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Lunar influenced community structure among Seagrass associated Epifaunal Macroinvertebrates

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Abstract

Seagrass-associated epifaunal macroinvertebrates communities are complex ecosystems patterned with diel shift rhythms and niche cycles. Most studies focus on diurnal rhythms as researchers engage in daytime collections, creating community structure frameworks accustomed to this analysis. Less is known to nocturnal cycles and diurnal-nocturnal shifts as community structure in these periods may offer a holistic ecosystems framework rather than a diurnal outlook. Moreso, literature is limited in lunar-influenced community structure in seagrass-associated epifaunal macroinvertebrates. This paper seeks to identify the community structure patterned on lunar illumination percentages based on waning gibbous, full moon, waxing gibbous, waxing crescent, and; waning crescent. Each phase differs in illumination percentage, and identifying community structure may depict activity and favorable adaptive mechanisms among the community. Four stations were established in Eastern Samar, Philippines, in a month-long collection, laying 50 meter transect lines with five quadrats placed every 10 meters in shallow waters covering seagrass beds. Results show that mollusks dominated the structure together with diverse echinoderms, arthropods, poriferans, and annelids. During the full moon, the species' relative abundance was the highest value compared to other lunar phases. This structure was followed by waning gibbous, waxing gibbous, waxing crescent, and; waning crescent. In reference to the illumination percentage, community structure was influenced in favour for a brighter lunar phase based on the computed relative abundance. As lunar illumination percentage was reduced, assemblages of epifaunal macroinvertebrates were also reduced. This community structure indicated assemblages in response to lunar illumination, lunar phases, and the framework of the seagrass ecosystems should be monitored using this outlook.

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Introduction

Generally, lunar behaviors result from established rhythmicity through evolutionary success as an outcome of favorable mechanisms such as mating, fertilization, nursery retention, and; predation (Omori, 1995). These favorable adaptive mechanisms influence reproductive rate, population density, and community structure. Literature has documented the reproductive cycles of planktons, corals, fishes, and mollusks as influenced by lunar phases but rarely in a community structure viewpoint. Reproductive success of organisms became an adaptive significance, establishing; the "rule of the game," and organisms exhibited community assemblages patterned upon this rhythm.

The lunar cycle refers to the 29.5 days- lunar month, required for the moon to orbit around the Earth, and; the 24.8 hours -lunar day, required for the moon to travel by the same spot around the Earth (Stolov, 1965; Bell & Defouw, 1966). These two lunar cycles give rise to several environmental patterns, such as illumination levels, tides, and geomagnetic fields (Kronfeld-Schor *et al.*, 2013; Naylor, 2001). Like all organisms, moonlight affects macroinvertebrates' behavior and survival, as moon phases directly affect the lunar intensity and tidal pattern. Shore crab (*Carcinus maenas*) molts habitually during spring tides than neap tides with fortnightly periodicity. Molting during neap tides, when the crab's habitat is exposed, is maladaptive for juveniles' lack of cover, making them susceptible to damaging wave action and predation (Naylor, 2001). Peak molting after the new or full moon is advantageous for the crabs since they are covered by seawater at high spring tides.

Species in diverse phyla exhibit lunar rhythms, mostly in their reproductive behavior. Many examples of varying complexity are known among annelids and all marine polychaetes. Their periodicities and causation are variable and often poorly understood. Sponges that release larvae (spawn) based on their perception of environmental light calculate the time of the day, establishing a lunar rhythm, either an endogenous circalunar clock or an exogenous rhythm driven directly by moonlight (Tessmar-Raible *et al.*, 2011). Other invertebrate phyla, such as Mollusca, Echinodermata and Arthropoda have also exhibited lunar rhythms, but most are poorly documented (McDowall, 1970).

Light changes during the lunar cycle influence rhythms among organisms in several non-mutually exclusive ways. Light intensities from the moon's phases change the ability of animals to use visual cues and senses like communication, navigation, and prey or predator location (Kronfeld-Schor *et al.*, 2013). Ecosystem functions affect the activity levels of predators, competitors, and prey, attributed to visual acuity and prey activity fluctuations (Kronfeld-Schor *et al.*, 2013). Prey visualization resulted in successful detection, capture, and even avoidance. Prey and predators are in a constant disposition of eating and being eaten; both are exposed to probabilities and risks of foraging. Predation with the influence of moonlight enables the organism to be successful in nocturnal foraging. As moonlight intensity changes, predation activities will also change, generating a pattern of a lunar rhythm.

Nighttime is an integral part of the diel cycle, and several macroinvertebrates have demonstrated nocturnal activity in different aquatic ecosystems (Florencio *et al.*, 2011). These rhythms, patterned into a lunar cycle, establish an assemblage of organisms accustomed to predictive behavior based upon adaptive significance at night time. Community structures depict distinct assemblages shifting from diurnal-nocturnal patterns, giving a complex dynamic in seagrass-associated epifaunal macroinvertebrates. Seagrass communities should be regarded in a parallel outlook and should be studied based on this temporal frame. In a study by Matillano and Rosada, 2022, diel collections manifested increased species richness compared to a diurnal collection showing that there were more active species at night compared to day time. As lunar phases influence population assemblages, community structure is also patterned within these rhythms. This paper seeks to (1) identify species of seagrass-associated macrofaunal invertebrates and; (2) depict the community structure patterned upon the lunar phases employing the same sites used by Matillano and Rosada, 2022.

Seagrasses provided complex and critical habitats for macroinvertebrates and had been confronted with continuous threats (Matillano, 2017) from both natural and human influence. In the Philippines, there are 16 seagrass species out of the 47 species worldwide (Fortes, 2012), harboring macroinvertebrates communities that are primarily active at night (Hessing *et al*., 2018). Diverse phyla such as Cnidaria, Annelida, Mollusca, Echinodermata, and Arthropoda were reported to exhibit lunar rhythms; however, it is poorly documented (Campbell *et al*., 2015).

Materials and methods

Study Sites

This study was conducted in the four established sites of Matillanao and Rosada, 2022 in four municipalities in Eastern Samar, Philippines: (1) Brgy. Batang, Hernani, Eastern Samar N 11⁰17.933, E125⁰36.265; (2) Brgy. San Roque, Llorente, Eastern Samar N 11⁰23.893, E 125⁰34.554; (3) Brgy. 1 Sabang, Balangkayan, Eastern Samar N 11⁰28.807, E 125⁰30.941 and (4) Brgy. Campakirit in Maydolong, Eastern Samar 11⁰29.230N, 125⁰.843E.

Data Collection Procedure

A month-long transect-quadrat collection was used to sample seagrass-associated epifaunal macroinvertebrate communities. Three (3) 50-meter transect lines were established in each sampling site with a 1 m^2 quadrat in the 10-meter interval. Samples were handpicked, processed, and preserved for further identification. Relative abundance was computed to elucidate the community structure based on the lunar phases: waning gibbous, full moon, waxing gibbous, waxing crescent, and; waning crescent.

Results and discussion

There were 831 nocturnal individuals representing five macroinvertebrate phyla: Echinodermata, Mollusca, Arthropoda, Porifera, and Annelida. Station 2 showed the highest species richness, followed by Stations 1, 4, and; 3, respectively. Molluscs dominated in all stations, with a significant amount in Station 2. This observation was also the same in Stations 1, 4, and 3, where molluscs have the highest species richness compared to other phyla. Molluscs were also observed in a high species richness during nocturnal periods (Rueda *et al*., 2008; Marina *et al*., 2012), implying dominance in the community structure. Among echinoderms, arthropods, annelids, and poriferans, Station 2 also has the highest species richness compared to other stations. The typical outlook on seagrass systems is established in a diurnal framework (Matillano *et al*., 2018), and establishing an alternative viewpoint using a different approach offers an inclusive or better model for studying community structures. In the Philippines, seagrasses and their associated organisms are studied for their economic and ecological importance from a daytime perspective (Perpetua *et al*., 2021; Lagud *et al*., 2020; Rendodo *et al*., 2017; Hamisain *et al*., 2020; Vinson *et al*., 2016) but never studied in diel-nocturnal contexts.

Table 1. Nocturnal Species richness grouped according to different phyla indicating community structure of seagrass-associated epifaunal macroinvertebrates.

Macroinvertebrate Phyla	Station 1	Station 2	Station 3	Station 4
Mollusca	113	264	95	101
Echinodermata	8	58	13	6
Arthropoda	6	26	15	18
Porifera	1	3	2	2
Annelida	1	3	2	2

Seagrass services never cease at night as macroinvertebrate community assemblages abound, providing structural habitat, food, nursery grounds, predator protection, and other niches compared to other ecosystems (Leopordas *et al*., 2014). Though this study is inconclusive, focusing primarily on observations of relative abundance, species assemblage structure implies primary productivity and other services dispensed by seagrasses during nighttime. Epifaunal macroinvertebrates' abundance manifests functions or conventional adaptive significance, establishing assemblages that may depict a functional community structure. Seagrass primary productivity is well understood in a diurnal framework and less known at night.

Secondary production within and among consumers has resulted in associative dependence among the taxa (Ismet *et al*., 2020) and herbivory by consumers such as echinoderms and arthropods, in return, is beneficial for seagrass growth (Wolkenhauer *et al*., 2010; Berthelsen & Taylor, 2014).

Few studies have discussed nocturnal activities and assemblages of seagrass-associated macrofaunal invertebrates as influenced by lunar illuminations, tidal patterns, magnetic patterns, and community assemblages. However, some studies have determined predictive mechanism as a convention for lunar illuminations affecting visual acuity, foraging, and predator-prey activities (Kronfeld-Schor *et al*., 2013; Tessmar-Raible *et al*., 2011; Horacio & Hsu, 2010).

Community structures as influenced by lunar phases were dearth in the literature, especially among seagrass-associated macrofaunal invertebrates. Percentage illuminations differ in every phase, such as; waning gibbous (99.9% - 50.1%), full moon (100%), waxing gibbous (50.1% -99.9%), waxing crescent (0.1 - 49.9%) and waning crescent (49.9% - 0.1%) (Phases of the Moon, 2022).

Table 2. Relative abundance of seagrass associated epifaunal macroinvertebrate about lunar phases.

Macroinvertebrate Phyla	Waning Gibbous	Full Moon	Waxing Gibbous	Waxing Crescent	Waning Crescent
Mollusca	17.56	18.29	15.88	14.92	14.19
Echinodermata	2.28	2.52	2.04	1.44	1.68
Arthropoda	2.04	2.88	2.16	1.44	1.20
Porifera	.96	.96	.96	.96	.96
Annelida	.12	.24	.12	.12	.12

Relative abundance was computed to depict community structures and illustrate patterns of assemblages based on these lunar phases. Full moon with 100% illumination showed the highest abundance in all phyla: Mollusca, Echinodermata, Arthropoda, Porifera and Annelida. As depicted in species richness (Table 1), mollusks were also observed as most abundant in all lunar phases: full moon (18.29), waning gibbous (17.56), waxing gibbous (15.88), waxing crescent (14.92) and waning crescent (14.19). The same observation was also monitored among echinoderms during full moon (2.52), waning gibbous (2.28), waxing gibbous (2.04), waxing crescent (1.44), and waning crescent (1.68).

This pattern was also observed in all other phases, where illumination percentages were reduced and relative abundance across phyla was also reduced. Differentiating waning gibbous (with 99.9-50.1 %illumination) and waning crescent (with 49.9- 0.1%) %illumination), relative abundance in waning gibbous is higher compared to waning crescent. As light reduction was observed, community assemblages lessened, as manifested in a decreasing relative abundance. This abundance indicates the inactivity of community assemblages patterned in the illumination, as they were not sampled in the collection. Mollusks indicated the highest relative abundance, dominating the community structure as influenced by lunar phases in seagrass ecosystems. Despite being burrowers, mollusks, especially bivalves, were seen at the surface and easily sampled during the collection. This surfacing at night exhibits rhythmic activity established by communities in response to adaptive dependence patterned to lunar phases and illumination percentages. Behavioral patterns, circalunar and circadian clocks had been directly influenced by lunar illumination. Lunar-controlled rhythms are widespread and essential for marine organisms (Lohmann & Willows, 1987; Tessmar-Raible *et al*., 2011; Kronfeld-Schor *et al*., 2013).

Conclusion

Seagrass-associated epifaunal macroinvertebrate community structures is patterned on lunar phases and illumination percentages. Community structure shows molluscan-dominated assemblages and a diverse phylum including Echinodermata, Arthropoda, Porifera and Annelida. This structure indicates the activity assemblages in response to lunar illumination, and the framework of the seagrass ecosystem should be monitored using this outlook.

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