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*Research Article*

# Biodiversity of intertidal mollusks in Surigao City, Philippines

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## Abstract
Intertidal zones are crucial ecological interfaces, but there is a lack of comprehensive studies on mollusk communities in Surigao City, Philippines. This research aimed to assess intertidal mollusk profiles, including species density, diversity, evenness, and richness, addressing a knowledge gap in regional mollusk biodiversity. Using a belt transect quadrat method in three sampling areas during 2021, the study employed a descriptive correlation design to investigate relationships between mollusk profiles and seawater physico-chemical parameters (conductivity, dissolved oxygen, pH, salinity, and temperature). In Surigao City's Day-asan, Hikdop Island, and Sibale, 44 gastropod species (19 families) and 11 bivalve species (9 families) were identified. Conidae and Strombidae families dominated. Average seawater parameters were conductivity 51.33, dissolved oxygen 7.45, pH 7.84, salinity 32, and temperature 28.52. Day-asan exhibited the highest species count (49), followed by Hikdop Island (42) and Sibale Island (37). Hikdop Island had the highest species density and evenness, Day-asan had the highest species diversity index, and Sibale Island had the highest species richness. Mollusk profiles showed no significant differences between sampling areas, and a strong negative correlation between pH and species evenness was observed. Surigao City displayed diverse mollusk biodiversity, but a declining trend in diversity indices was noted. This study fills a critical knowledge gap in understanding mollusk community dynamics, providing essential baseline data for future conservation and management strategies in the region, while also shedding light on the impact of environmental factors on intertidal mollusk populations in Surigao City.

**Keywords:** Biodiversity, Mollusks, Species density, Species diversity, Species evenness, Species richness

## INTRODUCTION

Mollusks are one of the most diverse and numerous animal groups, inhabiting a wide range of aquatic and terrestrial settings and acting as ecosystem engineers by helping to build aquatic bottom ecosystems and providing habitat, protection, and food for a vast range of other taxa (Fortunato, 2015; Best, 2023). It has been integral to human society and culture for thousands of years. This can be seen from how they are used in a plethora of human activities and norms such as agriculture, cuisine, commerce, and tourism (Allison *et al*., 2011; Burgos *et al*., 2019; Prado-Carpio *et al*., 2018). They are abundant as evidenced by the various peoples who have used them in their ways of living, yet despite this, mollusks are faced with a challenge. According to the International Union for Conservation of Nature, or IUCN (2016), approximately 1088 species are classified as endangered or critically endangered, with 27 percent of those assessed being classified as data deficient, indicating insufficient data to assess conservation status fully. As of September 2016, the International Union for Conservation of Nature (IUCN) listed 507 endangered mollusk species, 7.0% of all evaluated mollusk species. Additionally, the IUCN listed nine mollusk subspecies as endangered. These numbers highlight the significant number of mollusk species that are classified as endangered, emphasizing the need for conservation efforts to protect these species and their habitats (IUCN, 2016). The continued threat to mollusk populations is detrimental not only to the environment and ecosystem but also mankind due to how mollusks are incorporated in the culture of people. The status of taxonomic studies on Mollusks in the Philippines is characterized by a significant focus on marine species. Publications on Philippine mollusks are predominantly centered on taxonomic and biodiversity research, with around 80% of the publications focusing on marine species (Ramos *et al*., 2018). A total of 64,898 Philippine mollusk records were compiled, comprised of 14,482 distinct species (Garcia and Anticamara, 2023). Studies have identified a diverse range of species, with a total of 31 species from the class Gastropoda and Bivalvia being documented. This emphasis on taxonomic and biodiversity research underscores the importance of Mollusks in the Philippines and its implications for biodiversity science and conservation (Ramos *et al*., 2018).

Apart from human consumption and usage, mollusks are also important to the environment. Mollusks serve as prey to various animal species including fishes and birds. They are also known to be decomposers and recyclers of waste material, making their local environment clean (Baderan *et al*., 2019). Aquatic mollusks, such as gastropods, can be utilized as biological indicators of environmental quality in surface water bodies and a reliable technique of evaluating environmental changes, such as salinity, added chemical, and pollution parameters (Alhejoj, 2017; Putro *et al*., 2017; Reguera *et al*., 2018; Shevchuk *et al*., 2021). Given how important mollusks are to environmental health and human consumption, it is certainly a big deal if mollusks were to face population decline in the coming years. Horsák *et al*. (2007) reported mollusk distribution and abundance in connection to environmental conditions, and there is published data on intertidal mollusks, notably bivalves and univalves, in Surigao City. As a result, this study aimed to fill a knowledge gap by investigating intertidal mollusks in connection to environmental variation in Surigao City, Philippines.

## MATERIALS AND METHODS

### Study area

The sampling sites of the study were Hikdop Island, Sibale Island and Arellano District of Surigao City. These islands were chosen as the study area because they are perceived to have diverse mollusk ecosystem.

Hikdop Island is one of the major islands in Surigao City with the location at latitude 9.8886° or 9° 53' 19" north longitude: 125.5225° or 125° 31' 21" east with an elevation of 182 meters (597 feet). Sibale Island have a total area of 3.08 square kilometers (1.19 square miles) and a coastline length of 11.07 kilometers (6.88 miles). The island is located at 9.8953, 125.5690, and its elevation is estimated to be 113 meters or 370.73 feet above mean sea level at these coordinates. Arellano District is part of the mainland district of Surigao City. It is composed of seven barangays and is home to a diverse mangrove and marine ecosystems. Moreover, this district is known to be one of the sources of marine product in the city.

### Research design

A quantitative research method was utilized specifically the descriptive and correlational designs. These designs were deemed appropriate because they sought to describe intertidal molluscs' status as to density, diversity, evenness, and richness. Correlational design was also used to determine the relationship between the molluscs' profile and seawater's physicochemical parameter. This method produces static features of the situation and establishes the relationship between different variables (McBurney and White, 2009).

### Data gathering procedure and ethics

Before conducting the study, permission of ethical approval was secured asked for from the local governments and related agencies. Afterwards, the needed materials for the study were prepared and brought to the study area. The belt transect line quadrat method sampling design was used. This sampling design is a technique that utilizes divisions in a study to acquire samples from a population. The area was divided into transects, which were further divided into quadrats. Three transects of one hundred meters in length were set up in three sampling stations in every sampling area. Five quadrats were placed within each transect, with the quadrats placed twenty meters apart. Before finding and counting species, the physicochemical indicators like conductivity (uS/cm), dissolved oxygen (mg/L), pH, salinity (ppt), temperature (◦C), and turbidity of the seawater (NTU), were recorded. These were meas-

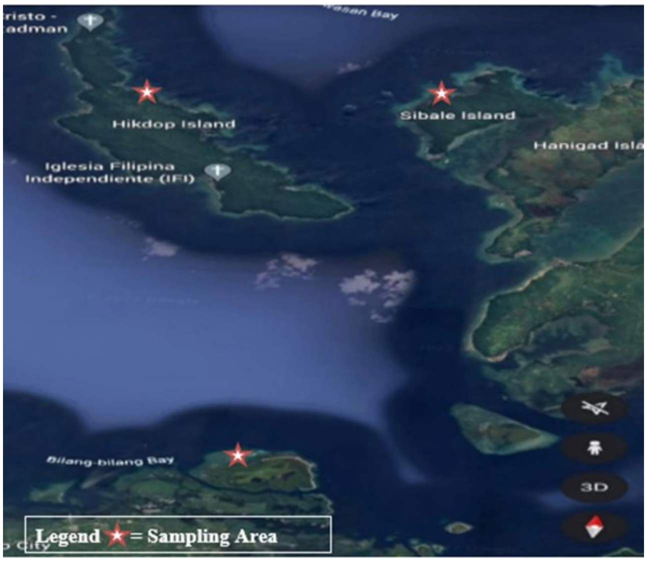


**Fig. 1.** *Map of the Research Locale showing sampling areas in Surigao City*

ured using a conductivity sensor, DO tester, pH meter, refractometer, thermometer, and turbidity sensor. All mollusks that were found by the researcher were counted and tallied. Species specimens was taken by the researchers to determine their taxonomic classifications from March to December 2021. The quantitative data of the mollusks was interpreted statistically using the statistical test.

### Data analysis

The study focused on the population density, species density, evenness, species richness, and overall species diversity of the intertidal mollusks and its correlation to the physico-chemical parameters.

Population density was calculated using the formula below:

Population Density =

$$\frac{\text{number of individuals of the same species}}{\text{area of the quadrat}} \quad \text{Eq. 1}$$

Species density is defined as number of species found per quadrat. It is calculated using the formula:

Species Density =

$$\frac{\text{summation of the number of species found in each quadrat}}{\text{number of quadrats per transect}} \quad \text{Eq.2}$$

Species evenness refers to how close in numbers each species in an environment is. The evenness of a community can be represented by Pielou's evenness index:

$$J = \frac{H'}{H'max} \quad \text{Eq.3}$$

where H' is the number derived from the Shannon diversity index and $H'_{max}$ is the maximum value of H'.

Species richness is determined using the Margalef's diversity index, also known as D. The equation below is the formula for the Margalef's diversity index.

$$D = \frac{(s-1)}{\ln N} \quad \text{Eq.4}$$

where s equals the number of species represented, and N equals the number of individual organisms.

As for species diversity, the Shannon-Wiener diversity index will be used. The index can be solved using the following formula:

$$H' = -\sum_{i=1}^{S} p_i \, In \, p_i \quad \text{Eq.5}$$

where $p_i$ is the proportion of the total number of individuals in the population in species "i" and S is the number of species observed.

As for statistical analysis, Pearson's correlation coefficient was used to determine the strength of the relationship between the species profile and the physico-chemical indicators of the seawater.

## RESULTS AND DISCUSSION

### Species of mollusks in Surigao City

A total of forty-four species of gastropods belonging to nineteen families were found in the three sampling areas in Surigao City. Day-asan in Arellano District of Surigao City had the highest number of species found with forty-nine, followed by Hikdop Island with forty-two species and Sibale Island with thirty-seven species. The family of Conidae and Strombidae had the highest number of species recorded, with seven species, followed by Cypraeidae, with five species. The family of Angariidae, Buccinidae, Chilodontidae, Costellariidae, Haliotidae, Mitridae, Naticidae, Potamididae, Trochidae, Turbinellidae, Volutidae had the lowest number of species found with only one. Eight species belonging to eight families were only found in Day-asan and two species belonging to two families were only found in Hikdop Island. The abundance of gastropods depends on the type of community structure and increases with increasing vegetation age (Cañada, 2020).

As to species of mollusks under bivalves, eleven species belonging to nine families were found in the three sampling areas. Cardiidae and Veneridae had the highest number of species found with two species each and all other species had only one each.

Sibale Island had the highest number of bivalves found, with 10, and Day-asan and Hikdop Island had nine species each. *Decapecten radula* under the family of Pectinidae was only found in Sibale Island, while *Lioconcha castrensis* of Veneridae family was only found in Day-asan.

Table 3 presents the physico-chemical parameters of seawater in the three sampling areas in Surigao City. Sibale Island had the highest average conductivity at 51.85, and Day-asan had the lowest at 50.51. Regarding dissolved oxygen, Sibale Island had the highest average with 7.49, while Day-asan had the lowest with 7.42. The dissolved oxygen concentration in ocean water usually remains between 7 and 8 mg/l (Virginia Institute of Marine Science, 2021). As to pH, Day-asan had the highest average at 7.97, and Hikdop had the lowest average at 7.78. Byrne *et al*. (1988) and Clayton and Bryne (1993) reported that the average pH of seawater is 8.1. The highest average salinity was 32.45 in Day-asan, while the lowest salinity was 31.41 in Sibale Island. The salt concentration in seawater (its salinity) was about 35 parts per thousand. In other words, about 3.5% of the weight of seawater comes from the dissolved salts. Hikdop Island had the highest average temperature at 28.58, while Day-asan had the lowest at 28.45. The physico-chemical parameters of saltwater in the three sampling regions did not differ significantly; these parameters were within mollusk-friendly environmental conditions.

**Table 1.** Intertidal mollusks species under gastropods/univalves in Surigao City

| Family | Species | Day-asan | Hikdop | Sibale |
|---|---|---|---|---|
| Angariidae | *Angaria Delphinus* | | | |
| Buccinidae | *Cantharus sp* | | | |
| Bursidae | *Bursa cubaniana* | | | |
| | *Bursa corrugate* | | | |
| Cerithiidae | *Cerithium nodulosum* | | | |
| | *Cerithium atratum* | | | |
| Chilodontidae | *Euchelus atratus* | | | |
| Conidae | *Conus capitaneus* | | | |
| | *Conus quercinus* | | | |
| | *Conus imperialis* | | | |
| | *Conus marmoreus* | | | |
| | *Conus miles* | | | |
| | *Conus vexillum* | | | |
| | *Conus ebraeus* | | | |
| Cypraeidae | *Cypraea sp.1* | | | |
| | *Cypraea sp.2* | | | |
| | *Cypraea arabica* | | | |
| | *Cypraea tigris* | | | |
| | *Monetaria annulus* | | | |
| Haliotidae | *Haliotis asinine* | | | |
| Mitridae | *Mitra eremitarium* | | | |
| Muricidae | *Chicoreus brunneus* | | | |
| | *Chicoreus torrefactus* | | | |
| Naticidae | *Natica fasciata* | | | |
| Neritidae | *Nerita polita* | | | |
| | *Nerita undata* | | | |
| Potamididae | *Terebralia palutris* | | | |
| Strombidae | *Canarium labiatum* | | | |
| | *Canarium urceus* | | | |
| | *Conomurex luhuanus* | | | |
| | *Euprotomus bulla* | | | |
| | *Lambis lambis* | | | |
| | *Lambis Scorpius* | | | |
| | *Lentigo lentiginosus* | | | |
| Tegulidae | *Tectus niloticus* | | | |
| | *Tectus fenestratus* | | | |
| | *Tectus virgatus* | | | |
| | *Tectus pyramis* | | | |
| Trochidae | *Trochus masculatus* | | | |
| Turbinellidae | *Vasum turbinellus* | | | |
| Turbinidae | *Turbo bruneus* | | | |
| | *Lunella cinerea* | | | |
| | *Astralium calcar* | | | |
| Volutidae | *Cymbiola vespertillo* | | | |

*Legend: Blue area indicates the presence of the mollusk species in the area*

**Species density in Day-asan, Hikdop Island, and Sibale**

Table 4 provides information on species density in Day-asan for March to December. It revealed that March had the highest mean species density of 13.93 while December had the lowest mean species density with 7.87. The average mean of species density for the month of March to December is 10.35. It was observed that there was a decreasing trend in species density. This could be due to various environmental changes, such as habitat deterioration caused by anthropogenic activities such as overharvesting, which were detected in the sampling regions. Furthermore, the increased tourism activities in the area could contribute to the decline in species density. Tourism greatly impacts African marine ecosystems and biodiversity (Karani and Failler, 2020) and 141 countries (Habibullah *et al.*, 2016).

In the species density of Hikdop Island, it was seen that March had the highest mean density of 14.20 while December had the lowest mean density of 7.80. The average mean for species density from March to December is 11.19. A decreasing trend of species density was observed during the span of the study, which could be attributed to the overexploitation of communities in the sampling area. Anthropogenic activities are the primary source of recent changes in marine biodiversity, and their continuance may result in habitat destruction

**Table 2.** Intertidal mollusks species under bivalves in Surigao City

| Family | Species | Day-asan | Hikdop | Sibale |
|---|---|---|---|---|
| Arcidae | *Anadara trapezia* | ✓ | ✓ | ✓ |
| Cardiidae | *Tridacna maxima* | ✓ | ✓ | ✓ |
| | *Vasticardium elongatum* | ✓ | ✓ | ✓ |
| Malleidae | *Maleus maleus* | ✓ | ✓ | ✓ |
| Pharidae | *Pharella javanica* | ✓ | ✓ | ✓ |
| Pectinidae | *Decatopecten radula* | | | ✓ |
| Pinnidae | *Atrina vexillum* | ✓ | ✓ | ✓ |
| Pteriidae | *Pinctada margaritifera* | ✓ | ✓ | ✓ |
| Spondylidae | *Spondylus regius* | ✓ | ✓ | ✓ |
| Veneridae | *Lioconcha castrensis* | ✓ | | |
| | *Periglyta puerpera* | | ✓ | ✓ |

*Legend: The blue area indicates the presence of the mollusk species in the area*

**Table 3.** Average physico-chemical parameters of seawater in three sampling areas

| Sampling area | Parameters | Mean±SD |
|---|---|---|
| Day-asan | Conductivity (µS/cm) | 50.51±0.04 |
| | Dissolved Oxygen (mg/L) | 7.42±0.10 |
| | pH | 7.97±0.13 |
| | Salinity (ppt) | 32.45±0.14 |
| | Temperature (◦C) | 28.45±0.09 |
| Hikdop | Conductivity (µS/cm) | 51.63±0.31 |
| | Dissolved Oxygen (mg/L) | 7.45±0.07 |
| | pH | 7.78±0.05 |
| | Salinity (ppt) | 32.13±0.03 |
| | Temperature (◦C) | 28.58±0.18 |
| Sibale | Conductivity (µS/cm) | 51.85±0.20 |
| | Dissolved Oxygen (mg/L) | 7.49±0.05 |
| | pH | 7.79±0.04 |
| | Salinity (ppt) | 31.41±0.06 |
| | Temperature (◦C) | 28.53±0.06 |

**Table 4.** Species density in Day-asan, Hikdop Island, and Sibale, Surigao City

| Month | Day-asan | Hikdop Island | Sibale |
|---|---|---|---|
| | MeanS±D | Mean±SD | Mean±SD |
| March | 13.93±4.20 | 14.20±6.47 | 13.80±1.78 |
| April | 13.13±3.80 | 13.87±5.90 | 13.67±1.62 |
| May | 12.40±3.74 | 13.73±6.05 | 12.93±1.30 |
| June | 11.47±4.37 | 12.93±5.49 | 12.20±1.60 |
| July | 9.93±3.71 | 11.80±5.07 | 11.53±1.50 |
| August | 9.53±3.60 | 10.60±4.85 | 10.40±1.04 |
| September | 8.93±3.83 | 10.00±4.51 | 9.13±1.10 |
| October | 8.27±3.25 | 8.73±4.23 | 8.07±1.33 |
| November | 8.00±2.95 | 8.27±3.76 | 7.33±0.92 |
| December | 7.87±2.86 | 7.80±3.30 | 6.80±0.87 |
| Average | 10.35±3.62 | 11.19±4.96 | 10.59±1.26 |

(García Molinos *et al*., 2016; Halpern *et al*., 2019; Mona *et al*., 2019).

Like the other two sampling areas, the species density of intertidal mollusks in Sibale Island, March had the highest species density while December had the lowest species density mean. As observed in the area, overharvesting is the main reason for decreased species density. Overharvesting, habitat degradation, and changes in water regimes are among the key factors affecting mollusk biodiversity in coastal Kenya (Alati *et al*., 2020), and Cambodia (Ngor, 2018). The average mean species density value from March to December was 10.59. Comparing the three sampling areas, Hikdop Island had the highest species density value at

**Table 5.** Species richness in Day-asan, Hikdop Island, and Sibale, Surigao City

| Month | Day-asan | Hikdop Island | Sibale |
|---|---|---|---|
| | **Mean±SD** | **Mean±SD** | **Mean±SD** |
| March | 6.94±0.77 | 5.45±1.80 | 6.03±0.36 |
| April | 7.16±1.01 | 5.50±1.83 | 6.06±0.37 |
| May | 7.27±0.97 | 5.52±1.82 | 6.15±0.40 |
| June | 7.04±1.22 | 5.55±1.77 | 6.11±0.42 |
| July | 6.91±1.35 | 5.69±1.77 | 6.21±0.42 |
| August | 6.90±1.70 | 5.68±1.87 | 6.23±0.55 |
| September | 6.60±1.89 | 5.54±2.13 | 6.08±0.41 |
| October | 6.42±1.70 | 5.31±1.95 | 5.98±0.64 |
| November | 6.35±1.66 | 5.34±1.92 | 5.92±0.60 |
| December | 6.45±1.63 | 5.36±1.78 | 5.81±0.51 |
| Average | 6.80±1.36 | 5.49±1.86 | 6.06±0.35 |

11.19, followed by Sibale Island with 10.59 and Day-asan had the lowest species density value with 10.35. The observed variation in mollusk species density among the three sampling areas may be attributed to differences in habitat diversity and environmental conditions. Hikdop Island's higher species density could be influenced by its more varied and favorable ecological niches, while Day-asan's lower density may result from a less diverse habitat and less optimal environmental conditions for mollusk species.

### Species richness in Day-asan, Hikdop Island, and Sibale, Surigao

Table 5 presents the species richness of intertidal mollusks in Surigao City. As shown in the result, May had the highest mean of species richness value at 7.27 followed by April with 7.16. The month of November had the lowest species richness value, with 6.35. The average mean species richness value from March to December is 6.80.

As to species richness in Hikdop Island, July had the highest mean species richness value with 5.69 followed by August at 5.68, while October had the lowest mean species richness value of 5.31. The average mean species richness for Hikdop Island from March to December is 5.49.

For the species richness in Hikdop Island, the month of July had the highest mean species richness value of 5.69 followed by August with 5.68, while October had the lowest species richness value of 5.31. The average mean species value for Hikdop Island from March to December was 5.49.

Comparing the three sampling areas, Day-asan had the highest mean species richness value, followed by Sibale Island, while Hikdop Island had the lowest mean species richness value, 5.49. Species richness exhibited significant variations that were consistent with natural processes in ecosystems, and its cycles can be disrupted by natural or anthropogenic activities such as pollution and habitat overexploitation, which are the primary drivers of changes in species richness and community structure (Okorondu *et al*., 2022).

### Species diversity in Day-asan, Hikdop Island, and Sibale

Table 6 describes the species diversity of intertidal mollusks in Day-asan, Surigao City. March had the highest species diversity index with 3.11, followed by April with 3.10. Meanwhile, December had the lowest species diversity index of 3.00. The average mean for species diversity for the ten-month sampling period was 3.03. As to species diversity of intertidal mollusk in Hikdop Island, March and April had the highest mean species diversity index of 3.14 followed by May with 3.13, while

**Table 6.** Species diversity in Day-asan, Hikdop Island, and Sibale, Surigao City

| Month | Day-asan | Hikdop Island | Sibale |
|---|---|---|---|
| | **Mean±** | **Mean±** | **Mean±** |
| March | 3.11±0.34 | 3.14±0.37 | 3.11±0.07 |
| April | 3.10±0.37 | 3.14±0.38 | 3.13±0.07 |
| May | 3.15±0.41 | 3.13±0.35 | 3.16±0.05 |
| June | 3.07±0.50 | 3.12±0.35 | 3.15±0.07 |
| July | 3.00±0.52 | 3.11±0.36 | 3.16±0.05 |
| August | 3.02±0.57 | 3.07±0.38 | 3.15±0.07 |
| September | 2.95±0.59 | 3.05±0.40 | 3.10±0.06 |
| October | 2.96±0.52 | 2.99±0.41 | 3.05±0.11 |
| November | 2.95±0.52 | 2.98±0.41 | 3.02±0.13 |
| December | 3.00±0.45 | 2.96±0.36 | 2.99±0.08 |
| Average | 3.03±0.47 | 3.07±0.37 | 3.10±0.07 |

December had the lowest species diversity index of 2.96. The average mean species diversity index for the 10 months sampling period was 3.07. The species diversity of intertidal mollusks in Sibale Island showed that the data revealed that May and July had the highest species diversity indices of 3.16, followed by June with 3.15. Meanwhile, December had the lowest diversity index at 2.99. The average mean for species diversity during the ten-month sampling period is 3.10. The data revealed a decreasing trend of the species diversity index, which could be attributed to anthropogenic activities observed in the area. Pollution and disturbance caused by agricultural development, transportation, and aquaculture, according to Cannicci (2009), have harmed mollusk biodiversity.

The diversity indices of the three sampling areas did not vary significantly, but the Sibale Island had the highest diversity index with 3.10, followed by Hikdop Island with 3.07, while Day-asan had the lowest diversity index with 3.03. Diversity could be an indicator of the ecosystem's health, and any change in this factor can be attributable to negative or positive changes in the community (Martinez *et al*., 2015).

**Species evenness in Day-asan, Hikdop and Sibale**

Table 7 provides information on the species evenness of intertidal mollusks in Day-asan, Surigao City. The month of December had the highest species evenness value, 0.92, while April had the lowest species evenness value, 0.87. The average mean species evenness during the sampling period is 0.89. The species evenness of Hikdop Island shows that March, April September, October and November had the same species evenness value of 0.97 while May, June, July, August and December had the same species evenness value of 0.96. The average mean of species evenness for the ten-month sampling month was 0.96. As to species evenness in Sibale Island, December and August had the highest species evenness value of 0.95, while March had a value of 0.92. The average mean species evenness value for the ten-month sampling period is 0.94. The species evenness values of the three sampling areas do not vary significantly, but comparing the three sampling areas, Hikdop Island had the highest species evenness value of 0.96 followed by Sibale Island of 0.94, while Day-asan had the lowest value of 0.89. Individual species creatures or species populations do not exist in nature, but they are part of an assemblage of species populations that live together in a specific habitat and benefit from the influence of certain ecological characteristics (Pakhira, 2018).

Table 8 exhibited the ANOVA results indicating the comparison of the profile of intertidal mollusks between the sampling areas. Gleaned from the Table are the p-values of 0.96, 0.53, 0.97, and 0.30 when the profile of the intertidal mollusks of the three sampling areas were compared in terms of density, richness, diversity, and evenness. The null hypotheses are not rejected since these p-values are greater than 0.05 significance level. These results imply that the profile of the mollusks in Day-asan, Hikdop island, and Sibale island do not significantly differ from each other.

The result can be attributed to the same community structures in the sampling areas, which are mainly seagrass structures and substrate cover and are close to a mangrove ecosystem and coral reef area. Moreover, the sampling sites are affected by anthropogenic activities like overharvesting, increased tourism activities and ecosystem degradation.

Table 9 presents the relationship between the physico-

**Table 7.** Species evenness in Day-asan, Hikdop Island, and Sibale, Surigao City

| Month | Day-asan | Hikdop Island | Sibale |
|---|---|---|---|
| | Mean±SD | Mean±SD | Mean±SD |
| March | 0.88±0.08 | 0.97±0.01 | 0.92±0.03 |
| April | 0.87±0.08 | 0.97±0.01 | 0.93±0.03 |
| May | 0.89±0.09 | 0.96±0.01 | 0.93±0.02 |
| June | 0.88±0.10 | 0.96±0.01 | 0.94±0.02 |
| July | 0.88±0.11 | 0.96±0.02 | 0.94±0.03 |
| August | 0.89±0.11 | 0.96±0.01 | 0.95±0.02 |
| September | 0.88±0.10 | 0.97±0.01 | 0.94±0.02 |
| October | 0.90±0.09 | 0.97±0.01 | 0.94±0.02 |
| November | 0.90±0.09 | 0.97±0.01 | 0.94±0.02 |
| December | 0.92±0.07 | 0.96±0.01 | 0.95±0.01 |
| Average | 0.89±0.09 | 0.96±0.01 | 0.94±0.02 |

**Table 8.** Comparison of the profile of intertidal mollusks in sampling areas

| Variable | F | P | Decision | Interpretation |
|---|---|---|---|---|
| Density | 0.04 | 0.96 | NR | NS |
| Richness | 0.72 | 0.53 | NR | NS |
| Diversity | 0.03 | 0.97 | NR | NS |
| Evenness | 1.47 | 0.30 | NR | NS |

*Legend: Decision = R (Rejected; NT (Not Rejected); Interpretation = S (Significant); NS (Not Significant)*

**Table 9.** Relationship between the physico-chemical parameters and the profile of Intertidal mollusks

| Parameter | Profile | R | p | D | I |
|---|---|---|---|---|---|
| Conductivity | Density | 0.10 | 0.79 | NR | NS |
| | Richness | -0.33 | 0.39 | NR | NS |
| | Diversity | 0.09 | 0.82 | NR | NS |
| | Evenness | 0.41 | 0.28 | NR | NS |
| Dissolved Oxygen | Density | -0.03 | 0.93 | NR | NS |
| | Richness | -0.20 | 0.60 | NR | NS |
| | Diversity | -0.28 | 0.47 | NR | NS |
| | Evenness | -0.42 | 0.27 | NR | NS |
| pH | Density | 0.08 | 0.83 | NR | NS |
| | Richness | 0.34 | 0.37 | NR | NS |
| | Diversity | -0.15 | 0.70 | NR | NS |
| | Evenness | -0.73 | 0.02 | R | S |
| Salinity | Density | -0.04 | 0.93 | NR | NS |
| | Richness | 0.16 | 0.69 | NR | NS |
| | Diversity | -0.10 | 0.80 | NR | NS |
| | Evenness | -0.24 | 0.53 | NR | NS |
| Temperature | Density | 0.27 | 0.48 | NR | NS |
| | Richness | -0.04 | 0.91 | NR | NS |
| | Diversity | 0.08 | 0.84 | NR | NS |
| | Evenness | 0.06 | 0.87 | NR | NS |
| Turbidity | Density | 0.01 | 0.99 | NR | NS |
| | Richness | 0.19 | 0.62 | NR | NS |
| | Diversity | -0.01 | 0.98 | NR | NS |
| | Evenness | -0.16 | 0.69 | NR | NS |

*Legend: Decision = R (Rejected; NT (Not Rejected); Interpretation = S (Significant); NS (Not Significant)*

chemical parameters of seawater and the profile of intertidal mollusks in Surigao City. The Table revealed p -values that were greater than 0.05 level of significance when the relationship between the physicochemical parameters of the seawater in three sampling areas and the profile of the intertidal mollusks was measured. This led to the nonrejection of the null hypotheses, indicating that the parameters and the profiles are not significantly related to each other.

However, a p-value of 0.02 was obtained between pH and evenness. The null hypothesis was rejected since the p-values were less than 0.05 level of significance. This implied that the two variables were correlated. The negative r-value, or -0.73 entailed a strong inverse correlation. This meant that a decrease in pH lead to higher evenness and an increase in pH led to a decrease in evenness. This result is consistent with the findings of the study by Wagey *et al*. (2015) that pH was negatively correlated to the abundance and evenness of mollusks.

Based on the study's findings, the pH in the sampling areas ranged from 7.75 to 8.4, which was beyond the neutral value of 7. Guerra-Garcia *et al*. (2011) demonstrated the effects of pH in mollusks and obtained pH values ranging from 8 to 8.33. In relation to this, a higher abundance of mollusks was associated with neutral pH and the abundance and diversity of mollusks was independent of the fluctuations of pH. This result was supported by Sharma *et al*. (2013), which indicated the negative relationship between the fluctuations of pH in the abundance and diversity of mollusks in Surigao City, Philippines.

The present research findings give baseline information on how environmental factors influence the size and diversity of intertidal mollusk populations in Surigao City. Assessing and maintaining coastal ecosystem biodiversity is critical because coastal ecosystems produce a high share of fish and shellfish supplies. Obtaining trustworthy information regarding the distribution and number of creatures present in each ecosystem or habitat is essential for practical conservation.

## Conclusion

Surigao City had a moderate to a high diversity of intertidal mollusks. There were species of intertidal mollusks that were unique in each sampling area. The physicochemical parameters of seawater in the three sampling areas of Surigao City were within normal values. There was a decreasing trend in terms of species density and species richness in the three sampling areas of Surigao City. The species density, diversity, evenness, and richness of intertidal mollusks in the three sampling areas of Surigao City did not vary significantly. The identified mollusks in Surigao City signify the area's ecological richness and biodiversity. Particularly, the varying species distribution underscores the importance of these mollusks in contributing to the local marine ecosystem's complexity and resilience. It is suggested that local government units should strictly implement environmental policies that protect marine resources and encourage the establishment of protected areas. Moreover, they should conduct periodic monitoring of mollusks using smart conservation management and research activities related to managing and developing marine resources. The Bureau of Fisheries and Aquatic Resources (BFAR) is encouraged to conduct quarterly monitoring and survey on the sampling area to identify whether this is a decrease or increase in the diversity of intertidal mollusks in the area. Moreover, they are encouraged to implement the developed mollusks monitoring system proposed in this study to conserve the marine resources in the area. The presence of mollusks in an environment can have insightful impacts by contributing to ecological balance through their roles in nutrient cycling, water filtration, and providing food for other species. Conversely, the absence of mollusks may disrupt these ecological functions, potentially leading to imbalances in the ecosystem and affecting the overall health of the environment.

## Conflict of interests

The authors declare that they have no conflict of interest.

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