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Diversity and abundance of economically important bivalves in north-western Bohol, Philippines

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Abstract
Diversity and abundance of bivalves found in mangroves and seagrass ecosystems of Northwestern, Bohol, Philippines were studied for five months using line transect method. Physico-chemical parameters such as depth, temperature, pH and dissolved oxygen in relation to occurrence of bivalves were also determined using CCA analysis. A total of 35 bivalve species were identified belonging to six orders, 14 families and 23 genera. Diversity index was higher in Calape (3.032) than Clarin (2.608) and Tubigon (2.607). This diversity index means that bivalves in Northwestern Bohol were in moderate condition. Meanwhile, the effect of earthquake was evident in the general evenness where Calape (0.63) was the highest while Clarin and Tubigon had similar result with 0.42 evenness index. This evenness index described ecological equilibrium in the community in which the value near to 1.00 means community is stable. Hence, Northwestern Bohol had unstable bivalve community. In terms of abundance, Clarin was the highest with 1085 total individuals. This was followed by Tubigon with 1022 and lowest in Calape with 853 total bivalves collected. Top five most abundant bivalves were *Scapharca indica* (24%), *Scapharca cornea* with 22% followed by *Anomalocardia squamosa* (7.9%), *Gafrarium tumidum* (6.5%) and *Trachycardium rugosum* (6%) respectively. These species of economically important bivalves with high abundance and distribution may be monitored for sustainability of wild stocks in the area. There may be a law regulating the intense collection of economically important bivalves in Northwestern Bohol to mitigate loss of these organisms knowing their unstable state.

Keywords: Earthquake, evenness and richness

Introduction
Biodiversity is the variety and variability of life forms on Earth [1]. This is an important measures linked with community stability that more species present in a community leads to more available alternative assemblages able to perform community key functions [2]. The Philippines was considered as one of the mega-diverse countries worldwide but also one of the world's biodiversity hotspots with 700 threatened species [3]. The peril of biodiversity includes natural calamities, climate change, pollution and human activities. Awareness on factors that affect biodiversity is very important to mitigate loss or possible extinction and for the conservation of economically important species.

A destructive 7.2 magnitude earthquake hit Bohol in late October 15, 2013 at 8:12:15 Philippine Standard Time (PST) documented by Mangosing (2013) caused by reverse fault [5]. This may be caused by undiscovered fault line in the past transecting Bohol running East North East-West South West parallel to the island's northwestern coast [6]. This had resulted to uplifted areas in Northwestern part of Bohol affecting mangroves and seagrass ecosystems. These were the towns whose residents mostly rely on fishing as their source of livelihood. They also supplied bivalves to nearby residential areas and in some stalls in Bohol public market. According to personal communication with local fishermen, they noticed a decrease in abundance of economically important bivalves after the earthquake. Hence, this study was conducted to assess present bivalve population.

Bivalves belonged to Phylum Mollusca and are distributed in vast array of habitat [7] constituting 12% freshwater, 35% terrestrial and 53% marine species [8]. Most bivalve species tend to burrow in the sand or mud and few creep on the bottom [9]. They play an important role in coastal ecosystems since they perform nutrient cycling, filter organic matters and plankton suspended in water. Their waste materials are deposited in the substrate where the nutrients are used by marine macrophytes and algae. They are also preyed upon by other species, such as shorebirds, fishes and crustaceans [10].

Bivalves are known to be of high nutritional value since they are a good source of protein [11], calcium and other nutrients which supply bone health [12]. Bivalves are a diverse group [13] present in mangrove [14] and seagrass ecosystem [15] which served as feeding, spawning and breeding ground for other organisms [16].

In Bohol, these ecosystems were affected by the recent earthquake causing upliftment and then drying up of extensive areas of mangroves (4,196 ha) and (5,900 ha) in northwestern Bohol. This may have possible implications to burrowing organisms particularly bivalves. Hence, studying bivalves which adopt sedentary lifestyle is necessary. Specifically, studying their diversity and abundance which signifies whether or not harvest of bivalves in the area is sustainable or not [17].

Areas of the study include Calape, Tubigon and Clarin which are located at a distance of approximately 8-33 kilometers away from earthquake epicenter, specifically in Sagbayan, where 40% of residences rely on fishing and gleaning as their means of livelihood. Considering that, it is imperative that diversity, abundance and occurrence of bivalves in these areas were determined for conservation of these resources. The physico-chemical parameters were also considered as they may directly affect the abundance of bivalves in each ecosystem.

Objectives of the Study

This study was conducted to determine the diversity and abundance of bivalves present in the mangrove and seagrass ecosystems in northwestern side of Bohol namely; Calape, Tubigon and Clarin. And to correlate the physico-chemical parameters such as depth, dissolved oxygen (DO), pH and temperature to abundance of bivalves in each town.

Materials and Methods

Sampling was done by setting the transect line seaward perpendicular to the coastal line [19]. This was adopted in the study of Katsanevakis & Thessalou-Legaki, 2009 but with certain modifications [20]. In the latter study, they used 50 meters line transect length with 5m transect quadrats. However, in this study a 100 meters line transect used in each sites. Each of the 100 meters transect line was overlaid with 1m x 1m quadrat with ten meters interval from each quadrat. All bivalves present within the quadrat were handpicked and preserved in 95% alcohol for identification. There were six transects deployed in each site, three replicate transects in both ecosystem each with 50 meters interval. A total of 90 transects were installed in all sites from September 2016-January 2017. The starting point of the line transect were randomly selected along the area.

Sediment Analysis

Substrates were collected using a 20 cm PVC core borer in each transects with three replicates for every site. These were placed in a ziplock and were brought in the laboratory of sediment analysis. The grain size classification was based on Wenthworth grain size analysis [21-22].

Study Site

Bohol is an island province of the Philippines (Figure 1) in Central Visayas region which is famous of its biodiversity and was the epicentre of the earthquake. As a small island, it was affected greatly when a 7.2 magnitude earthquake calamity happened last October 15, 2013. The three municipalities of Calape, Tubigon and Clarin were the most affected areas. Clarin was the nearest with 8 kilometers away from earthquake epicenter (Sagbayan), followed by Tubigon (15kms) and Calape (33kms) respectively. Station 1, Calape is located at 9° 53' 20" North, 123° 53' 0" East. This is the third income class municipality in the province. Municipal water of the area is about 12,486 hectares and 21.68 kilometers shoreline length excluding offshore island [18].

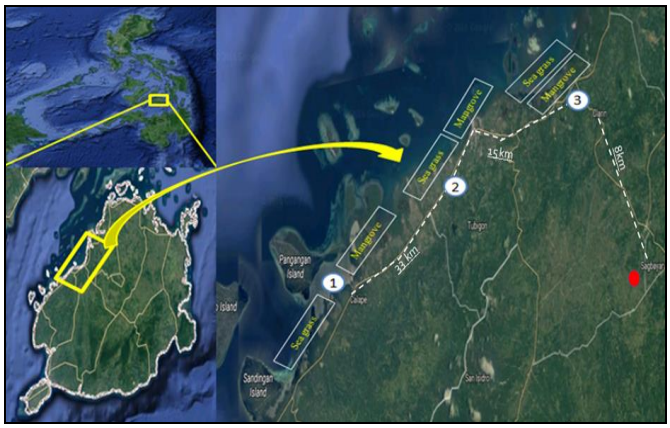

Fig 1: Map of the Philippines, Bohol and the three Sampling Sites with red dot indicating epicentre of the earthquake and broken lines distance from the epicenter (Google Earth, 2017)

Station 2, Tubigon (9° 57' 6" North, 123° 57' 43" East) is the second class municipality and the nearest seaport in Bohol to Cebu. It is a coastal town with 12 coastal barangays and 6 islands in which 40% of the population rely on fishing as a livelihood. Mangroves were found along the coast with seagrass beds on its intertidal areas [18]. Sediment observed in the area were soft substrata comprised of sand and mud preferable for burrowing organisms. Finally, Clarin (Station 3) is located at 9° 53' 20" North, 123° 53' 0" East. This is the third income class municipality in the province. Municipal water of the area is about 12,486 hectares and 21.68 kilometers shoreline length excluding offshore island [18]. Large mangroves and seagrass beds abound the coastal area.

Results and Discussion

Table 1 showed that diversity of bivalves in Calape (3.032) was higher than Clarin (2.608) and Tubigon (2.607). Differences of diversity between two ecosystems could be due to heterogeneity of so many factors [23]. Diversity index which was lesser than three means moderate state [24]. Therefore, diversity of bivalves in Northwestern Bohol was in moderate condition.

Table 1: Diversity Index of Bivalves Species in Northwestern Bohol, Philippines

Study Sites	Diversity (D)	Evenness (H')	Richness (H'max)	Total No. of Individuals (N)
Clarin	2.608	0.42	4.4	1085
Tubigon	2.607	0.42	4.5	1022
Calape	3.032	0.63	4.7	853

Meanwhile, general evenness was 0.63 in Calape which was the highest while Clarin and Tubigon had similar result with 0.42 respectively. This evenness index described ecological equilibrium in the community in which the higher the

evenness, the better environmental quality and the more suitable for animal life even though there were some species having higher number than the other [25]. The value near to 1.00 means community is stable [26] hence Northwestern Bohol had unstable bivalve community. This could be due to the result of earthquake. Richness index was highest in Calape with 4.7, followed by Tubigon with 4.5 and Clarin with 4.4. This result was categorized as moderate based on the species richness index of Jorgensen (2005) that richness index ranging from 2.5 to 4.0 was considered moderate. This means that mangrove and seagrass ecosystem of Clarin, Tubigon and Calape were rich of bivalves species.

The most abundant species was *Scapharca indica* with 24% relative abundance (Figure 1). This could be due to its rapid growth and high tolerance [28]. Similar study of Kastoro & Razak (1986) in Jakarta also showed high abundance of *S. indica* even after habitat deterioration due to industrialization [29]. Second most abundant species was *Scapharca cornea* with 22% relative abundance value. The abundance of this species could be attributed to their sediment preference which was a sandy muddy one which was the substrate present in the study area. According to Pathansali (1966), this bivalve species like soft sediments [30]. This was the same result in the study of Broom (1982) in Malaysia which also found highest abundance of *Scapharca cornea* [31].

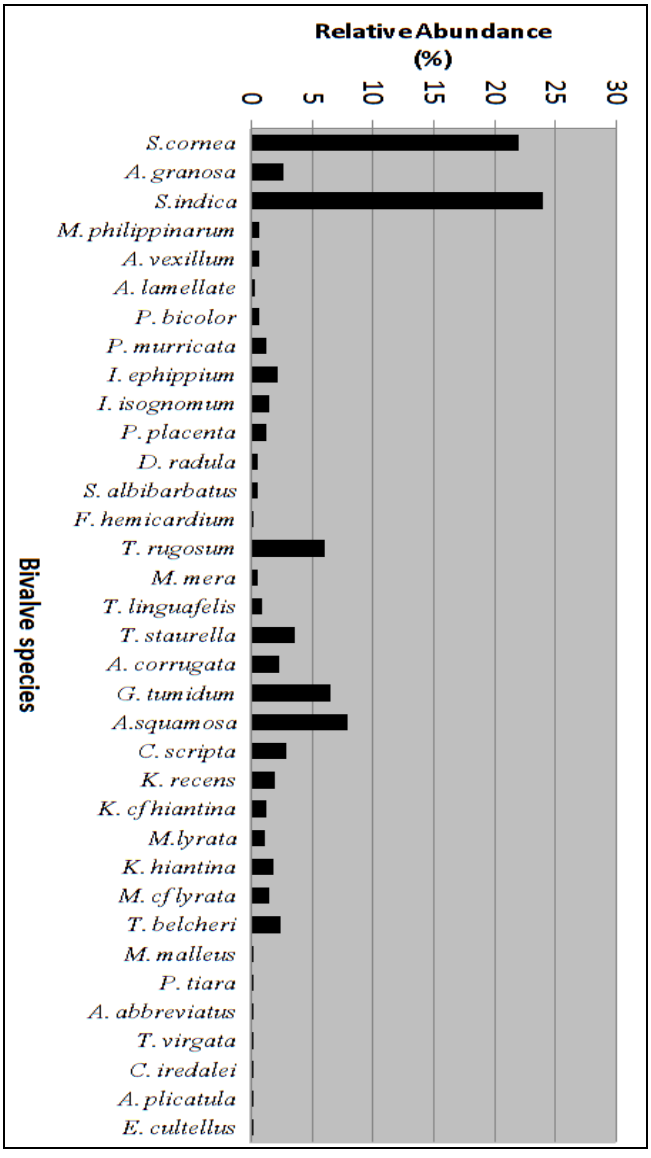

Fig 2: Abundance of Bivalves in Northwestern Bohol, Philippines

Third most abundant species was *Anomalocardia squamosa* of Order Veneroida with 7.9% abundance. These were tiny clams that were least collected in study areas due to its low economic importance according to personal interview of common gleaners. These were found mostly in mangrove ecosystem burrowing on muddy substrates at 2-3 centimeters depth. Their high abundance could also be due to their dominating behavior and uniform distribution [32]. The fourth most abundant was *Gafrarium tumidum* 6.5%. Same with *A. squamosa*, this species likes sandy muddy substrates which were the substrate observed in the study area. This could be the reason of their abundance. These species also have a capacity to reproduce quickly depending on environmental factors like temperature and salinity [33]. Fifth of the most abundant bivalve species was *Trachycardium rugosum* with 6% relative abundance. This species also prefer soft sediments since they are filter-feeders [34]. Hence, they were abundant in Clarin, Tubigon and Calape areas which have soft sediment composition. The result of this study was analogous to the study of Zusron *et al*. (2015) which also showed abundance of *Trachycadium rugosum* in Indonesia found on muddy substrate [35].

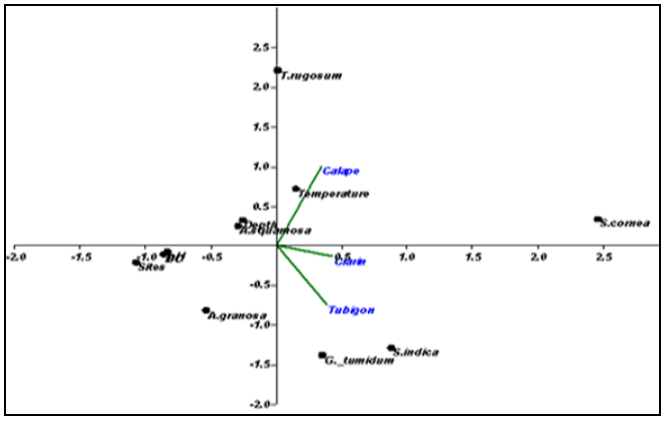

Fig 3: Canonical Cluster Analysis (CCA) Map

As shown in Canonical Cluster Analysis Map (Figure 3), the frequency of occurence of bivalve species *S. indica*, *A. granosa* and *G. tumidum* which are abundant species in Clarin and Tubigon areas is associated with pH and DO. These species would likely occur when pH and DO are low. Whereas, for species *A. squamosa*, and *T. rugosum* their occurrence in Calape area were associated with temperature and depth. For T. *rugosum*, they mostly occur when temperature and depth are higher. However, for *A. squamosa*, they prefer to occur at lower depth and temperature. However, for bivalve species *S. cornea* which were abundant in Calape, they occur with higher pH and DO.

Conclusion and Recommendation

This study showed that there were diverse bivalve species present mangroves and seagrass ecosystem of Northwestern, Bohol, Philippines which were represented by the 35 identified species. Their abundance was due to the muddy substrate in the area which was favorable for these bottom-dwellers.

Continuous monitoring of these economically important bivalves may be implemented since these resources are in unstable condition as an effect of earthquake as shown in their evenness index. Also, considering, their economic value gleaning activity of these least abundant species may be regulated for sustainability of these wild stocks in area.

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Appendix
Economically important bivalves present in Northwestern Bohol, Philippines.

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