

Limpets on the Rocky Shores of Southern Antique, Panay, Island: Distribution, Abundance, and Size Structure

Demie P. Putong*, Karen A. Villarta-Lane

Marine Biology Laboratory, Division of Biological Sciences, College of Arts and Sciences, University of the Philippines Visayas, Miagao (5023), Iloilo

ABSTRACT

Limpets are key herbivores in marine ecosystems, especially in high-energy rocky intertidal habitats where they regulate algal proliferation, create microhabitats, and foster unique biological communities. Despite their ecological significance, the limpet ecology in the Philippines remains understudied. This study assessed the distribution, abundance, and size structure of limpets on rocky shores at the southern tip of Panay Island, Philippines. Three study sites were surveyed using the standard transect-quadrat method to determine species composition and densities, with shell lengths (SL) measured to assess population size structure. A total of 331 limpets were recorded across all sites, representing three species: *Siphonaria javanica*, *Siphonaria laciniosa*, and *Patelloida saccharina*. The abundance of each species varied between sites. *S. javanica* exhibited the highest density, with an overall mean of 2.27 individuals 0.25 m⁻², while *P. saccharina* had the lowest count with only four individuals observed. Limpets predominantly occupied the mid shore (1.00 m above Chart Datum, C.D.) and high shore (1.50 m above C.D.) levels, with each species demonstrating a preference for specific tidal heights. Shell lengths ranged from 1.00 to 29.00 mm, with most individuals having relatively small shells. The average SLs were 3.37 mm for *S. javanica*, 6.99 mm for *S. laciniosa*, and 5.60 mm for *P. saccharina*. This study is the first to document limpets on the rocky shores of Panay Island, providing baseline data on their ecology in the Philippines. Continued field monitoring and studies on population and reproductive biology are recommended to further understand the dynamics of these limpet populations.

KEYWORDS:

limpets, rocky shore, abundance, vertical distribution, shell length

INTRODUCTION

Limpets are significant herbivorous marine animals that are found in numerous intertidal and subtidal marine habitats (Underwood 1979; Branch 1981; Creese 1982; Hawkins and Hartnoll 1983; Coleman et al. 2006). They are commonly distributed in high-energy rocky intertidal habitats (Branch 1981; Little 1989) due to the abundant presence of algae on rocky shores, which provides a rich nutritional substrate for the thriving populations of limpets and other invertebrates. Their presence plays a vital role in maintaining the balance and productivity of ecosystems (Branch 1981; Moreno and Jaramillo 1983). Through their grazing, they function as a regulatory mechanism in algal population (Jenkins et al. 1999; Hawkins and Hartnoll 1983), including seaweeds which serve

as crucial habitats and nourishment sources for diverse marine species (Hawkins and Hartnoll 1985; Kenelly 1987). Their movement establishes essential microhabitats for small invertebrates (Lubchenco and Gaines 1981; Steneck and Watling 1982) and they influence competitive interactions with other species (Underwood 1979) that can impact ecological succession rates (Branch 1985) and contribute to the development of distinct biological communities (Anderson and Underwood 1997). Hence, limpets are duly recognized as keystone species within intertidal communities (Menge et al. 2010; Henriques et al. 2017). On rocky intertidal zones, limpets display vertical zonation patterns based on numerous factors such as food availability (Chelazzi et al. 1994; Hutchinson and Williams 2002), desiccation and osmotic stress (Wallace 1972; William and Morrill 1995), predation by visual predators (Branch and

*Corresponding Author:

Division of Biological Sciences, College of Arts and Sciences, UP Visayas
Email address: dputong@up.edu.ph

Cherry 1985) and wave action (Williams and Morritt 1995; Tanaka et al. 2002) wherein these factors vary between seasons. Due to these interesting characteristics of limpets, numerous studies have focused on the density and distribution of limpets globally (Underwood and Jernakoff 1984; Tanaka et al. 2002; Navarro et al. 2005; Coleman et al. 2006). However, few studies on tropical limpets have been conducted particularly in the Philippines. Existing local studies have investigated the ecology (Villarta et al. 2017) and movement pattern (Zapanta et al. 2020) of *Patelloida saccharina* in the Philippines; however, studies particularly on the abundance and vertical distribution of limpets in general remain lacking.

The coast of southern Panay, particularly in Tobias Fornier, Antique, where rocky shores are prominent provides an ideal setting for investigation on tropical limpets. This study generally aimed to provide information on the population of limpets found on rocky shores of southern Antique. Specifically, this study (1) determined the species composition,

abundance, and distribution of limpets in the area, (2) determined the size structure of different limpets found in the area, and (3) correlated environmental parameters to the structure of limpet populations. This study is the first to investigate the limpet populations on Panay Island, Philippines, and provides baseline data useful in future related investigations.

MATERIALS AND METHODS

Study Sites and Field Sampling

To obtain comprehensive insights into the abundance and distribution of limpets in the eastern shorelines of the southern tip of Panay Island, three semi-exposed rocky shore (as described by Little et al. 1996) sites in Igdalaguit, Tobias Fornier, Antique, were selected to represent the study area (Figure 1). Site 1 (N 10.50513°, E 121.92092°) was characterized by moderately sloping, dark granitic rock with rugged surfaces and visible crevices. Site 2 (N 10.50527°, E 121.92007°) is distinguished by dark basaltic rocks

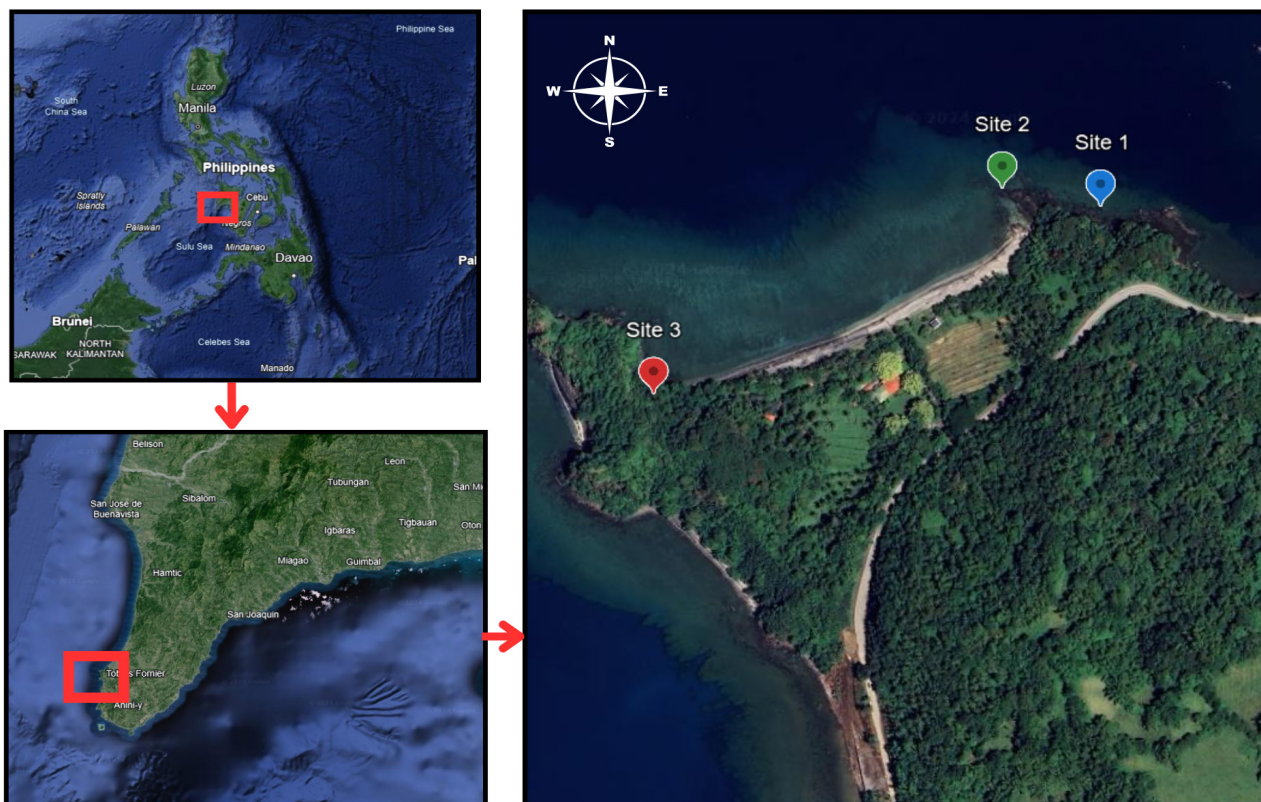


Figure 1. Location of the study sites in Tobias Fornier, southern Antique, Panay, Philippines. (Top left: Map of the Philippines highlighting Panay Island, enclosed in a red square. Lower left: Map showing the southern tip of Panay Island, with the location of Tobias Fornier outlined in a red square. Close-up image of the study area, indicating the locations of the three study sites.)

with a steeper slope compared to Sites 1 and 3. It is continuously exposed to sunlight throughout the day. Site 3 (N 10.50352°, E 121.91706°) has basaltic rocks with a gently sloping surface (Figure 2). Field sampling was conducted once on each site during low tide in February 2024. Measurements of rock temperature, air temperature, and water temperature were taken during the survey using a thermocouple wire connected to a handheld digital thermometer device (HT 9815). The rock slope, measured in degrees, at each site was recorded using a clinometer positioned at different locations along the uppermost transect and oriented downwards along the slope of the rock surface.

height occupied by each species was calculated by averaging the heights at which individuals of each species were found. This was calculated using the following formula:

$$\text{Mean Height (m, above C.D.)} = \frac{\sum(H_i \times N_i)}{T}$$

Where H_i is the tidal height above Chart Datum; N_i corresponds to the number of limpets_{*i*} at a particular tidal height and T is the total number of limpets_{*i*} tallied in all tidal heights of each sampling site.

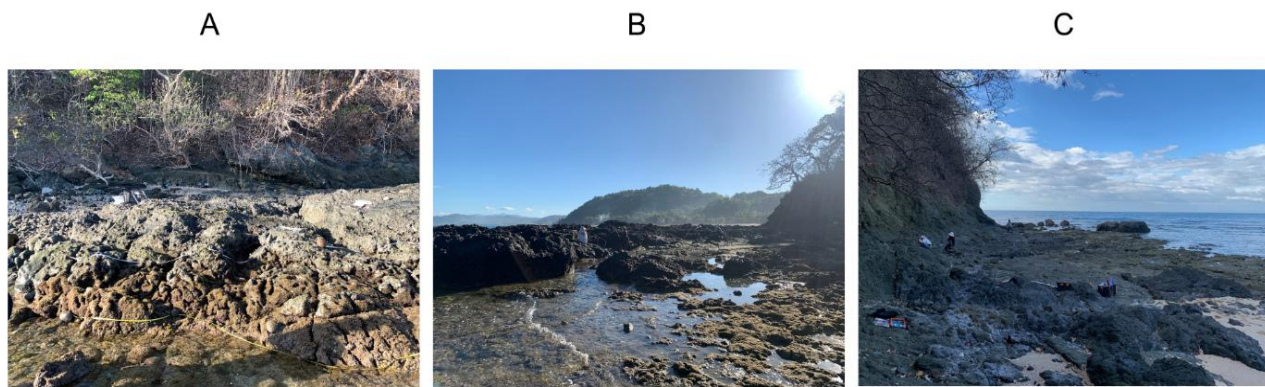


Figure 2. Study sites in Tobias Fornier, southern Antique, Panay, Philippines (A = Site 1; B = site 2; C = site 3).

Species Composition, Abundance, and Distribution

The study employed the standard transect method (Krebs 1989) to systematically record species composition in the area. At each site, four 20 m transects were positioned parallel to the shore at different tidal heights, with height intervals of 0.50 m, ranging from 0.00 to 1.50 m above chart datum (C.D.). At sites 2 and 3, the lowest shore (0.00 m above C.D.) could not be included as the rocky area does not extend to this level. Along each transect, 10 quadrats (50 cm x 50 cm) were positioned randomly. In each quadrat, all limpets encountered were identified to the lowest taxonomic classification, following the “FAO Species Identification Guide for Fishery Purposes” by Carpenter and Niem (1998) based on their size and shell characteristics.

All observed limpets were identified and counted to determine the density per species. The overall abundance and mean density of each limpet species were recorded for each vertical height at each sampling site. Additionally, the mean vertical

Size structure

At each site, the shell length (SL; mm) of all limpets observed in each quadrat was measured to the nearest 0.10 mm using a caliper. Measurements were grouped into 1 mm size classes and plotted for each tidal height at each site.

Data analysis

To determine differences in abundance, mean density was calculated for each limpet species at each tidal height in each of the three study sites. Overall mean densities were then calculated for each site. A one-way ANOVA was performed to assess differences in limpet densities between and within sites, using transects as the unit of statistical analysis and quadrats as the sampling units. To assess the distribution of each limpet species, the mean tidal height for each species was determined by calculating the average tidal height occupied by each limpet species at each site.

RESULTS

Species Composition, Abundance, and Distribution

Limpets, though part of a common ecological functional group, can belong to different and unrelated taxonomic groups. A total of three species were observed across all sites, with two species from family Siphonariidae namely, *Siphonaria javanica* and *S. laciniosa* and one species from family Lottiidae identified as *Patelloida saccharina* (Figure 3). The shared conical shape of the two families is a product of convergent evolution. *Siphonaria* is a pulmonate species belonging to the family Siphonaridae (Hodgson 1999), whereas *Patelloida* is a prosobranch gastropod from the family Lottiidae (Graham 1988). The pulmonate nature of *Siphonaria* provides an adaptive advantage in the high shore zone, while *Patelloida* is typically restricted to the low-mid zone.

(Figure 4). The densities of *S. javanica* showed no significant differences across different tidal heights in all the sampling sites ($p > 0.05$ in all sites). The overall mean densities of *S. javanica* also did not show significant differences across all sites ($p = 0.19$). The lowest abundance of *S. javanica* was observed at site 1, with an average density of 0.58 individuals 0.25 m^{-2} . At site 1, *S. laciniosa*, the second most abundant limpet species in the study area, was dominant with an average density of 2.30 individuals 0.25 m^{-2} . Significant differences in the densities of *S. laciniosa* were observed across different tidal heights ($p = 0.04$) with more individuals recorded at the high shore zone. *S. laciniosa* mean densities across all sites also varied significantly ($p = 0.003$). *P. saccharina* had the lowest abundance, being recorded only at 2 sites, with a total of four individuals (site 2: $n = 2$; site 3: $n = 2$) observed throughout the survey. The overall

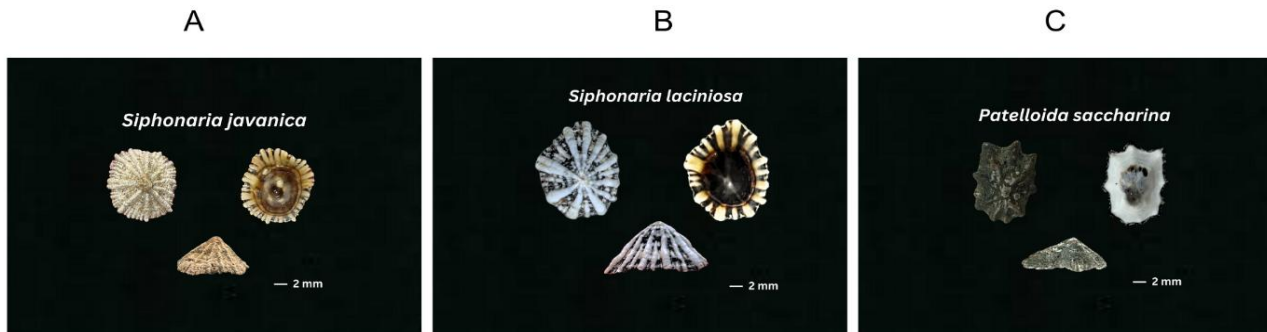


Figure 3. Dorsal, ventral, and lateral views of the shell of the limpets, A = *Siphonaria javanica* (Lamarck, 1819), B = *Siphonaria laciniosa* (Linnaeus, 1758), and C = *Patelloida saccharina* (Linnaeus, 1758).

S. javanica, commonly the Javanese false limpet, was observed at all three sites and was identified by its brownish exterior with prominent white ribs, particularly the major ones, and a dark apex. Meanwhile, *S. laciniosa*, the fringed false limpet, which was observed at all sites, was recognized by its conical shell and characterized by gray outer coloring with lighter colored ribs. A closer inspection revealed a dark brown inner margin with whitish bars. The Pacific sugar limpet, *P. saccharina*, was identified by its conical shell and radial sculpture. It was only observed at two sites (sites 2 and 3).

A total of 331 limpet individuals were recorded across the three study sites, with the abundance of each species varying by site. *S. javanica* dominated in two out of the three sites (sites 2 and 3), with an overall mean density of 2.27 individuals 0.25 m^{-2} , accounting for 63.44% of the total limpets recorded

mean densities of all limpet individuals across sites showed no significant differences ($p > 0.05$).

The mean tidal heights of the three limpet species across three study sites indicated that each species preferred specific resting heights, which varied by site. *S. javanica* preferred the high shore zone ($>1.00 \text{ m}$ above C.D.) where they were usually found clumped within rock crevices whereas *S. laciniosa* did not exhibit a uniform vertical pattern across the sites but was generally found at lower heights (0.60 to 1.20 m above C.D.) compared to *S. javanica* (0.90 to 1.40 m above C.D.) (Figure 5). *P. saccharina* showed a narrow distribution, being found only in the mid shore zone (0.80 to 1.00 m above C.D.) of the sites where it was observed. Among the three limpets, *S. laciniosa* had the most extensive vertical distribution across sites, being observed in the low-mid and high shore zones (Figure 5).

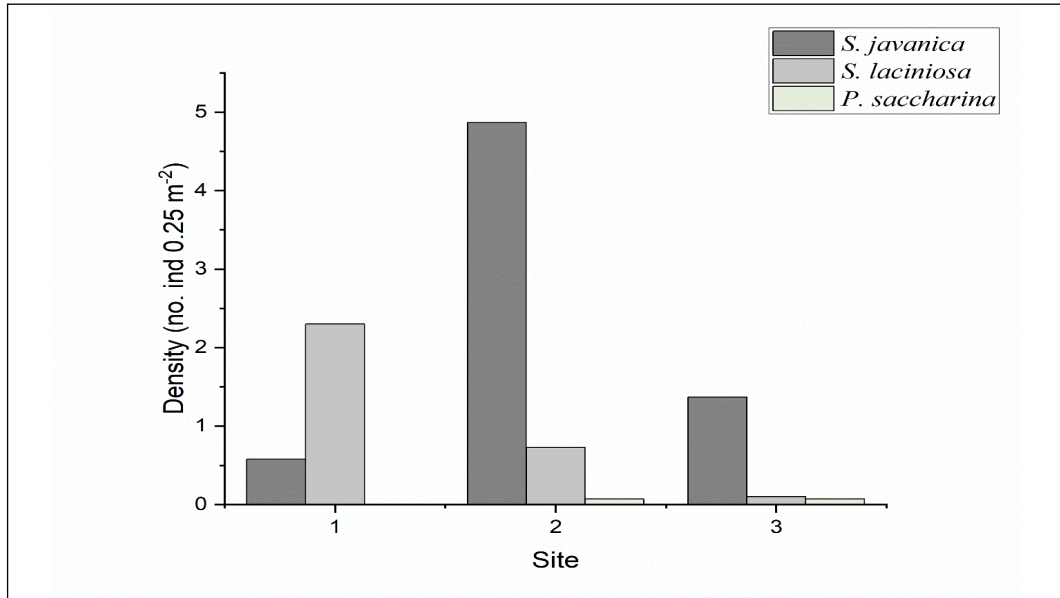


Figure 4. Mean density per 0.25 m² of the limpets *S. javanica*, *S. laciniosa*, and *P. saccharina* across the three sites in Tobias Fornier, southern Antique. (Note: error bars were omitted for clarity)

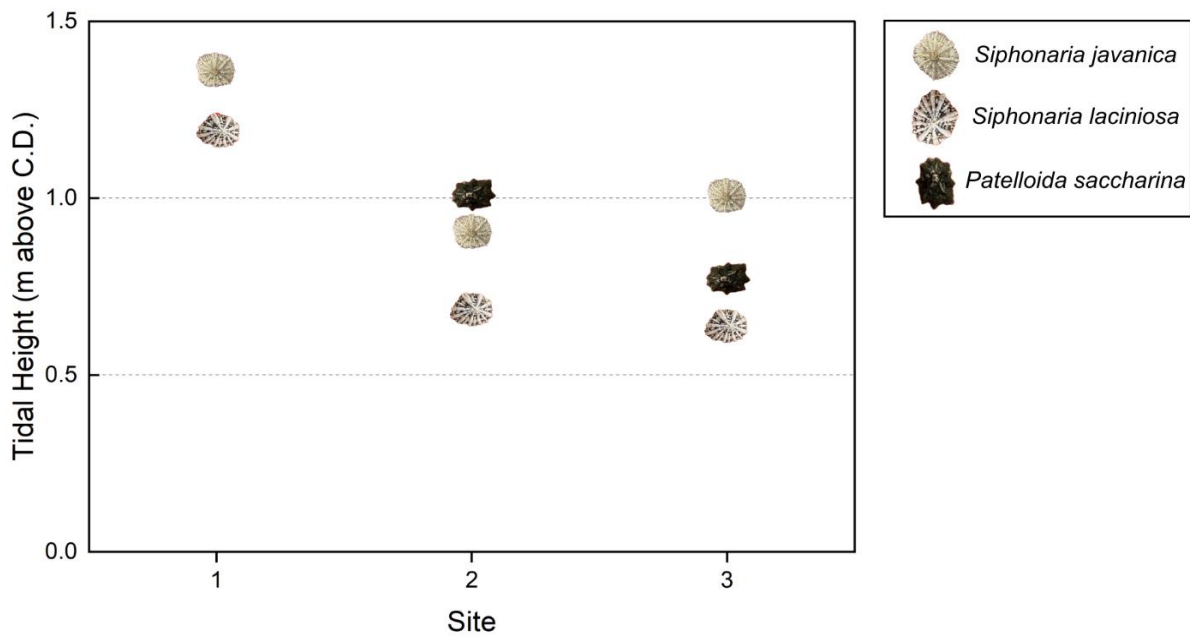


Figure 5. Mean tidal heights occupied by the limpets *S. javanica*, *S. laciniosa*, and *P. saccharina* on rocky shores in Tobias Fornier, southern Antique.

Size structure

The shell length (SL) of *S. javanica* recorded across the sites during the survey ranged from 1.00 to 16.40 mm. The individuals generally had relatively small SLs (Figure 6), with an overall average of 3.37 mm ($n = 210$). Shell lengths greater than 5 mm were rare, with only two individuals observed at sites 1 and 2, and one individual at site 3.

For *S. laciniosa*, shell lengths ranged from 1.20 mm to 29.00 mm, with an overall mean of 6.99 mm ($n = 117$) across all sites. Some individuals had relatively large shell lengths (>10 mm), but the frequency of these larger individuals was low compared to those in the 1.00 to 5.00 mm range. At site 1, two cohorts representing different size groups within the *S. laciniosa* population were observed (Figure 7).

The shell length distribution of *P. saccharina*, was documented only at sites 2 and 3, as no individuals were present at site 1 (Figure 8). At site 2, there were only two individuals of *P. saccharina*, both with shell lengths measuring less than 5.00 mm.

Association Between Densities and Environmental Conditions

At site 1, the mean rock temperatures of the mid shore and high shore (30.4°C and 30.8°C, respectively), where the majority of limpet individuals were observed, were relatively lower than the average rock temperature in the low mid shore (34.9 °C). Trees were observed beyond the splash zone, providing some shade to the upper shore levels and contributing to lower temperatures in those areas. At site 2, with a shoreline orientation facing south, both rock and air temperatures measured in the early part of the day exceeded 30.0°C. Despite these relatively high temperatures, this site recorded the highest limpet abundance ($n = 170$). It had a steep slope (-7.6° to -48.0°) with numerous crevices on the rock surfaces. At site 3, the highest rock surface temperature (42.6 °C) was recorded on a clear, hot, sunny day during the afternoon low tide. High daytime temperatures may have likely contributed to the low limpet abundance ($n = 46$) in this site.

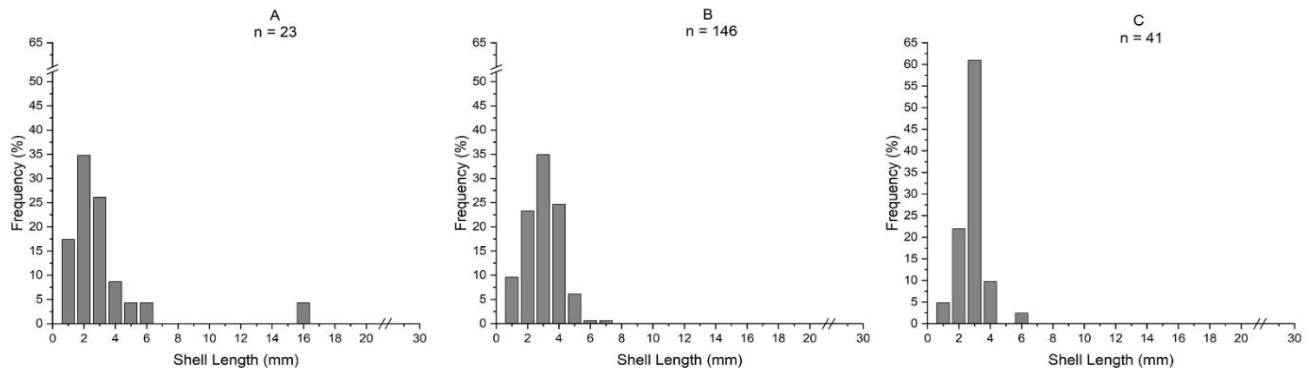


Figure 6. Size frequency distribution of the Javanese false limpet, *Siphonaria javanica*, in rocky shore sites (A = Site 1; B = site 2; C = site 3) surveyed at Tobias Fornier, southern Antique.

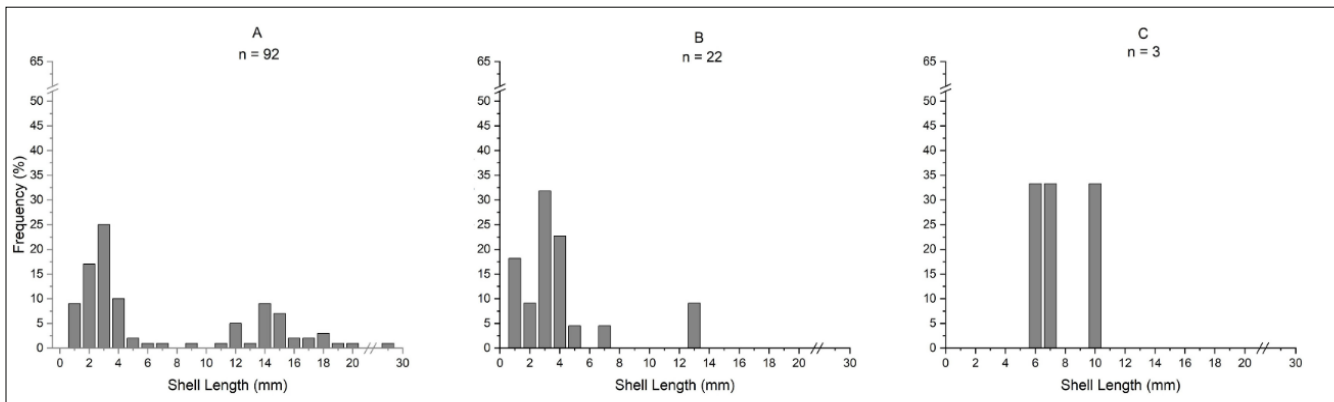


Figure 7. Size frequency distribution of the fringed false limpet, *Siphonaria laciniosa*, in rocky shore sites (A = Site 1; B = site 2; C = site 3) surveyed at Tobias Fornier, southern Antique.

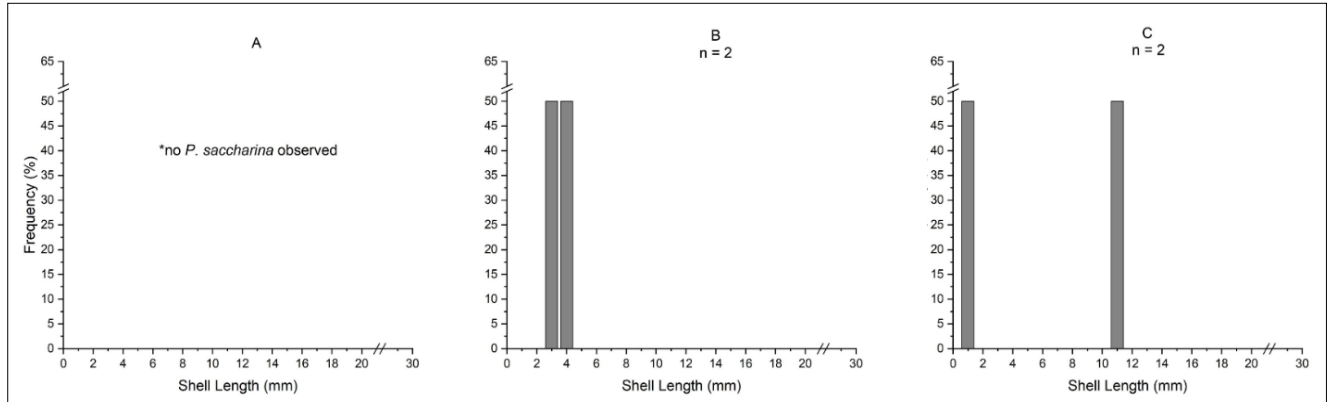


Figure 8. Size frequency distribution of the Pacific sugar limpet, *Patelloida saccharina*, in rocky shore sites (A = Site 1; B = site 2; C = site 3) surveyed at Tobias Fornier, southern Antique.

DISCUSSION

Species Composition, Abundance, and Distribution

Three species of limpets were recorded: *S. javanica*, *S. laciniosa*, and *P. saccharina*. All three species are native to the Philippines (Poutiers 1998) and are commonly found in the Indo-West Pacific region (Vermeij 1978). *S. javanica* and *S. laciniosa* both exhibited high recorded densities (Figure 3). These two limpets, belonging to the family Siphonariidae, are widely distributed across the Philippines (Young and Fontanilla 2014). These limpets, which are known to graze various algal communities, may have played a role in promoting the development of distinct biological communities in the area.

The distribution of these species varied across tidal zones, with *S. javanica* primarily found in the upper drying zone and *S. laciniosa* at lower tidal levels. This vertical zonation aligns with their known ecological preferences and is consistent with findings from earlier studies (Vermeij 1971; Morton and Morton 1983). However, *P. saccharina* was recorded at low densities, with only four individuals observed. The overall success particularly in the family Siphonariidae may be attributed to their ability to withstand high temperatures and desiccation through various adaptations (Chambers and McQuaid 1994). Limpets of Siphonariidae family are also versatile grazers, feeding on a diverse array of microalgae such as filamentous algae, leafy algae, and macroscopic corticated algae (Underwood 1980; Chambers and McQuaid 1994; Hodgson 1999).

S. javanica was found mostly on high levels on the shore. It has been reported to occur primarily on tropical coasts as a high intertidal species, occupying the upper levels of the shore (Vermeij 1971). It can

tolerate much higher temperatures than those found in temperate regions or by other species inhabiting the lower levels on the shore. According to Hodgson (1999) *Siphonaria* species tend to inhabit a narrow vertical zone along the shoreline rather than being evenly distributed across a broader range of tidal elevations. This observation aligned with the vertical distribution of *S. javanica* in the study. Additionally, Lewis (1963) discovered a link between the ability of intertidal animals to regulate their body temperature and the specific tidal height they inhabit. Across the three study sites, *S. javanica* predominantly occurred at high shore zones. While not definitively confirmed in this survey, it can be suggested that individuals of *S. javanica* demonstrated a higher tolerance to temperature when compared to other recorded limpet species.

S. laciniosa, which were mostly observed at tidal heights lower than *S. javanica*, are reported as low intertidal species (Vermeij 1971). A study by Morton and Morton (1983) in Hong Kong found that *S. laciniosa* were frequently found in habitats characterized by wave exposure, and this may account for their occurrence at a lower tidal level than its congeneric, *S. javanica*.

P. saccharina showed relatively low densities across all study sites, with only 4 individuals observed during the survey. The density of *P. saccharina* has been shown to significantly vary across a temporal scale (Morton and Morton 1983; Villarta et al. 2017). In Southern Guimaras, Philippines, *P. saccharina* was more abundant during the southwest monsoon (Villarta et al. 2017). In the current study, the survey was conducted during the northeast monsoon, likely explaining the low abundance of *P. saccharina* observed. The four individuals recorded, which

were found in the low and mid shores, matched observations in Hong Kong (Liu and Morton 1998) and in Guimaras, Philippines (Villarta et al. 2017) where *P. saccharina* favored lower shores due to the brief periods of sun exposure.

Size structure

Small-sized limpets were the most commonly observed group in the study area. Larger limpets were primarily found in the high shore, with data indicating apparent relationship between shell size and tidal zone. Specifically, larger shell lengths were recorded at higher tidal levels, consistent with findings by Bazterrica et al. (2007) in Argentina. Additionally, Vermeij (1972) observed that gastropods in the high shore tend to grow larger due to reduced vulnerability to physical stress, which aligns with our observations. However, the largest limpet was observed in the lower tidal zone, suggesting that other factors, such as habitat characteristics, environmental conditions, or ecological interactions, might play an important role in determining vertical distributions.

The smaller shell lengths observed in this survey could not be conclusively explained due to the limitation of a single sampling event. It is possible that the limpets surveyed in southern Antique were still juveniles at the time of sampling. Shell length is often associated with age, with juveniles having smaller shells and mature limpets having larger ones (Bretos 1980; Hollyman et al. 2018). In addition, spawning activity varies across species and regions (Branch 1981). The spawning periods of *S. javanica* and *S. laciniosa* in tropical regions are poorly studied (Chim and Tan 2009), including in the Philippines where no information is available. In Singapore, Chim and Tan (2009) found *Siphonaria guamensis* exhibited intense spawning activity from late July to late October and again from mid-August to early October at the mid shore zone. During the southwest monsoon, *S. guamensis* had an extended egg mass deposition period of up to four months, aligning with elevated temperatures and reduced rainfall. Similarly, Villarta et al. (2017) found that the gonadosomatic indices (GSI) of *P. saccharina* in southern Guimaras, Philippines were higher during the southwest monsoon. However, only data for *P. saccharina* has been reported and more information on the reproduction of other limpet species is needed. This study is the first to observe limpet populations on Panay Island, so no comparisons can be made for the shell length of the limpets in the area. Nonetheless, it provides primary data on limpet ecology in Antique,

Panay Island, Philippines, although further research is necessary to gain a deeper understanding of the dynamics of these limpet populations.

Environmental parameters

S. javanica and *S. laciniosa* were frequently found in crevices, which is common for intertidal invertebrates inhabiting sheltered microhabitats such as cracks, crevices, or biogenically altered habitats during low tides, particularly in tropical regions (Branch 1976; Williams and Morritt 1995). In contrast, most *P. saccharina* individuals were found on bare rock, as also observed by Sangphueak et al. (2024) in Thailand. Although microhabitats were observed in this study, they were neither quantified nor evaluated based on the presence of limpets. As a result, no direct analysis could be performed to establish correlations. The temperature conditions that species encounter vary greatly and are influenced by the characteristics and physical features of the shore. For example, vertical rock surfaces on most coasts tend to be cooler than horizontal ones (Williams and Morritt 1995). Among the various local topographical and environmental elements in the rocky intertidal area, the aspect (i.e., north-south directionality) is considered to be highly significant, such that a general trend towards greater taxon richness and abundance on the north-facing surfaces is observed (Firth et al. 2016). In this study, additional data is required to effectively correlate the influence of various environmental factors on the density and distribution of species.

Long-term field monitoring, which would track changes and trends in the populations over extended periods (seasonal and temporal scales), could provide valuable data on the life history of limpets in the area. This may include additional information on breeding cycles, reproductive success, and recruitment patterns. These investigations would offer comprehensive insights into the population dynamics and help in identifying critical factors influencing their abundance and distribution.

ACKNOWLEDGEMENTS

The authors thank the local government unit of Tobias Fornier, Antique, and Mayor Ernesto Tajanlangit III for the hospitality during our stay in Tobias Fornier. The assistance of Ackley Lane, Mia Jane Geneblaza, Blaise Bagarinao, and Louise Angela Etino is greatly appreciated for their support and help during the fieldwork. The authors are also grateful to the Marine Bio laboratory and the Division

of Biological Sciences of UPV for providing access to their equipment and facilities.

ETHICAL DECLARATION

This study, titled “*Limpets on the Rocky Shores of Southern Antique, Panay Island: Distribution, Abundance, and Size Structure*”, was conducted in accordance with all ethical guidelines and standards. Ethical approval was not required for this research, as they study focused solely on the collection of data on limpets, which does not involve human participants or endangered species. All necessary permissions for fieldwork were obtained.

CONFLICT OF INTEREST STATEMENT

The authors declared that there are no conflicts of interest regarding the publication of this paper.

LITERATURE CITED

- Anderson MJ, Underwood AJ. 1997. Effects of gastropod grazers on recruitment and succession of an estuarine assemblage: a multivariate and univariate approach. *Oecologia*. 109: 442–453. doi:10.1007/s004420050104
- Bazterrica MC, Silliman BR, Hidalgo FJ, Crain CM, Bertness MD. (2007). Limpet grazing on a physically stressful Patagonian rocky shore. *Journal of Experimental Marine Biology and Ecology*. 353(1): 22–34. doi:doi.org/10.1016/j.jembe.2007.08.018
- Branch GM. 1976. Interspecific competition experienced by South African *Patella* species. *The Journal of Animal Ecology*. 45: 507–529. doi:10.2307/3888.
- Branch GM. 1981. The biology of limpets: physical factors, energy flow, and ecological interactions. Aberdeen University Press
- Branch GM, Cherry MI. 1985. Activity rhythms of the pulmonate limpet *Siphonaria capensis* Q. & G. as an adaptation to osmotic stress, predation and wave action. *Journal of Experimental Marine Biology and Ecology*. 87: 153–168. doi:10.1016/0022-0981(85)90088-7
- Bretos M. 1980. Age determination in the keyhole limpet *Fissurella crassa* Lamarck (Archaeogastropoda: Fissurellidae), based on shell growth rings. *The Biological Bulletin*. 159(3): 606–612. doi:10.2307/1540826
- Boaventura D, Alexander M, Della Santina P, Smith ND, Ré P, da Fonseca LC, Hawkins SJ. 2002. The effects of grazing on the distribution and composition of low-shore algal communities on the central coast of Portugal and the southern coast of Britain. *Journal of Experimental Marine Biology and Ecology*. 267: 185–206. doi:10.1016/S0022-0981(01)00372-0
- Carpenter, K.E., and V.H. Niem (eds.).1998. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, Corals, Bivalves, and Gastropods.
- Chambers RJ, McQuaid CD. 1994. A review of larval development in the intertidal limpet genus *Siphonaria* (Gastropoda: Pulmonata). *Journal of Molluscan Studies*. 60(4). doi:10.1093/mollus/60.4.415
- Chelazzi G, Della Santina P, Santini G. 1994. Rhythmical timing and spatial scattering of foraging in a homer limpet (*Patella rustica*). *Behavioral Ecology*. 5: 288–292. doi:10.1093/beheco/5.3.288
- Chim CK, Tan KS. 2009. Vertical distribution, spawning and recruitment of *Siphonaria guamensis* (Gastropoda: Pulmonata) on a seawall in Singapore. *Raffles Bulletin of Zoology*. 22: 269–278
- Coleman RA, Underwood AJ, Benedetti-Cecchi L, Åberg P, Arenas F, Arrontes J, Castro JJ, Hartnoll RG, Jenkins SR, Paula J, et al. 2006. A continental scale evaluation of the role of limpet grazing on rocky shores. *Oecologia*. 147(3): 556–564. doi:10.1007/s00442-005-0296-9
- Creese RG. 1982. Distribution and abundance of the acmaeid limpet, *Patelloida latistrigata*, and its interaction with barnacles. *Oecologia*. 52: 85–96. doi:10.1007/BF00349015
- Firth LB, White FJ, Schofield M, Hanley ME, Burrows MT, Thompson RC, Skov MW, Evans AJ, Moore PJ, Hawkins SJ. 2016. Facing the future: the importance of substratum features for ecological engineering of artificial habitats in the rocky intertidal. *Marine and Freshwater Research*. 67(1): 131. doi:10.1071/mf14163
- Graham AF. 1988. Molluscs: prosobranch and pyramidellid gastropods : keys and notes for the identification of the species

- Hawkins SJ, Hartnoll RG. 1983. Grazing on intertidal algae by marine invertebrates. *Oceanography and Marine Biology*. 21: 195–282
- Hawkins SJ, Hartnoll RG. 1985. Factors determining the upper limits of intertidal canopy-forming algae. *Marine Ecology Progress Series*. 20: 265–271
- Henriques P, Delgado J, Sousa R. 2017. Patellid limpets: An overview of the biology and conservation of keystone species of the rocky shores. In: Ray S, editor. *Organismal and Molecular Malacology*. 1. London: INTECH. p. 71–95
- Hodgson AN. 1999. The biology of Siphonariid limpets (Gastropoda: Pulmonata). In: Ansell A, Gibson RN, Barnes M, editors. *Oceanography and Marine Biology*. 1. London: CRC Press. p. 253–322
- Hollyman PR, Laptikhovskiy VV, Richardson CA. 2018. Techniques for estimating the age and growth of molluscs: Gastropoda. *Journal of Shellfish Research*. 37(4): 773–782. doi:10.2983/035.037.0408
- Hutchinson N, Williams GA. 2002. An assessment of variation in molluscan grazing pressure on Hong Kong rocky shores. *Marine Biology*. 142(3): 495–507. doi:10.1007/s00227-002-0985-4
- Iveša L, Chapman MG, Underwood AJ, Murphy RJ. 2010. Differential patterns of distribution of limpets on intertidal seawalls: experimental investigation of the roles of recruitment, survival and competition. *Marine Ecology Progress Series*. 407: 55–69. doi:10.3354/meps08539
- Jenkins R, Hawkins SJ, Norton TA. 1999. Direct and indirect effects of a macroalgal canopy and limpet grazing in structuring a sheltered intertidal community. *Marine Ecology Progress Series*. 188: 81–92. doi:10.3354/meps
- Kennelly SJ. 1987. Inhibition of kelp recruitment by turfing algae and consequences for an Australian kelp community. *Journal of Experimental Marine Biology and Ecology*. 112: 49–60. doi:10.1016/S0022-0981(87)80014-X
- Krebs CJ. 1989. *Ecological methodology*. 2. New York: Harper Collins Publishers
- Lewis JB. 1963. Environmental and tissue temperatures of some tropical intertidal marine animals. In: *The Biological Bulletin*. Chicago: The University of Chicago Press. p. 277–284
- Lindberg DR, Warheit KI, Estes JA. 1987. Prey preference and seasonal predation by oystercatchers on limpets at San Nicolas Island, California, USA. *Marine Ecology Progress Series*. 39(2): 105–113
- Little C, Williams GA, Trowbridge CD. 1996. The biology of rocky shores. Oxford: Oxford University Press
- Little C. 1989. Factors governing patterns of foraging activity in littoral marine herbivorous Molluscs. *Journal of Molluscan Studies*. 55: 273–284
- Liu JH, Morton B. 1998. The impacts of pollution on the growth, reproduction and population structure of Hong Kong limpets. *Marine Pollution Bulletin*. 36(2): 152–158
- Lubchenco J, Gaines SD. 1981. A unified approach to marine plant-herbivore interactions. I. Populations and communities. *Annual Review of Ecology and Systematics*. 12: 405–437. doi:10.1146/annurev.es.12.110181.002201
- Menge BA, Foley MM, Pamplin J, Murphy G, Pennington C. 2010. Supply-side ecology, barnacle recruitment, and rocky intertidal community dynamics: do settlement surface and limpet disturbance matter? *Journal of Experimental Marine Biology and Ecology*. 392: 160–175. doi:10.1016/j.jembe.2010.04.032
- Moreno CA, Jaramillo E. 1983. The role of grazers in the zonation of the intertidal macroalgae of the Chilean coast. *Oikos*. 41:73–76. doi: 10.2307/3544348
- Morton B, Morton J. 1983. The sea shore ecology of Hong Kong. Hong Kong: Hong Kong University Press
- Navarro PG, Ramírez R, Tuya F, Fernandez-gil C, Sanchez-jerez P, Haroun RJ. 2005. Hierarchical analysis of spatial distribution patterns of patellid limpets in the Canary Islands. *Journal of Molluscan Studies*. 71(1): 67–73. doi:10.1093/mollus/eyi009

- Poutiers JM. 1998. Gastropods. In: Carpenter KE, Niem VH, editors. The living marine resources of the western central pacific: *Volume 1: Seaweeds corals, bivalves and gastropods*. Rome, Italy: Food & Agriculture Organization of the United Nations (FAO). p. 363-648
- Sangphueak S, Hui TY, Lau SLY, Williams GA, Wangkulangkul K. 2024. Habitat partitioning in two intertidal limpets, *Siphonaria guamensis* (Heterobranchia) and *Patelloida saccharina* (Patellogastropoda), from southern Thailand. *Zoological Studies*. 63: 11. doi:10.6620/ZS.2024.63-11.
- Silva A, Hawkins S, Boaventura D, Thompson R. 2008. Predation by small mobile aquatic predators regulates populations of the intertidal limpet *Patella vulgata* (L.). *Journal of Experimental Marine Biology and Ecology*. 367(2): 259–265. doi:10.1016/j.jembe.2008.10.010
- Steneck RS, Watling L. 1982. Feeding capabilities and limitation of herbivorous molluscs: a functional group approach. *Marine Biology*. 68: 299–319. doi:10.1007/BF00409596
- Tanaka MO, Duque-Estrada TEM, Magalhães CA. 2002. Dynamics of the acmaeid limpet *Collisella subrugosa* and vertical distribution of size and abundance along a wave exposure gradient. *Journal of Molluscan Studies*. 68(1): 55–64. doi:10.1093/mollus/68.1.55
- Underwood AJ. 1979. The ecology of intertidal gastropods. *Advances in Marine Biology*. 16: 111–210
- Underwood AJ. 1980. The effects of grazing by gastropods and physical factors on the upper limits of distribution of intertidal macroalgae. *Oecologia* 46: 201–213
- Underwood A, Jernakoff P. 1984. The effects of tidal height, wave-exposure, seasonality and rock-pools on grazing and the distribution of intertidal macroalgae in New South Wales. *Journal of Experimental Marine Biology and Ecology*. 75(1): 71–96. doi:10.1016/0022-0981(84)90024-8
- Vermeij GJ. 1971. Temperature relationships of some tropical Pacific intertidal gastropods. *Marine Biology*. 10: 308–314. doi:10.1007/BF00368090
- Vermeij GJ. 1972. Intraspecific shore-level size gradients in intertidal molluscs. *Ecology* 53(4):693–700. doi:10.2307/1934785
- Vermeij GJ. 1978. Biogeography and adaptations: patterns of marine life. Cambridge, MA: Harvard University Press. doi:10.1126/science.203.4387.1333.
- Villarta KA, Ontoy AFL, Villanueva IKD, Ybañez MAD. 2017. An initial exploration into the population dynamics and reproduction of *Patelloida saccharina* on rocky shores in Taklong Island National Marine Reserve (TINMR), Southern Guimaras, Philippines. *Philippine Journal of Natural Sciences*. 22: 30–42
- Wallace L. 1972. Some factors affecting vertical distribution and resistance to desiccation in the limpet *Acmaea testudinalis* (Müller). *The Biological Bulletin*. 142(1): 186–193. doi:10.2307/1540255
- Williams GA, Morrill D. 1995. Habitat partitioning and thermal tolerance in a tropical limpet, *Cellana grata*. *Marine Ecology Progress Series*. 124: 89–103. doi:10.3354/meps124089
- Young PNY, Fontanilla IKC. 2014. Biodistribution of the informal group Basommatophora in the Philippines. *University of the Philippines Diliman Journals Online*
- Zapanta EYT, Fortaleza MA, Elumba ME, Uy RCL, Nañola CLJ. 2020. Diel movement patterns of Pacific sugar limpet, *Patelloida saccharina* (Gastropoda: Patellogastropoda: Lottiidae) in response to semi-diurnal tides of Samal Island, Philippines. *Zenodo* (CERN European Organization for Nuclear Research). doi:10.26107/rbz-2020-0095

Date received: June 30, 2024

Date accepted: November 1, 2024

Author:

Demie P. Putong, *Division of Biological Sciences, College of Arts and Sciences, University of the Philippines Visayas, Miagao (5023), Iloilo; email: dpputong@up.edu.ph*

Karen A. Villarta-Lane, *Marine Biology Laboratory, Division of Biological Sciences, College of Arts and Sciences, University of the Philippines Visayas, Miagao (5023), Iloilo; email: kavillarta@up.edu.ph*