Preliminary assessment of *Tripneustes gratilla* populations in Seagrass Beds of the Spermonde Archipelago, South Sulawesi, Indonesia

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**Abstract.** Many sea urchins, including *Tripneustes gratilla*, are well known for their role as herbivores, contributing to the control of fast growing macroalgae that can potentially overgrow and dominate seagrass beds and reef flats. *T. gratilla* is a short-spined sea urchin that can be easily found and collected by hand from the seagrass meadows which are their main habitat, especially during low tide. The exploitation of this species in Indonesia began to expand several years ago when the demand for *T. gratilla* gonads started to rise, for both commercial purposes and household consumption. This study aimed to determine the population and distribution of *T. gratilla* in seagrass ecosystems across the Spermonde Archipelago, South Sulawesi, Indonesia. The results indicate that the abundance and size distribution of *T. gratilla* are affected by several factors, i.e. seagrass condition, water quality, and the intensity of sea urchin collection. The results also emphasize the urgent need for developing and implementing effective management to ensure the sustainability of this important sea urchin species.

1. Introduction

The role of sea urchins as one of the main herbivore groups is crucial for coral reef and seagrass ecosystem health [1–3]. Heavy fishing pressure combined with high nutrient loads will result in multiple stressors on coral reef and seagrass ecosystems, and may eventually lead to a phase shift from seagrass or coral reef to a new state, typically macroalgal dominated habitats [4–6]. Fisheries management in the Spermonde Archipelago [7], as in Indonesia more generally [8–10], has been very challenging and often lacking in effectiveness, especially when dealing with small scale artisanal fisheries in the coastal area. The use of multiple gears, catching multiple species, without quotas and/or size limitations has caused many coral reef and seagrass ecosystems to become heavily overfished [7,11]. While people in some countries, such as Australia, do not in general prefer herbivorous fishes, fishermen and the general public in Indonesia tend to consume almost all kinds of...
fish, including herbivores such as rabbitfish and parrotfish [12,13]. Consequently, in many places herbivory has been largely taken over by invertebrate herbivores such as sea urchins (e.g. Diadema sp. and Tripneustes gratilla). The role of sea urchins as key herbivores was well documented during the Diadema antillarum die off in the Caribbean, which resulted in an uncontrollable take-over of many reefs by macroalgae [14]. In other cases, the roles of herbivores has been able to compensate the impacts from nutrient loading in seagrass beds through grazing on the fast growing epiphytic algae that can cover the seagrass leaves [15].

Despite their critical roles, scientific information is still lacking on the dynamics of sea urchin populations in Indonesia, especially in the Spermonde Archipelago. Few studies have explored and predicted sea urchin population dynamics and their relative abundance in Indonesia [16,17]. Insufficient data and analyses of the distribution and abundance of these species indicate very little, if any, attention by government to the management of sea urchin resources, many of which may have been overexploited without it being realized [18,19]. Introducing total protection for sea urchins without a sound scientific basis is also not strategic, because a total ban is difficult to implement and will not always be directly beneficial to seagrass or coral reef ecosystems. For example, sea urchin outbreaks might result in overgrazing and can be unfavourable for the surrounding ecosystems [20,21].

Sea urchin exploitation has a very long history around the world, especially for the consumption of their gonads, for example in Chile, Japan, and the Philippines [22,23]. Although there are very few published scientific journals on Indonesian sea urchins, the fact is that, to date, almost no specific management or policies are in place to ensure their sustainable use [16,24–26]. Sea urchin exploitation is mostly through gleaning, a technique which is very easy for Indonesian fishermen and other coastal community members, including woman and children [27,28]. Basically they only need to walk in the seagrass areas during low tide, and then they can collect the sea urchins, putting them into a basket and bringing them to shore. If they keep doing this over the long term, without any management in place, it is very likely that the sea urchin populations can be endangered [19,29,30]. The lack of attention by key stakeholders, especially the government, regarding the urgency of managing sea urchin resources, is likely attributed to several factors, such as (i) misunderstanding of the critical roles of sea urchins in maintaining ecosystem balance and productivity [2], indeed people sometimes even consider sea urchins as ‘pest organisms’; (ii) sea urchin gonad exploitation is not specifically recorded, hence their total economic value is also unknown. Therefore, it is crucial to improve our understanding of the population status, distribution, and the utilization of sea urchins in general, and in particular the species Tripneustes gratilla. The general aim of this study was to investigate the variability in T. gratilla abundance and size in relation to seagrass condition and anthropogenic impacts in the Spermonde Archipelago.

2. Methods
This study was conducted from June to August 2020 in the Spermonde Archipelago, off the western coast of South Sulawesi Province, Indonesia. The Archipelago can be divided into three zones representing inshore-offshore water quality gradients [31]. Two sites were selected in each of these three zones: Lae Lae and Samalona in the inshore zone, Barang Lompo and Bone Batang in the mid-shelf zone, Lankai and Lanjukan in the offshore/outer zone (Figure 1).

We used secondary data (summarized from the published literature) to describe the inshore-offshore water quality gradient of the Spermonde Archipelago [32–35]. Water quality close to Makassar City (e.g. Lae Lae and Kayangan Islands) is much more turbid with relatively higher nutrient concentrations compared to offshore areas such as the reefs around Lanjukan and Kapoposang Islands, especially during the rainy season (Table 1). Therefore, the sites selected for this study which range from inshore to off shore zones can be considered to be affected by a water quality gradient in the following order (decreasing magnitude of impact): Lae Lae, Samalona, Barang Lompo, Bone Batang, Lankai, and Lanjukan.
Figure 1. Study sites along the inshore-offshore gradient of the Spermonde Archipelago, Makassar Strait, Indonesia) with two sites in each zone; Lae Lae and Samalona Islands (inshore zone), Barang Lompo Island and Bone Batang (mid-shelf zone), Lankai and Lanjukan Islands (outer zone)

Table 1. Water quality gradient measured at different zones (inshore, mid-shelf, offshore) in the Spermonde Archipelago.

| Parameters                  | Inshore | Mid-shelf | Offshore | Source (sites)            |
|-----------------------------|---------|-----------|----------|---------------------------|
| Water Clarity (m)           | < 6     | 17-18     | > 20     | [32,33] (Kayangan,        |
| Chl. a (mg/m$^3$)           | 1.52    | 0.75-0.82 | 0.47     | Samalona, Barang          |
| NO$_3$ (µM)                 | 0.85    | 0.49-0.63 | 0.34     | Lompo,                    |
| PO$_4$ (µM)                 | 0.41    | 0.3-0.31  | 0.18     | Kapopoulos)               |
| SPM                         | 19.25   | 8.22-8.62 | 5.26     |                           |
| Sediment Traps (mg/cm$^2$/day) | 2.8    | 0.6-0.7   | NA       |                           |
| NO$_3$ (µg/L)               | 69.6-136.05 | 43.4-75.35 | 33.8-42.4 | [34] (33 sites;           |
| PO$_4$ (µg/L)               | 37.56-42.23 | 23.0-44.15 | 27.2-39.52 | inshore, mid-shelf,       |
| Chl. a (µg/L)               | 0.83-4.4 | 0.58-1.6  | 0.46-0.58 | offshore)                 |
| Chl. a (µg/L)               | 0.62-1.59 | 0.32-1.07  | 0.56-1.17 |                           |
| POC (µg/L)                  | 130-236.3 | 60.7-126.9 | 52.8-104.8 | Samalona, Bone            |
| DOC (µM)                    | 61.7-95.4 | 52.2-147.1 | 68.0-133.8 | Batang, Lanjukan)         |
| C$_{org}$/N ratio           | 6.72-7.84 | 6.69-9.57  | 5.65-9.76 |                           |

Surveys were conducted at all six study sites (Figure 1) to assess the general condition of seagrass meadows (percentage cover) as well as the number and the size of $T. gratilla$ observed. The data were collected from three 100 m transects at each site, laid perpendicular to the shoreline from the coast towards the sea and separated from each other by a distance of 50 m. To estimate seagrass condition, 50x50 cm quadrats were placed every 10 m starting at the beginning of the transect. Seagrass percentage cover was estimated in 4 of the 25x25 cm grids of each quadrat, with seagrass percentage cover categories of 0, 12.5, 25, 50, 75, and 100% (LIPI, 2016). Sea urchins ($T. gratilla$) were counted within a 5m x 100m belt transect, extending 2.5 m to the left and to the right of the transect line.
500 m²). The diameter of each *T. gratilla* found in the belt transect was measured with a precision of 0.1 mm using callipers. One-way Anova was performed to evaluate between site differences on each parameter measured.

3. Results and Discussion

Seagrass percentage cover (%) at the six study sites (inshore, mid-self, and offshore) is presented in Figure 2. Seagrass cover in the inshore zone close to Makassar City was only ≈1% around Lae Lae Island and ≈5.3% around Samalona Island. The highest seagrass percentage cover was found around Barang Lompo (≈44.3%), significantly higher (P<0.05) compared to Bone Batang (≈32.6%) and Lankai (≈31.1%).

![Figure 2. Seagrass percentage cover (%) along the gradient from inshore to mid-shelf and offshore zones of the Spermonde Archipelago](image)

The low seagrass percentage cover around *Lae Lae* (≈1%) was likely influenced by long-term exposure to high turbidity due to sedimentation and eutrophication close to the Makassar City mainland. Although sedimentation and eutrophication are not very high in Samalona, the geomorphology of this small island is not very suitable for seagrass development, for example the reef flat is small in extent and sand movement around the island is dynamic. A combination of all of these factors could have caused the relatively low (only 5.3%) seagrass cover around Samalona. On the other hand, the low seagrass percentage cover around Lanjukan (1%) at the outer zone of Spermonde Archipelago was most likely mainly due to the high exposure of the reef flat to large waves and strong currents around this island.

The higher seagrass percentage cover around Barang Lompo (44.3%), Bone Batang (32.6%), and Lankai (31.1%) could most likely be attributed to several factors. These include relatively better water quality as indicated in Table 1 (low sedimentation, low nutrient concentrations, and higher water clarity), more suitable geomorphology (wider reef flat zones with sandy substrates), and relatively lower exposure to wave action and currents. The seagrass meadow at these three sites were dominated by mix of two dominant species *Enhalus acoroides* and *Thalassia hemprichii* with a lesser density of *Cymodocea rotundata*. Reports of anthropogenic seagrass degradation also indicate the need for serious attention to seagrass ecosystem management, including the restoration of degraded meadows [36–38].

The numbers of *T. gratilla* found varied along the inshore to offshore zone, as shown in Figure 3. The number of *T. gratilla* found in Bone Batang (9.3/500m²) was significantly higher (P<0.05) compared to Barang Lompo (6.3/500m²) and Lankai (5.7/500m²). At the other three sites (Lae Lae,
Samalona and Lanjukang) *T. gratilla* were not found. The observed absence of sea urchins at these three sites could likely be attributed to the very low percentage cover of seagrass (Fig. 2) as the main habitat for this species.

![Figure 3](image3.png)

**Figure 3.** Average number of *T. gratilla* found on 500m$^2$ transects along the gradient from inshore to mid-shelf and offshore zones of the Spermonde Archipelago. Error bars denote standard deviation (SD).

The average diameter of *T. gratilla* observed at each site is presented in Figure 4. Among the three sites where *T. gratilla* were found, the largest mean sea urchin diameter was recorded from Bone Batang (68.6 mm) but was not significantly different from Lankai (62.6 mm). Interestingly, *T. gratilla* from those two sites were significantly larger ($P < 0.05$) compared to those from Barang Lompo (51.3 mm). This result is particularly interesting when taking into account that seagrass percentage cover was in fact highest around Barang Lompo (Figure 2).

![Figure 4](image4.png)

**Figure 4.** Average diameter of *T. gratilla* found on 500m$^2$ transects along the gradient from inshore to mid-shelf and offshore zones of the Spermonde Archipelago. Error bars denote standard deviation (SD).
Sea urchin gleaning is a common practice in Indonesia and in many parts of the world \cite{19,22,27,28,39,40}. A rapid survey on the exploitation of sea urchins at the study sites indicated that only people living on Barang Lompo Island regularly collected \textit{T. gratilla} and used their gonads as a complementary food or source of protein.

The well-established habit of gleaning for \textit{T. gratilla} in Barang Lompo, as compared to no sea urchin gonad consumption at the other sites (Bone Batang and Lankai), was most probably the main reason for the significantly smaller size (diameter) of \textit{T. gratilla} compared to the other two sites. This trend indicates that the exploitation of sea urchins in this area could be posing a risk to the sustainability of the populations and the gleaning fishery \cite{41}. Similarly to other exploited organisms, due to the importance of sea urchins for their ecological roles and as a source of protein or income, there is a need for further study and to develop management strategies and implement management actions to ensure their sustainable use.

4. Conclusion

The distribution and the abundance of the sea urchin \textit{Tripneustes gratilla} in the Spermonde Archipelago appear to be determined by several key factors. These include the condition of seagrass meadows, with higher \textit{T. gratilla} abundance found where the seagrass percentage cover was higher. The diameter of \textit{T. gratilla} population was affected by anthropogenic factors, with smaller sea urchins associated with frequent harvesting for human consumption around Barang Lompo Island. The water quality gradient appeared to have a negative effect on seagrass distribution and percentage cover, especially in the inshore zone, which in turn also affected the distribution and abundance of \textit{T. gratilla}. Due to its strategic role as an important herbivore in seagrass ecosystems, there is an urgent need to manage the populations of this sea urchin.

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