the percentage of coral reef cover in the waters surrounding Kayu Angin Bira Island, with a substantial correlation coefficient of 0.853 (as indicated in Table 2). Notably, the coefficient of determination (R square) obtained from our calculations is 0.7284, equivalent to 72.84%. This implies that the presence of clams is significantly influenced by the coral reef cover, accounting for 72.84% of the variation, while the remaining 27.16% is attributed to other contributing factors. Fig. 4 provides a visual representation of this correlation between coral reef cover and clam abundance.

According to Astuti (2017), the correlation coefficient (r) is positive, it signifies a direct and proportional relationship between variables X and Y. In simpler terms, as variable X increases, the value of variable Y also increases, as illustrated in Fig. 4. The results of our correlation analysis affirm a very strong relationship, which aligns with Neo's [2] statement that clams play a pivotal role in maintaining the balance of the coral reef ecosystem, acting as keystone species for coral reef communities. Consequently, clams share a directly proportional relationship with coral reefs.

"The decline in clam populations can be attributed to habitat destruction caused by clam poaching techniques that damage coral reefs. Some species of clams live attached to the coral substrate and stuck between the living corals, there are even species of clams that immerse themselves in the coral. To collect clams that live attached to the coral, it is usually done by damaging the coral using crowbars or iron picks so that the coral will be broken and damaged. If this continues, the damage to the coral will become worse and the clam population will automatically decrease" [26].

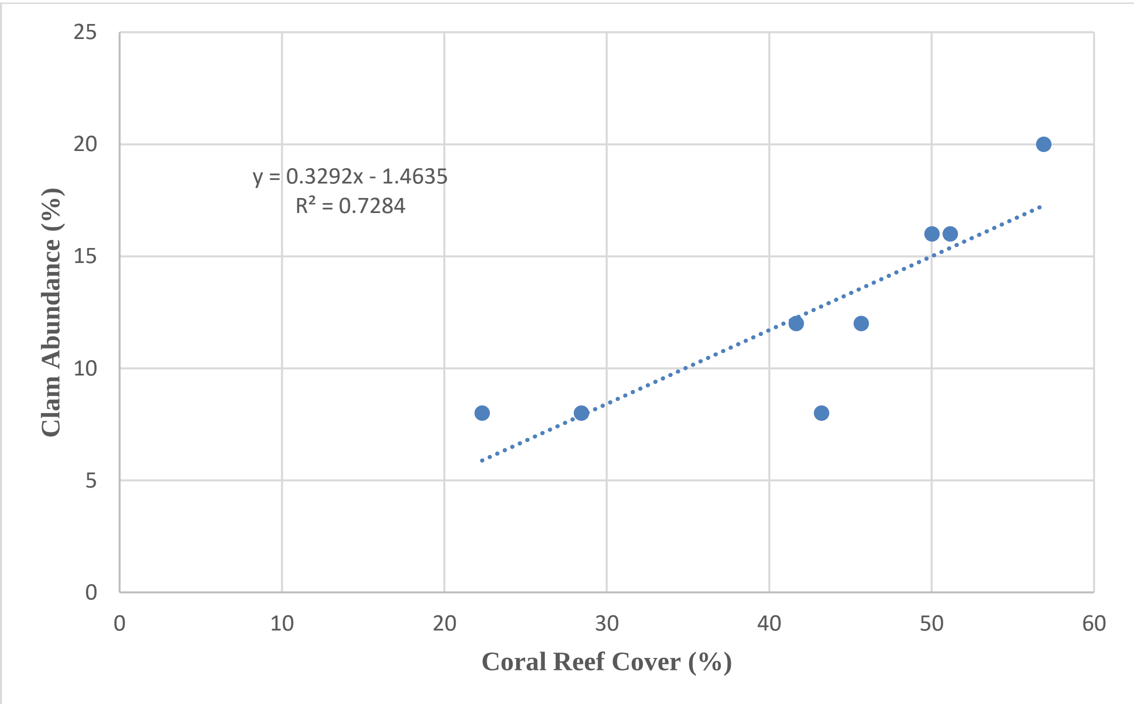

Fig. 4. Correlation of percent coral cover and clam abundance

The decline in clam populations can be vaused by habitat destruction resulting from clam poaching techniques that harm coral reefs. Certain clam species attach themselves to coral substrates, nestled among living corals, and some even immerse themselves within the coral structure. The collection of clams attached to coral typically involves damaging the coral using tools like crowbars or iron picks, leading to coral breakage and damage. If this practice continues, it will worsen coral damage and inevitably lead to a reduction in clam population.

4. CONCLUSION

Based on the results of research on the abundance and diversity as well as spatial distribution patterns of clams in the coral reef waters of Kayu Angin Bira Island, Kepulauan Seribu, the following conclusions were obtained:

In the waters surrounding Kayu Angin Bira Island, only two types of clams were discovered: *T. Squamosa* and *T. Crocea*, with a total count of 25 individuals. Across the four stations, categorized by differences in depth, the relative abundance of clams ranged from 8% to 20%. The diversity index falls within the low category, while the uniformity index registered in the high category. The spatial distribution pattern of clams in the waters surrounding Kayu Angin Bira Island appears to be uniform.

Based on the correlation of coral reef cover percentage and clam abundance, it a positive relationship, implying that changes in clam abundance, whether high or low, directly correspond to variations in the percentage of coral reef cover.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/107689