

Reproductive activity and morphometric assessment of three commercial species of sea cucumber (Echinodermata) from Karimunjawa National Park, Indonesia

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Abstract. Mustagfirin, Wijayanti DP, Subagiyo. 2021. Reproductive activity and morphometric assessment of three commercial species of sea cucumber (Echinodermata) from Karimunjawa National Park, Indonesia. *Biodiversitas* 22: 3333-3341. Sea cucumbers are benthic animals that have economic value and play an important role in the environment. Exploitation on large scale to fulfill high market demand, caused overexploitation. The number of sea cucumbers in Karimunjawa decreased as a result of limited management. There is no study conducted on the commercial sea cucumbers (*Holothuria edulis*, *Pearsonothuria graeffei*, and *Bohadschia vitiensis*) in Nyamuk Island, Karimunjawa. The objectives of the research were to determine the morphometric assessment and the reproductive cycle of the three species. The morphometric assessment of weight showed that the weight of *H. edulis* ranges 247.3-2539g, *P. graeffei* 415.3-428.1g, and *B. vitiensis* 672.4-678.1g, respectively. The first maturity size of gutted body weight (GWB₅₀) for *H. edulis* was 127.84g, *P. graeffei* 357.61g, and *B. vitiensis* 279.34g. The gonad somatic index (GSI) range 13.60-15.60% for *H. edulis*, 14.75-12.25% for *P. graeffei* and 10.83-14.57% for *B. vitiensis*. The result of gonad somatic index with a value above 10% means that it has entered the spawning phase. The above data indicated that the three commercial species spawned monthly, during new moon. It is likely that the spawning peak occurred when the temperature was increased. However, the pattern of reproductive activity in this study was limited at Nyamuk Island. Future studies are needed to observe whether there is a correlation between the increasing water temperature and the reproductive activity of the three sea cucumbers.

Keywords: *Bohadschia vitiensis*, commercial sea cucumber, *Holothuria edulis*, morphometry, *Pearsonothuria graeffei*, reproductive activity

INTRODUCTION

Holothurians are known as sea cucumber worldwide, *bêche de-mer* in France, *namako* in Japan, *plingkao* in Thailand, and *haishen* in China, while in Indonesia common known as *teripang*, *gamat*, or *gamet* (Pangkey et al. 2012). In terms of ecology, sea cucumbers are marine organisms that have a vital ecological function in coral reef ecosystems (Conand 2008; Purcell et al. 2016; Buccheri et al. 2019). The sea cucumber is known to reduce the impact of ocean acidification and help the production of calcium carbonate deposits, by releasing ammonia as a byproduct of the digestive process (Schneider et al. 2011). Sea cucumber could recycle the nutrient by eating sediment consisting of organic matter and making nutrients at the bottom of the water through the feeding process (Uthicke 2001). Previous research from Wolkenhauer et al. (2010) shows that sea cucumbers play bioturbation benthic activity by filtering bottom sediment as a bioremediation. According to Purcell et al. (2016) sea cucumbers support enriching the ecosystem.

Sea cucumbers are one of the most potential export commodities in Indonesia (Choo 2008; Pangkey et al. 2012). The increasing demand from the market has led to the rapid exploitation of sea cucumbers (Sulardiono 2016;

Husain et al. 2017). The exploitation efforts had a significant impact on the decline of the populations of sea cucumbers (Hasan 2019). However, the related parties (stakeholders and government in the fisheries sector in Indonesia) have not given much attention to sea cucumber resources which have a low price (Husain et al. 2017).

Karimunjawa National Park (KNP) is known to have various species of sea cucumbers (Sulardiono 2011), some of those are commercial species (Mustagfirin and Hartati 2017). Commercial sea cucumbers most commonly found in KNP are *Holothuria edulis*, *Pearsonothuria graeffei*, *Bohadschia vitiensis*, and *Stichopus vastus* (Sulardiono 2016). These sea cucumbers may be located mainly in complex reef habitats (Conand et al. 2010; Sulardiono and Hendarto 2014). These commercial sea cucumbers usually live at a depth of 0 to 10 m (Dissanayake and Stefansson 2012). Fishermen usually catch the sea cucumbers by handpicking using a traditional compressor as an apparatus in diving or called Traditional SCUBA (Mustagfirin 2020, unpublished data).

Nyamuk Island, one island of the KNP, is home to many commercial sea cucumbers (Mustagfirin and Hartati 2017). For example, every year around 1,478 kg of various dried sea cucumbers were traded from the island (Mustagfirin 2020, pers. com). However, there is currently

no specific management of sea cucumber fishery in Karimunjawa including at Nyamuk Island. Moreover, although many species are traded, there are little data on the reproductive biology of the sea cucumber. The research about sea cucumber is limited to gonad studies, asexual modes such as fission, and how to cultivate the species (Sulardiono 2011). There is almost no information on reproductive activity and the morphometry of the commercial species. Therefore, it is necessary to conduct a study on the reproductive biology of the commercial sea cucumber species at Nyamuk Island as the important to manage the species in the future.

Many environmental factors are notion to have an effect on the reproductive activity in holothuroid (Hartati and Yanti 2006). For example, observation in laboratory experiments showed the influence of water temperature manipulation on sea cucumber *Holothuria atra* spawning (Yudiati et al. 2001). The moon cycle also affects the spawning time of some species (Mackey and Hentschel 2001; Ramofafia et al. 2001). *H. vagabunda* was reported to spawn during new moon at Jepara Waters, Central Java (Hartati and Yanti, 2006) while *H. scabra* spawning was observed during full moon at Langgur, Southeast Maluku (Rahantoknam 2017).

Here, we investigate the reproductive activity of the three commercial species under the influence of moon cycle, by observing the gonad somatic index (GSI) of the species and we analyze the morphometry, sex ratio, size, and weight at first maturity. Sea surface temperature was also recorded as one possible environmental trigger to observe whether or not it has influence in sea cucumbers spawning, at least at Nyamuk Island, Karimunjawa National Park, Central Java, Indonesia.

MATERIALS AND METHODS

Study area

The research was conducted during September–November 2020, and samples were collected based on the moon cycle (*first quarter, full, third quarter, and new moon*). Samples were collected at Nyamuk Island waters, Karimunjawa National Park, Central Java, Indonesia. The map is presented in Figure 1.

Procedures

Sample collection

A total of 250 individuals of each species namely *H. edulis*, *P. graeffei*, and *B. vitiensis* were obtained from the compressor divers (traditional fisherman). The three species are quite abundant with number of catching in 2017 reaching 88,000 individuals based on (Mustagfirin 2020, unpublished data). The researchers in this study took samples (750 sea cucumbers) or 0.84% of the total sea cucumbers based on data in 2017 and explaining that the three species are not locally rare. The divers collected the samples at night with underwater lights. Collection was done every day for three months (September–November) and following the moon phase through 2 cycles (*first quarter, full, third quarter, and new moon*). Number of samples taken following a certain moon phase is presented in Table 1. The sample was then measured of its morphometry and reproductive activity. Each individual was dissected to identify the sex and to determine the stage of the gonad. The reproductive activity was determined by classifying the stage of gonad maturity of each sample of the species following (Conand 1981). The samples were used in morphometric measurements and reproductive activity was the same. The rest of samples were reared in bucket of water alive (4 hours after being first captured) until the measurement process was carried out.

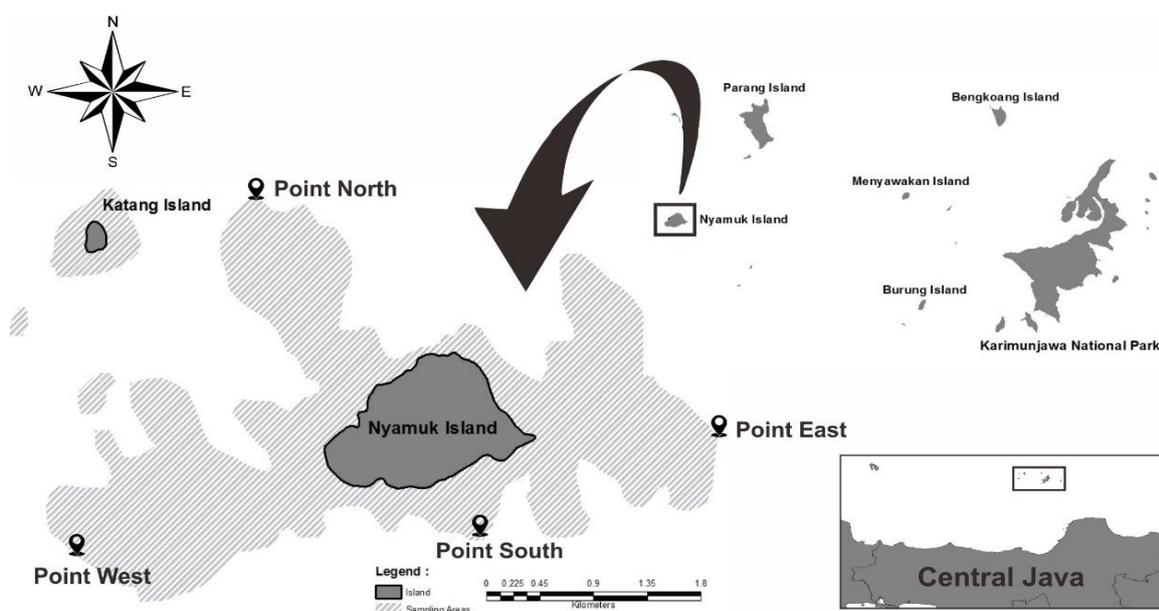


Figure 1. Study sites in Nyamuk Island waters, Karimunjawa National Park, Central Java, Indonesia and the study location of each sampling, Point North ($5^{\circ}47'49.34''\text{S}$, $110^{\circ}10'33.18''\text{E}$), East ($5^{\circ}48'47.03''\text{S}$, $110^{\circ}12'32.45''\text{E}$), South ($5^{\circ}49'18.32''\text{S}$, $110^{\circ}11'26.18''\text{E}$) and West ($5^{\circ}49'18.99''\text{S}$, $110^{\circ}9'35.51''\text{E}$)

Table 1. Samples of sea cucumbers of the study

Moon cycle	Moon cycle 1 (Sep-Oct)			Moon cycle 2 (Oct-Nov)		
	<i>H. edulis</i>	<i>P. graeffei</i>	<i>B. vitiensis</i>	<i>H. edulis</i>	<i>P. graeffei</i>	<i>B. vitiensis</i>
First quarter	35	35	35	35	35	35
Full moon	35	35	35	40	40	40
Third-quarter	30	30	30	30	30	30
New moon	25	25	25	20	20	20
Total	125	125	125	125	125	125

Morphometric assessment

The following parameters were measured (based on wet) total length (TL), gross weight (GSW), total width (TW), cuvierian weight (CW), respiration tree weight (RTW), feces weight (FW), and the gutted body weight (GBW). The (TL) and (TW) of sea cucumber were measured by using *measure picture application* to ensure level of object accuracy using camera (Hartati et al. 2019). This study used application measurement considering that sea cucumbers are elastic, releasing water, and easily deformed (Purcell et al. 2009). Each individual gonad weight (GW) was weighed using an electronic scale. The ventral part of each animal was excised and the entire gonad was removed. The others part of sea cucumber including the cuvierian tubule, respiration tree, feces, and were weighed using electronic scales and measured to the nearest 0.01g. The calculated part of sea cucumber will be used to determine the size of the first maturity, and number of individuals used to determine the sex ratio of the sea cucumber population on Nyamuk Island.

Reproduction activity

Males and females were identified by gonad morphology and color (Conand 1981). Reproductive individuals for three species were classified into five stages of sexual development following the criteria of Mustofa (2014): recovery (I), growth (II), maturity (III), partly spawned (IV), and spawned (V). The reproductive cycle of the sea cucumbers was compared with the lunar cycle and monthly average water temperature.

Water Temperature assessment

Measurement of water temperature (°C) was carried out at the sampling location at night by using WQC (water

quality checker) tools at depth of 3 meters below sea level. Measurement of water temperatures is carried out following the peak moon phase in each phase with three replicates. The results obtained were tabulated and used to compare the temperature parameter conditions with the reproductive activity of sea cucumbers.

Data analysis

Gonad somatic index

The gonad index was calculated using the ratio between the gonad weight (GW) and the GBW through the formula (Asha and Muthiah 2008):

$$GSI = \frac{GW}{GBW} \times 100\%$$

Size and weight at first maturity

First sexual maturity was defined as the gutted body weight (GBW₅₀) and determination by using modification method Spearman-Kärber (Udupa 1986), and the Total size (TL₅₀), width (TW₅₀) or (GWS₅₀), which the gonads of each individual were mature. It was determined by plotting the relationship between the percentage of individuals with mature gonads and their size or (GBW) classes (Conand 1981). Other measurement sex ratio of sea cucumber in the analysis by using chi-square analysis of the end.

RESULTS AND DISCUSSION

Morphometric assessment

Morphometric assessment of each species *H. edulis*, *P. graeffei*, and *B. vitiensis* presented in (Table 2).

Table 2. Result of morphometric assessment (*H. edulis*, *P. graeffei*, and *B. vitiensis*) in Nyamuk Island, Karimunjawa National Park, Central Java, Indonesia

Type of morphometric	<i>H. edulis</i>		<i>P. graeffei</i>		<i>B. vitiensis</i>	
	Male	Female	Male	Female	Male	Female
Total of species	93	157	92	158	83	167
Total Length (TL) (cm)	21.88	21.79	28.82	28.20	29.05	28.32
Total Width (TW) (cm)	3.67	3.52	6.31	6.42	10.79	10.38
Gross Weight (GSW) (grams)	247.3	253.9	428.1	415.3	678.1	672.4
Gutted Body Weight (GBW) (grams)	158.7	166.9	311.8	298.8	495.6	494
Respiration Tree Weight (RTW) (%)	7	7	7	8	13	13
Cuvierian Weight (CW) (%)	4	3	6	6	6	6
Feces Weight (FW) (%)	25	24	14	14	8	8

Sex-ratio, weight and size at first maturity

The sex ratio showed *H. edulis* and *P. graeffei* (1:1.7) and *B. vitiensis* (1:2) with (*chi-square test*, $\chi^2=19.36$, $P=0.02$). Total individual presented in (Table 3).

The size at first maturity of *H. edulis* (GBW₅₀) was 127.84g, while (TL₅₀), first maturity was 18.83cm, and (GSW₅₀) range was 217.33g (Figure 2a). *P. graeffei* (GBW₅₀) range was 357.61 g, while (TL₅₀) range was 28.59 cm, and (GSW₅₀) range was 459.59g (Figure 2.B). Sea cucumber of *B. vitiensis* (GBW₅₀) range was 279.34g, while (TL₅₀) range was 32.74 cm, and (GSW₅₀) range was 460.82g (Figure 2c). Weight at first maturity (GBW₅₀) and average of male and female sea cucumber weight caught at Nyamuk Island, was presented in (Figure 2).

Gonad somatic index

The measurement of gonad somatic index of the three species of sea cucumbers and related to the moon cycle, showed that spawning peak occurred during new moon (Figure 3). *H. edulis* had the highest gonad somatic index value (males and females) in the new moon with a GSI value is 13.60% and 15.60% respectively, while the lowest (males and females) GSI occurred in the first quarter with a value of 0.06% and 0.22%. Similar results were obtained from the gonad somatic index measurement of *P. graeffei* (males and females). The highest GSI value was found during new moon with 14.75% and 12.25% conceived the

gonads. While the lowest value was found in the first quarter moon with GSI of 0.12% and 0.57%. Other results showed similar from *B. vitiensis* (males and females), which had the highest GSI values of 10.83% and 14.57% in new moon. While the lowest (male and females) GSI value of 0.26% and 2.16% in the third quarter moon.

Gonad maturity level

Gonad index was used to observe the reproductive activity of sea cucumbers, where this method determines the trend of gonad maturity monthly or annually, to look at the pattern of reproductive activity of the three species in the research location. Gonad index of *H. edulis* (males and females) showed 37 individuals (14.80%) had spawned, *P. graeffei* showed 38 individuals (15.20%), showed spawned, and *B. vitiensis* showed 42 individuals (16.80%) spawned (Figure 4). The percentage of males and females is presented in Table 3.

Water temperatures parameters

The water temperature in this study showed higher range (31.87-32.27°C) at night when the spawning peak occurs during the new moon. Conversely, the GSI will be lower during the first quarter moon when the temperature decreased (Figure 5).

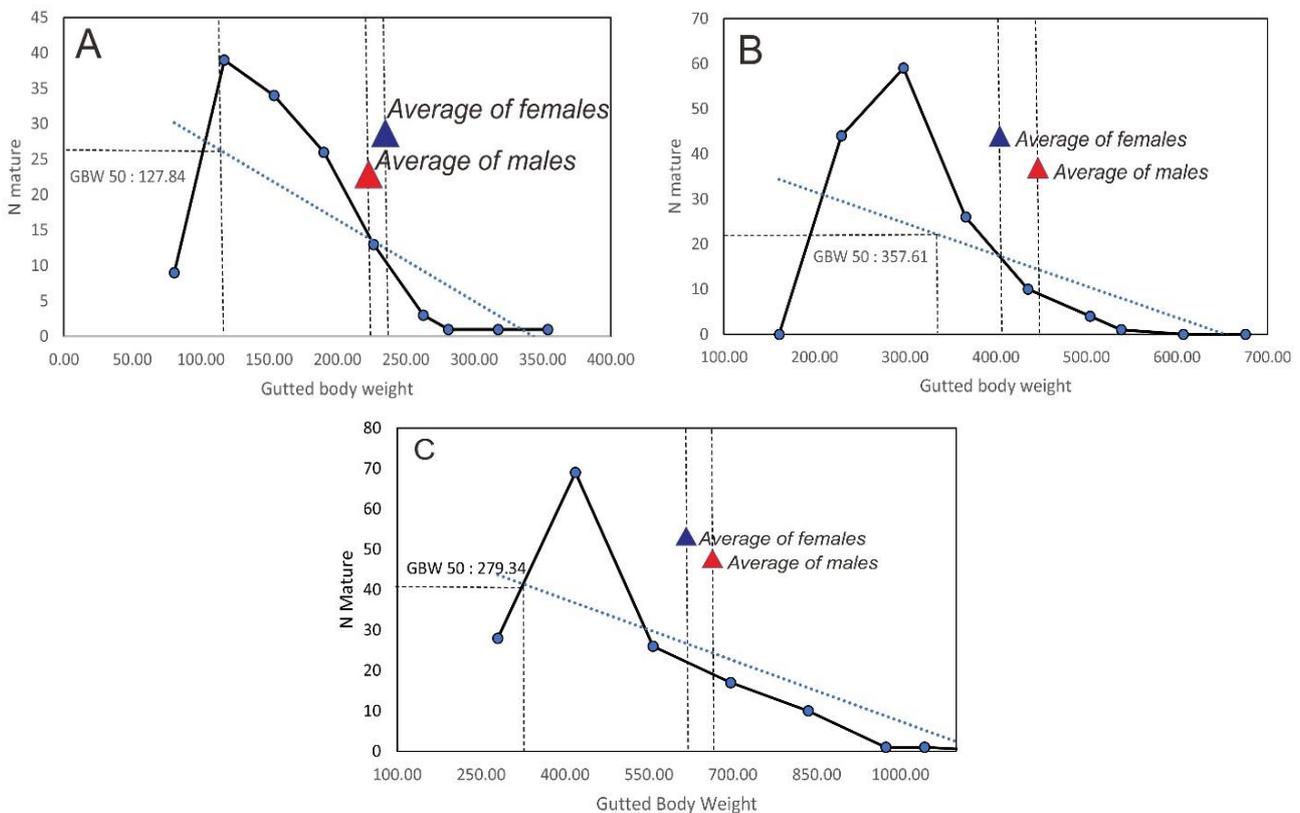


Figure 2. Result of gutted body weight at first maturity from each species (A. *H. edulis*; B. *P. graeffei*; and C. *B. vitiensis*) with average caught weight of sea cucumber fishery in Nyamuk Island, Karimunjawa National Park, Central Java, Indonesia

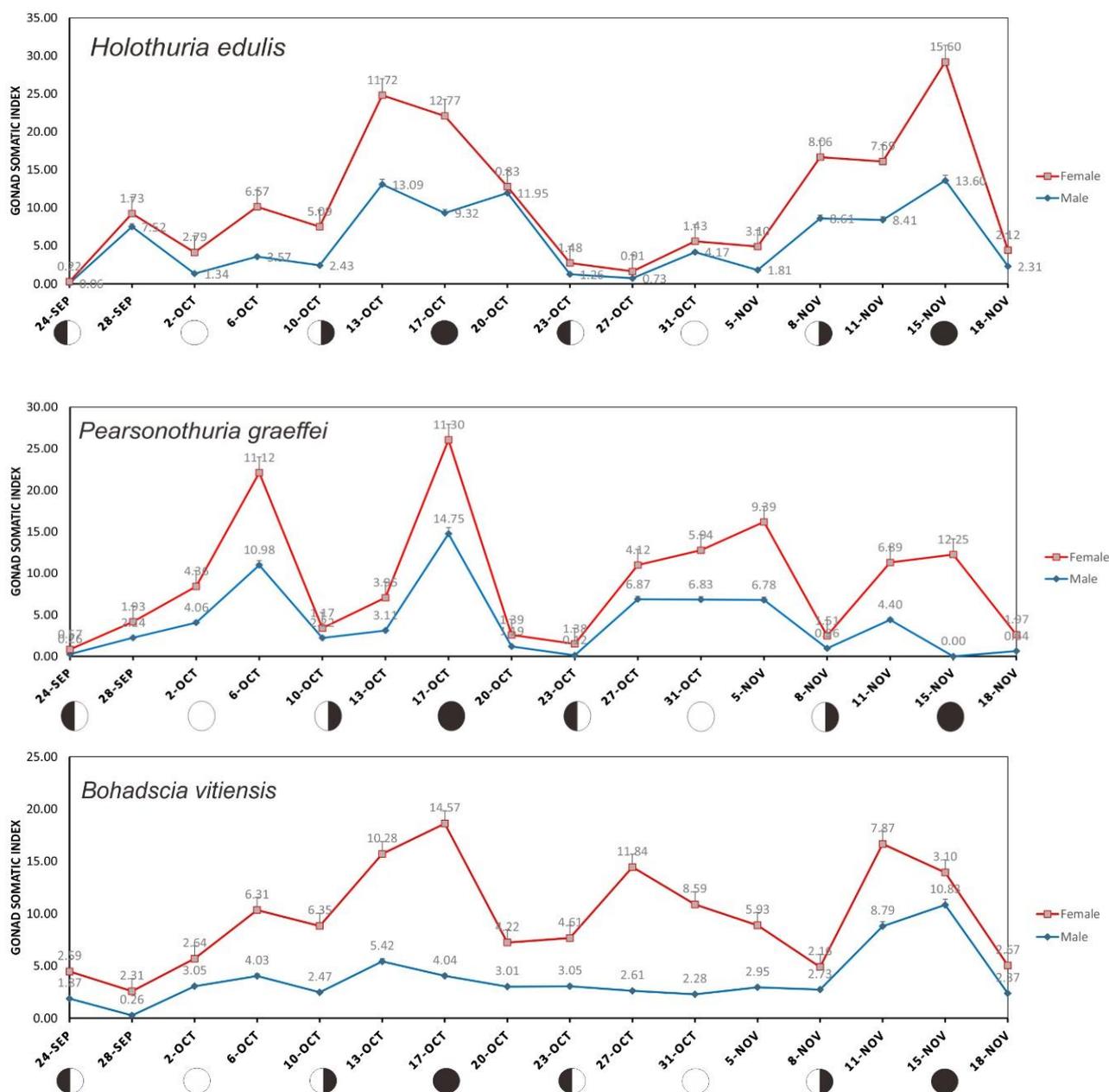


Figure 3. Result of reproductive activity by using GSI (gonad Somatic Index) from each species (*H. edulis*, *P. graeffei*, and *B. vitiensis*) compared with moon cycle in Nyamuk Island, Karimunjawa National Park, Central Java, Indonesia

Table 3. Result of total individual male and females gonad maturity during the study time

Gonad Index	<i>H. edulis</i>		<i>P. graeffei</i>		<i>B. vitiensis</i>	
	Males	Females	Males	Females	Males	Females
Recovery (I)	17	36	25	36	12	22
Growth (II)	26	44	15	29	21	42
Maturity (III)	18	30	22	40	19	38
Partly spawned (IV)	19	23	18	27	16	38
Spawned (V)	13	24	12	26	15	27
Total	93	157	92	158	83	167

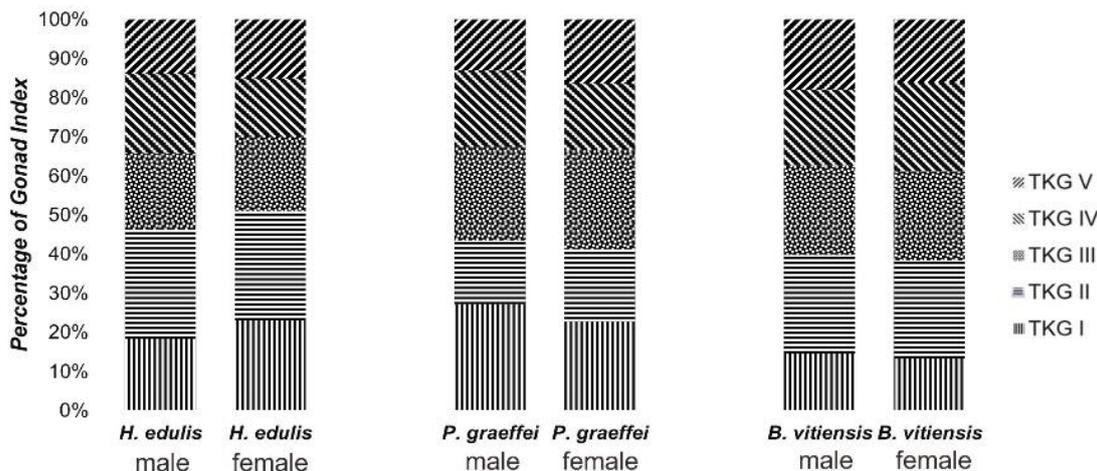


Figure 4. Percentage of gonad index (males and females) *H. edulis*, *P. graeffei*, and *B. vitiensis* during the study in Nyamuk Island, Karimunjawa National Park, Central Java, Indonesia

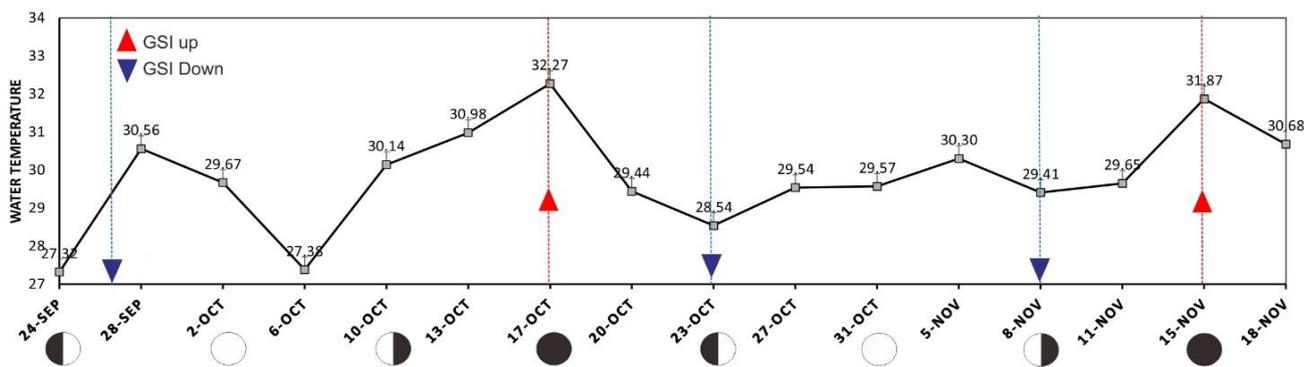


Figure 5. Result of average temperature (in-situ) in reproductive activity measurement, compared with gonad somatic index in Nyamuk Island, Karimunjawa National Park, Central Java, Indonesia. (▲: mostly GSI up at the time, ▼: Mostly GSI down at the time)

Discussion

The size at first maturity (Figure 2.A) from *H. edulis* based on gutted body weight (GBW_{50}) range was 127.84g. According to Navaro et al. (2012), this species had similar result with *H. sanctori* from Gran Canaria, Canarian Archipelago Spain with a range of 110g. The result of total length (TL_{50}) of *H. edulis* also showed similar result amount 17 cm and was comparable with *H. scabra* by observation from (Kithakeni and Ndaro 2002). The result of gross weight (GSW_{50}) also showed that *H. edulis* had similar to *H. sanctori* at Gran Canaria, Canarian Archipelago with range of 200 g (Navaro et al. 2012). The results of *H. edulis* indicate that all the parameters in KNP are similar to another country, even have a slight different result.

The size at first maturity (Figure 2.B) from *P. graeffei* (GBW_{50}) was 357.61g, (TL_{50}) 28.59cm, and (GSW_{50}) 459.59g. This species was difficult to compare with other studies, because different parameters of weight or size were used and data was not always available (Kohler et al.

2009). The result of size at first maturity *P. graeffei* was presented in (Figure 2.B).

The size at first maturity (Figure 2c) of *B. vitiensis* (TL_{50}) was about 32.74 cm. Omar et al. (2013) explained, similar results to the same species from Urghada, Red Sea, Egypt range 24.5-26.1 cm. The size at first maturity is a common parameter used in almost all fisheries to set fishing limits (Navaro et al. 2012).

All the calculated parameters, along with gross weight (GSW_{50}) data from each species of *H. edulis*, *P. graeffei*, and *B. vitiensis* were compared with average caught assessment of sea cucumber fisheries in Nyamuk Island. The result showed that (GSW_{50}) value was lower than average caught of sea cucumber (morphometric assessment) (Table 2). The average size of *H. edulis* was higher (247.3-253.9g) than (GSW_{50}) range (217.33g). Sea cucumber *P. graeffei* with average (415.3-428.1g) was lower than (GSW_{50}) range (459.59g). Other species *B. vitiensis* with average (672.4-678g) was higher than (GSW_{50}) range (460.82g). These results indicate that average caught (morphometric of weight) of sea cucumber

in Nyamuk Island was above the average size (weight) of first maturity for *H. edulis* and *B. vitiensis*. Other results of average caught weight *P. graeffei* under the weight of first maturity, or there is sea cucumber fishing activity below the size in Nyamuk Island. Navaro et al (2012) explained that the size at first maturity was a relevant parameter for managing sea cucumber fishery and helps limit catch size. However, to effectively manage these resources, other parameters must also be studied further. That caused size at first maturity as indicator conservation is not enough to quantify sea cucumber fisheries activity (Navaro et al. 2012).

The sex ratio of *H. edulis* and *P. graeffei* was found as (female: male) with result from (1:1) throughout the sampling period. Moreover, the species from *B. vitiensis* showed a significant difference result as not (1:1) in this research. The result from *H. edulis* and *P. graeffei*, sex ratio usually precise with a balanced result (Dissanayake and Stefansson 2012; Omar et al. 2013). However, the result from some species of sea cucumber indicates a slightly unbalanced ratio with more females than males, or vice versa (Shiell and Uthicke 2005). This result from *B. vitiensis* showed unbalanced ratio. We assumed, those caused the capture of sea cucumbers in Nyamuk Island (KNP) was overexploitation in this species. The different ratios of individual sea cucumbers also indicated not only happened caused overexploitation. Gaudron et al (2008) explained that unbalanced ratio can also indicate optimal rate of reproduction from some species of sea cucumber. However, this statement needs justification from other research and more research especially about unbalanced sex ratio of sea cucumber in Nyamuk Island (KNP).

The result of Gonad Somatic Index of each species with value of more than 10% or stage (V) can be interpreted as the peak of spawning activity of sea cucumber (Figure 3). The result showed that *H. edulis* had highest GSI around new moon. Hartati and Yanti (2006) reported that *H. vagabunda* in Jepara waters had the highest GSI in the new moon. Purwati and Luong (2003) showed that *H. leucospilota* also had high GSI and spawned in the new moon. Furthermore, Morgan (2000) reported that *H. scabra* showed the lunar spawning rhythm, which spawning occurred around new moon. *P. graeffei* demonstrated the same results as *H. edulis*, which spawned during new moon. Muthiga (2005) reported that *P. graeffei* spawn on the reef edge off Vabbinfaru Island North Male Atoll in the new moon. Another species, *B. vitiensis* showed the same result as *H. edulis* and *P. graeffei*, which spawned in the new moon. Desurmont (2008) also reported that species *Stichopus herrmanni*, experienced spawning in the new moon. Those observations indicated that those species had the same result of highest gonad maturity (GSI) occurred in the new moon in various sea waters in the world. Furthermore, it needs further research in various areas to prove this hypothesis.

Sea cucumbers showed an annual reproductive cycle (Conand 1993). Sea cucumber also showed continuous reproduction activity throughout the year (throughout Indonesia, including in this research location) (Darsono 1999). The peak of gonad somatic index (GSI) from *H.*

edulis, *P. graeffei*, and *B. vitiensis* showed always happened in the new moon during October-November when water temperature tends to be warm. Mackey and Hentschel (2001) explained, that the lunar cycle is used by sea cucumber as a cue to initiate reproduction activity (e.g start the gonad maturation or spawning time). Others factor such us an environmental also affected the reproduction cycle of sea cucumbers (Ramofafia et al. 2003; Hartati and Yanti 2006). The results of this study also indicate that there was a correlation between the lunar cycle and the spawning events (Mercier et al. 2000). The spawning cycle observations from *H. edulis*, *P. graeffei*, and *B. vitiensis* in this research, showed that those species could spawn every month throughout the year followed reference by (Sulardiono 2011). However, further studies should focus on the annual reproductive activity of these three commercial sea cucumber species in Karimunjawa National Park to confirm this statement.

The timing of reproduction activity from sea cucumber was reported to be determined by other proximate factors such as water temperature (Darsono 1999). In this research, *H. edulis*, *P. graeffei*, and *B. vitiensis* spawn in warm water conditions (31.87-32.27°C). Navaro et al. (2012) explained that maximum reproductive activity was observed during warm months when the water conditions are warmer than usual. Despalotovic et al. (2004) also reported that *H. tubulosa* spawning occurs in warm seawater temperatures in the Adriatic Sea. Temperature stimulation research showed that temperature manipulation stimulated spawning of the sea cucumber up to (90%) (Yudiati et al. 2001). The temperature of seawater seems to play a crucial role in reproductive activity. Understanding the effect of temperature on the spawning was important to predict and estimated spawning time of sea cucumbers in nature. However, further research is needed to obtain more robust data on the correlation between water temperature and spawning cycle in sea cucumber species.

In conclusion, the size at first maturity (GBW_{50} , TL_{50} , and GSW_{50}) of three commercial species of sea cucumber (*H. edulis*, *P. graeffei*, and *B. vitiensis*) showed similar results, respectively. These species from KNP was compared between other species and different place around the world and showed the same result on size at first maturity. These species had balanced sex ratio (*H. edulis*, *P. graeffei*) in the wild, while (*B. vitiensis*) with unbalanced sex ratio indicated cause overexploitation in KNP and other factors. The average catch assessment of sea cucumber fisheries in Nyamuk Island, was above the average size of first maturity for *H. edulis* and *B. vitiensis*, except *P. graeffei*. The gonad somatic index (GSI) indicated that these three commercial species of sea cucumber have spawn every month in the new moon around Sep-Oct in KNP. Others, when sea cucumber showed a reproductive activity in the wild, the seawater temperature in KNP was disposed of in warm water conditions. This condition indicated that seawater temperature might play a crucial role in reproduction activity of sea cucumbers.

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