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THE STATUS OF MOLLUSK DIVERSITY AND PHYSICAL SETTING OF THE MANGROVE ZONES IN CATANDUANES ISLAND, LUZON, PHILIPPINES

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ABSTRACT

The status of mollusk diversity and physical setting of mangrove areas in Catanduanes island, Luzon (Philippines) are described. A total of 57 species of mollusks, consisting of 27 gastropods and 30 bivalves were recorded in the island. Registering higher values of species diversity indices (Margalef) and species richness (Menhinick) are the prosobranch, *Terebralia sulcata*; corbiculid bivalve, *Geloina coaxans*; potamidiids, *Cerithidea cingulata* and *Cerithidea rhizophorarum*; and two other species of the genus *Littorina* (*Littorinopsis*). Using the physiographic model, majority of the mangrove areas under study follow the composite river and wave-dominated setting with some few areas having the wave-dominated, tide-dominated allochthonous setting.

Keywords: Mollusk diversity, mangrove areas, Philippines

INTRODUCTION

In recent years, there had been an increased interest on the status of mangrove areas in tropical coastal ecosystems for economic and ecologic reasons (McNeely *et al.* 1990, Maler 1997, Masagca 2006). These are the most biologically diverse of all marine ecosystems but are being degraded worldwide by human activities potentially leading to numerous extinctions (Rios-Jara 2009). Conservation efforts targeted toward these ecosystems could help in averting the loss of tropical biodiversity. The first step according to Hamilton and Snedaker (1984) towards the attainment of the goals of conservation and sustainable use of the mangrove ecosystem is to develop data base. This is a comprehensive collection of information on such subjects as the areas and distribution of mangroves their flora and fauna present.

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In the tropical coastal environments, the mollusks are among the most diverse invertebrates and the vast majority is found intertidally, in estuaries, coastal lagoons, and in the shallow areas of the continental shelf (Brusca & Brusca 1990, Hendrikx *et al.* 2007). Mollusks have colonized all possible habitats (from deep sea to high mountains) and are found to be abundant in tropical littoral zones (Shanmugam & Vairamani 2009). In the mangrove swamps, the mollusks and crustaceans are the most conspicuous faunal elements (Macnae 1968, Morton 1990).

Recognizing the importance to conserve the remaining mangroves and their associated faunal elements, such as the mollusks of Catanduanes (Philippines), as well as the paucity of studies on malacological diversity, this inquiry was carried out. The mollusk fauna of this island has received little attention. Studies were carried out mostly by faculty members and their students at the Catanduanes Colleges in Virac, Catanduanes but are unpublished. Earlier inventories of mollusks from the areas under consideration were performed by the present authors in the 1980s and continued until 2009. Most of these researches are included in the book of abstracts in conferences and in not easily accessible technical reports and undergraduate theses. Studies also refer to specific municipalities and environments of the coastal areas. More complete lists of species from this island are now being prepared in order to have a comprehensive cataloguing and reporting in journals and other conference proceedings.

The structure of mangrove ecosystem is related to the abiotic components. The abiotic components are composed of the physical and chemical environment such as solar radiation, temperature, rainfall, nutrients and water supply (Aksornkoae 1993). On the environmental setting or physical setting, Thom (1984) stressed that a basic task confronting the mangrove ecologist is to explain the development of mangrove communities through time. In an attempt to explain the mangrove associated fauna in the island under study, the species diversity of mollusks and physical setting of the mangrove areas are described here with the hope in finding possible explanations to the local area distribution in future publications.

The paper deals with the species of bivalves and gastropods found in the most representative environments of the mangrove areas and includes a checklist of species and species richness along 10 different municipalities (within the 6 ecological zones of the island) with mangrove stands found in estuaries, riverine and marine dominated mangrove areas associated with the shallow subtidal of the continental shelf. This list is an attempt to both provide a more complete inventory of the mollusks fauna of this island and update the taxonomic names. In addition, the materials collected were deposited in the currently organized biodiversity reference collections project of the Pacifictech in Catanduanes and the Natural Sciences Department Reference Collections at the Catanduanes State Colleges, Philippines.

MATERIALS AND METHODS

Location of the study

Catanduanes is an island province (total land area of 1,483 sq km) of the eastern part of the Philippine archipelago (13.5° to 14.1°N Lat. and 124° to 125° E Long.).

Highest elevation of the island is 803 m above sea level. The monsoonal climate of the province consists of two distinct dry season and wet season. Typical diurnal range of temperatures is 25° to 32°C with minimal variations throughout the year. Relative humidity varies from 75 to 89%. Most likely, the current that affects the island is the North Equatorial Current moving westward across the Pacific.

Research methods, sources of data and sampling procedures

Heywood (1995) propounded that characterizing biodiversity involves the observation and characterization of the main units of variation (e.g. Genus and species) as well as the quantification of variation within and between them (e.g. taxonomic relatedness). Ocular and transect surveys were employed in gathering data on the mangrove associated components of the mangroves in the island. Primary data were from direct systematic surveys or observation of the mangrove areas in the island. Laboratory observations were done to identify the mollusks not identified *in situ*.

The study sites cover the whole island, except for a landlocked municipality and a coastal town without a distinct mangrove area suited for scientific observation. There were 6 study zones established in the province for the purpose of showing the whole province as an ecological unit for analysis.

Data gathering procedures

The procedures developed by Sasekumar (1984) and that of Dartnall and Jones (1986) were followed in this inquiry. Before field surveys were carried out in the zones (Table 1), specific objectives were determined and information sought were clearly explained to the research assistants. Using the topographic maps imaginary transect lines were assigned for every ecological zone. Using *Google Earth*, topographic maps were enhanced and traced for overlaying and comparison of existing maps obtained from NAMRIA. One of the most difficult decisions made when obtaining data for the mollusks was how many replicate samples were to be required at each study station or substation to get the reliable information. Many taxa of mollusks are not distributed uniformly over the bottom of the mangrove ecosystem. Different habitats (i.e. sand, mud, gravel or organic material) will support different densities and species of organisms. During field surveys, even on a relatively homogeneous bottom, it was observed that mollusks tend to aggregate. With this, replicate samples (or 10 quadrats) were used to evaluate this variability.

Table 1. Arbitrary ecological zones on Catanduanes Island, Luzon

Zone	Zonal Location	Municipality
I	Northern	Pandan (PAN-06)
II	Northwestern	Caramoran (CAR-04)
III	Northeastern	Panganiban (PAG-07), Viga (VIG-09), Bagamanoc (BAG-01)
IV	Southern	Virac (VRC-10)
V	Southeastern	Bato (BAT-03), Baras (BAR-02), Gigmoto (GIG-05)
VI	Southwestern	San Andres (SAN-08)

From the reference point, 20 to 21 quadrats measuring 1m x 1m were determined in each transect line. To permit comparison of mollusks communities, it was ensured that all the quadrats in the transect line were ecologically similar. During the survey, obstructions like boulders of large logs lying on transects were encountered. To compensate for this invalid quadrat, the wooden sheet frame was thrown at any direction to sample the mollusks. Collection and identification of mollusks were carried out following several keys with the assistance of Mr. Jaime Cabrera, Conchologist of the Philippine National Museum (PNM).

Mollusk biodiversity measurements were made using Margalef's Index of Community Diversity (Magurran 1988) and Menhinick's Index for Species Richness (Shanmugam & Vairamani 2009). As measure of species diversity, Margalef's index is calculated from the total number of species present and the abundance or total number of individuals, wherein the higher the index the greater the diversity. The species richness index of Menhinick attempts to compensate for sample effects by dividing richness, *S*, the number of species recorded, by *N*, the total number of individuals in the sample (Magurran 1988).

Physical setting

In an attempt to explain the mangrove associated mollusk in Catanduanes, three models were used for convenience in describing the physical setting of mangrove ecosystems, namely: 1.) Succession Model 2.) Gradient Analysis Model, and 3.) Physiographic Model. However, considering the applicability of the third model, discussion based on this model was focused in this paper. Maps from NAMRIA as well as data obtained from Google Earth were used in this report.

RESULTS AND DISCUSSIONS

Mollusks associated with mangrove areas of Catanduanes island, Philippines

The bivalves and gastropods were registered in the mangrove areas found in ten (10) coastal municipalities of the island province. For the first time, a total of 57 taxa of mollusks, composed of 27 species of gastropods and 30 species of bivalves that were identified in the mangrove areas under consideration. The bivalves belong to 4 orders, 13 families, and 23 genera, and the gastropods belong to 3 orders, 12 families, and 14 genera (Table 2).

Early inventory of the bivalves and gastropods in brackishwater areas (including the mangrove areas) of Catanduanes is attributed to the work of Mendoza and Tribiana (1997) which comprises 15 species of gastropods (belonging to 10 genera, 10 families and 3 orders); and 22 species of pelecypods (belonging to 17 genera, 11 families and 3 orders). Their work provides baseline information on species list, but not on new species, redefinitions of taxonomic relationships, new records, and their geographic distributions which will be the focus of future serial reports on the malacalogical fauna of the island. However, most of the literature on the mollusks from this part of the Philippines refers to coastal benthic communities of the Maqueda Channel in Lagonoy Gulf and the eastern coasts of the island facing the Philippine Sea.

Table 2. Total number of orders, families and genera of bivalves and gastropods identified in the mangrove areas of Catanduanes.

Mollusks	Order	Family	Genera	Species	%
Bivalves	4	13	23	30	47.9
Gastropods	3	12	14	27	52.1
Total	7	25	36	57	100

Combining the reports on mollusks contained in the papers of Mendoza & Tribiana (1997), Masagca (2000), Masagca and Masagca (2009) and other unpublished undergraduate theses at the Catanduanes State Colleges, Philippines, an updated taxonomic list of the mollusks found in the mangrove areas of Catanduanes is presented below.

CLASS GASTROPODA Cuvier, 1797
Subclass Prosobranchia A. Milne-Edwards, 1848
Order Archaeogastropoda Thiele, 1925
Superfamily Trochacea Rafinesque, 1815
Family Trochidae Rafinesque, 1815
Genus *Monodonta* Lamarck, 1799

1. *Monodonta labio* Linnaeus, 1758
2. *Trochus niloticus* Linnaeus, 1758
3. *Trochus pyramis* Born, 1778
4. *Trochus maculatus*

Superfamily Neritaceae Rafinesque, 1815
Family Neritidae Rafinesque, 1815
Genus *Nerita* Linnaeus, 1758

5. *Nerita chamaeleon* Linnaeus, 1758
6. *Nerita planuspira* Anton, 1839
7. *Nerita* (*Theliostyla*) *squamulata*
8. *Nerita undulata* Linnaeus 1780

Order Mesogastropoda Thiele, 1925
Superfamily Littorinacea
Family Littorinidae Gray, 1840
Genus *Littorina* Ferussac, 1822

9. *Littorina* (Littorinopsis) scabra Linnaeus, 1758
10. *Littorina littoralis* Linnaeus. 758
11. *Littorina* (*Littorinopsis*) *planospira*

Superfamily Cerithiacea Fleming, 1822
Family Cerithiidae
Genus *Cerithium* Bruguiera, 1789

12. *Cerithium patulum* Sowerby, 1834
13. *Cerithium pfefferi* Dunker, 1822
14. *Cerithium vertagus* Linnaeus

Family Potamididae
Genus *Cerithidea* Swainson, 1840

15. *Cerithidea rhizophorarum* A. Adams, 1855

16. *Cerithidea cingulata* Gmelin, 1822

Genus *Telescopium* Linnaeus, 1758

17. *Telescopium telescopium* Linnaeus, 1758

Genus *Terebralia* Swainson, 1840

18. *Terebralia sulcata* Born, 1778

Family Strombidae

Genus *Strombus* Linnaeus, 1758

19. *Strombos gracilior* Sowerby, 1825

Family Cypraecidae

Genus *Cypraea*

20. *Cypraea clandestine* Linnaeus, 1767

21. *Cypraea erosa* Linnaeus, 1758

22. *Cypraea moneta* Linnaeus, 1758

Order Neogastropoda

Family Buccinidae

Genus *Cantharus* Roding, 1798

23. *Cantharus undosus* Linnaeus, 1758

Family Melonggeniidae

Genus *Melonggena* Schumacher, 1857

24. *Melonggena galeodes* Lamarck

Family Muricidae

Genus *Pteronotus* Swainson, 1833

25. *Pteronotus elongate*

Superfamily Buccinacea

Family Nassaridae

Genus *Nassarius* Dumeril, 1806

26. *Nassarius olivaceous* Bruguiera, 1789

Superfamily Muricacea

Family Thaididae

Genus *Morula* Schumacher, 1817

27. *Morula fiscella* Gmelin, 1791

CLASS BIVALVIA LINNAEUS, 1758

Subclass Pteriomorphia Beurlen, 1944

Order Arcoida Stoliczca, 1817

Superfamily Arcacea Lamarck, 1809

Family Archidae Lamarck, 1809

Genus *Anadara* Gray, 1847

28. *Anadara antiquate* Linnaeus, 1758

29. *Tegilaria granosa* Linnaeus, 1758

Genus *Barbatia* Gray, 1842

30. *Barbatia* sp.

Order Pteroida Newell, 1965

Superfamily Pteriacea Gray, 1847

Family Pteriidae

Genus *Pteria*

31. *Pteria maxima*

Family Isognomidae

Genus *Isognomon* Lightfoot, 1786

32. *Isognomon ephippium* Linnaeus, 1758
33. *Isognomon isognomon*

Family Placunidae Yonge, 1977

Genus *Placuna* Lightfoot 1788

34. *Placuna placenta* Linnaeus, 1758
35. *Placuna sella* Gmelin 1791

Subfamily Ostreacea Rafinesque, 1815

Family Ostreidae Rafinesque, 1815

Genus *Crassostrea* Sacco, 1897

36. *Crassostrea echinata* Quoy & Gaimard, 1836
37. *Crassostrea lugubrious* Sowerby
38. *Crassostrea tuberculata* Lamarck, 1819

Order Mytiloida Ferussac, 1822

Superfamily Mytilacea Rafinesque, 1815

Family Mytilidae Rafinesque, 1815

Genus *Septifer* Recluz, 1848

39. *Septifer bilocularis* Linnaeus, 1758

Family Dreissenidae

Genus *Dreissena* van Beneden, 1838

40. *Dreissena* sp.

Family Cardiidae Lamarck 1809

Genus *Regozara*

41. *Regozara flava* Linnaeus, 1758

Genus *Trachycardium*

42. *Trachycardium pristipleura* (Dall, 1901)

Family Corbiculidae Gray 1847

Genus *Geloina* Gray 1842

43. *Geloina coaxans* Gmelin, 1791

Subclass Heterodonta Neumayr, 1884

Order Veneroida H & A. Adams, 1856

Superfamily Veneracea Rafinesque, 1815

Family Veneridae Rafinesque, 1815

Genus *Circe* Schumacher, 1817

44. *Circe (Lioconcha) castrensis* Linnaeus, 1758
45. *Circe scripta* Linnaeus, 17*58*

Genus *Grafarium* Roeding, 1789

46. *Grafarium tumidum* Roeding, 1789
47. *Grafarium pectinatum* Linnaeus, 1758

Genus *Marcia* H. & A. Adams, 1857

48. *Marcia* sp. H. & A. Adams, 1857

Genus *Dosinia* Scopoli, 1777

49. *Dosina* sp. (Reeve)

Genus *Pitar* Romer 1857

50. *Pitar frizelli* J. G. Hertlein & A. M. Strong, 1948

Genus *Tivela* Link 1807

51. *Tivela delesertii* (Sowerby, 1854)

Genus *Venus* Linnaeus 1758

52. *Venus (Paphia) euglypta* Philippi 1847

53. *Venus merunaria* Linnaeus, 1857

Family Mactridae Lamark 1809

Genus *Mactra* Linnaeus 1767

54. *Mactra* sp.

Family Donacidae Fleming 1858

Genus *Donax* Linnaeus 1758

55. *Donax mirabilis* Linnaeus, 1857

Family Lucinidae Fleming 1828

Genus *Lucinoma* Dall 1901

56. *Lucinoma annulatum* Reeve, 1850

Genus *Anodontia* Link 1807

57. *Anodontia alba* Link, 1807

Most of the species (57) were collected in the mangrove areas found in the municipalities of Bato, San Andres and Panganiban. The number of species per family varies considerably (1 to 10 species). Six families of bivalves (46.2 %) and 6 families of gastropods (50%) are represented by one single species; the most diverse families of bivalves are: Veneridae (10 species), Archidae (3), Ostreidae (3), and the most diverse families of gastropods are: Potamididae (4), Neritidae (4), and Trochidae (4).

The bivalves found in the northeastern portion (Zone III) mangrove areas in Viga and Panganiban are typically associated to soft substrata. These areas are rich with alluvial deposits. A few epifaunal bivalves live adhered to the mangrove roots. This group includes the mytiliid *Septifer bilocularis*, the oysters *Crassostrea echinata, C. lugubrious, Isognomon ephippium* and *I. isognomon*. The windowpane shells, *Placuna placenta* and *P. sella* are found in the soft muddy substrates of the mangrove areas in the island.

Gastropods found in the mangrove areas of San Andres, Baras and Bato are mostly associated to the marine environment. Three species of the family Cypraecidae and 4 species of the family Trochidae were obtained from the mangrove areas which are usually associated to estuarine habitats and sandy substrata. The collections of the species belonging to the family Trochidae, with 4 species (*Monodonta labio* Linnaeus, 1758, *Trochus niloticus* Linnaeus, 1758, *T. pyramis* Born, 1778 and *T. maculates* are obtained from the sandy-muddy substrates of the mangrove areas in the southeastern portion (Zone V) composed of Bato and Baras and in the southwestern portion (Zone VI) composed of San Andres. In general, the said mangroves in these municipalities consisting of Tide Dominated Allochthonous and Wave-Dominated settings have greater number of mollusk species. There is a great possibility that the substrates are derived from carbonate materials.

The mangrove areas in Bato and to some extent, San Andres have shallow water bodies that contain a distinctive group of species, some living on the roots of the mangrove *Rizophora apiculata* and *R. mucronata*. Species that are exclusive to the mangrove habitat were recorded; among these, the members of family Neritidae (*Nerita chamaeleon*, *N. (Thylostyla) squamulata*), family Littorinidae (*Littorina scabra, L. littoralis* and *L. planospira)*, and the prosobranchs of the family Potamididae (*Terebralia sulcata, Telescopium telescopium, Cerithidea cingulata, C. rhizophorarum, Cerithium pathulum, C. pfefferi* and *C. Vertagus*).

The long spired prosobranch, *T. sulcata* Born, 1778 occurs in the mangrove areas in large numbers particularly in most types of muddy substrates. This prosobranch has close association with *Cerithidea rhizophorarum* in the mudflats. *T. sulcata* is proposed as a biological indicator in pollution studies because of its fast growth and distributional range (Masagca 2000). The presence of the gastropods, *Cypraea moneta* and *Littorina* sp. in the mangrove sites of San Andres, Bato and Baras indicates the greater marine influence on the macrofauna of these areas.

Species diversity and richness of mollusks in the mangroves of Catanduanes

Table 3 presents the various reports on the mollusks associated with mangroves in the Philippines and other countries.

Table 3. Summary of mollusks associated with mangroves in different locations.

Locations	Author/s	Gastropods	Bivalves	Total No. of Mollusks species
Philippines	Zamora (1989)	49	15	64
Australia	Tomlinson (1986)	Nd	nd	95
Indonesia	Soemodihardjo and Sorianegara (1989)	51	37	88
Catanduanes	This report	27	30	57

Note : nd = no data

Zamora (1989) reported 49 species of gastropods and 15 species of bivalves associated with mangroves in the Philippines. There seems to be a higher number of bivalve species reported earlier by Mendoza and Tribiana (1997) and this report compared to that of Zamora (1989). The former may have included truly marine species of pelecypods, which are said to be abundant in the Agoho mangrove area characterized by Tide Dominated Allochthonous Setting favoring the presence of additional species of mollusks. The zonal distribution and systematic study of Reyes (1979) in Puerto Galera, Mindoro identified 15 species of gastropods and 10 species of bivalves.

In Australian mangroves, Tomlinson (1986) noted 95 species of mollusks, and in other southeast Asian countries, Indonesia has 51 species of gastropods represented by families Potamidae, Ellobidae, Nassaridae, Thiaridae, Littorinidae, Neritidae and Muricidae. Mangrove bivalves in Indonesia are represented by Corbiculidae, Veneridae, Cerithidae, Melongenidae, Ostreidae, Mytilidae, Spondylidae and Arcidae (Soemodihardjo & Soerianegara 1989).

Estimation of the parameters for diversity of mollusk fauna was initially carried out in the island using 21 quadrats in each of the 8 study locations. Data in the number of mollusks obtained during sampling for this study was recorded. Summary of the computation as to Species Diversity uses Margalef's species diversity index. It can be gleaned from Table 4 that *Terebralia sulcata* had the highest diversity index at 0.59, followed by *Cerithidea rhizophorarum* (0.44), *Geloina coaxans* (0.42), *Anadara antiquate* (0.36), *Nerita (Thelostyla) squamulata* (0.25) and *N. chamaeleon* (0.24). Molluscan species with diversity indices below 0.1 are *Morula fracella* (0.098), *Monodonta labio*, *Dossinia* sp. (0.088), *Crassotrea tuberosum* (0.071), *Barbatia* (0.081) and *Cypreae moneta* (0.083). In Margalef's index of community diversity, the higher value the higher the diversity. De la Cruz and Banaag (1967) reported the abundance of gastropods belonging to the genera *Cerithidea*, *Littorina* and *Moneta*. These genera are also abundant in the mangrove areas of Catanduanes. In Venezuelan mangroves, the genera *Neritina, Littorina* and *Thais* are reported to be abundant in roots and trunks of the mangrove trees.

Table 4. Species Diversity (Margalef's Index) of mollusks found in the mangrove areas of Catanduanes island, Luzon, Philippines.

Species of Mollusk	Species Diversity (Margalef's index) of Mollusks in the Different Mangrove Areas									Rank
	I	II	III	IV	V	VI	VII	VIII	Mean	
Anadara antiquata	0.35	0.3	0.33	0.23	0.24	0.45	0.90	0.09	0.361	4
Barbatia	0.15	0.05	0.05	0.05	0.10	0.10	0.10	0.05	0.081	24
Cerithidea cingulata	0.10	0.1	0.14	0.05	0.05	0.10	0.50	0.41	0.180	10
Cerithidea rhizophorarum	0.80	0.6	0.62	0.05	0.05	0.05	0.60	0.73	0.438	2
Cerithium pfefferi	0.20	-	0.05	0.09	0.10	0.05	0.15	-	0.106	20
Cerithium patulum	0.15	-	-	-	-	0.05	0.25	0.05	0.125	18
Crassostrea echidna	0.35	0.05	0.05	0.09	-	0.15	0.1	-	0.131	14.5
Crassostrea tuberosum	-	-	0.09	0.09	0.05	-	0.05	-	0.070	26
Cyprea moneta	0.05	0.10	-	-	0.10	-	-	-	0.083	23
Dossinia sp.	0.10	0.01	-	0.14	-	0.10	-	-	0.088	22
Geloina coaxans	0.60	0.2	0.48	0.55	0.48	0.05	0.6	0.41	0.421	3
Grafrarium tumidum	0.35	0.05	0.19	0.14	-	0.10	0.2	-	0.172	12
Isognomon ephipium	0.15	0.1	0.14	0.18	0.10	0.15	0.1	-	0.131	14.5
Littorina (Littorinopsis) planospira	0.40	0.05	0.29	0.23	0.05	0.60	0.2	0.09	0.239	7
Littorina (Littorinopsis) scabra	0.25	0.25	0.33	0.23	-	0.35	0.15	0.05	0.230	8.5
Marcia	0.25	0.05	0.09	0.18	-	0.05	-	0.14	0.127	17
Monodonta labio	-	0.05	0.14	0.05	-	0.1	-	0.05	0.078	24
Morula fracella	0.25	0.10	0.05	0.09	0.05	0.05	-	-	0.098	21
Nassarius	0.05	0.15	0.05	0.09	0.10	0.10	-	-	0.173	11
Nerita olivaceous	0.40	0.05	0.09	0.18	0.05	0.20	0.15	-	0.128	16

Table 4. Continued

Species of Mollusk	Species Diversity (Margalef's index) of Mollusks in the Different Mangrove Areas									Rank
	I	II	III	IV	V	VI	VII	VIII	Mean	
Nerita chamaeleon	0.85	0.05	0.14	0.14	0.05	0.55	0.10	0.05	0.241	6
Nerita (Theleostyla) squamulata	0.40	0.1	0.09	0.18	0.24	0.65	-	0.09	0.250	5
Septifer bilocularis	0.15	0.15	0.09	0.14	0.05	0.20	-	0.09	0.124	19
Tegillaria granosa	0.35	-	0.09	0.09	0.14	0.35	0.10	0.05	0.167	13
Telescopium telescopium	0.30	0.1	0.29	0.23	0.19	0.25	0.35	0.05	0.220	8.5
Terebralia sulcata	0.90	0.45	0.33	0.68	0.29	0.75	0.75	0.50	0.593	1

Note: The dash (-) sign indicates none (or 0) Species Diversity index.

Table 5 presents a summary of the species richness of mangrove-associated mollusks in all municipalities of Catanduanes island. The richness of mollusks found in mangrove areas of 3 municipalities, Pandan (1.69), Baras (1.27) and Bato (1.19) are higher than 1.0. The other 5 municipalities have lower richness values but almost approaching 1.0. The capital municipality of Virac (the most populous in the island in terms of human population) registered the lowest species richness index at 0.73. Based on the factors affecting biodiversity as enumerated by Shanmugam and Vairamani (2009), the mollusks diversity in the island under study are 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 in the municipalities of Virac, Viga and Panganiban (showing lower species richness indices at 0.73, 0.77, and 0.74, respectively). The effects of natural calamities on the biodiversity of mollusks in this island located in the "typhoon highway" of the Philippines appear to have greater significance. Sudden heavy downpour, typhoons, floods and tidal surges can lead to death of mollusks. The mollusks from rivers and estuaries of the island are carried by flood waters to the coastal waters and back during tidal surges. The present study observed empty shells which were also considered in the collections aside from the live specimens. It is highly likely that they are part of the mangrove areas surveyed. Although some shells may be transported for several kilometers, they still will be found within the extensive areas covered in this inquiry.

Table 5. Species richness (Menhinick's index) of mollusks found in the mangrove areas in the different municipalities of Catanduanes.

Municipality	Area	Species Richness using Menhinicks's Index	Ranking
Bagamanoc	I	0.81229	5
Baras	II	1.27565	2
Bato	III	1.19571	3
Pandan	IV	1.69940	1
Panganiban	V	0.74492	7
San Andres	VI	0.92861	4
Viga	VII	0.76692	6
Virac	VIII	0.72802	8
	Sum	8.15195	
	Mean	**1.01893**	

Physical setting of the mangrove areas in Catanduanes

Under the Physiographic Model, there are five terrigenous setting, namely, (1) River Dominated Allochthonous (RDA), (2) Tide Dominated Allochthonous, (3) Wave Dominated Barrier Lagoon (Autochthonous), (4) Composite River and Wave Dominated Setting, and (5) Drowned Bedrock Setting (Thom 1984). In addition, three carbonate settings are also considered in the discussion.

In the northeastern zone (Zone II) of the island, the presence of small rivers in Bagamanoc would indicate that mangrove areas have RDA setting. The mangrove stands at the mouth of Malaquio rivulet opens to the Tahidan point in this zone. Also on this zone, specifically the mangrove areas of Viga and Panganiban indicate that the dominant setting is characterized by RDA also. Using the topographic maps (1: 1,000) from NAMRIA Philippines, and Google Earth generated maps indicate that the mangrove setting corresponds to RDA. There is a low tidal range as observed in the study area, evidenced by narrow tidal changes during the day, even during the neap tides.

Oco River discharge of freshwater and sediments leads to the rapid deposition of terrigenous silts and clay to form the huge deltas found in Viga reaching to Panganiban. This formation favored the rapid growth of *Nypa* fruticans during the natural regeneration and anthropogenic action by clearing the areas when gathering leaves for thatching of roofs. It could be claimed that deposition of allocthonous materials from the Oco River may have greatly influenced the mono−specific growth of *Nypa*. But the human intervention of planting more *Nypa* for economic purposes has invariably enhance towards monospecific growth of the *Nypa* in the area as also observed in the southeastern zone comprised of the municipalities of Bato, Baras and Gigmoto. Human interference by planting new fronds of *Nypa* have contributed much to the widespread growth of the palm in the said zones of the island. Relating this monospecificity of *Nypa* palm growth in the areas mentioned could have greater implications to biobelting or biowalling for the tsunamis (see Masagca & Masagca 2009).

In the southern location (Zone IV), the Composite River and Wave-Dominated Setting is observed in Palnab-Pajo Area. Pajo River in the municipality of Virac, provides the freshwater supply and sediments of the said mangrove area. Based on the available topographic maps and actual ground data survey by morphometry, it appears that the setting of the mangrove area in Palnab-Pajo represents a combination of high wave energy and high river discharge. The sand that is de-bounced by Pajo river is redistributed by waves forming sand sheets, hence a coastal plane is formed.

In the southwestern location (Zone VI), it shows that the Agojo Mangrove ecosystem differs from the rest of the physical setting of the others. A Tide Dominated Allochthonous Setting (TDAS) occurs in this mangrove area. However, considering the absence of a major river that drains water and sediments, it shows that the carbonate setting is more observable. Agoho is an inlet and possible deposition dominated by the accumulation of carbonate due to wave or tide reworking is not remote.

In the northwestern location (Zone II), the mangroves of Caramoran are formed at the mouth of the rivulets near Tubli and Toytoy rivers. A composite river and wave-dominated setting is observed similar to other municipalities. The mangrove stands found in Talisay and San Roque of the municipality of Bato have the Composite River and Wave Dominated Setting. The active channel is found in Batalay and shows to be fixed in position. Colonization of mangroves is widespread towards Talisay, San Roque and even as far as San Pedro. There are also slight mangrove formations at the mouth of the Bato River, where high tidal energy and bidirectional currents are observed near the Guinobatan areas with mangrove patches. *Nypa* formation is very dominant in the mangrove areas that contribute to the *Nypa* palm thatching industry or (*tiklad* industry) of the municipality. Along the eastern coast of Catanduanes, the presence of small rivers in the municipality of Baras provides the avenue for having the Wave-Dominated-Allochthonous setting.

CONCLUSIONS

Based on the results presented, it can be concluded that among the 57 species of molluscs identified, consisting of 27 gastropods and 30 bivalves, higher values in species diversity and richness of these mollusks are the prosobranch, *Terebralia sulcata*; corbiculid bivalve, *Geloina coaxans*; potamidiids, *Cerithidea cingulata* and *Cerithidea rhizophorarum*; and two other species of the genus *Littorina* (*Littorinopsis*).

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