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Mollusk Species Diversity in Mangrove Ecosystems of Northern Samar: Basis in the Design of Mangrove Rehabilitation Programs

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Keywords
mollusk, mangrove ecosystem, species richness and evenness, mangrove rehabilitation

Abstract
This study was conducted to assess the mollusks species diversity in the mangrove ecosystems of Northern Samar which included coastline of the University of Eastern Philippines (Study Site I), Brgy. Langob, Laoang, Northern Samar (Study Site II), Sitio Bel-at, Brgy Progress, Biri, Northern Samar (Study Site III) and Lalaguna Mangrove Protected Area in San Isidro, Lavezares, Northern Samar (Study Site IV). In the four (4) study sites, a comprehensive survey revealed the presence of ten (10) distinct mangrove species, which were classified into five (5) diverse families. A remarkable total of 343 individual mangroves were recorded during the study. Forty-nine (49) mollusk species were identified belonging to 17 different families of Class Gastropoda, six (6) families of Class Bivalvia and one (1) of Class Polyplacophora with a total of 935 individuals of mollusks. Shannon diversity indices showed that mangrove species in study site II had a greater diversity index of 1.7109 compared to the other sites that have lesser diversity. Simpson's species dominance should the highest value of 0.4425 in study site IV. Based also on the Shannon diversity indices, the mollusk highest number of individual species of 2.6341 (29 species) was in study site I which is considered low diversity. The Simpson's species dominance had the highest value of 0.3349 in study site II, while the species richness had the highest value of 1.773 in study sites III and IV, and species evenness had the highest value of 0.7823 in study site I. Mangrove rehabilitation/restoration program could therefore be implemented by the local government units in Northern Samar and the University of Eastern Philippines.

1. Introduction

The Philippines boasts an impressive mollusk population, consisting of approximately 22,000 species, as documented by Cabrera (1987). This accounts for approximately 10% of the estimated global mollusk species richness, which is at least 200,000 species, as indicated by Rosenberg (2014) and further supported by Ramos et al. (2018). Mollusks hold great ecological significance, contributing to the overall health of ecosystems, as well as playing a crucial role in the Philippine economy and public health. They fulfill vital functions within the ecosystem, such as providing nutrition, as noted by Van Der Wal (1996), and serving as habitats, as emphasized by Gutierrez et al. (2003). Moreover, in specific cases, they even contribute to the enhancement of ambient environmental conditions, as demonstrated by Coen et al. (2007).

Mollusks exhibit remarkable diversity and abundance, occupying various aquatic and terrestrial habitats. They play a vital role as ecosystem engineers, actively shaping aquatic bottom environments and serving as habitats, sources of protection, and food for numerous other species. Throughout history, mollusks have held significant importance for humans, and to this day, they remain economically valuable on a global scale.

Mollusks have successfully colonized a wide range of habitats, spanning from the depths of the sea to high mountain regions. Within mangrove swamps, they are particularly abundant in the tropical littoral zones (Shanmugam and Vairamani, 2009; JT Masagca et al., 2010). In these swamps, mollusks and crustaceans stand out as the most prominent faunal components (Macnae, 1968; Morton, 1990; JTMasagca et al., 2010). Mollusks belong to the classification of shellfish, which represents the second most diverse group of animals in terms of numbers (De Vera et al., 2015). These creatures are highly susceptible to

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environmental changes due to their soft bodies, shells, and permeable skin. Nonetheless, they have managed to adapt to various habitats, including mangroves. Unfortunately, modern mollusk populations are facing decline as a result of habitat disturbances caused by pollution, typhoons, and overexploitation by coastal communities.

The Philippines stands as a true biodiversity gem, showcasing an unparalleled richness in both quantity and proportion. Recognized among the prestigious group of 17 mega-diverse nations, the country owes its distinction to a combination of factors, including its unique geographical isolation, varied habitats, and remarkable levels of endemism. Notably, the Philippines secures the fifth spot globally in terms of plant species diversity, sheltering an astonishing 5% of the planet's flora. Furthermore, when it comes to mangroves, the Philippines takes the lead, harboring a staggering 50% of the world's approximately 65 mangrove species. Unfortunately, the country's rich biodiversity, including its mangroves, is being threatened by both human activities and natural disturbances, leading to ongoing losses (Garcia et al., 2014).

With its vast expanse of over 7,000 islands, the Philippines stands as an archipelagic nation blessed with one of the most extensive coastlines globally, spanning an impressive distance of 36,289 km. Due to its favorable geographical location, the country exhibits a remarkable level of diversity when it comes to mangroves. Notably, according to research conducted by Premavera et al. (2004), Kathiresan and Bingham (2001), and KB Garcia et al. (2014), the Philippines is estimated to be the home of at least half of the world's approximately 65 mangrove species. Additionally, the country holds recognition as one of the top 15 nations worldwide in terms of the abundance of mangroves, as noted by Long and Giri (2011).

Mangrove forest ecosystem has a complex structure and high viability of abiotic conditions and therefore provides many different microhabitats a multitude of invertebrates' fauna. The feeding and bioturbation activities of gastropods contribute significantly to the mangrove fauna, particularly through their consumption of algal detritus. This important role has been highlighted in studies by Bouillon et al. (2002), Kristensen et al. (2008), Lee (2008), and Zvonareva et al. (2016).

Mollusks, a prominent group of invertebrates in the mangrove community, are believed to have a crucial role in shaping and maintaining the mangrove ecosystem (Nagelkerken et al., 2008; Printrakoon et al., 2008; as mentioned in Kabir et al., 2014). They are recognized as significant contributors in transferring organic matter from mangroves to higher trophic levels, such as fish and birds. Despite their ecological and economic importance, there is limited quantitative information available regarding the diversity, density, and biomass of mollusks in mangroves (Jiang and Li, 1995; Nagelkerken et al., 2008; Printrakoon et al., 2008; as cited in Kabir et al., 2014), and numerous mollusk species are currently under the threat of extinction (Kabir et al., 2014).

Bivalves and gastropods are recognized as the primary mollusk species found in mangrove forests and exhibit distinct zonation patterns both horizontally and vertically. Gastropods are widely distributed throughout the mangrove forest, likely due to their mobile nature, whereas bivalves tend to be limited to a narrow zone closer to the sea. This distribution pattern is influenced by factors such as feeding preferences, larval settlement restrictions, and sediment characteristics, including pH and organic matter content. The distribution and population dynamics of mangrove mollusks in the intertidal zone are intricately tied to various factors. As we move towards the lower intertidal zone, the richness and abundance of these mollusks tend to increase. However, it is not solely the location that affects their diversity and abundance. The physical structure of the mangrove forest, the presence of mangrove detritus, and the age of the mangroves also play significant roles in influencing the overall characteristics of the mangrove mollusk community (Kabir et al., 2014).

Various factors within the mangrove ecosystem significantly impact the mollusk community. The structure of the mangrove forest, including pneumatophores and epiphytic algae, combined with sediment characteristics enriched in organic carbon, higher pore-water salinities, and smaller grain size, along with the composition of nutrient-poor, tannin-rich mangrove detritus, influence mollusk abundance, biomass, and diversity. Comparative studies within mangrove stands also highlight variations in benthic biomass and diversity correlated with mangrove age (Kabir et al., 2014).

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The significant density and biomass of mollusks found in mangroves provide compelling evidence of their ecological significance in transforming primary production derived from trees into animal tissues that are accessible to higher trophic levels (Kabir et al., 2014).

Shrimp pond aquaculture is responsible for over 50% of the decline in mangrove areas, while other factors contributing to the global degradation of mangrove systems include extensive urban, agricultural, and industrial development, as well as pollution and overfishing (Macintosh 1996; Vallela et al., 2001, cited by Kabir et al., 2014). These losses of mangroves have led to a decrease in biodiversity and the abundance of macrofauna, particularly seafood. To address the habitat loss of mollusks and other marine species, various management approaches and methods, such as mangrove rehabilitation or restoration, are employed. This approach can involve coordinated efforts between the community and the Department of Environment and Natural Resources (DENR) to restore the habitat for mollusks and promote their recovery.

Limited research has been conducted on mollusks in mangrove forests, especially in the specific province mentioned. Therefore, the study on mollusk species diversity in the mangrove ecosystems of Northern Samar: basis in the design of a mangrove rehabilitation program was conceptualized.

2. Materials and Methods

The study was conducted from December 2019 to March 2020. As baseline data were collected by the researcher, the sampling was done only once in every sampling site. The study focused on the diversity of mollusks and mangrove species in Northern Samar, specifically in the coastline of the University of Eastern Philippines campus (Study Site I), Bgy Langob, Laoang Northern Samar (Study Site II), Bel-at, Brgy. Progress, Biri, Northern Samar (Study Site III) and Islet of San Isidro, Lavezares, Northern Samar, a Mangrove Protected Area (MPA) (Control Site) Figure 1.

This study determined the mollusk species in the mangrove ecosystem to provide information on its biodiversity in terms of diversity, dominance, richness and evenness indices using the Shannon index and Simpson index of dominance.

The physico-chemical is monitored or measured through its salinity, temperature, pH and the type of substrates to determine if it is meeting the quality for its mangrove ecosystem.

The biological observation involves the collection and identification of mangrove and mollusk species. The data on mangrove species were collected in three (3) 10 m x 10 m quadrat in every sampling site, while the mollusk species were collected in the three (3) 1 m x 1 m quadrat or plot within the 10 m x 10 m quadrat. The sampling process commenced from the shoreline and extended towards the sea (De Vera et al., 2015). The results obtained from the study will be valuable in formulating a mangrove rehabilitation program aimed at conservation and protection efforts.

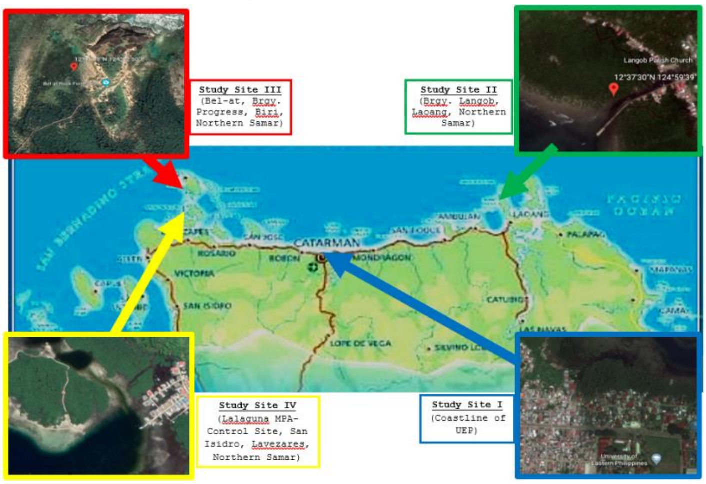

Figure 1. Location of the study sites of Northern Samar.

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Sampling Technique

Transect-line plot sampling technique was used in measuring species diversity of mangrove species. Three (3) 100 meters transect lines were stretched out along the seaward to landward portion of the mangrove forest, to validate the study sites being studied (Morallos, 2019). A 10m x 10m quadrat (English et al. 1997) and an interval of 20 meters to the next transect-line in every sampling site, the mangrove species were identified and counted inside the plot or quadrat, the observation and collection of specimen of mangrove species present in the study area was done. Samples of the mangrove species were identified by the use of mangrove identification guide of the Philippines and it was verified by a local taxonomist of the Fisheries Department or in the College of Science. For the diversity of mollusks, the sampling was done within the 10 m x 10 m quadrat, three (3) 1 m x 1 m quadrat was laid out to establish the mollusk plots. All mollusk species were identified and counted inside the plot or quadrat where the observation and collection of specimen of mollusk species present in the study area was done. The sampling process began from the shoreline and extended towards the open sea (De Vera et al. 2015).

Mollusks Collection

Only live mollusks were collected within the nine (9) quadrats in each sampling site were collected/handpicked. Mollusks that could not be identified were consulted with local fisherfolk and experts specializing in mollusks (De Vera et al. 2015). Samples were classified based on class of mollusks. Identification was based on the family, scientific name and its local name. All the identified mollusks were verified by Dr. Helena T. de la Rosa, former Biology professor/Biologist.

Physico-chemical characteristics in four (4) study sites in Northern Samar

Water temperature, pH, salinity, and substrate type were measured and/or observed during each sampling visit, using the standard measuring devices such as the thermometer, refractometer and pH meter.

Data Analysis

The data were analyzed based following formulas (De Vera et al., 2015).

a) **<u>Shannon index of diversity</u>**,

$$H = \sum_{i=1}^{S} -(P_i * \ln P_i)$$

Where:

H = the Shannon diversity index

Pi= fraction of the entire population made up of species i

s = numbers of species encountered

Σ = sum from species 1 to species S

Note: The power to which the base e (e = 2.718281828.......) must be raised to obtain a number is called the natural logarithm (ln) of the number.

<u>To calculate the index:</u>

1. Divide the number of individuals of species #1 you found in your sample by the total number of individuals of all species. This is Pi

2. Multiply the fraction by its natural log (P1 * ln P1)

3. Repeat this for all of the different species that you have. The last species is species "s"

4. Sum all the - (Pi*ln Pi) products to get the value of H

b) <u>Simpson index of dominance</u>[5]

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where:

D = index of dominance

n = number of individuals in a species

N = total number of individuals in all species

The value N is the total number of organisms of all species, and n is the total number of organisms of a particular species. Zero represents infinite diversity, and 1 represents no diversity. Since this is not intuitive, D is often subtracted from 1 to give the higher values.

c) Species Richness index (Menhinick's index)

$D = s/\sqrt{N}$

D - species richness by Menhinick's index

s – number of different species

N – total number of individual organism in a sample

- Species richness is the number of different species present in an area. The more species present in a sample the "richer" the area.

d) **Species Evenness index**

$J = H/H_{max}$

Where:

J = species evenness

H = index of species diversity

$H_{max} = \log_n S$

Results and Discussions

Table 1 shows a total of ten (10) mangrove species were identified, categorized into five (5) different families, and a total of 343 individuals were observed across the four (4) study sites. This count is lower compared to the findings of Morallos (2019) in Northern Samar, which identified 15 mangrove species belonging to nine (9) families and 11 genera. Among the identified species, the family Rhizophoraceae had the highest representation with four (4) species. These species are: *Rhizophora apiculate* Blume, *Bruguira gymnorrhiza* (Linnaeus), *Rhizophora mucronata* and *Rhizophora stylosa.* Followed by the family Avicenniaceae with three (3) species, these were the *Avicennia marina*, *Avicennia officinalis* and *Avicennia rumphiana* Hall.f. Based on the results *Rhizophora apiculata* Blume belonging to family Rhyzophoraceae is present in all study sites, which is the highest number of individuals. The mangrove species mentioned serves as an indicator of the intermediate estuarine zone. *R. apiculata* is known for its ability to withstand high currents and tides, as well as its tolerance for a maximum salinity of up to 65 ppt. It exhibits optimal growth at a salinity range of 8-10 ppt (Robertson & Alongi, 1992, as cited by Canizares, et al., 2016). These findings would mean that species of mangroves are still available; however, there is a great need for the increase of their frequency considering their multifarious functions in the ecosystem.

Table 1. The Species of Mangrove Encountered in Four (4) Study Sites in Northern Samar

Family	Species	Common Name	STUDY SITES			
			I	II	III	IV
Avicenniaceae	*Avicennia marina*	Miyapi	x	-	-	-
	Avicennia officinalis	Miyapi	x	x	x	-
	Avicennia rumphiana Hall.f.	Miyapi	-	x	-	-
Combretaceae	*Lumnitzera littorea*		x	x	x	-
Myrsinaceae	*Aegiceras corniculatum*	Saging-saging	-	x	x	-
Rhizophoraceae	*Rhizophora apiculata Blume*	Bakhaw Lalaki	x	x	x	x

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	Bruguira gymnorrhiza (Linnaeus)	Pototan	-	-	-	x
	Rhizophora mucronata	Bakhaw Babae	-	-	x	x
	Rhizophora stylosa		x		x	x
Sonneratiaceae	*Sonneratia alba*	Pagatpat	x	x	-	-
	Total number of Species		6	6	6	4
	Total number of Families		4	5	4	1

Legend: x present in the study sites

– Absent in the study sites

Figure 2 illustrates the diversity indices, including species diversity, dominance richness, and evenness. Among the study sites, Study site II (Laoang, Northern Samar) exhibited the highest mangrove species diversity, richness, and evenness indices, while Study site IV (Lalaguna MPA Control Site, San Isidro, Lavezares, Northern Samar) recorded the highest species dominance. The diversity values for the Shannon-Weiner index were classified according to the scale developed by Fernando (1998) as cited by Morallos (2019). It shows a scale of >3.5000 (very high diversity), 3.0000-3.44999 (high), 2.5000-2.9999 (low diversity), and <1.9999 (very low diversity), where zero (0) means no diversity (Morallos, 2019). The study reveals that the diversity indices of four (4) sites were not similar and all were very low diversity indices. The study further reveals that the number of mangrove species is not equally distributed and considered very low diversity indices. The results indicate that most mangroves found in the four (4) study sites were between four (4) to six (6) species only. This means that the abundance of the species in all sites is not equally distributed resulting to a very low value of species diversity indices (Morallos, 2019). The reduction in mangrove diversity is attributed to the impact of pollution, including the introduction of fertilizers, pesticides, sewage, and other harmful chemicals, which are transported through river systems from upstream sources. These pollutants have detrimental effects on the organisms inhabiting mangrove forests, leading to their decline. Additionally, oil pollution can suffocate mangrove trees by clogging their roots. Deforestation for fuel and climate change which affects the sea levels are continuously rising. Human activities and the presence of coastal communities can disrupt the delicate equilibrium of mangrove ecosystems, leading to their destruction. Mangroves face various threats, including dredging, filling, and diking, as well as water pollution caused by oil spills and herbicides. Additionally, the expansion of urban development contributes to the loss of mangrove habitats. The permanent deforestation of mangrove species and the exploitation of the remaining forests have negative consequences, reducing the diversity of mangrove species and altering the overall structure of these ecosystems (Malik et al., 2015 as cited by Morallos, 2019). Very low species diversity indices among the four study sites are due to natural and human impact. Patches of mangrove forest are clear cut through timber harvesting and collection of firewood which contribute to the degradation of mangrove species (Malik, et al. 2015 cited by Morallos, 2019). The natural impact caused by the strong typhoon may reduce the species diversity, production, and growth of mangrove species. Annually, the Philippines faces the vulnerability of storm surges and powerful winds brought by typhoons. As a response to these climate events, the planting of mangroves has been recognized as an adaptation strategy (Garcia et al., 2013 as cited by Morallos, 2019). This means that the human and natural impact should be considered in the rehabilitation programs/projects in the community level that will be implemented in such event (Morallos, 2019). This further means that due to the low mangrove species diversity indices, mangrove rehabilitation or restoration should be implemented by the concerned agencies.

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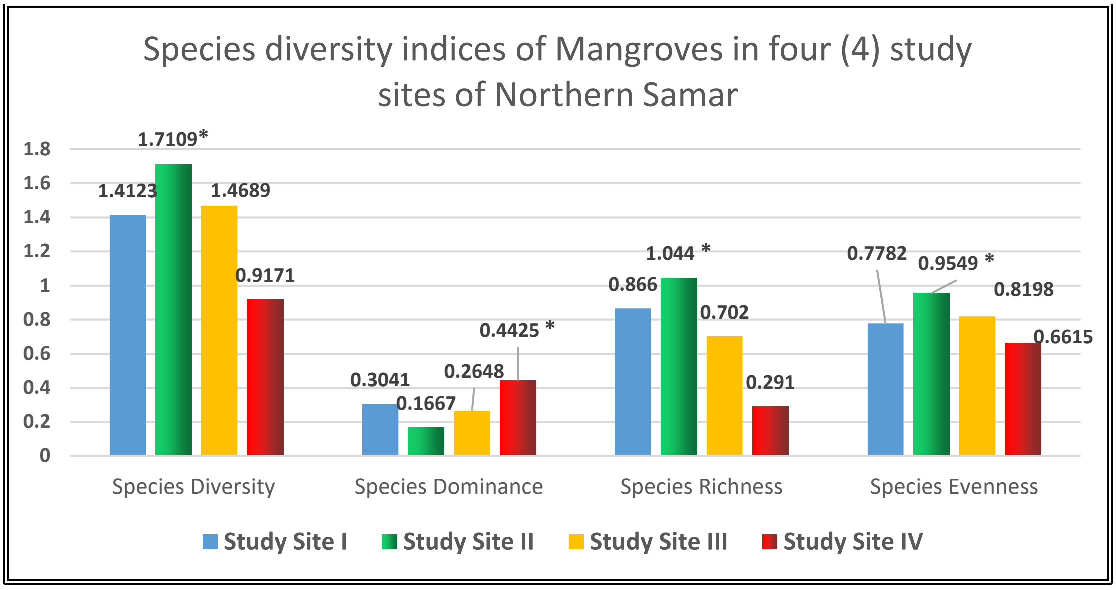

Fig. 2. Species Diversity Indices of Mangroves in Four (4) Study Sites in Northern Samar.

The mollusk species encountered in four (4) study sites in Northern Samar

A total of 17 families and 41 species belonged to Class Gastropoda; six (6) families and seven (7) species of Class Bivalvia and one (1) family with one (1) species for Class Polyplacophora with a total mollusk species of 935 individuals encountered in the four (4) study sites as shown in Table 2.

Study Site I (UEP, Catarman, Northern Samar) had 25 gastropod species which belonged to 11 families, and four (4) bivalve species which belong to four (4) families. Study Site II (Brgy. Langob, Laoang, Northern Samar) had 15 gastropod species which belong to eight(8) families, two (2) bivalve species which belong to one (1) family and one (1) species of class Polyplacophora with one (1) family. Study site III (Bel-at, Brgy. Progress, Biri, Northern Samar) had 20 gastropod species which belong to nine (9) families and two (2) species of bivalves which are belonged to two (2) families. Study Site IV (Lalaguna, Brgy. San Isidro, Lavezares, Northern Samar) had 20 gastropod species which belong to 10 families and two (2) species of bivalves which belong to two (2) families. Table 2 further reveals that *Littoraria intermedia* (Philippi, 1846), *Terebralia palustris* (Linnaeus, 1767) *Terebralia sulcata* (Born, 1778), *Nerita plicata* (Linnaeus, 1758), *Nerita undata* (Linnaeus, 1758) and *Tectus fenestratus* (Gmelin, 1791) which belong to the family Littorinidae, Potamididae, Neritidae and Trochidae, respectively were all present in in four (4) study sites.

Based on the results, the *Clypeomorus petrosus* (Wood, 1828) belonging to family Cerithiidae was the most abundant species in the Study Site I with the total individuals of 82. The *Terebralia sulcata* (Born, 1778) belonging to family Potamididae had the highest number of individual species encountered in the Study Sites II and III with the total of 111 and 49, respectively. Whereas, *Littoraria intermedia* (Philippi, 1846) belonging to family Littorinidae was highest in Study Site IV with the total of 55 species encountered.

Dela Cruz and Camacho, as cited by De Vera et al., 2015 documented the occurrence of nine (9) mollusk species within the natural mangrove stand located at the river mouth of Kayanga and Dasol Bay, Pangasinan. Conversely, the manmade mangrove stand in western Pangasinan recorded a total of 14 mollusk species. The higher diversity and richness of species observed in Victory, Bolinao can be attributed to a larger area dedicated to mangrove species plantation. The presence of mangroves, which offer both habitat structure and food resources, likely influenced the prevalence of mollusk species in Pilar, Bolinao, as well as the equitable distribution of species in Tori-tori, Anda. The Pilar mangrove rehabilitation area was planted with three (3) species of *Rhizophora*, while Tori-tor, Anda was established with a single (1) species of *Rhizophora* (De Vera et al., 2015).

Vivencio, (2011) documented a total of 13 mollusk species. Among these, nine (9) species were gastropods, namely *Cassidula nucleus*, *Chicoreus sp*., *Canus figulinus*, *Littoraria scabra*, *Nasarrius* (Zeuxis) *olivaceus*, *Nerita albicilla*, and *Telescopium Telescopium*. Additionally, four (4) species of pelecypods were identified, namely I*sognomon ephippium*, *Katelysia japonica*, *Lanceolaria grayana*, and *Polymesoda erosa*.

The most common identified mollusk species in all study sites were *Nerita plicata* (Linnaeus, 1758) *Nerita undata* (Linneaus, 1758) *Terebralia palustris* (Linnaeus, 1767) *Terebralia sulcata* (Born, 1778) *Tectus fenestratus* (Gmelin 1791). *Terebralia sulcata* (Born, 1778) had the highest value 21.39 percent relative abundance followed by *Littoraria intermedia* (Philippi, 1846) with the value of 13.80 percent. Higher diversity of snails (e.g. *Terebralia sulcata*, *Terebralia palustris* and *Littoraria intermedia*) in mangrove ecosystem occurs because of sufficient food. The population of *T. palustis* alone is capable of consuming approximately five times the daily leaf production of *Rhizophora mucranata*. Furthermore, the leaf consumption by *T. palustis* is not limited to low tide; these species also feed during high tides (Fratini et al., 2004 as cited by Kabir et al., 2014). Bivalves exhibit remarkable proficiency as filter feeders, proficiently capturing suspended particles from diverse origins (Plaziat 1984; Kathiresan and Bingham 2001 as cited by Kabir et al., 2014). Furthermore, specific bivalves, like shipworms (Teredinidae), contribute significantly to the decomposition and recycling of deceased wood, emphasizing their ecological role in this process (Ponder et al., 2000 as cited by Kabir et al., 2014).

Research indicates that an upsurge in snail population density can have a considerable adverse effect on the quality and diversity of epiphytic algae (Wtason, 2002 as cited by Kabir et al., 2014). On the contrary, certain gastropods, such as *T. palustris*, play a role in the consumption of *A. marina* and Rhizophoracea propagules, thereby influencing the process of mangrove restoration and regeneration (Plaziat, 1984; Dahdouh-Guebas, 2001; Fratini et al., 2004; Bosire et al., 2008 as cited by Kabir et al., 2014). Additionally, some gastropods act as seed predators in mangrove ecosystems, playing a crucial role in shaping plant community structure (Smith et al., 1989 as cited by Kabir et al., 2014).

Table 2. The Mollusk Species Encountered in Four (4) Study Sites of Northern Samar.

No. Family	Family	No. Species	Species	English Name	Study Sites			
					I	II	III	IV
Class Gastropoda								
1	Angariidae	1	*Angaria strata* (Reeve, 1843)	Sea snail	-	-	-	x
2	Buccinidae	2	*Cantharus fumosus* (Dillwyn, 1817)		-	-	-	x
3	Cerithiidae	3	*Cerithium tenellum* (Sowerby 1855)		-	-	x	x
		4	Clypeomorus coralium (Kiener, 1841)	Necklace or channeled cerith	x	-	x	x
		5	*Clypeomorus petrosus* (Wood, 1828)		x	-	-	-

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		6	*Rhinoclavis nobilis* (Reeve, 1855)		x	-	-	-
4	Conidae	7	*Conus thallasiarchus* (Sowerby I, in Sowerby II, 1834)	Strawberry conch	-	-	-	x
5	Cypraeidae	8	*Cypraea annulus* (Linnaeus, 1758)	ring cowrie	x	-	-	-
6	Littorinidae	9	*Littoraria ardouiniana* (Heude, 1885)	Mangrove periwinkle	x	-	-	-
		10	*Littoraria coccinea* (Gmelin, 1791)	Mangrove periwinkle	x	-	-	-
		11	*Littoraria intermedia* (Philippi, 1846)	Mangrove periwinkle	x	x	x	x
		12	*Littoraria pallescens* (Philippi, 1846)	Mangrove periwinkle	x	-	-	-
		13	*Littoraria (Littoraria) irrorata*	Mangrove periwinkle	x	x	x	-
7	Melongenidae	14	*Volema (Melongena) paradisiaca* (Roding, 1798)	Crown conches	x	x	x	-
8	Muricidae	15	*Cronia sp.*		x	x	x	-
9	Nassariidae	16	Nassarius (Niotha) gruneri (Dunker, 1846)	Dog whelks	-	-	x	-
10	*Neritidae*	17	*Nerita insculpta* (Recluz, 1841)	Marine snail (Sihi)	x	-	-	-
		18	*Nerita japonica* (Dunker, 1860)	Marine snail (Sihi)	-	-	x	x
		19	*Nerita (Theliotyla) planospira* (Anton 1839)	Marine snail (Sihi)	-	x	x	-
		20	*Nerita (Ilynerita) planospira*	Marine snail (Sihi)	-	-	x	x
		21	*Nerita plicata* (Linnaeus, 1758)	Marine snail (Sihi)	x	x	x	x
		22	*Nerita polita* (Linnaeus, 1758)	Marine snail (Sihi)	x	-	x	x
		23	*Nerita trifasciata* (Le Guillon, 1841)	Marine snail (Sihi)	x		x	x

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		24	*Nerita undata* (Linneaus, 1758)	Marine snail (Sihi)	x	x	x	x
		25	*Nerita turrita* (Gmelin, 1791)	Marine snail (Sihi)	x	-	-	-
11	Onchidiidae	26	*Onchidella nigricans* (Quoy & Gainard, 1832)	Air breathing sea slug	-	x	-	-
12	Planaxidae	27	*Planaxis sulcatus* (Born, 1791)	Periwinkle	x	-	-	-
13	Potamididae	28	*Cerithidia cingulata* (Gmelin, 1791)	Sea snail	-	-	x	-
		29	*Telescopium telescopium* (Linnaeus, 1758)	Horn snail (Bagongon)	-	x	-	-
		30	*Terebralia palustris* (Linnaeus, 1767)	Sea snail (Daludalo)	x	x	x	x
		31	*Terebralia sulcata* (Born, 1778)	Sea snail (Daludalo)	x	x	x	x
14	Strombidae	32	*Strombus (Canarium) labiatus labiatus* (Roding 1798)	True conchs (Guyod)	-	-	-	x
		33	*Strombus (C.) urceus* (Linnaeus, 1758)	True conchs (Guyod)	x	-	-	x
		34	*Strombus (C.) urceus urceus* (Linnaeus, 1758)	True conchs (Guyod)	-	-	-	x
15	Trochidae	35	*Monodonta labio*, (Linnaeus 1758)	Toothed top shell	x	x	x	-
		36	*Tectus fenestratus* (Gmelin 1791)	Fenestrate top shell	x	x	x	x
		37	*Trochus maculatus* (Linne 1758)	Maculated top shell	x	-	-	x
16	Turbinellidae	38	*Vasum turbinellum* (Linnaeus, 1758)	Vase snail	-	-	x	-
17	Turbinidae	39	*Bolma rugosa (Linnaeus, 1767)*	Marine gastropod	-	-	-	x
		40	*Turbo (Marmarostoma) bruneus* (Roding 1791)	Dwarf turban/sea snail	-	x	-	-

		41	*Turbo (Lunella) cinereus* (Born, 1778)	Smooth moon turban(sea snail)	x	x	-	-
				Number of Gastropod Species	**25**	**15**	**20**	**20**
Class Bivalvia								
1	Arcidae	1	*Anadara antiquata* (Linnaeus, 1758)	Ark clams (Ark Shell)	x	-	-	x
2	Corbiculidae	2	Polymesoda (Geloina)coaxans (Gmelin, 1791)	Mangrove clam (Tuway)	x	-	-	-
3	Lucinidae	3	*Ctena decussata* (O G Costa, 1829)	Marine bivalve	x	-	x	-
4	Pinnidae	4	*Atrina pectinata pectinata (Linnaeus, 1767)*	Comb penshell	-	-	x	-
5	Spondylidae	5	*Spondylus squamosus* (Schreibers, 1793)	Spiny oyster (true oyster)	-	-	-	x
6	Veneridae	6	*Circe scripta* (Linnaeus, 1758)	Script Venus	-	x	-	-
		7	*Gafralium pectinatum* (Linnaeus, 1758)		x	x	-	-
				Number of Bivalve Species	**4**	**2**	**2**	**2**
Class Polyplacophora								
1	Chitonidae	1	*Acanthopleura gemmata (Blainville, 1825)*	Chiton (Tarukog)	-	x	-	-
				Number of Polyplacophora Species		**1**		
				Total Number of Species per study site	**29**	**18**	**22**	**22**

Legend: **x** present

- absent

Species diversity indices were presented in Figure 3. Based also on the Shannon diversity indices, the mollusk highest number of individual species of 2.6341 (29 Species) was in study site I which is considered low diversity. All the three (3) study sites were very low mollusk diversity. The Simpson's species dominance had the higher value. All the three (3) study sites were very low mollusk diversity. The Simpson's species dominance had the highest value of 0.3349 in study site II, while the species richness had the highest value of 1.773 in study site III and IV, and species evenness had the highest value of 0.7823 in study site I. Salmo (2010) as cited by De Vera et al., 2015, noted that there is evidence of distinct patterns in the biomass fluctuations of mollusk species as mangrove stands age. The maturation of mangroves leads to the development of a forest structure and increased biomass, which provides mollusks with both shelter and a food source. Previous research has shown that the composition of mollusk assemblages is

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significantly influenced by vegetation and sediment characteristics, particularly due to the presence of high forest biomass and organic content. Salmo's study specifically identified seven sand-associated species: *A. perspectiva, C. cancellata, N. arcularis, N. polita, P. philberti, T. linhuafelis,* and *V. Vulpecula*. Additionally, *A. nodifera* and *C. cingulata* were observed to exhibit increased biomass in mature mangrove stands. Moreover, rehabilitated mangroves have been found to support the colonization of mollusks. The mollusks diversity under study was observed to be affected by irrational or over-exploitation practices, human exploding population, human activity stress in the natural beds of mollusks, expansion of agricultural diversity and activities showing lower species diversity indices. The effects of natural calamities on the biodiversity of mollusks in the Philippines appear to have greater significance. Sudden heavy downpour, typhoons, floods and tidal surges can lead to death of mollusks (Masagca et al., 2010).

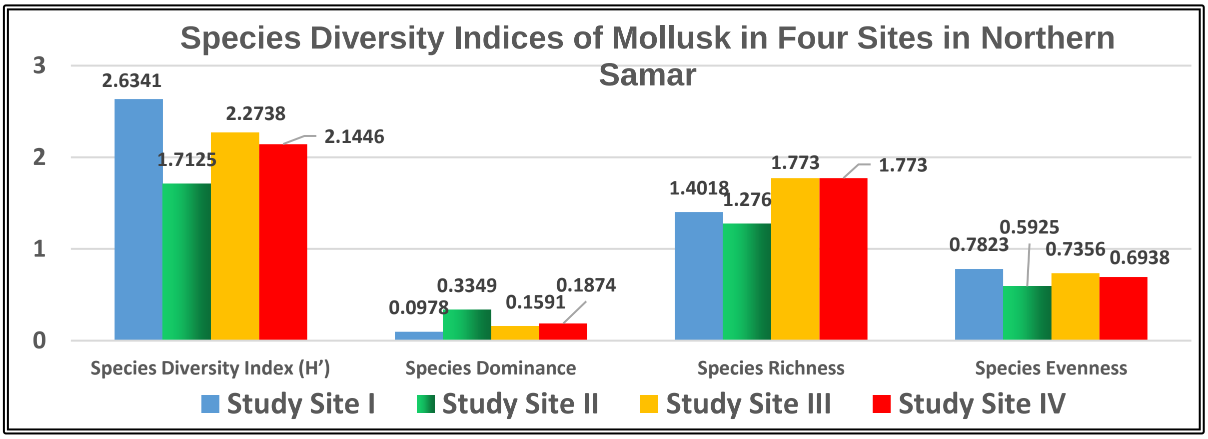

Figure 3. Species Diversity Indices of Mollusk in Four (4) Study Sites in Northern Samar.

Figure 4 showed the physico-chemical characteristics of the four study sites were within the normal range and therefore beneficial and favorable to all marine organisms.Mangrove species are more productive under conditions of moderate salinity of about 25 ppt (Salmo III & Juinio-Menez, 2001 cited by Morallos, 2019). Mangroves are tree species that thrive in intertidal zones characterized by high salinity levels. However, the ability of different species to tolerate salt varies (Liang, 2008). Mangrove species have a common characteristic of tolerating high-salinity seawater (Liang, et al., 2008, as cited by Morallos, 2019). This means that the abundant species can adapt in terms of changing environmental conditions (Morallos, 2019). All mangrove species showed optimal growth at 50% seawater (Khan, 2001). The standard salinity range of coastal and marine waters ranges from 30-35 ppt (DAO No. 2016-08). The study sites with higher salinity were Study Sites I, III and IV. The growth and physiological processes of mangroves exhibit variations due to their intricate structure and differences in flooding patterns, tidal inundation, rapid nutrient influx, and soil types. This complexity has been noted in studies by Clough (1984) and Naidoo (1987) as cited by Morallos (2019).

Mangroves exhibit various adaptations to cope with the dynamic environment, including the exclusion of salt through their roots (Scholander, 1968; Hegemayer, 1997, cited by Kabir, et al. 2014). Salinity levels within a mangrove can vary from 0.5 to 35 parts per thousand (ppt). One factor contributing to this variation is the tidal influence, where the salinity matches that of polyhaline seawater when the mangrove is flooded by the sea (Ng and Sivasothi, 2001, cited by Kabir, et al. 2014). The standard temperature for water quality ranges from 25ºC – 31ºC (DAO No. 34, s. 1990; Morallos, 2019). This implies that the change of temperature of the soil and water will lead to the decline of the growth and development including the species richness and species diversity of the mangrove ecosystem (Morallos, 2019). The standard range of pH for coastal and marine waters ranges from 6.5-8.5 (DAO No. 2016-08; cited by Morallos, 2019). According to Salmo III & Juinio Menez (2001) as cited by Morallos, (2019), the mangrove flora are more

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productive under conditions of neural acidity (pH 6 to 7), year-round and exposure to moderate terrestrial-water runoff. This means that various sites are within the normal condition and favorable in the decomposition process of microbes that would increase the nutrients toward the productivity of mangrove species (Morallos, 2019).

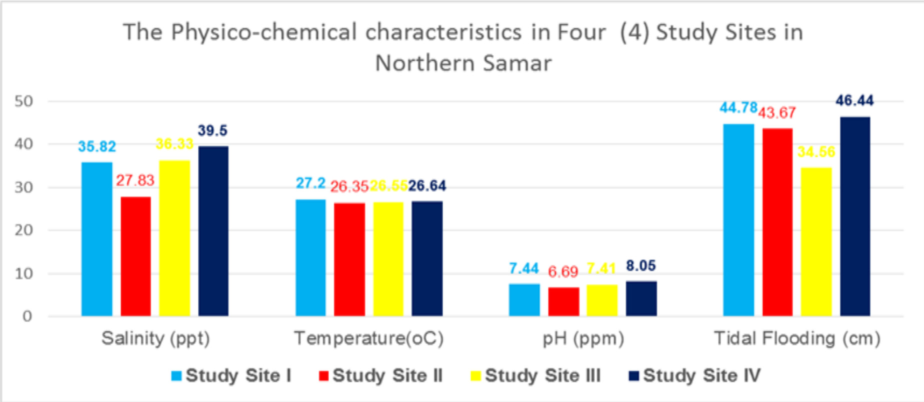

Figure. 4. Physico-chemical characteristics of the four (4) sites of Northern Samar.

Table 3 presents a comparison of mollusk species diversity among the four study sites in Northern Samar, while Table 5 displays the ANOVA results for the species diversity. The F-test was used to assess differences. The findings indicate that there is no significant variation in the species diversity of mollusks among the four (4) study sites (F = 1.05, ns). Additionally, the test indicates that there is no significant difference in the likelihood of encountering mollusk species across the four mangrove areas.

This further suggests that the study sites have almost the same mangrove ecosystem and physico-chemical characteristics of the study sites. The sediments in all four study sites were found to have high levels of organic carbon, pore-water salinities, and smaller median grain size (Demopoulos, 2004 as cited by Kabir et al., 2014).

Table 3. Test of Difference on the Number of Species of Gastropods and Bivalves Encountered in different Study Sites in Northern Samar

ANOVA

				F Value		
DIVERSITY	Sum of Squares	df	Mean Square	F computed	f α0.05	Interpretation
Between Groups	1065.88	3	355.29	1.05	2.68	Not significant
Within Groups	29488.25	87	338.95			
Total	30554.13	90				

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Site	N
3	22
4	22
2	18
1	29

3. Conclusions

Based on the findings, the following conclusions and implications are drawn. Ten (10) mangroves species belong to five (5) families, Rhizophora *apiculata* Blume belonging to Family Rhizophoraceae is present in all study sites which is highest in number of individuals. While for the mollusks, 41 gastropods species belong to 17 families; seven (7) bivalves species belong to six (6) families and one polyplacophora species belongs to one (1) family sampled from the study sites, *Terebralia sulcata* belonging to family Potamididae is highest in number of individuals because sufficient food abounds in the mangrove areas.

Gastropods and bivalves play a significant role in the mangrove ecosystem as they are the primary mollusk species and contribute to the detritus-based food webs. This indicates that gastropods are widely distributed in mangrove forests, possibly due to their mobility, while bivalves are typically restricted to a narrow zone closer to the sea. This confinement can be attributed to factors such as feeding habits, limitations on larval settlement, and sediment texture, including low pH and high organic matter content. The diversity and abundance of mangrove mollusks tend to increase as we move towards the lower intertidal zones. These patterns are influenced by various environmental factors, including the availability of organic matter, sediment characteristics, and the age of the mangrove ecosystem.

Both mangrove and mollusk species in the Shannon-Weiner diversity indices have low to very low diversity in the four (4) study sites of Northern Samar. Dominance, species richness and evenness of mangrove species are highest in Study Site II (6 mangrove species). While in mollusk species dominance based on Simpson's index, the highest is in Study Site I (29 mollusk species); species richness highest value is in Study Sites III and IV (both 22 mollusk species) and in mollusk species evenness, the highest value is in Study Site I with almost complete evenness. Natural and manmade threats (i.e., pollution, climate change, typhoon, tsunami) cause the decrease of mangrove and mollusk species diversity.

The physico-chemical characteristics are almost within the standard except for the salinity.

The mollusk species diversity has no significant difference.

Recommendations

Based on the results of the study, the following recommendations were made:

1. Stakeholders of the LGUs of the province may put forward mangrove-related rehabilitation activities and /or projects to win back species diversity, dominance richness and evenness.

2. Similar endeavors be done by various agencies to bring back the status of mollusks as source of food or alternative livelihood.

3. Every LGU may assign a specific office to do regular monitoring and evaluation of the physico-chemical characteristics of estuarine, coastal and other ecosystem.

4. Local government environment-protection enthusiasts may consider the best practices of other

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LGUs in protecting and conserving mangroves and mollusk resources/ecosystems

5. Differences in ecosystem characteristics may be identified as priority consideration in the design of activities, projects and programs along ecosystems rehabilitation.

6. Rehabilitation programs of other established communities may be a good guide for the province to design a strong and grounded rehabilitation programs for Northern Samar.

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