Initiatives, Prospects, and Challenges in Tropical Marine Biosciences in Jagna Bay, Bohol Island, Philippines

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Abstract. Marine specimens exhibit diversity in structure as an offshoot of their survival and ecological role in marine communities. The shell structure of gastropods, for example, is so diverse that taxonomic classification could hardly catch up with the myriad specimens many of which remain unidentified, nameless, or worse, unrecorded as large numbers become extinct. As a step towards alleviating the lack of comprehensive marine life assessment, we discuss initial studies conducted in Jagna Bay in the northern part of Bohol Sea to determine the level of biodiversity in this locale. The methods of collecting specimens and their identification are discussed as exemplified by a specimen belonging to the genus *Cycloscala*. Data collected for specimens whose sizes range from around 1 mm to 250 mm helps establish baseline indicators that could determine ecological balance in this area for monitoring longitudinal effects of climate and human intervention. Given the remarkable marine biodiversity, the perennial challenge is to uncover and learn from the biological structure and functions of many marine specimens for possible applications in different emerging technologies. We illustrate this by citing recent examples where our understanding of marine life inspires innovations for tomorrow's technology.

INTRODUCTION

Studies show that [1-3] "the Philippines is not only part of the center but is, in fact, the epicenter of marine biodiversity, with the richest concentration of marine life on the entire planet" [1]. Located within the Coral Triangle are the 7,641 islands of the Philippines whose waters are considered by marine biologists as a hotspot in biodiversity. The Philippines has a total coastline of 36,289 km, more extensive than China's 14,500 km or Japan's 29,751 km [4]. Given the opportunities and challenges in marine biosciences, we focus in this paper on a certain marine locality – Jagna Bay in the relatively unstudied Bohol Sea in the southern part of the island Bohol, Philippines.

Insights from marine life could be gained both from the long term survival of certain species and from the rapid extinction of others. There is, for instance, already an alarming rate of unidentified and unrecorded mollusks that have gone extinct, with more than 70% of known mollusk extinctions occurring on oceanic islands [5]. Hence, in this study, we use as biodiversity parameters the concentration of mollusks, echinoderms, crustaceans, and other invertebrates which make up a great majority of macroscopic marine life rather than focusing, for instance, on different fish species as a measure of biodiversity as done in other papers [2,3]. Initial explorations of Jagna Bay are discussed where two methods of collecting specimens are used. We illustrate the task of identifying specimens by taking as an example a *Cycloscala* specimen retrieved from Jagna Bay. We then establish baseline data and initial determination of the amount of biodiversity in the locale for specimens within the size range of around 1 mm to 250 mm.

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The story of survival and evolution of marine life through millions of years can be revealed by studying structures of fossils and living specimens and their functions at the macro and molecular level. Some marine creatures evolved under extreme conditions characterized by cold temperatures, high pressure, and the absence of light. How they generate food and energy, and how they protect themselves from a hostile environment are something science continuously needs to understand and learn from. We therefore briefly highlight at the end of the paper some areas where studies of marine life could lead to new materials, novel pharmaceutical drugs, and alternative ways of generating energy.

RESEARCH INITIATIVES AT JAGNA BAY

A study of marine life often starts with the collection, sorting, and identification of marine specimens. We discuss in this Section the activities initiated in Jagna Bay in the northern part of Bohol Sea which involves senior high school students of Central Visayan Institute Foundation. A systematic scientific study of Jagna Bay would have impact not only for conservationists, but also possibly for scientists and engineers who may find inspiration from the structures and functions of marine life found in the area.

The Bohol Sea is bounded in the south by Mindanao Islands and the island of Bohol on the north (see, Figs. 1 and 2). To the west, Bohol Sea is linked with the Sulu Sea via the Dipolog Strait and to the east, with the Pacific Ocean through the 58 m deep Surigao Strait. With a basin-like topography, water exchange in the Bohol Sea is driven by two systems. From the Pacific in the East, a small net inflow of surface water flows westward through Surigao Strait into the northern part of Bohol Sea and is exported to the Sulu Sea in the west via the Dipolog Strait. On the other hand, from the Sulu Sea, an eastward-flowing water layer below 400 m drives the Sulu Sea overflow across Dipolog Strait into the Bohol Sea. The complex three-dimensional circulation in Bohol Sea has been described as a "double-estuarine type" circulation [6]. Note that Sulu Sea in the west is where the UNESCO World Heritage Tubbataha Reefs Natural Park is located, while the Pacific side in the east has the Philippine Deep with a depth of more than 10 km and trench length of approximately 1,320 km.

Although there are many ways to study the Bohol Sea, from a geomarine perspective to water current dynamics, our initial interest is to get a handle on the biodiversity that abounds and its practical repercussions. Except, perhaps, for the discovery of the British collector Hugh Cuming of the *Conus gloriamaris* in a reef near Jagna in 1837 there has been no recorded systematic study of marine mollusks in Jagna Bay.

FIGURE 1. The Bohol Sea is bounded in the south by Mindanao and on the north by Bohol Island. To the east is the Philippine Deep, to the west the Tubbataha Reefs Natural Park in Sulu Sea. Image: "Bohol Sea, Central Philippines. Map. Google Maps. Google, 09 May 2016. Web. 09 May 2016."

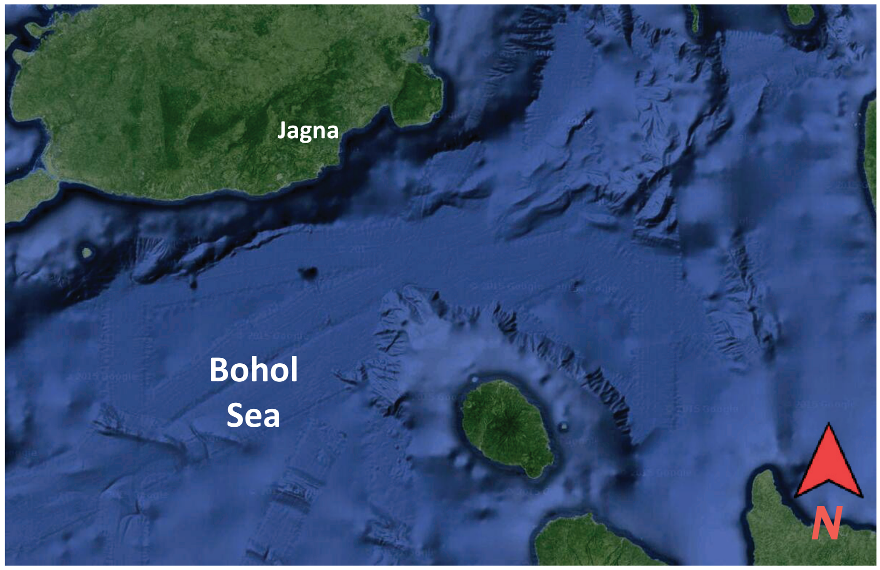

FIGURE 2. Topography of Jagna Bay and Bohol Sea. Image: "Jagna Bay and Bohol Sea. Map. Google Maps. Google, 09 May 2016. Web. 09 May 2016."

Collecting, Sorting, and Identifying specimens

Two methods have been employed in gathering specimens in Jagna Bay. The first uses *lumun-lumun* nets [7] which are dropped at depths of 80 m to 120 m. The nets are left under the sea normally for a duration of one to eight months. During this time, a community of marine life grows with the nets acting as their habitat. The nets, once retrieved, could yield some surprising specimens. The second method used is the more traditional intertidal collection at low tide. The specimens collected are kept in the Marine Science Museum of Central Visayan Institute Foundation (CVIF) and preserved in ethanol 95% for further analysis.

On March 15 and 16, 2016, *lumun-lumun* nets [7] were dropped in Jagna Bay. Two nets were retrieved on April 18, 2016 (Coordinates: 9.65^0 N, 124.4^0 E and 9.63^0 N, 124.35^0 E). The topography of Jagna Bay is shown in Fig. 2. As an example, among organisms collected using the method of *lumun-lumun* nets was a live *Cycloscala* specimen whose shell seems closest in morphology to the species *C. hyalina*.

Intertidal collection of specimens, on the other hand, was done on April 18, 2016 (5:15 PM – 6:00 PM) and April 19, 2016 (4:00 PM – 5:00 PM). On April 18, 2016 the lowest and highest tides occurred at 3:25 AM (0.21 m) and 9:22 PM (1.12 m), respectively. On the other hand, for April 19, 2016, lowest and highest tides were at 3:57 AM (0.2 m) and 10:10 PM (1.16 m), respectively. The April 19 collection was done when the tide was 0.32 m.

Cycloscala Dall, 1889 (Gastropoda: Epitoniidae)

The existence and distribution of epitoniid species have been of recurring interest as more areas around the world are being explored. In this Section, we report the retrieval of a live gastropod, genus *Cycloscala* Dall, 1889 [8], from Jagna Bay using the method of *lumun-lumun* nets [7]. This would be the first documented sighting of a *Cycloscala* specimen in this relatively unexplored area off the southern part of Bohol Island. This is important in understanding the spatial and temporal patterns of occurrence, abundance, dispersal and distribution area of species belonging to this genus.

The shell morphology of the retrieved specimen (see, Fig. 3) is analyzed to initially determine if it is a variant of another *Cycloscala* species, or if it belongs to a new species or subspecies. The classification of Epitoniidae has been observed to reveal apparent genetic reshuffling of a certain number of characteristics [9]. Comparison at DNA level, however, may be hindered by retrieval of merely empty shells or, sometimes, just the existence of fossils. An evaluation based on shell morphology thus remains important since shell characteristics are natural outcomes of coding at DNA level.

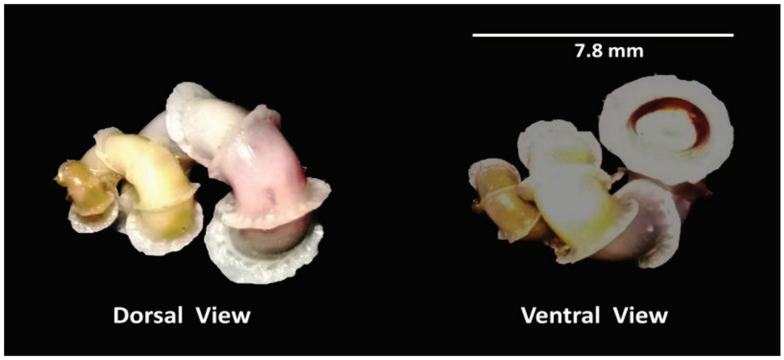

FIGURE 3. Dorsal and ventral view of a *Cycloscala sp.* retrieved at Jagna Bay.

Description of Shell Structure

The shell which is intact has a length of 7.8 mm. A blunt paucispiral protoconch (ca. half whorl) has a yellow color. A teleoconch of ca. 2 ½ whorls consists of a yellowish early whorl followed by a pinkish white whorl. The slowly expanding separated helical whorls are completely disconnected with no contact between successive whorls. This separation of whorls is easily seen by the naked eye. The thick and highly pronounced axial ribs are non-aligned from whorl to whorl (Figure 3). The ribs are liberally spaced with 6 ribs on the last whorl. The outer edges of the ribs are semi-ragged in outline. The inner part of the ribs attached to the main body (suture) has almost uniform wave-like undulations or indentations. The shell's surface, including interspaces between ribs, is smooth, shiny, and lacks ornamentation. The aperture is circular with a diameter of about 1.95 mm. The aperture has unusually wide lips with thickness that could range from 0.5 mm to 0.53 mm.

For the retrieved specimen, the completely disconnected whorls are similar to *C. hyalina* (G. B. Sowerby, 1844), *C. revoluta* (Hedley, 1899), *C. echinaticosta* (d'Orbigny, 1842), or *C. armata*. However, the specimen's yellow blunt paucispiral protoconch somehow differentiates it from the rather pointed protoconch typical of *C. hyalina* [10, Figs. 18-20], *C. revoluta* [10, Figs. 33-34], or *C. echinaticosta* [10, Figs. 4-7]. *C. armata*, on the other hand, has ribs with periodic heavy peaked rims or denticles [10] absent in our specimen. Since protoconch morphology aids species identification, we note that a rather blunt protoconch also characterizes the holotype of *Scalaria (Cycloscala) paucilobata* de Boury, 1911. The difference lies in the outer rims of our specimen's ribs which, although semi-ragged, do not have the regularly pronounced wavy rib edges of the holotype for *Scalaria paucilobata*.

A feature which also differentiates our specimen is the paucity of teleoconch whorls (ca. 2 ½ whorls) distributed in the retrieved specimen's length of 7.8 mm. Interestingly, the holotype of *C. armata* has more, with ca. 3.25 whorls for a shorter length of 4.7 mm [10], whereas the holotype for *Scalaria paucilobata* has ca. 4 whorls for its 6 mm length. The DNA coded ratio of the number of whorls w_h to a specimen's length l, i.e., w_h / l, may be an underemphasized characteristic that could additionally differentiate various *Cycloscala* species. For instance, holotypes of *Scalaria paucilobata*, *C. armata* [10], *C. gazae* [9], *C. crenulata* [11], *C. sardellae* [10], and *C. montrouzieri* [10] would roughly have $w_h / l = 0.67$, $w_h / l = 0.69$, $w_h / l = 0.73$, $w_h / l = 0.75$, $w_h / l = 0.76$, and $w_h / l = 1.25$, respectively. Likewise, a *Cycloscala hyalina* (Sowerby, 1844) found in January 1950 in Gunnamatta Bay, Port Hacking, NSW, Australia (C.460971) has around $w_h / l = 0.69$. Our retrieved specimen, however, has a low ratio of about, $w_h / l = 0.32$ (Table 1).

The new geographic location of retrieval and distinct shell morphology of our specimen makes it of taxonomic interest. As subject of ongoing analysis, we propose to refer to the specimen as *Cycloscala cvifencis*, until homotopic matching with existing species has been achieved. The *cvifencis* refers to Central Visayan Institute Foundation (CVIF) which together with the team of Prof. Baldomero M. Olivera of University of Utah conducted the expeditions in Jagna Bay.

Genus *Cycloscala* Dall, 1889 SPECIMEN	Number of Whorls / Length (w_h / l), per mm
*Scalaria paucilobata**	0.67
*C. armata**	0.69
C. hyalina§	0.69
C. gazae *	0.73
*C. crenulata**	0.75
*C. sardellae**	0.76
C. echinaticosta◊	0.90
*C. montrouzieri**	1.25
C. cvifencis n. sp.	0.32

TABLE 1. Number of whorls per length for different specimens. Estimated measurements are from holotypes (with *); from specimen found in Gunnamatta Bay, Port Hacking, NSW (C.460971) (with §); and specimen in ref. [12] (with ◊).

This report of a retrieved mollusk from the unexplored Jagna Bay not only adds to the distribution database for genus *Cycloscala*, but also aids in the continuing effort of determining whether a particular species is endemic or not in an area.

Longitudinal Study of the Biodiversity Index

As part of a longitudinal or time series study of biodiversity in Jagna Bay, a follow up of the intertidal collection done in 2016 was conducted on 3 May 2017 from 5:20 AM to 6:20 AM at the coast of Can-upao, Jagna, Bohol. We present in this section an initial report of the biodiversity index for the 2017 collection. At depths of around 38 cm below sea level, intertidal collection was done by three groups of senior high school students. The location of Group 1 was at 9°38’39.70” N, 124°21’57.89” E, with Group 2 at 9°38’34.21” N, 124°21’58.63” E, and Group 3 at 9°38’30.72” N, 124°22’2.10” E (see Fig. 4). Possible microorganisms not visible to the naked eye were generally excluded from the collection, although *Cypraea* species having approximately 158 eggs was observed (see Fig. 5). The specimens collected by the three groups are summarized in Tables 2, 3, and 4 [13-15].

FIGURE 4. Location of three groups (📍) during the 2017 intertidal specimen collection at Can-upao, Jagna, Bohol, Philippines and their relative distance to each other. Image: “Can-upao Bay, Jagna, Bohol, Philippines. Map. Google Maps. Google, 05 May 2017. Web. 05 May 2017.”

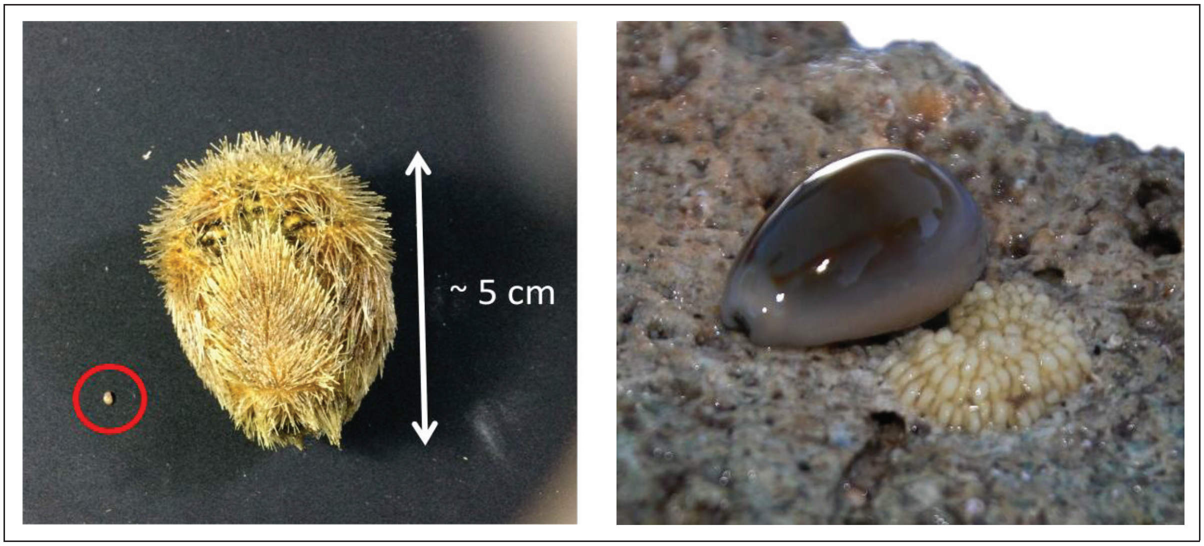

FIGURE 5. Encircled in red is a 0.2 cm bivalve found inside a sea urchin (Left). *Cypraea* with eggs (Right).

SPECIMEN	Number of Individuals n	n / N	$(n / N)^2$
Lepas sp.	46	0.48	0.23
Cypraea sp.	12	0.13	0.02
Cypraea tigris	2	0.02	0.00
Cypraea moneta	1	0.01	0.00
Cypraea annulus	3	0.03	0.00
Holothuria sp.	5	0.05	0.00
Mitra sp.	3	0.03	0.00
Ophiocoma sp.	3	0.03	0.00
Conus ebraeus	9	0.09	0.01
Conus catus	1	0.01	0.00
Conus sp.	1	0.01	0.00
Brachyura	1	0.01	0.00
Sargassum sp.	1	0.01	0.00
Pinna sp.	1	0.01	0.00
Unknown SP 1	6	0.06	0.00
Total Number of Individuals: $N = 95$			$\mu = \Sigma (n / N)^2 = 0.26$

TABLE 2. Specimens collected by Group 1 at 9°38'39.70" N, 124°21'57.89" E.

Computing for Simpson's diversity index [16], $D = 1 - \mu$, can only be approximately done since some of the specimens have not yet been identified down to the species level. As it stands, in this preliminary report, Simpson's diversity index for the data given in Table 2 is $D = 0.74$. Identifying specimens like the barnacles in Table 2 down to species level would greatly increase the value of D. Note that, $D = 1$ represents extreme diversity, whereas $D = 0$ means no diversity.

We note that a specimen found in the 2017 intertidal collection was *Atrina fragilis* Pennant, 1777, a bivalve which has 8 to 12 radiating ribs on its shell. Its natural habitat is known to be 200 m to 400 m under the sea. Hence, finding this specimen about 38 cm below sea level is a bit surprising and this event deserves a separate discussion [17].

SPECIMEN	Number of Individuals n	n / N	$(n / N)^2$
Costellaridae	32	0.25	0.06
Calcinus sp.	8	0.06	0.00
Tripneustes sp.	6	0.05	0.00
Bivalve	9	0.07	0.00
Thalassia sp.	7	0.06	0.00
Ophiocoma sp.	16	0.13	0.02
Conus musicus	1	0.01	0.00
Cypraea moneta	20	0.16	0.03
Holothuria sp.	1	0.01	0.00
microscopic bivalve	1	0.01	0.00
microscopic shrimp	1	0.01	0.00
Protoreaster nodosus	3	0.02	0.00
Astropecten articulates	12	0.09	0.01
Clypeaster sp.	4	0.03	0.00
Valonia ventricosa	1	0.01	0.00
unknown eggs in jelly-like tissues	5	0.04	0.00
Total Number of Individuals: $N = 127$			$\mu = \Sigma (n / N)^2 = 0.12$

TABLE 3. Specimens collected by Group 2 at 9°38'34.21" N, 124°21'58.63" E.

Simpson's diversity index for specimens collected by Group 2 is, $D = 1 - \mu = 0.88$, which reflects high diversity. Table 4 below summarizes the collection of Group 3 [15].

SPECIMEN	Number of Individuals n	n / N	$(n / N)^2$
Ophiocoma sp.	28	0.20	0.04
Calcinus sp.	43	0.30	0.09
Brachyura	2	0.01	0.00
Tripneustes sp.	7	0.05	0.00
Astropecten sp.	14	0.10	0.01
Linckia laevigate	2	0.01	0.00
Cypraea moneta	11	0.08	0.01
Holothuria sp.	10	0.07	0.00
Trochus sp.	4	0.03	0.00
Nudibranch	2	0.01	0.00
Octopus sp.	2	0.01	0.00
Cypraea annulata	1	0.01	0.00
Conus ebraeus	8	0.06	0.00
Conus chaldeus	1	0.01	0.00
Unknown SP 2	2	0.01	0.00
Unknown SP 3	2	0.01	0.00
Unknown SP 4	1	0.01	0.00
Unknown SP 5	1	0.01	0.00
Unknown SP 6	1	0.01	0.00
Unknown SP 7	1	0.01	0.00
Total Number of Individuals: $N = 143$			$\mu = \Sigma (n / N)^2 = 0.15$

TABLE 4. Specimens collected by Group 3 at 9°38'30.72" N, 124°22'2.10" E.

Simpson's diversity index for specimens collected by Group 3 is, $D = 1 - \mu = 0.85$, which again shows high diversity.

Table 5 summarizes the result for the diversity indices obtained from the three groups. Noting that the value of the diversity index D ranges from 0 to 1, an average value of $D = 0.82$ implies high biodiversity in the area of collection. In fact, the obtained D value could still significantly go up if further identification of specimens down to species level is done, especially the *Lepas sp.* in Table 2, the *Costellaridae* in Table 3, and *Calcinus sp.* in Table 4. Even at this initial stage, however, we already have a sense of the biodiversity in the area which should merit further studies.

SIMPSON'S DIVERSITY INDEX, *D*			
Group 1	**Group 2**	**Group 3**	**AVERAGE**
***D* = 0.74**	***D* = 0.88**	***D* = 0.85**	***D* = 0.82**

TABLE 5. Simpson's diversity index for marine specimens visible to the naked eye at the coast of Can-upao, Jagna, Bohol, Philippines.

An estimate of the density of specimens was also obtained. Each group randomly picked three 1 m^2 areas and counted the number of individual specimens inside each area. This is summarized in Table 6 where the 1 m^2 areas are called Stations labelled by 1A, 1B, 1C, 2A, 2B, etc., with Roman numerals referring to the group [13-15]. The specimens in Table 6 are also included in the specimen count in Tables 2 - 4.

STATION	**Number of individuals in 1 m^2 Area**	**CLASSIFICATION**
1A	7	1 *Cypraea sp*., 1 *Sargassum sp.*, 3 *Ophiocoma sp.*, 2 Unknown SP 8
1B	3	3 *Cypraea sp*. (1 with approx. 158 eggs)
1C	7	7 *Conus ebraeus*
2A	1	1 *Clypeaster sp.*
2B	31	5 *Calcinus sp.*, 1 bivalve, 3 *Tripneustes sp*., 8 *Costellaridae*, 1 *Conus musicus*, 4 *Thalassia sp.*, 4 *Ophiocoma sp*., 5 *Cypraea sp*.
2C	14	3 *Thalassia sp.*, 3 *Tripneustes sp.*, 2 *Costellaridae*, 5 bivalves, 1 *Cypraea*
3A	21	5 *Ophiocoma sp.*, 4 *Calcinus sp.*, 3 *Tripneustes sp.*, 3 *Cypraea moneta* , 2 *Holothuria sp.*, 2 *Conus sp.*, 1 *Cypraea annulata*, 1 *Brachyura*
3B	11	6 *Ophiocoma sp.*, 3 *Tripneustes sp.*, 2 *Astropecten sp.*
3C	12	2 *Astropecten sp.*, 2 *Holothuria sp.*, 2 *Conus ebraeus* , 1 *Ophiocoma sp.*, 1 *Trochus sp.*, 1 *Tripneustes sp.*, 1 *Calcinus sp.*,1 *Conus chaldeus*, 1 Unknown SP 1

TABLE 6. Excluding microorganisms, the average number of individuals is 12 per square meter.

MARINE BIOMIMICRY: PROSPECTS AND CHALLENGES

The relatively unexplored Bohol Sea may yield marine life that could inspire new technology. This, however, would require input from the biosciences and disciplines such as biochemistry, physics, mathematics, molecular biology, and engineering. To illustrate this rich area of biomimicry, we draw from experiences of other researchers to briefly discuss how structures and functions of selected marine organisms can have remarkable impact in the discovery of new materials, novel pharmaceutical drugs, and ways of generating energy. Some of the specimens mentioned in this Section, such as cone snails and shipworms, do thrive in Bohol Sea.

New Materials

There is a wide range of materials manufactured by nature which remains unknown to science. Mollusks, for instance, which comprise around 23% of all named marine organisms, provide untapped sources of new materials and designs that could drive emerging technologies. We illustrate this by citing examples of mollusks whose shells have already inspired scientists and engineers.

1. *Crysomallon squamiferum*: This mollusk has a tri-layered shell structure which not only presents a new material but also mechanical design principles of an iron-plated multilayered structure acting as a natural armor. Discovered in 2003 in a hostile hydrothermal vent environment [18], the shell consists of an outer layer embedded with iron sulfide granules, a thick organic middle layer, and a calcified inner layer. The structural system of this natural armor sustains both mechanical loading and thermal fluctuations with mechanisms to prevent catastrophic failure. The multilayered armor design of *C. squamiferum* is resistant to penetration, bending, and tensile load such that the structure-property-performance relationships as described by H. Yao et al inspire technological interest for a variety of civilian and defense applications for soldiers and vehicles [19].
2. *Patella pellucida*: This blue-rayed limpet as small as a fingernail has a shell with a nanoarchitecture that could serve as design guide for engineering color selective transparent displays. The translucent shell is configured to reflect blue light while absorbing all other wavelengths of incoming light. In a 2015 paper by L. Li et al [20], they showed that about 30 microns beneath the shell surface are two distinct structural features. There is a zigzag pattern of calcium carbonate layers with regular spacing above a layer of randomly dispersed spherical particles. The zigzag patterns act as a filter reflecting only blue light and the rest of the light absorbed by the spherical particles. The engineering challenge is to incorporate this design for possible application in car windows, windshields, glasses, and advanced transparent optical displays.
3. *Placuna placenta*: This bivalve has translucent outer shell that allows 80% of visible light to go through. Commonly called capiz shells in the Philippines, they are often used as window panes and material for decorative items. In a 2014 paper by L. Li and C. Ortiz [21], the shell was found not only resistant to penetration, but also capable of multi-hit events with its property for energy-dissipation and damage localization. The shell isolates damage by creating a boundary around the edge of the stress region such that it is 10 times more efficient in dispersing the impact of a blow than pure mineral. Being optically clear, the material is strong enough to make bullet-proof windshields or even blast shields for combat vehicles inspiring its artificial reproduction to create extremely tough and lightweight exoskeletons for use by soldiers.

Discovering naturally crafted materials in new design configurations are compelling reasons why a more comprehensive study of marine life should be undertaken.

Novel Pharmaceutical Drugs

Recent medical drugs derived from studies of marine life are best exemplified by the venom of predatory cone snails belonging to the genus *Conus*. Cone snails inhabit tropical and subtropical seawater and one sting, for instance, from *Conus geographus* will kill a human adult within hours [22]. The venom consists of a mixture of peptides known as conotoxins which has exhibited striking effectivity and diversity [23]. Studies of conotoxins are expected to yield drugs related to the cure of epilepsy, Parkinson’s disease, diabetes, cancer, and other diseases of the central nervous system [24]. We cite a couple of examples.

1. *Conus magus*: From this cone snail, the conotoxin ω-MVIIA known commercially as Prialt (ziconotide) is used for the treatment of chronic pain. Prialt is more powerful than morphine and non-addictive [25].
2. *Conus geographus* and *Conus tulipa*: From the venoms of these two fish-hunting cone snails were recently found specialized insulin in large amounts [26]. The specialized insulin is released by the cone snail into the water disabling hypoglycemic fish making them easier to capture. As far as insulin goes, the one produced by these cone snails are shorter than any and consists only of 43 amino acids.

There remains a lot to be discovered in studying venoms of cone snails. As of April 2015, the accepted number of cone snail species is 706 in the World Register of Marine Species (WORMS) [27-30]. Each cone snail species, however, would have around 200 different conotoxins, or probably thousands if all variants and fragments are explored [29]. In just one type of cone snail, *Conus episcopatus* found along the east coast of Australia, thousands of conotoxins were found [28]. Noting that, there is little overlap in the type of conotoxins between two conus species [22,28], this implies that there may be a minimum of 140,000 conotoxins to investigate and explore as possible pharmaceutical drugs. To date, roughly around ten conotoxins have reached human clinical trials. We would literally need an army to develop pharmaceutical drugs from cone snail venoms in a reasonable amount of time.

Innovations in Generating Energy

1. *Tridacna derasa*, *T. maxima* and *T. crocea*: Research done on these giant clams found in Palau island, east of the Philippines, could provide two lessons on energy generation [31]. Firstly, these oversized molluscs harbor a three-dimensional biophotonic system that could revolutionize solar energy generation. Tiny iridescent cells inside the mantles of giant clams filter and distribute light to allow algae of the genus *Symbiodinium* to grow within their shells. These live iridescent cells called iridocytes allow clam tissues to have five times more light particles or photons than other tissues. Roughly spherical in shape, iridocytes are packed with reflective proteins. Secondly, there is ongoing research on algae as source of biofuel. Algae, however, need just the right amount of sunlight to grow. Inside the giant clam, the algae are efficiently piled into vertical microcolumns allowing light to shine not only at the top but also at the sides of the columns. The way giant clams harness and channels light illuminating millions of symbiotic algae could provide insights on how to have an efficient large-scale production of algae for renewable energy.

2. *Lyrodus pedicellatus, Teredo navalis*: These wood-boring mollusks known as shipworms may hold the key for large scale production of cellulosic ethanol from wood [32]. Wood is made of cellulose which is difficult to break down into sugar. Shipworms, however, break down wood for nutrition using digestive enzymes produced by bacteria in their gills. The shipworm's enzymes convert cellulose into sugar which can then be used to make biofuels like ethanol. The wood-degrading enzyme could be synthesized providing a new pathway for industrial production of renewable biofuels [33].

CONCLUSION

The marine activities discussed in this paper could likewise be done in other coastal towns in the Philippines. The establishment of a marine baseline data would help in the long term monitoring of changes brought about by climate change, typhoons, earthquakes, and human intervention. Moreover, these studies not only help in understanding marine ecological balance, but could also reveal new tropical species that may inspire applications in various emerging technologies.

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