Gonadosomatic index and distribution of some edible sea urchins in North Sulawesi waters, Indonesia

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Abstract. Sea urchin, one of species model for developmental biological research, has recently become an established aquaculture species. The main product of this fauna, 'roe', is categorized as the most valuable seafood product. Despite their high commercial values, aquaculture development of edible sea urchins in Indonesia, particularly North Sulawesi, remains less documented. This study aimed to preliminary investigate reproductive performance through gonadosomatic index (GSI) and distribution of some edible sea urchin species in North Sulawesi waters. Four widely distributed species, *Diadema setosum*, *Diadema savignyi*, *Echinothrix calamaris* and *Tripneustes gratilla*, were collected from Makalisung, Kema, North Sulawesi and were subjected to shell diameter, body and gonad weight measurement. Among four species, *T. gratilla* demonstrated the highest mean of GSI (6.70±1.54%), body weight (124.30±6.58 g), shell diameter (66.20±1.30 mm) and gonad weight (8.14±1.61 g). In terms of distribution, *D. setosum*, *D. savignyi* and *T. gratilla* were the most distributed species in North Sulawesi waters with the density up to 35100, 24100 and 8400 individuals ha^{-1}, respectively. Of the sampling locations, Kema showed the highest diversity and density of sea urchins. The findings of this study suggest that *T. gratilla* is a potential sea urchin species for aquaculture development in North Sulawesi.

Key Words: aquaculture development, gonad, reproductive biology, urchin.

Introduction. Commercial harvesting of sea urchins has been globally documented since the 19^{th} century such as in North and South America, Japan, Maine and New Hampshire (Saito 1992; Hagen 1996). Sea urchin aquaculture has been developed to address the extinction of many commercial sea urchins species worldwide due to the large scale of harvest. Global aquaculture of sea urchins was started in 1960s in Japan, where the demand for the sea urchin gonad is high (Saito 1992; McBride 2005). The more recent aquaculture development of sea urchins has also been reported in Australia, China and Philippines (McBride 2005) following the aquaculture success in Belgia, Japan, New Zealand and the United States (Kirchhoff 2005). Meanwhile, sea urchin aquaculture in Indonesia is poorly documented.

Sea urchins are edible species due to accessibility, palatability and cultural history (Lawrence 2007). The majority of edible sea urchins are shallow water species which is accessible for coastal communities (Lawrence & Bazhin 1998). Palatability is also an important factor for sea urchin consumption. In Chilean waters, sea urchin *Tetrapygus niger* is abundantly found in shallow water but is not consumed by local communities due to this species is not palatable (Lawrence & Bazhin 1998).

Apart from being considered for their high commercial value of gonads, sea urchins also play an important ecological role in marine ecosystems. Moore (1966) reported that some sea urchin species from the genera of *Diadema* and *Strongylocentrotus* are key species to control algal cover particularly in sea grass ecosystem. In coral reef, sea urchin *Diadema antillarum* is an effective grazer which is beneficial for coral polyp growth by reducing algal turf and substrates that hinder coral recruitment (Alves et al 2003). Therefore, continuously harvesting wild sea urchin will potentially lead to adverse effects on marine ecosystems.

The previous studies of sea urchin in Indonesia were focused on bio-ecology and locality distribution (Supono et al 2014; Nomleni et al 2020), morphometric observation and proximate composition of gonad (Silaban & Srimariana 2013; Wulandari & Warsito 2022; Hoar et al 2023), gametogenesis (Darsono 1993), antimicrobial compounds (Sidiqi et al 2019), habitat suitability for breeding (Radjab et al 2020) and phylogeography (Vimono et al 2023). An effort to rear wild-captured sea urchin in net cage has been recorded in Kepulauan Seribu, Jakarta (Adi 2010). However, this practice may not be sustainable as it relies on the harvesting of wild broodstock for gonad productions.

Gonad assessment (namely gonadosomatic index and gonad development stage) has been used as measures to understand the reproductive cycle of sea urchin. Some species of Indonesian sea urchins have been reported to spawn throughout the year with spawning period depending on geographical areas (Aziz & Darsono 1979). Indonesia has a typical annual temperature variation of surface seawater, ranging from 28.2 to 29.2ºC (Levitus & Boyer 1994). This temperature ranges are beneficial for sea urchin reproduction as temperature of 25ºC is lowest critical temperature to achieve natural spawning (Pearse 1970). However, despite the similar range of seawater temperature among regions in Indonesia, peak spawning season is locally and species-specific (Tjendanawangi & Dahoklory 2011). Siikavuopio et al (2006) reported that the reproductive cycle of sea urchin, including gonad maturation, is affected by seasonal variation and geographical conditions. Aziz & Darsono (1979) reported that the spawning of sea urchin, *Diadema setosum* in Pulau Tikus, Kepulauan Seribu peaked in January, February, April and October. In contrast, sea urchin *Tripneustes gratilla* reached peak spawning in December in Nusa Dua Bali (Darsono & Sukarno 1993) and July and August in Teluk Kupang (Tjendanawangi & Dahoklory 2011; Aslan 2005).

In North Sulawesi waters, sea urchin research is limited on ecology and distribution as part of echinoderm studies. At least 30 species of sea urchin representing 12 families, of which 9 species are potentially edible species, were recorded in 32 sites of North Sulawesi waters (Supono et al 2014). Makalisung, located administratively in Kema, North Sulawesi demonstrates seagrass ecosystem expanding for about 3 km and also algal cover dominated by green algae (Chlorophyceae) with 12 to 20% coverage (Murni 2014). This ecological feature is suitable for living habitat of sea urchin. Setyawan et al (2014) reported that stomach content of *D. setosum* and *Echinothrix calamaris* were composed of 40 to 65% of algal and grass leaves fragment. However, information of sea urchin reproductive cycles, particularly in Makalisung and other areas of North Sulawesi remains unknown. This study aims to investigate the gonadosomatic index of some edible sea urchins in Makalisung, North Sulawesi and also to review their distribution in North Sulawesi waters. By establishing the GSI of some potential edible sea urchin and also their density and distribution across North Sulawesi waters, aquaculture development of edible sea urchin is potential to be applied in these areas.

Material and Method

Material. Materials used in this study included GPS device (GPS map 65s, Garmin Indonesia), digital caliper 799 Starrett with 0.01 mm accuracy, scale Ohouse-Scout, utility tong with nylon end, bucket and Petri disc.

Description of the study sites. There were two types of data collection used in the present study. First data were GSI of four edible sea urchin species which were sampled in three sites (500 m apart from one location to another) within one location in Makalisung, Kema, North Sulawesi, Indonesia (indicated by star symbol in Figure 1) GSI sampling of sea urchin was conducted during low tide by hand picking using utility tong with nylon end in August 2017. Four species of sea urchins, i.e. *Diadema setosum*, *Diadema savignyi*, *Echinothrix calamaris* and *Tripneustes gratilla* were collected and subjected to wet gonad, body weight and diameter measurement. Second data were originated from the previous studies which investigated the distribution and density of the four species sampled for GSI in North Sulawesi areas. These data were plotted on the map to identify the distribution of the four edible sea urchin species and their density to represent their abundance in North Sulawesi waters (indicated as 17 black dots across North Sulawesi waters in Figure 1).

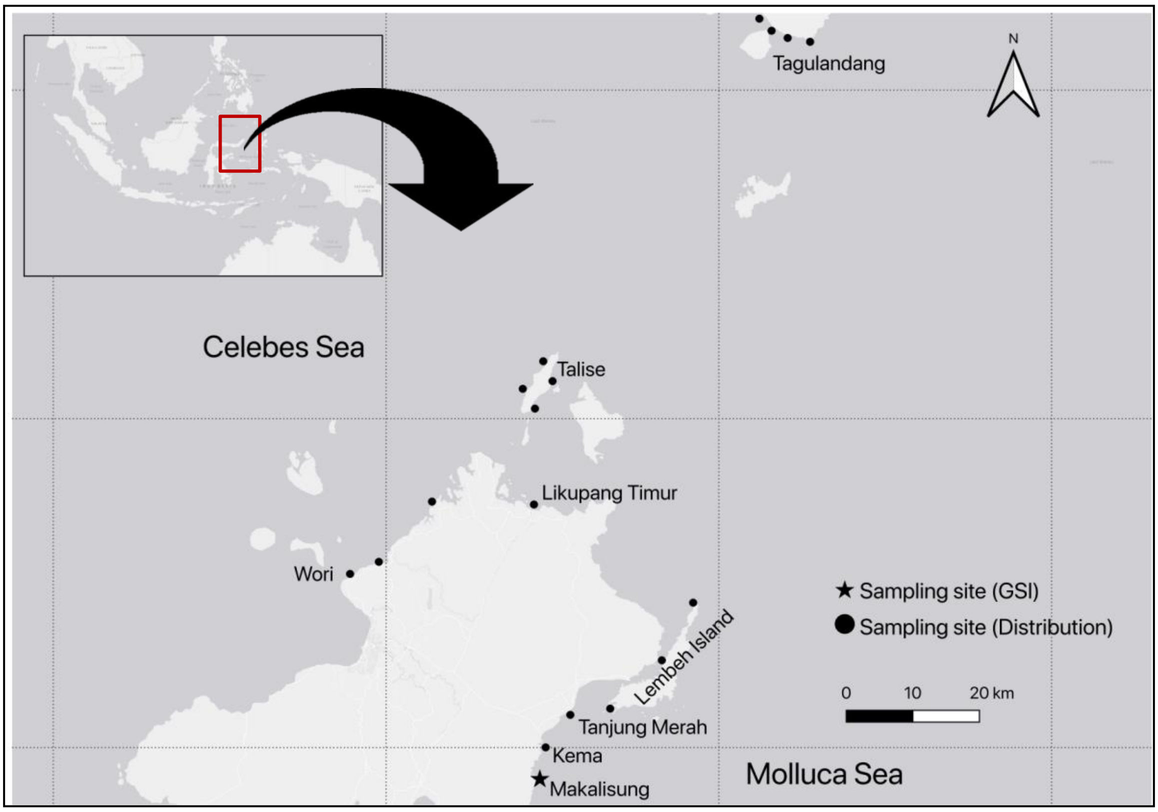

Figure 1. Sampling sites for gonadosomatic index (GSI) in Makalisung indicated by star symbol and 17 sampling sites of sea urchin distribution identified from the previous studies across North Sulawesi water indicated by black dot symbol.

Methods. Horizontal shell diameter of each species was measured using a digital caliper. Wet body and gonad weight were measured using a digital scale with accuracy of 0.01 g (Joil, Indonesia). Gonadosomatic index (GSI) of each species was determined following Sánchez-España et al (2004) as follow:

$$GSI = \frac{\text{Wet weight of gonads}}{\text{Wet weight of whole animal}} \times 100$$

Meanwhile, literature review from the previous studies was done to investigate the distribution of edible sea urchin in North Sulawesi. It included species distribution and density in North Sulawesi waters. Sea urchin distribution data were provided for all potential edible sea urchin species recorded in 32 sites of North Sulawesi water. Of these localities, data from nine sites were presented in this study as they were sampled using quadrant transect method.

Statistical analysis. The means of all parameters observed were compared using one-way ANOVA using SPSS version 22 for Mac OS X after conforming the normality and homogeneity of variances. Tukey post hoc test was used to identify any significant difference among groups at a significance level of 0.05.

Results. Mean comparison analysis using one-way ANOVA showed that body weight ($F_{(3,12)}$ = 8.41, $p < 0.01$) and gonad weight ($F_{(3,12)}$ = 8.19, p = 0.08) were significantly different among species, but shell diameter was not significantly different among species ($F_{(3,12)}$ = 2.82, p = 0.08), The sea urchin, *T. gratilla* demonstrated the highest GSI and other parameters measured in this study. The mean of GSI (6.70±1.54%), body weight (124.30±6.58 g), shell diameter (66.20±1.30 mm) and gonad weight (8.14± 1.61 g) of *T. gratilla* were the highest among four sea urchin species. Despite the lowest body size (67.52±11.42 g of body weight and 55.29±3.76 g of shell diameter) *D. setosum* demonstrated the second highest values of GSI and gonad weight with 5.81±0.21% and 3.94±0.68 g respectively. *D. savignyi* demonstrated the lowest GSI (1.17± 0.11%) and gonad weight (1.01±0.07 g) (Figure 2).

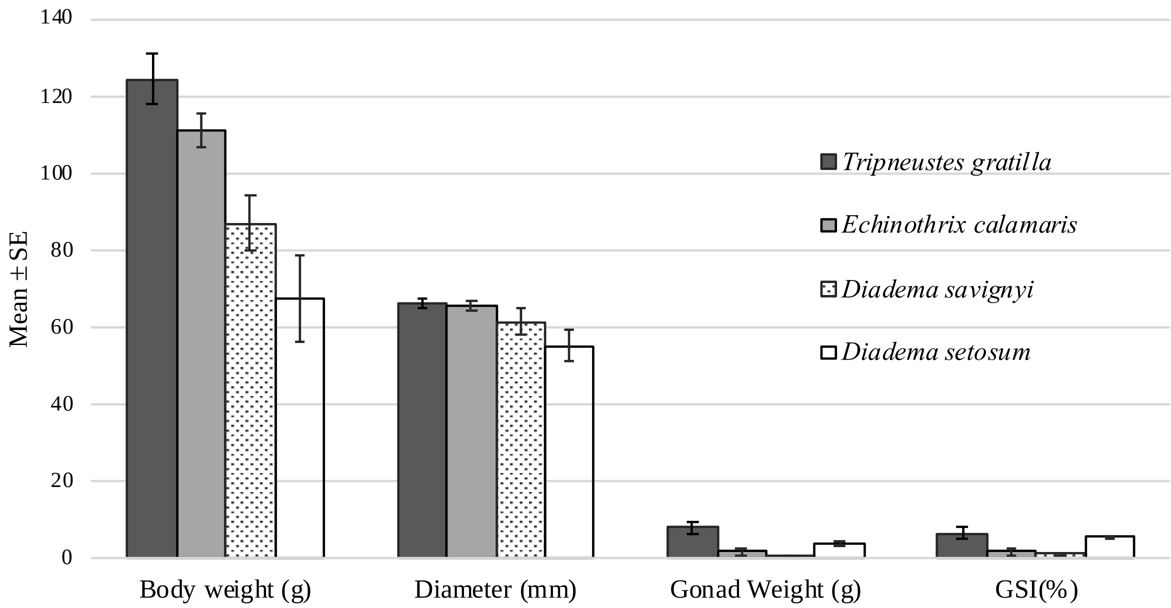

Figure 2. Mean (±SE) of body weight, diameter, gonad weight and GSI of four sea urchin species.

Review from the previous studies showed that from 9 locations sampled using quadrant transect, Kema was the most diverse and abundant location (Table 1). In Kema, three widely distributed sea urchin species i.e. *D. setosum*, *D. savignyi* and *T. gratilla* were recorded to be the most abundant species reaching up to 35,100, 24,100 and 8,400 individuals ha^{-1}, respectively.

Table 1

Sea urchin species density and distribution in North Sulawesi waters

Locality	*Density (ind ha⁻¹)*				*Sources*
	T. gratilla	*D. setosum*	*D. savignyi*	*E. calamaris*	
Talise	1600	2800	1100	0	Yusron (2012)
Tanjung merah	1888	2222	0	0	Yusron & Susetiono (2005)
Likupang Timur	2440	6170	200	330	Supono (2011)
Kema	8400	35100	24100	1700	Supono & Arbi (2010)
Tagulandang	250	12500	5000	870	Supono & Manik (2013)
Wori	580	5500	3670	1580	Supono & Susetiono (2010)
Langsa	0	0	0	4000	Supono & Susetiono (2010)
Tiwoho	2333	0	12667	0	Supono & Susetiono (2010)
Darunu	0	22000	2000	0	Supono & Susetiono (2010)

Discussion. The GSI evaluation, a ratio of gonad weight to body weight, is a common method used to assess reproductive cycle of animals through variation in gonad size (Devlaming et al 1982). It has been suggested that gonad weight depends on the size of the animal and the developmental stage of gonad (Ibrahim et al 2017). Thus different sizes of animals are commonly sampled to investigate the reproductive stage (Devlaming et al 1982).

Sea urchin *T. gratilla* in this study demonstrated the highest GSI among other species. Morphometrically, *T. gratilla* demonstrated bigger body size and larger diameter compared to other sea urchins sampled in this study, resulting in the highest GSI. GSI is influenced by expression of body size such as body weight and diameter (Devlaming et al 1982). Kasim (1999) reported that a positive correlation is demonstrated between body diameter and weight, and gonad weight of *T. gratilla.* Juliana (2007) reported that similar pattern was shown in *T. gratilla* and *D. setosum,* in which gonad weight increases with body size. However, opposite results were shown in the present study, where only *D. setosum* demonstrated a linear relationship between body weight, diameter and gonad weight, where the increase of body weight and shell diameter was followed by increasing gonad weight. Despite the lowest body size and diameter, *D. setosum* in the present study demonstrated higher gonad weight compared to *E. calamaris* with higher shell diameter and body weight.

While further studies are needed to justify this discrepancy, it may be related to any differences in the developmental stage of gonad and spawning peak season. During recovering stage, gonad weight are at the lowest percentage of body weight and increases gradually at the following stages which are growing stage and maturation stage (Tjendanawangi & Dahoklory 2011; Agatsuma et al 2012). Despite the lack of information on the spawning peak season in North Sulawesi, it has been reported in other areas where the spawning peak season of *T. gratila* occurred in June in East Lombok (Setyawan et al 2014) and Teluk Kupang (Tjendanawangi & Dahoklory 2011). Similarly, the spawning peak season of *D. setosum* in Pulau Pari, Kepulauan Seribu occurred in June (Darsono 1993). If similar spawning period is shown in North Sulawesi waters, as gonad assessment in the present study was conducted in August, sea urchins in this study may be at the spent stage which demonstrates lower gonad weight.

The high GSI demonstrated in *T. gratilla* may also relate to food availability in the sampling site. Sea urchins were collected from seagrass ecosystem expanding along the coastal line of Makalisung, Kema. The dominant seagrass species in the sampling location was *Thalassia hemprichii* covering 16 to 42% of the seagrass area (Murni 2014). *T. gratilla* is known to be a seagrass grazer. Stomach content analysis of this sea urchin shows that it was composed by up to 85% seagrass fragment of *T. hemprichii* (Hattori et al 1985; Mukai & Nojima 1985; Darsono & Sukarno 1993).

The distribution of sea urchins is influenced by several factors such as population of predators, food availability and harvesting activities (Birkeland 1989). There are at least 34 species of reef fish preying on sea urchins (Birkeland 1989). In terms of food availability, majority of sampling sites in North Sulawesi featured sea grass and macroalgal cover (Supono & Arbi 2010; Murni 2014) which is the main food source of sea urchins, except in Langsa and Tiwoho which is dominated by rocky substrates with less seagrass cover (Supono 2011).

There is no established information about commercial exploitation of sea urchin in North Sulawesi. However, harvesting of sea urchin, particularly *T. gratilla*, for domestic consumption and as bait for traditional fishing trap (*bubu,* a fish trap made of bamboo) was frequently observed in some areas such as Kema, Makalisung and Lembeh Strait. In terms of abundance, the density of sea urchins in North Sulawesi was relatively lower as compared to other areas in Indonesia. *T. gratilla* was recorded up to 12,000 ind ha^{-1} in Bali (Darsono & Sukarno 1993) and 15,500 ind ha^{-1} in Bone, Sulawesi (Vonk et al 2008).

Conclusions. The finding of the study suggests that *Tripneustes gratilla* is a potential aquaculture species demonstrating the highest gonadosomatic index. Further study will include identifying the gonadal development stage to provide information about spawning season and site suitability for aquaculture development of this species in North Sulawesi.

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Conflict of interest. The authors declare that there is no conflict of interest.

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