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ISSN: 1656-4707
E-ISSN: 2467-5903
Homepage: www.palawanscientist.org

Population status and lunar periodicity of spawning of *Tripneustes gratilla* (Echinodermata: Echinoidea), in Jose Abad Santos, Davao Occidental, Philippines

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Received: 05 Apr. 2024 || Revised: 09 Nov. 2024 || Accepted: 29 Jan. 2025
Available online: 09 May 2025

How to cite:
Molina JR, Sumondong Jr. MG, Tigaldao JM, Melindo HGA, Padayag S and Bersaldo MJI. 2025. Population status and lunar periodicity of spawning of *Tripneustes gratilla* (Echinodermata: Echinoidea), in Jose Abad Santos, Davao Occidental, Philippines. The Palawan Scientist, 17(2): 1-12. https://doi.org/10.69721/TPS.J.2025.17.2.01

ABSTRACT

The population structure and lunar periodicity of spawning were investigated from January to February 2024 across three sites in Jose Abad Santos, Davao Occidental, Philippines. Monthly field surveys were conducted using the belt transect method to assess population structure, while laboratory analyses were performed to examine the lunar periodicity of spawning across different lunar phases. A total of 160 individuals of *Tripneustes gratilla* (Linnaeus 1758) were recorded with an estimated mean density of 645.83 ± 171.50 ind ha^{-1} and mainly dominated by adult size classes having a test diameter (TD) of 61 - 65 mm followed by pre-adults of 51 - 55 mm TD and only very few recruits 33 – 40 mm TD. The relationship between the TD and weight of *T. gratilla* displayed a high positive correlation. It exhibited a negative allometric growth with a *b* value of less than 3 in three sites. The result of the gonad index (GI) and fecundity showed that the highest GI and total number of eggs occurred during the full moon while the lowest occurred during the new moon with notes on sexual maturity at 54 mm TD. While the findings of this study provide valuable insights, they are not conclusive regarding the population structure and lunar spawning periodicity, as the study was conducted over only two months. Long-term monitoring is needed for a more accurate understanding of the status of *T. gratilla* at these sites.

Keywords: fecundity, gonad index, lunar phase, size structure, test diameter-weight relationship

INTRODUCTION

Tripneustes gratilla (Linnaeus 1758), also known as the "collector sea urchin", is a rounded sea urchin distinguished by its unique physical characteristics. Its body is covered with colorful, short spines and tube feet (Toha et al. 2017), which it uses for defense and movement. They are highly reproductive (prolific) marine invertebrates (Lawrence and Agatsuma 2007). In some species of sea urchin, for example, a single female can release up to 100 million eggs during one spawning period (Küçükdermenci et al. 2017). The sexual maturity of *T. gratilla* has a test diameter (TD) of 50 – 70 mm based on the observation of Junio-Meñez et al. (1998) done in the laboratory and field. The *T. gratilla* spawns year-round but the timing of spawning peaks may vary among localities (Tuason and Gomez 1979).

Spawning time are influenced by several abiotic factors (water temperature, photoperiod, moon cycle) and biotic factors (food availability and phytoplankton abundance) (Brockington et al. 2001; Perez et al. 2010; Vaitilington et al. 2005; Muthiga 2005; Lawrence and Agatsuma 2013). The peak of the spawning phase is identified by the variance in the gonad index (GI) (Vladimir et al. 2004; Gaudette et al. 2006). The development of sea urchin gonads can be assessed by observing an increase in the GI value (Lutfiyani et al. 2021). The GI values range is used to reference the maturity of the sea urchin gonads. The maximum value of GI is reached by sea urchins when it is close to the spawning time and decreases from spawning until spawning is completed (Nasrullah et al. 2018).

The gonad of sea urchin has a high concentration of bioactive compounds such as polyunsaturated fatty acids (PUFAs) especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Dincer and Cakli 2007), and it is thought to be beneficial in the treatment of numerous diseases such as cancer, cardiovascular diseases and arrhythmia (Pulz and Gross 2004). Hence, it is economically important to support small-scale fisheries and commercial trade (Andrew et al. 2002). However, *T. gratilla* is at risk of overexploitation due to uncontrolled harvesting for local food and livelihood (Junio-Meñez et al. 2008b). A scenario occurred in 1992 where overexploitation and improper management led to the depletion of wild stock sea urchins (Regalado et al. 2010; Junio-Meñez et al. 2008b). In the Philippines as of 2015, catch landings of *T. gratilla* accounted for 140 metric tonnes (MT) (Sonu 2017). The world landings of sea urchins peaked at 120,000 MT in 1995 and now decreased to about 82,000 MT in 2018. The decreasing pattern reflects the overexploitation of most fishery grounds and highlights the need for appropriate conservation policies, stock enhancement, fishery management, and aquaculture development (Rahman et al. 2022). Sea urchins are primarily exploited through gleaning; gleaners only need to walk in the seagrass areas during low tide to pick the sea urchins, place them in a basket, and carry them to shore (Furkon et al. 2019; 2020). Most of the gleaners prefer to catch sea urchins during full moon or new moon because it contains more roe during that lunar phase (Bin Nurhasan et al. 2011). The excessive gleaning of sea urchins has resulted in a low number and small test-diameter size of individuals in the wild (Nane and Paramata 2020).

Several initiatives have been launched to sustainably manage the *T. gratilla* fishery in the Philippines. This includes improvement of fisheries management (i.e. establishment of marine protected area and size quota) (Junio-Meñez et al. 2008b), and community-based sea urchin culture (Ungson 2004). In Nalvo, Sta. Maria, Ilocos Sur, a community-based sea culture, is adapted to provide income for fishermen while sustainably managing the sea urchin fishery (Ungson 2004). The International Union on Conservation of Nature (IUCN) Red List has not evaluated the *T. gratilla* yet. Since there is no management system in place or local restrictions on the sea urchin fishery, overexploitation of *T. gratilla* in particular is now an issue (Toha et al. 2017).

Sea urchin fishing is a primary source of food and revenue for the locals, therefore socioeconomic restrictions make it difficult to implement localized fisheries regulations, such as size limits and closed seasons (Junio-Meñez et al. 2008b). Furthermore, it is not wise to introduce a total banning on sea urchin collection without a sound scientific basis, as adopting so will not always be advantageous for the seagrass and coral reef ecosystems and might be difficult to enforce (Tamti et al. 2021). For instance, outbreaks of sea urchins in the macrophyte communities may lead to overgrazing, which could be detrimental to the nearby ecosystems (Eklof et al. 2008; Wallner-Han et al. 2015). There is a need to explore alternative or complementary approaches to marine resource management. There are few published works done in the Philippines, especially in Bolinao, Pangasinan (Junio-Meñez et al. 2008b), La Union (Prado et al. 2012), Southern Guimaras (Regalado et al. 2010), Kalayaan Islands, Palawan (Balisco 2015), Northern Mindanao, and in Sta. Cruz, Southern Mindanao (Bangi et al. 2013) with regard to the investigation of the population structure of this highly valuable sea urchin species. However, localized studies are still insufficient. Factors that control the reproduction of *T. gratilla* are still poorly understood (Muthiga 2005; AbouElmaaty et al. 2023). Understanding its reproductive cycle, however, is crucial for effective fishery management and aquaculture initiatives (AbouElmaaty et al. 2023). In Jose Abad Santos, Davao Occidental, no studies have been conducted on *T. gratilla* to date. However, its collection and harvesting are common due to the area's open-access nature. If left unmanaged, this could lead to the collapse of the fishery. Thus, this study was conducted to determine the population status (i.e. population density, size structure, and test diameter-weight relationship) and lunar periodicity of spawning (i.e. gonad index and fecundity) of *T. gratilla* that would serve as a useful reference for the local government unit and other key stakeholders in the formulation of strategic measures to sustainably manage this important resource that has been long exploited.

METHODS

Study Area

Jose Abad Santos is a coastal municipality in the province of Davao Occidental. It comprises 26 barangays, with 23 located along the coast. Among the 23 coastal barangays, the barangay Kitayo, Balangonan, and Bukid have abundant *T. gratilla* where locals have open access to fishing that is sold in bottles in the local market, resulting in an overharvesting due to the demand in these regions. These coastal barangays encompass various ecosystems including the extensive seagrass beds, serving as a primary food and shelter to the abundant *T. gratilla* in the area. The three sampling sites are geographically positioned at Kitayo (5°33'45.99"N and 125°20'45.90"E), Balangonan (5°33'42.63"N and 125°22'11.17"E), and Bukid (5°33'33.57"N and 125°22'26.45"E) (Figure 1).

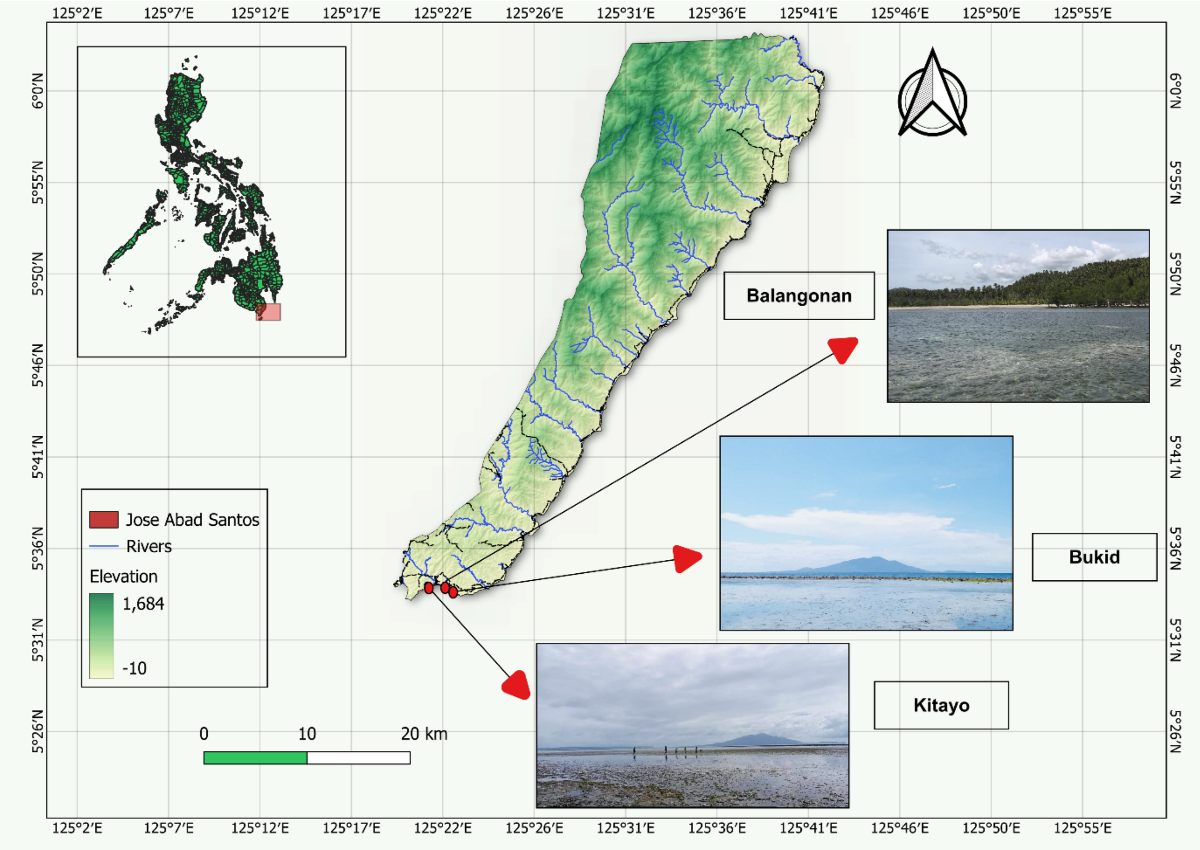

Figure 1. Map of the study area in Jose Abad Santos, Davao Occidental. The red dots are the three sampling sites namely: Barangay Kitayo, Balangonan, and Bukid.

Sampling Procedure

To determine the population density of *T. gratilla,* sampling was done from 06 to 20 January and 03 to 17 February 2024 in the three established sampling sites. Three 100 x 4 m belt transects, 50 m away from each other were laid perpendicular to the shoreline of each study site. For ease of observation, sampling was conducted in the daytime during the lowest low tide. The sampling was conducted by wading or snorkeling up to 1 m to 1.5 m depth. All *T. gratilla* found within 2 m on each side of the transect were recorded and collected for the test diameter-weight measurement. All *T. gratilla* individuals collected were brought to the shore for TD and weight measurements. The total wet weight of sea urchins was measured in grams (g) using an analytical weighing scale (Sartorius ENTRIS224-1S, Germany). The TD was measured in millimeters (mm) with the jaws of calipers positioned between spines while making sure that the measurement was from the center of an ambulacrum to the opposite inter-ambulacrum and that the sea urchin was not tipped (Lawrence 1975). All live specimens of *T. gratilla* collected were carefully returned to the area where they were found.

Gonad index is the percentage of the total body weight of the urchin that is made up by the gonad (James and Siikavuopio 2012), and fecundity is the number of eggs in the ovaries that will mature during a particular spawning season (Cailliet et al. 1986). To determine the GI and fecundity of *T. gratilla* during each lunar phase, 10 individuals from each site with a TD of >50 mm (considered sexually mature; Juinio-Meñez et al. 1998; Lawrence and Agatsuma 2013) were sampled for 2–3 days every lunar phase (full moon, last quarter, first quarter, and new moon) (Table 1). Samples were bought from the gleaner who collected the sea urchin individuals from the three sampling sites. Samples were placed in a pail and were brought to the laboratory for GI and fecundity measurements. In the laboratory, the TD and weight of the samples were measured and then dissected by removing the Aristotle Lantern to expose its gonads. To accurately assess the GI of an individual urchin, the whole urchin was weighed (total weight), and the gonads were removed, cleaned, and then weighed (weight of gonad). Gonadal maturity stages were determined by ocular observation and through microscopic analysis. Gonadal stages were based on the work of Perez et al. (2010) (Table 2; Figure 2). For fecundity measurements, only mature ovaries were sampled. Before the actual estimation of the fecundity of *T. gratilla*, mature ovaries were fixed in Gilson's fluid and stored in an individual container. Fecundity was determined by the gravimetric method. The total number of eggs in each ambulacrum was weighed and a sub-sample of at least 0.01 g was counted using a compound microscope.

Table 1. The number of samples with a test diameter >50 mm was collected for gonad index and fecundity measurements in every lunar phase from January to February in three sampling sites of Jose Abad Santos, Davao Occidental.

Sampling sites	January				February				Total
	Last quarter 4 Jan. 2024	New moon 11 Jan 2024	First quarter 18 Jan. 2024	Full moon 26 Jan. 2024	Last quarter 3 Feb. 2024	New moon 10 Feb. 2024	First quarter 16 Feb. 2024	Full moon 24 Feb. 2024	
Kitayo	10	10	10	10	10	10	10	10	80
Balangonan	10	10	10	10	10	10	10	10	80
Bukid	10	10	10	10	10	10	10	10	80

Table 2. Gonadal maturity stages were based on the work of Perez et al. (2009) but were modified for better understanding.

Gonads	Male	Female
Immature	The gametes look pale-soft tissue	The gametes look pale and circular with large distinct nuclei
Mature	Extreme milky sperm appears as white fluid	Egg/ova are uniform perfectly spherical bodies with small but distinct nuclei and are yellow-gold in color
Spent	The gonads are almost empty, although small clusters of sperm may be found	The gonads appear empty, containing only a small number of relict ova

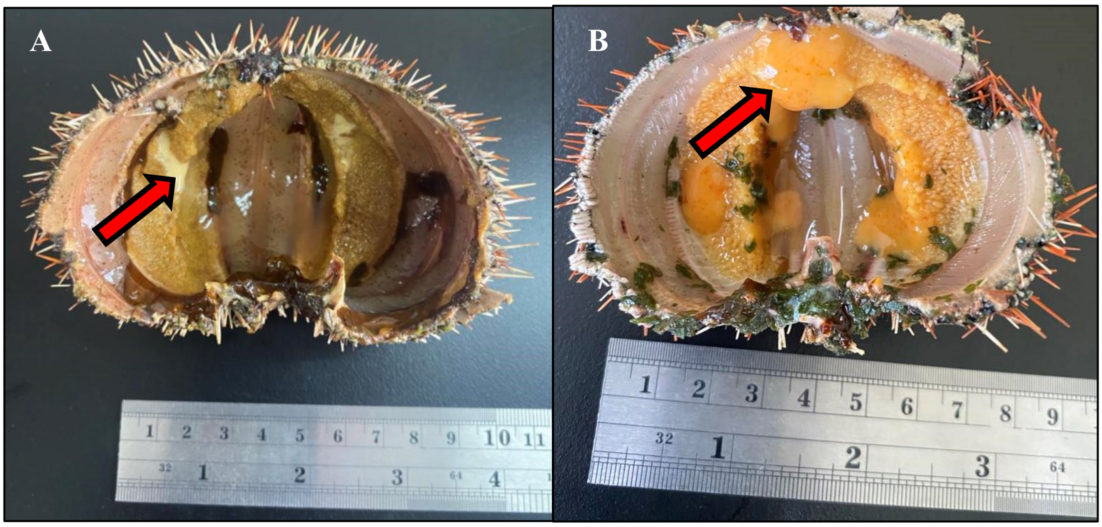

Figure 2. Image of mature male (A) and mature female (B) *Tripneustes gratilla.* The red arrow is the distinguishable characteristic of a male with creamy white sperm and yellow gold eggs in female.

Data and Statistical Analyses

Population density was estimated from the number of individuals per transect over the total area of the belt transect. The resulting values were then extrapolated to individuals per 10,000 m^2 or 1 hectare. An estimated density (D) of *T. gratilla* was obtained using the formula:

$$D = \frac{total\ number\ of\ T.gratilla\ per\ transect}{total\ area\ of\ belt\ transect\ x\ 10{,}000\ m^2} \quad \text{(Eq. 1)}$$

The size structure of *T. gratilla* was analyzed using TD data, which were grouped into size classes at 5 mm intervals. The percentage of each size class was calculated by dividing the number of individuals in a specific class by the total number of individuals of all size classes, then multiplying the result by 100.

The relationship between TD length (L) and total weight (W) was determined using the equation:

$$W = aL^b \quad \text{(Eq. 2)}$$

W is the total weight in grams, *L* is the total length in millimeters, a is the intercept and *b* is the slope of the regression. Parameter estimation was made through logarithmic transformation of *L-W* data pairs and ordinary least-squares linear regression (Pauly 1984):

$$Log\ W = Log\ a + b*Log\ L \quad \text{(Eq. 3)}$$

when *b* is equal to 3, the growth is isometric, if *b* is greater than 3, the growth is positively allometric and if less than 3, the growth is negatively allometric (Elmasry et al. 2023; Rahman et al. 2013; Suryanti et al. 2024). The *b* value is interpreted as negatively allometric (b < 3); isometric (b = 3), and positively allometric (b > 3) (Rahman et al. 2013; Suryanti et al. 2024).

The gonad index was calculated using the formula of Lawrence et al. (1965):

$$GI = \frac{Gonad\ weight\ (g)}{Total\ weight\ of\ T.\ gratilla} x100 \quad \text{(Eq. 4)}$$

The fecundity (total number of eggs) in the ovaries was obtained from the equation of Holden and Raitt (1974):

$$F = \frac{nG}{g} \quad \text{(Eq. 5)}$$

Where *F* is the fecundity of *T. gratilla*, *n* is the number of eggs in the subsample, *G* is the total weight of the ovaries, and *g* is the weight of the subsample in the same units.

Density data were analyzed for normality using the Shapiro-Wilk test and for equal variances using Levene's test, both at a significance level of 0.05. A non-parametric approach was used since the data did not meet the assumptions of normality and equal variances. Specifically, the Kruskal-Wallis test was applied to compare *T. gratilla* density across sampling sites, while the Mann-Whitney U test was used for pairwise comparisons between sampling months. For the gonad index and fecundity data, normality was tested with the Kolmogorov-Smirnov test ($P < 0.05$). As these data met the assumptions of normality and equal variances, a one-way Analysis of Variance (ANOVA) was used to determine significant differences ($P < 0.05$) across four lunar phases. All statistical analyses were done using Statistical Package for the Social Sciences (SPSS Software version 20).

RESULTS

Density

A total of 160 individuals of *T. gratilla* were recorded during the belt transect survey from January to February 2024 in the three sites in Jose Abad Santos, Davao Occidental, Philippines with an estimated mean density of 645.83 ± 171.50 ind ha^{-1}. Mean density was significantly higher in January at 991.67 ± 415.56 ind ha^{-1} compared to February at 300 ± 25 ind ha^{-1}. The highest population density was recorded in January in Bukid with a mean population density of 1400 ± 346.41 ind ha^{-1} while the lowest population density was recorded in February in Balangonan with a mean population density of 275 ± 43.59 ind ha^{-1} (Figure 3). The density of *T. gratilla* significantly varied between January and February ($P < 0.05$, $P = 0.007$) but not across three sampling sites ($P > 0.05$, $P = 0.1495$).

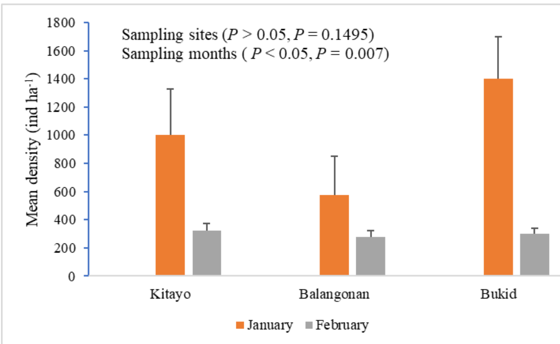

Figure 3. Population density (ind ha^{-1}) of *Tripneustes gratilla* from January to February 2024 in the three sampling sites of Jose Abad Santos, Davao Occidental, Philippines. Vertical bars are the standard deviation.

Size structure

The largest and smallest individual was recorded in Balangonan with a TD of 85 mm (199.56 g) and 33 mm (33.21 g). The size structure of *T. gratilla* individuals recorded in this study was generally dominated by size classes at 5 mm intervals was 61 - 65 mm TD (23.75%) followed by 51 – 55 mm TD (23.125%). The least size classes observed were with TD ranging from 33 – 40 mm at only 0.625%. The body weight of *T. gratilla* with size classes of 31 – 35 mm ranges from 33.21 to 35.27 g while the size classes of 51 – 55 mm weigh ranges from 38.27 to 153.08 g. In addition, the body weight of individuals > 61 mm of *T. gratilla* ranges from 95.35 to 199.56 g (Figure 3). Most of the *T. gratilla* found in Bukid is comprised of size classes with TD of 51 – 55 mm (28.57%) followed by 61 – 65 mm (22.85%) (Figure 4). On the other hand, Balangonan and Kitayo were dominated by 61 – 65 mm TD size classes. Smaller individuals with size classes of 31 – 35 mm TD were only observed in Balangonan with a relative frequency of 2.78%.

Test Diameter-Weight Relationship

The relationship between TD and body weight is best explained by the equation $W = 0.0786TD^{2.41}$ in Kitayo, $W = 0.2596TD^{2.20}$ in Balangonan, and $W = 0.0102TD^{2.49}$ in Bukid (Figure 5). In addition, TD and body weight on the samples collected for gonad index and fecundity is represented by the equation $W = 0.012654\ TD^{2.51}$ in the last quarter, $W = 0.00729TD^{2.56}$ in the new moon, $W = 0.248575TD^{2.22}$ in the first quarter, and $W = 0.451508TD^{1.95}$ in the full moon (Figure 6). The relationship between the TD and weight of *T. gratilla* displayed a high positive correlation in all three sites and across four lunar phases. Results of regression analysis on the test diameter and weight of *T. gratilla* showed negative allometric growth with a *b* value of less than 3 in all three sampling sites.

Gonad Index and Fecundity

The male: female sex ratio of *T. gratilla* collected was 124 males: 116 females with TD ranges from 50 – 91 mm and weight ranges from 56.16 – 315.6 g. The size of mature gonads recorded was 54 mm TD and weighed up to 53.10 g. The mean GI varied significantly in four lunar phases and three sites ($P < 0.05$, $P = 0.000430$). The GI was observed to be highest during the full moon in three sampling sites with a mean GI of 6.77% ± 0.18 followed by the first quarter at GI = 5.97% ± 0.16. On the other hand, the lowest GI value was observed during the new moon with a mean GI of 4.98% ± 0.20 (Figure 7). A total of 22 to 25 mature ovaries for each lunar phase were examined for fecundity estimates. The estimated fecundity of *T. gratilla* varied in each lunar phase ($P < 0.05$, $P = 0.00000$) and fecundity was relatively the highest during the full moon with a mean number of eggs of 129,842 ± 8319.99 while the lowest fecundity was found during the new moon with a mean number of eggs of 25,090 ± 9773.96. The mean fecundity during the last quarter was 93,623 ± 5985.85 and 87,283 ± 8263.54 eggs during the first quarter (Figure 8). The highest fecundity occurs in Bukid during the full moon while the lowest mean recorded was in Kitayo during the new moon.

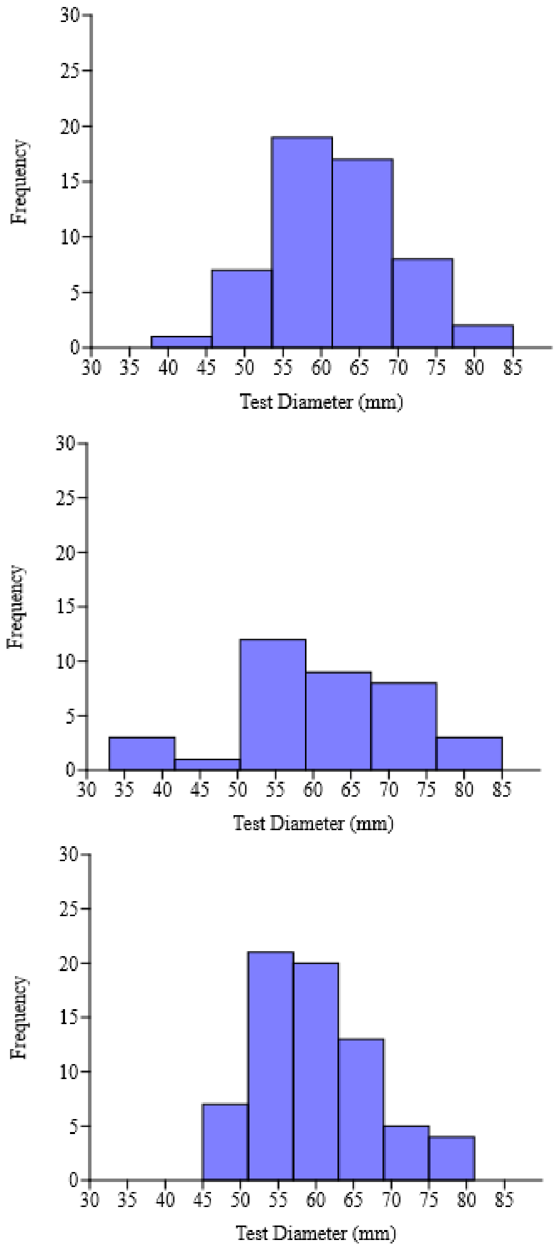

Figure 4. Size structure of *Tripneustes gratilla* from January to February 2024 in the three sampling sites of Jose Abad Santos, Davao Occidental Philippines: Kitayo (top), Balangonan (middle), and Bukid (bottom).

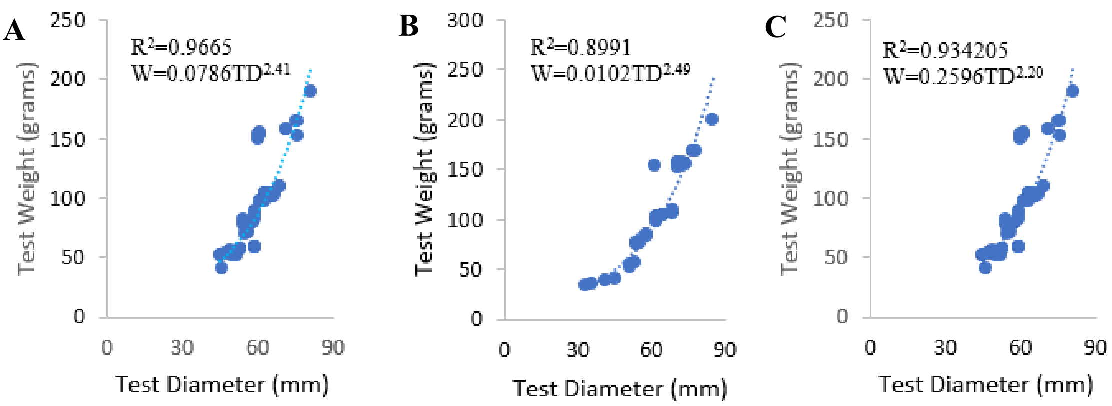

Figure 5. Test diameter-weight relationship of *Tripneustes gratilla* (n = 160) was collected from January to February 2024 in the three sampling sites of Jose Abad Santos, Davao Occidental, Philippines: Kitayo (A), Balangonan (B), and Bukid (C).

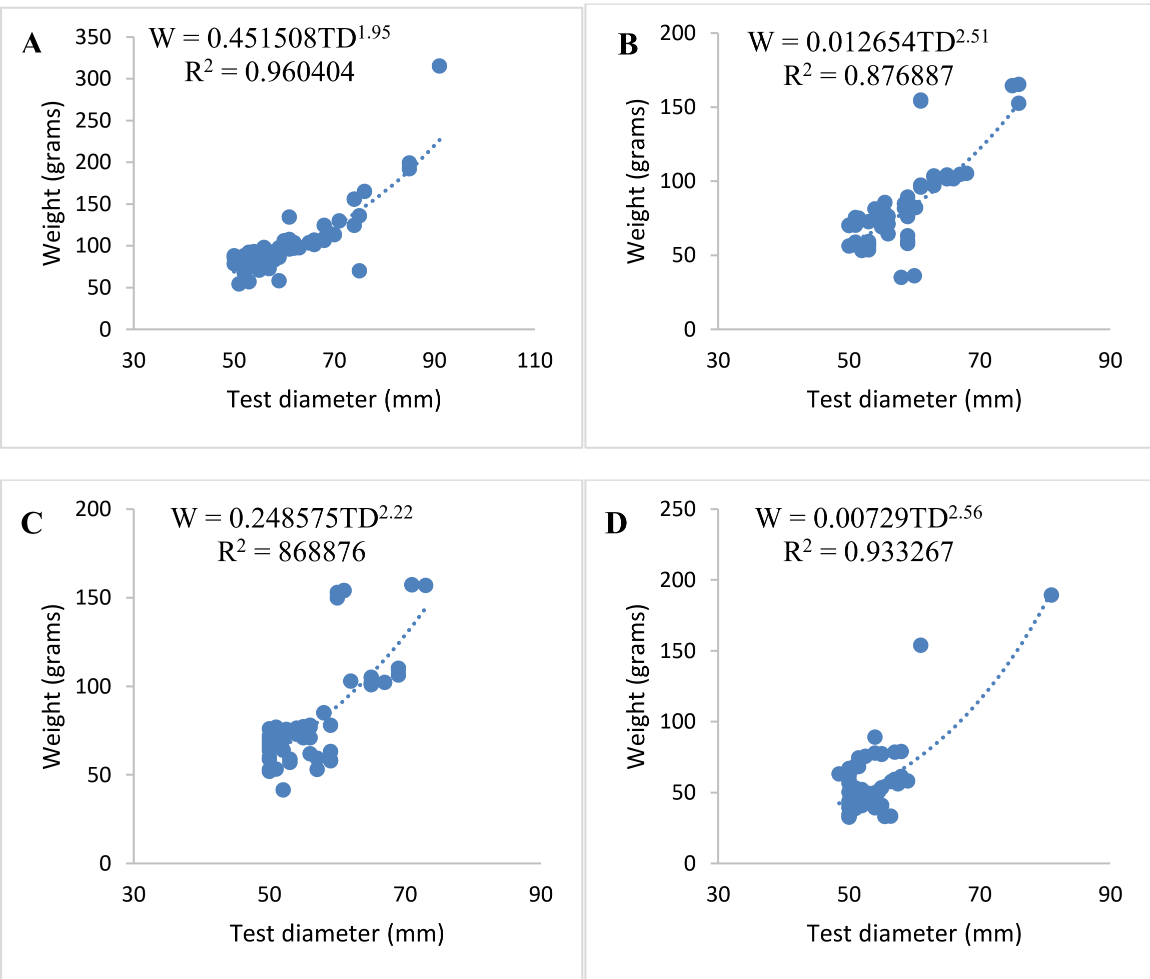

Figure 6. Test diameter-weight relationship of *Tripneustes gratilla* collected in each lunar phase from January to February 2024 in the three sampling sites of Jose Abad Santos, Davao Occidental, Philippines: Full moon (A), Last Quarter (B), New Moon (C), and First Quarter (D).

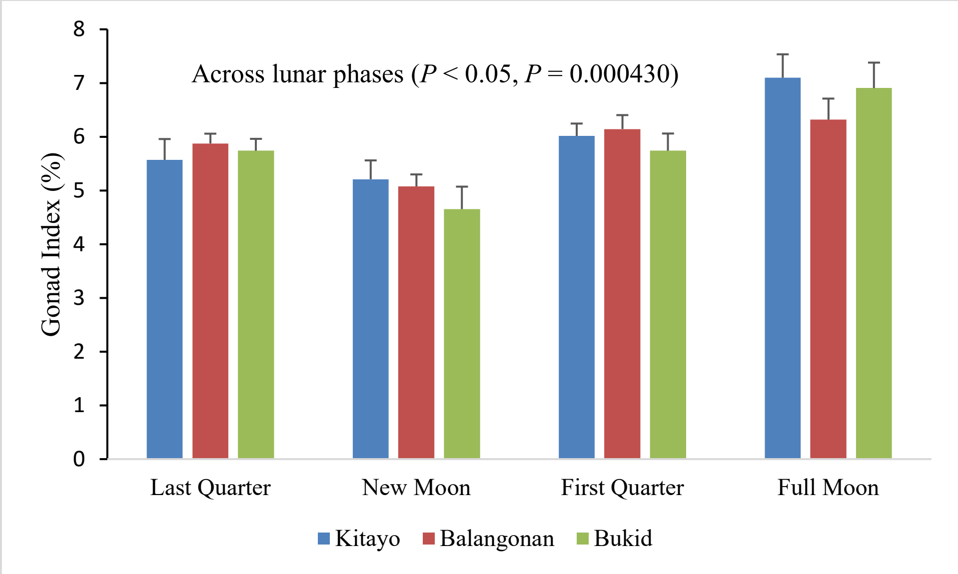

Figure 7. Gonad index of *Tripneustes gratilla* from four lunar phases in three sampling sites of Jose Abad Santos, Davao Occidental, Philippines. Vertical bars are the standard deviation.

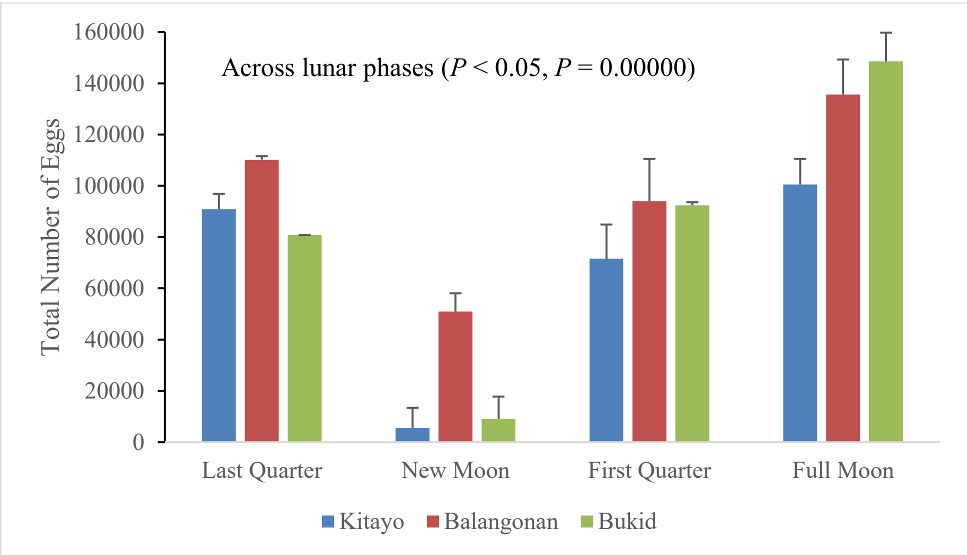

Figure 8. Fecundity of *Tripneustes gratilla* from four lunar phases in three sampling sites of Jose Abad Santos, Davao Occidental, Philippines. Vertical bars are the standard deviation.

DISCUSSION

A total of 160 individuals of *T. gratilla* were recorded with an estimated mean density of 645.83 ± 171.50 ind ha^{-1} in the three study sites of Jose Abad Santos, Davao Occidental, Philippines from January to February 2024. This result is comparably lower to estimates reported in the Philippines from northwestern Luzon at 1,000 ind ha^{-1} (Junio-Menez et al. 2008b), in southern Guimaras, Iloilo at 2,600 ind ha^{-1} (Regalado et al. 2010) and Pag-Asa Island, Kalayaan, Palawan at 3,500 ind ha^{-1} (Balisco 2015), but higher in Balaoan, La Union at 600 ind ha^{-1} (Prado et al. 2012) (Figure 9). The lower density observed, compared to other localities, may be related to the level of exploitation in the area. In locations with limited accessibility and stricter enforcement, sea urchin densities tend to be higher. For example, Balisco (2015) reported high sea urchin density on Pag-asa Island, a relatively inaccessible area with only a few resident families and assigned military personnel, where the degree of exploitation is lower compared to more accessible areas. The significant difference in density between January and February could be attributed to the fishing pressure done by gleaners. Based on the actual observation, only a few gleaners captured sea urchins due to the low demand and consistently bad weather in the sites during January. It is possible that by the time the field assessments were done in February, these gleaners may have already collected most of the *T. gratilla* such that during our samplings only a few individuals were left. The current data may point out that *T. gratilla* collection was quite common and uncontrolled in the three sampling sites. The negative pressure inflicted by this activity may have resulted in fewer individuals observed. However, a year-round study should be made including the catch assessment to understand better the changes in the density of *T. gratilla* in the area.

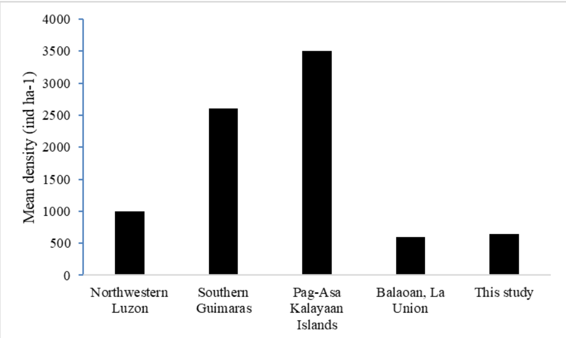

Figure 9. Population density of *Tripneustes gratilla* from different localities in the Philippines.

The individual of *T. gratilla* is considered recruit (<40 mm TD), pre-adults (40 – 60 mm TD), and adults (>60 mm TD) based on the reports of Bangi et al. (2013), and Prado et al. (2012). The largest and heaviest individual recorded during the belt transect survey was found in Balangonan, with a TD of 85 mm and a weight of 199.56 grams. However, individuals collected for GI and fecundity measurements reached a TD of 91 mm and weighed up to 315.6 grams. The largest individual recorded was comparably larger than those in Balaoan, La Union at 50 mm TD (Prado et al. 2012), and southern Guimaras in Iloilo at 82 TD (Regalado et al. 2010), in Pag-Asa Island, Kalayaan, Palawan at 88 mm TD (Balisco 2015) but smaller than in northwestern Luzon at 92 mm TD (Bangi et al. 2013) (Figure 10). The size structure of *T. gratilla* individuals recorded during the belt transect survey was generally dominated by adult size classes of 61 – 65 mm TD and only very few recruit individuals with a TD of 33 – 39 mm were observed (Figure 9). The low number of recruits recorded may be attributed to sampling limitations caused by the cryptic nature of juveniles hiding in rock crevices, algae, and seagrass leaves, which makes observation difficult (Balisco 2015). However, it is very alarming to note that all gleaners capture *T. gratilla* at all sizes regardless if it is below 40 mm TD in the three sampling sites. This nonselective harvesting practice may lead to the collapse of sea urchin fishery, if continuously unregulated (Ungson 2004). The prohibition of harvesting small-sized sea urchins in the area and establishing a size catch limit (>60 mm TD) (Junio-Meñez et al. 2008b) is highly recommended for the sustainable management of this important resource.

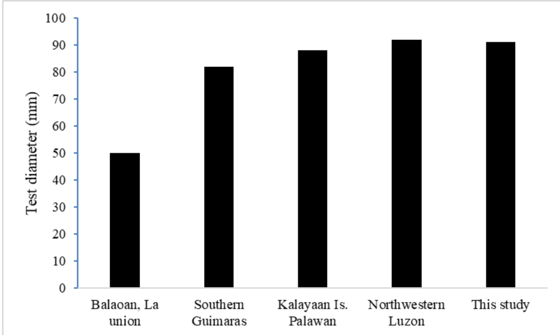

Figure 10. Largest size of *Tripneustes gratilla* recorded from different localities in the Philippines.

The relationship of the TD and weight in three sampling sites exhibited a negative allometric growth ($b < 3$) with a high positive correlation. Similar findings were also observed in the studies of Regalado et al. (2010) and Balisco (2015) which indicated that *T. gratilla* in their respective sampling areas displayed negative allometric growth. Negative allometry describes a condition in which a sea urchin's TD increases faster than its body weight, meaning weight does not increase proportionally with TD as it would if both grew at the same rate (Elmasry et al. 2023; Rahman et al. 2013; Suryanti et al. 2024). Factors such as diet, reproductive behavior, and the number of samples of *T. gratilla* would affect their growth (Balisco 2015). In other literature, this negative allometry reflects poor conditions for growth such as low food availability, increased fishing pressure, high predation, and pollution (Siddique and Ayub 2016; Mon et al. 2020; Elmasry et al. 2023). The seagrass in Kitayo is mostly dominated by *Syringodium isoetifolium* (Ascherson Dandy 1939) and *Cymodocea rotundata* (Ascherson and Schweinfurth 1870) while in Balangonan is dominated by *Thalassia hemprichii* (Ascherson 1871) and *S. isoetifolium.* On the other hand, seagrass beds in Bukid are dominated by *T. hemprichii* with patches of *Sargassum* species. The food preferences of sea urchins are largely influenced by the availability of specific types of food dominant in their surroundings (Kasim 2009). Seagrasses and seaweeds, commonly abundant at study sites, serve as primary food sources for *T. gratilla*; however, variations in available food items may contribute to differences in growth rates. According to Junio-Meñez et al. (2008a), *T. gratilla* exhibited higher TD growth rates when fed *Sargassum* spp. Regalado et al. (2010) further suggested that seasonality and the type of available food significantly impact growth rates and maximum attainable size in sea urchins. While this study did not investigate the availability or types of food in the study sites, further research is necessary to determine if these factors affect the reproductive biology of *T. gratilla* in these areas.

The peak of the spawning phase is determined by the variance in the gonad index (Vladimir et al. 2004). This is by far the first study on the spawning aspects such as gonad index and fecundity of *T. gratilla,* done in Davao Occidental. The highest gonad index during the full moon compared to other lunar phases indicates that the spawning period peaks during the full moon and then decreases towards the new moon. Sea urchins reach their greatest GI value near the time of spawning and then it starts to decline until spawning is over (Nasrullah et al. 2018). Other sea urchin species also exhibit spawning peaks during the full moon. For example, *Diadema savignyi* (Audouin 1809), *Echinothrix diadema* (Linnaeus 1758), *Diadema setosum* (Leske 1778), and *Strongylocentrotus intermedius* (Agassiz 1864) have been observed to spawn during the full moon (Zhadan et al. 2018). Additionally, *Lytechinus variegatus* (Lamarck 1816) in southern Brazil shows spawning associated with both the full moon and new moon phases (Aparecida et al. 2015). In contrast, other studies have documented spawning during the new moon. For instance, *T. gratilla* on the Kenyan coast reaches peak spawning around the new moon, which then declines to a minimum near the third quarter (Muthiga 2005). This pattern was similarly observed by Juinio-Meñez et al. (2008a) and Johnson and Ranelletti (2017). Another species, *Echinothrix calamaris* (Pallas 1774) also exhibits spawning during the new moon (Coppard and Campbell 2005). The result of fecundity showed that *T. gratilla* at 54 mm TD or more was already sexually mature. The total number of eggs in *T. gratilla* is relatively highest during the full moon while the lowest fecundity was found during the new moon. The variation in the observable total number of eggs may be attributed to the sizes of the sample collected. Gonad production increases when its size reaches 70 mm and has shown no observed decreasing pattern even when its size reaches 100 mm (Toha et al. 2017). According to Basch and Tegner (2007), larger sea urchins can enhance their reproductive output, which results in increased volume for the growth of gonadal tissue and an increase in fecundity. Thus, the gonads are in their greatest bulk ready for release. The lunar phase may play a role in the timing of the spawning of *T. gratilla* (Muthiga 2005; Juinio-Meñez et al. 2008a). However, the timing of spawning may not only be attributed to lunar phases but other factors should also be considered on the cues as to when the sea urchin spawns such as temperature, photoperiod, and food availability (Brockington et al. 2001; Perez et al. 2010; Vaitilington et al. 2005). It is recommended to regulate collections of *T. gratilla* in the sites, particularly during the full moon phase, as this may coincide with the peak of spawning. This will help ensure that a greater number of *T. gratilla* individuals can release gametes (eggs and sperm) and maximize the population's recruitment potential.

While the findings of this study provide valuable insights, they are not conclusive regarding the population structure and lunar periodicity of spawning. Continuous long-term monitoring of sea urchin populations is essential for a comprehensive understanding of the population dynamics of *T. gratilla* at these sites. Short-term data may not fully capture the variability in density and reproductive biology, whereas long-term monitoring can offer a more accurate picture of the status of *T. gratilla* in these sites. It is also crucial to consider other factors, such as seasonal habitat changes, food preferences and availability, and additional influences on spawning timing.

FUNDING

The authors did not receive support from any organization for the submitted work.

ETHICAL CONSIDERATIONS

A gratuitous permit no 01012-102524 from the Bureau of Fisheries and Aquatic Resources (BFAR) was secured in the collection of samples.

DECLARATION OF COMPETING INTEREST

No potential conflict of interest was reported by the authors

ACKNOWLEDGMENTS

The authors would like to thank the following individuals for the technical support to make this study possible: Mr. Jopy Caneda, Ms. Jilliane Rae Cabili, and Ms. Junarie Joy Tuba. We would also like to acknowledge the local government unit of Barangay Kitayo, Balangonan, and Bukid for their assistance in the conduct of the study. We sincerely thank the reviewers for their time and effort in evaluating this paper. The quality and clarity of this paper were much enhanced by their critical remarks and thorough suggestions.

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ROLE OF AUTHORS: *JRHM – conceptualization, methodology, supervision, writing-original draft and revising manuscript; MJrGS, JMT, HGAM and SP – data collection (field sampling and laboratory analyses); BMJ – Data analyses and data validation. All authors read and approved the final manuscript.*

Responsible Editor: Roger G. Dolorosa, PhD