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Research Article

Distribution, Condition and Gonad Maturity of the Invasive Pacific Oysters (*Crassostrea gigas*, Thunberg 1793) in Cimanuk Delta, Indramayu, West Java, Indonesia

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ABSTRACT

Pacific oyster (*Crassostrea gigas*) is an invasive species which is able to adapt a wide range of environmental conditions. The study was conducted from August to October 2014. The objective of this study was to asses the distribution pattern, condition and length of first mature gonad (Lm 50%) of the Pacific oysters in mangrove ecosystem of Cimanuk Delta, Indramayu, West Java, Indonesia. This study was conducted in two adjacent areas namely Pabean Ilir and Pagirikan subdeltas. The oysters were collected from the estuary, brackish water ponds and the coastal flat, and observation was done for their abundance, total length (mm) and weight (g). Morphological and histological methods were used to estimate the gonad maturity stage. Analysis were carried out to estimate distribution pattern and condition factor. According to the study, the *C. gigas* distribution pattern was clumped. The condition factor of the oyster was higher in the brackish water pond and estuary than in the coastal flat. The *C. gigas* was found in various gonad maturity stages (GMS) I – IV. The oyster was hermaprodit protandry and had length of fisrt mature gonad (Lm 50%) of 47,46-48,43 mm (male) and 75,27-75,50 mm (female).

Keywords: *Pacific oyster (Crassostrea gigas), gonad maturity stage (GMS), cimanuk delta, Indonesia*

1. Introduction

Pacific oyster (*Crassostrea gigas*) is one of the important fishery resources in Indramayu waters. The oyster can be found in the waters of Cimanuk Delta of Indramayu, West Java, Indonesia. Habitat of the oyster is generally found in the estuary (Kennedy, 1996), as well as in Pabean Ilir and Pagirikan Subdeltas in the Cimanuk Delta which are also estuarine waters with mangrove vegetation.

Pabean Ilir and Pagirikan Subdeltas are mangrove ecosystems with a different vegetation density, which the former has mangrove density higher than that of the latter (Descasari, 2014). The mangrove ecosystem with a high density is allegedly more supportive in Pacific oyster life because of its function in maintaining a more optimal environment. The mangrove ecosystem has an ecological function in maintaining the existence of the environment such as preventing the intrusion of sea water (Widiastuti, 1998), inhibiting the occurrence of abrasion, trapping sediment and providing food. While a low density one will cause the river water to enter and exit the coast easily, so the ability to trap sediment (inorganic) will be reduced. River water which carries the inorganic particles will enter the aquatic ecosystem and cause to coastal area to become turbid (Riani, 2012). Such condition can disrupt aquatic biota that can cause changes in population dynamics (Powell et al., 2012).

Due to the decrease of mangrove vegetation, the ecological function of mangrove ecosystem as a provider of life will decrease. It is, among others, will affect the growth, reproduction and recruitment of biota in the surrounding water. Such conditions will impact on the productivity of the oyster. The lower density of the mangrove causes the lower the oyster population density (Asriyanti, 2012). Some studies of molluscs have been done at several areas in Indonesia, *i.e*. population structure of *Gelonia* sp (Irwani and Suryono, 2006), morphometrics and growth of *Anadara pilula* (Satrioajie et al., 2013), identification of *Meretrix* sp (Jabarsyah and Arizono, 2016), and population aspect of *Meretrix* sp (Firman and Salim, 2016), while study about secondary productivity and reproduction of an

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invasive species (in Indramayu especiallty) *C. gigas* has never been done.

This study aimed to analyze the distribution pattern, condition factor, length of first mature gonad of the *C. gigas* in the mangrove ecosystem in Cimanuk Delta of Indramayu, West Java. The results of this study are expected to be one of the additional information in determining the Pacific oyster fishery management policy, especially in Cimanuk Delta in Pabean Ilir and Pagirikan Subdeltas of Indramayu, West Java of Indonesia.

2. Materials and Methods

Time and location

The study was conducted over three months i.e. August, September, and October 2014 with a sampling interval of 30 days. The study location was situated in the mangrove ecosystem of Cimanuk Delta in Pabean Ilir and Pagirikan Subdeltas of Indramayu, West Java. Sample collection of the oysters at each site was conducted at three sites by stratification that is in the waters near the brackish-water pond (Station 1), Estuary (Station 2) and coastal flat (Station 3). The locations of the study can be seen in Figure 1.

Oyster samples collection

The *C. gigas* samples were collected using the stratified random sampling at two locations: Pabean Ilir and Pagirikan subdeltas with layers of habitat of brackis water pond waters (Station 1), estuary (Station 2) and coastal flat (Stations 3). The collection was conducted in the three stations and each station had three replications. At the same station, water quality analysis in the form physical and chemical parameters of the waters was also conducted. The waters physical parameters measured including the depth (using a scaled measuring instrument of rope with an accuracy of 0.5 mm) and the transparency (using *sechi disk*). The chemical parameters such as water salinity and pH were observed using a salinorefractometer and a pH stick, respectively. Sampling of the Pacific oyster was conducted using transect of 1x1m^2. The measurement oysters (shell) length was carried out using calipers (with an accuracy of 0.5 mm), the total weight of the oysters was measured using a scale (with accuracy of 0.5 gram) and the weight of oyster meat was measured using a digital scale (with an accuracy 0.0005 g).

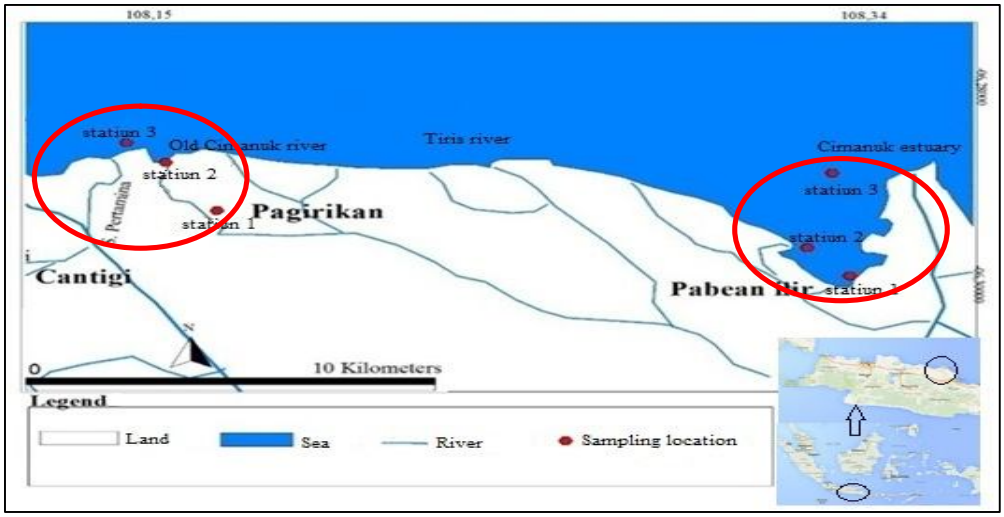

Figure 1. Sampling site in the Cimanuk Delta of Indramayu, West Java, Indonesia.

Data collection

The data in the study consisted of main and supporting data. The main data were obtained from the sample collection and direct measurement. The sample collections of the Pacific oysters were carried out for three months with a sampling interval of one month in Pabean Ilir and Pagirikan by hand from a transect of 1x1m^2. The main data included measurements of length, weight, number of oysters in the observation areas and gonads maturity stage. Measurement of the length and width of the *C. gigas* was conducted using a measuring instrument of calipers. The parts of the Pacific oyster body measured are presented in Figure 2. Measurement of length was determined based on the length of *C. gigas* shells (Figure 2). The weight of the *C. gigas* was determined by the total weights of the Pacific oyster meat and shells.

Determination of the gonad maturity stages was conducted according to morphological and histological characters. The determination of the level of maturity of gonads based on their morphology was based on Marteil (1976), Le Dantec (1957) *in* Reynoso (2000) (**Table 1**) whereas the determination of the level of maturity of gonads based on their histology was conducted in the Laboratory of Bioecology and conservation of aquatic resources (Department of Aquatic Resources Management) and in the Laboratory of Fish Health (Department of Aquaculture), Faculty of Fisheries and Marine Science, Bogor Agricultural University.

The secondary data were obtained from the Ministry of Forestry and Agriculture, the Office of Fisheries of Indramayu and from the interviews with local communities. The data included the utilization of oysters and conditions of Java's northern waters around Indramayu which became the supporting data in the study.

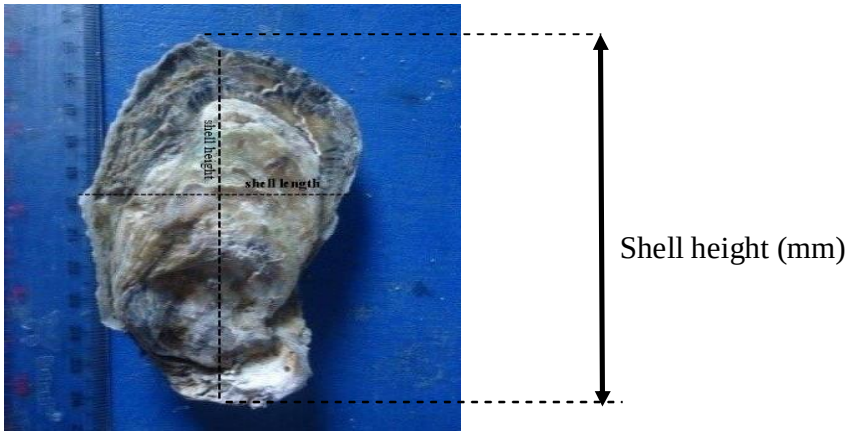

Figure 2. Measurement of pacific oyster (*C. gigas*) length

Table 1. Determination of Gonad Maturity Stage (GMS) of Pacific oysters based on their morphological characters (Marteil 1976 and Le Dantec 1957 *in* Reynoso 2000)

GMS	Characteristics
I and V	Gonads empty, and no gonads are visible on the outside (resting phase)
II	Gonads begin to develop, but they are still difficult to distinguish (Developing phase)
III	The gonads begin to be full and cover visceral tissue of all parts of the body. Size of the gonad is elongated and thick (maturing phase)
IV	Gonads begin to shrink and deflate, and their color began to fade (not darkness) and their surface looks more watery (partial spent phase)

Data analysis

Population distribution pattern

The population distribution pattern of the Pacific oyster can be determined by Morisita Dispersion Index (I_d) using the following formula (Brower and Zarr 1977)

$$I_d = n\frac{\sum xi^2 - N}{N(N-N-1)}$$

Notes: I_d = Morisita Distribution Index
n = Number of stations
N = Total of Pacific oyster at the three stations (ind)
x = Total of Pacific oyster at the –i station (ind)

According to Widiastuti (1998), if the distribution pattern of the Pacific oyster is random, the value of I_d is equal to 1, but if the distribution is even in each sample plot (uniform) then Id is equal to 0. Moreover, if the distribution is in clumps, then the value of I_d is equal to the number of stations.

Condition factor

Condition factor is determined in accordance with the growth pattern. If the growth pattern is isometric, the determination of factor conditions uses the following formulation (Effendie 1997):

$$K_t = \frac{10^5}{L^3}$$

If the growth pattern is allometric, the following formula used follows:

$$K_t = \frac{W}{aL^b}$$

Notes: K_t = Condition factor based on the total length
L = Total length
W = Weight
a = *intercept*
b = *slope*

Length maturity (Lm)

Length of gonads for the first time they are mature is calculated using Spearman Karber method (Udupa 1986) as follows:

$$m = \left[xk + \left(\frac{x}{2}\right)\right] - (x \sum p_i)$$

The trust interval is 95%, and log m is limited as follows:

$$\text{antilog}\left(m \pm 1.96\sqrt{x^2 \sum \frac{p_i \times q_i}{n_i - 1}}\right)$$

with

$$q_i = 1 - p_i$$

Notes: m = Antilog m (long log when gonads reach their maturity for the first time)
xk = Log of median value of the last length class
x = Log of length addition at the median value
p_i = Proportion of mature gonads at the length class interval of -i
n_i = Number of oysters at the length class interval of -i

In addition, the calculation of the average length of the size of first mature gonads of 50% of samples (Length maturity of 50%) was also calculated using the method of Rao and Sharma (1984) by plotting the cumulative frequency in percent for any length of oyster, thus the standard logistic curve can be obtained. The value of Lm 50% was obtained by plotting the y axis when the 50% frequency is cumulative on the x axis (length oysters).

3. Results and Discussion

Results

Frequency distribution

Sampling of Pacific oysters for three consecutive months (August, September and October) was observed, and measurements on their length was conducted and analyzed using the length frequency distribution. The results of the analysis of the distribution is shown in the graph of length frequency distribution (Figure 3).

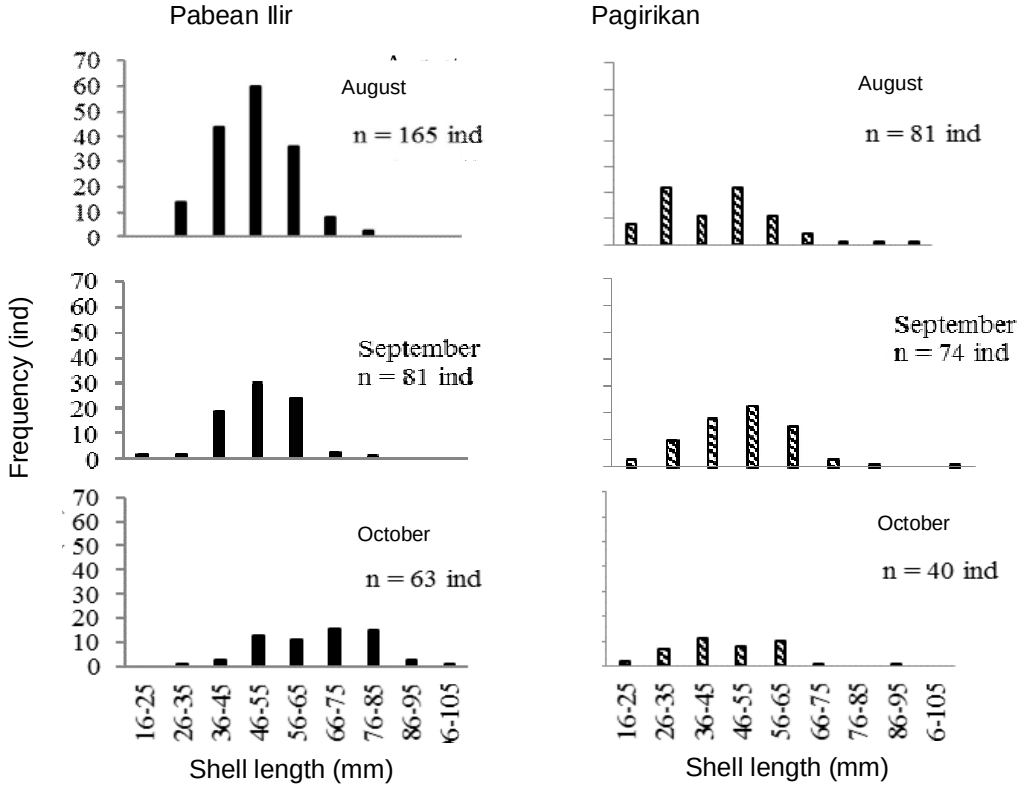

Figure 3. Frequency distribution of Pacific oyster (*C. gigas*) at Cimanuk Delta, Indramayu

From the graph of the length frequency distribution of the Pacific oysters in Pabean Ilir (Figure 3), it can be seen that in August the size of the oyster from the sampling was at the class interval of 26 to 75 mm with the highest frequency occurred in the class interval of 46-55 mm. In September, the size of Pacific oysters was between the class interval of 16 and 85 mm. In October, the length of the oyster is the class interval of 26-105 mm, with the highest frequency in the class interval of 66-75 mm. The minimum and maximum lengths of the oyster obtained during the study were 16 mm and 102 mm, respectively.

Population distribution pattern

The Pacific oyster population distribution pattern in Cimanuk Delta was analyzed using Morisita Index. The result of the analysis using the morisita index is presented in Table 3.

Table 3. Morisita Index of the Pacific oysters (*C. gigas*) in Cimanuk Delta, Indramayu

Location	Morisita Index	Chi square test	Population distribution pattern
Pabean Ilir	6.7	rejected H_0	Clumps
Pagirikan	2.7	rejected H_0	Clumps

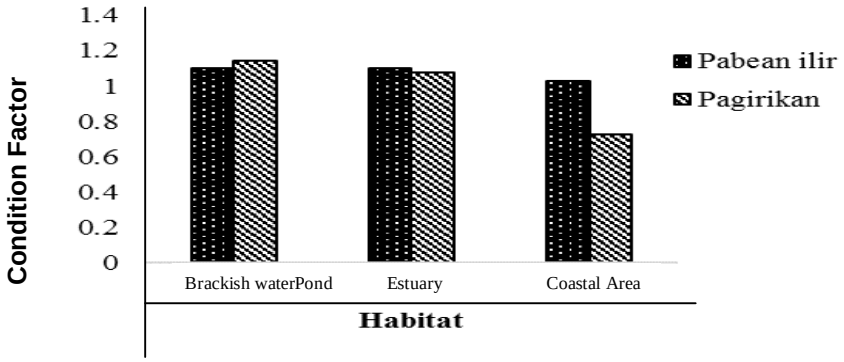

Figure 4. Condition factor of the Pacific Oyster (*C. gigas*) at Cimanuk Delta, in deferent habitat

Figure 4 shows the values of the condition factor of the *C. gigas* in Delta of Cimanuk based on their habitat. The results of the analysis shows that the two locations in Cimanuk Delta, namely, Pabean Ilir and Pagirikan Subdeltas, have the biggest condition factor in the habitats of brackish water ponds and estuaries while at the coastal flat has the smallest condition factor. Figure 4 also shows that Pabean Ilir and Pagirikan Subdeltas have the lowest value in their coastal waters habitat.

Gonad maturity stages (GMS)

Determination of the gonad maturity stage of the Pacific oyster was performed on both male and female. The morphological character determination of male and female was based on the length of Pacific oysters where the Pacific oysters male have a smaller size of shells than the female one. Determination of the maturity level of gonads based on their morphological character is based on Marteil 1976 and Le Dantec 1957 *in* Reynoso 2000. The result of the observation on the male and female gonad maturity stages based on their histological characters is presented in Figure 5.

The analysis result of Morisita Index in Table 5 was then tested using the chi square test with H_0 hypothesis *i.e.* the distribution of oysters is uniform and H_1 *i.e*. the distribution pattern is not uniform. Chi-square test results indicate that rejected H_0 means that the distribution pattern of the Pacific oyster population in Cimanuk Delta is clumped.

Condition factor

Condition factor shows the fattiness value, and this value may change as influenced by internal and external factors. The analysis on the Pacific oyster condition factor on each habitat aims to find better environmental conditions for their life. The results of the condition factor analysis at different habitats in Cimanuk Delta is presented in Figure 4.

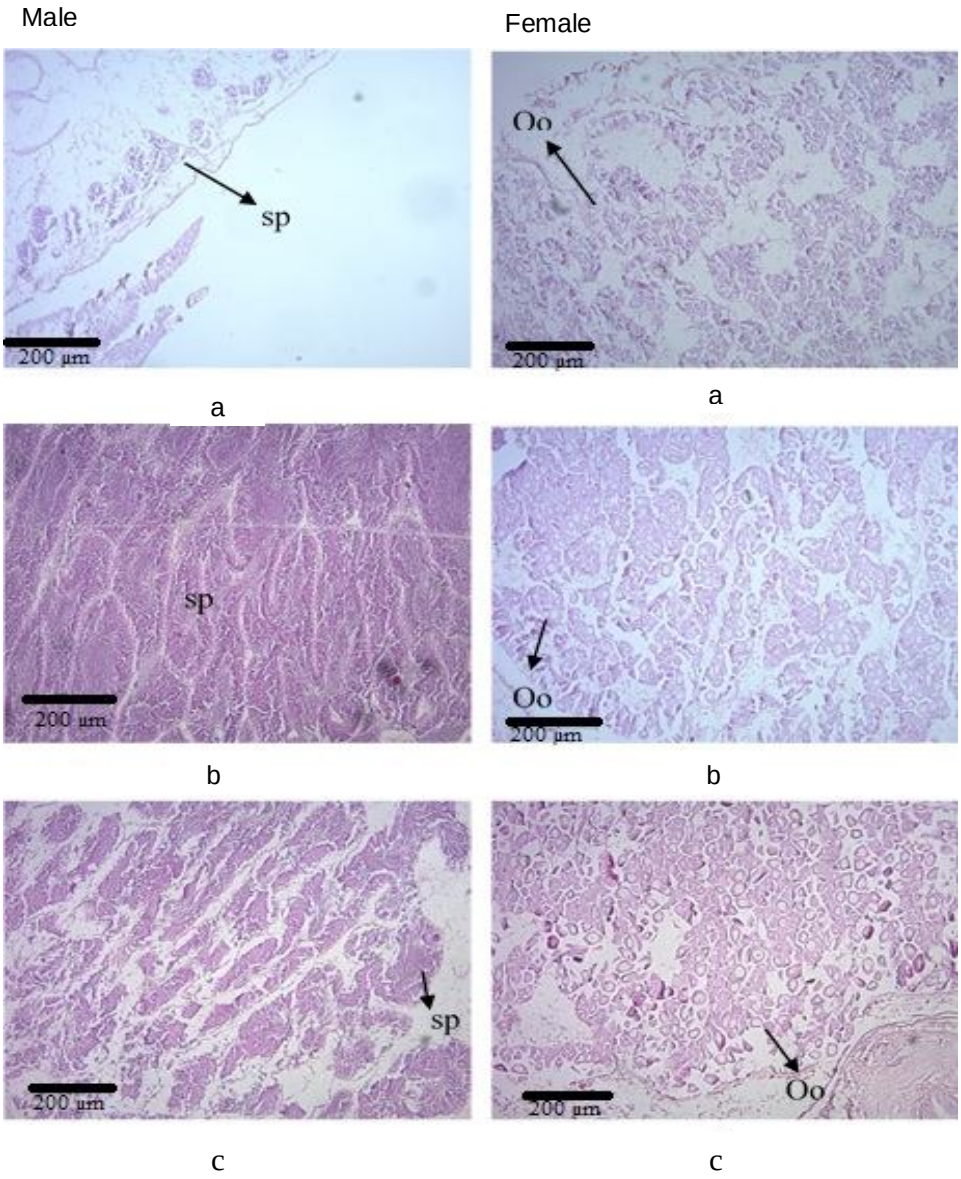

Figure 5. Histology gonad of male (a.GMS I, c.GMS III, e.GMS IV) and female gonads (b.GMS I, d. GMS II, f. GMS III) gonads of the Pacific oyster (*C. gigas*) (sp: sperm, ooc: oosit)

Figure 5 showed the results of the histological character of male and female gonad of the pacific oysters with the maturity levels of GMS I, GMS III and GMS IV (male) and GMS I, GMS II and GMS III (female). The histological character of gonad of male pacific oysters in GMS I were characterized by sperm cells begin to develop and early gametogenesis, GMS III was characterized histologically by a mature sperm cell and is spread out. The GMS IV of male oyster was distinguished by the spawning of half of the gonads and only half of them appear to have mature sperm. The female *C. gigas* in GMS I were histologically characterized by their early gametogenesis cells and oocytes begin to take shape with a diameter of 0.48 micrometer (Reynoso et al. 2000). The females of GMS II were characterized by their oocytes which begin to show clearly with no uniform size ranging from 12.1 to 30 micrometers, and the female of GMS III have oocytes which are nearly uniform in size with a diameter ranging from 30.1 to 41 micrometers.

The *C. gigas* gonad maturity stage in every month of study with different interval of length class are presented in Figure 6 and 7.

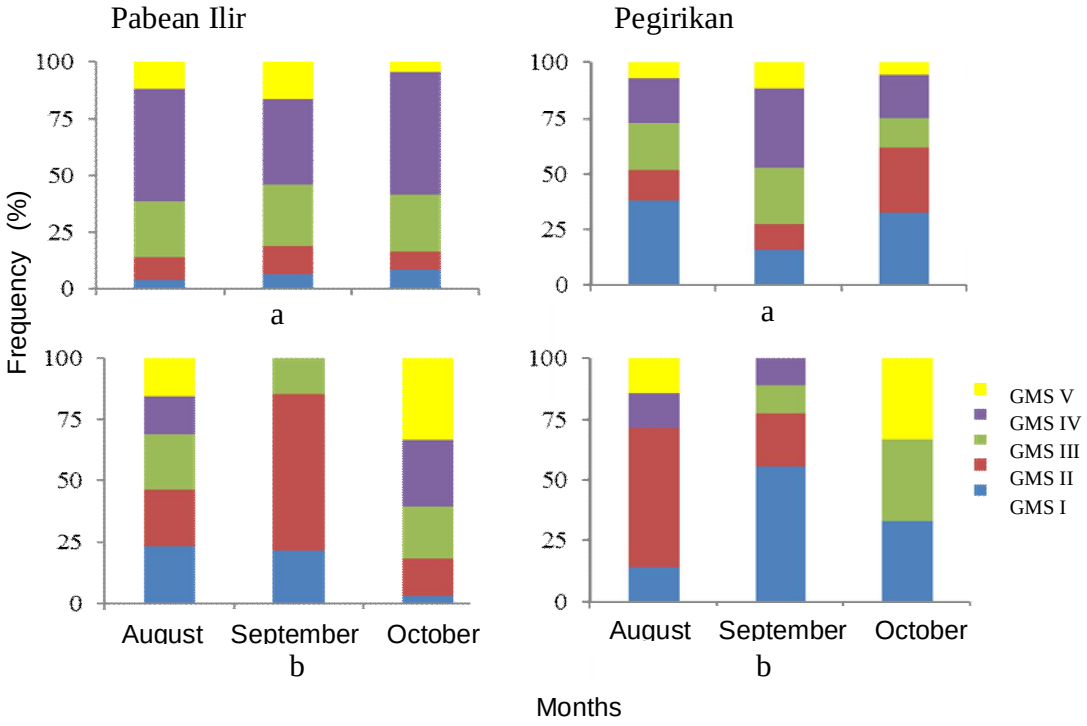

Figure 6. Gonad maturity stage (GMS) of Pacific oyster (*C. gigas*) on monthly sampling in Pabean Ilir (a.male, b.female), Pagirikan (a. male, b.female)

Figure 6 showed the percentage of Pacific oyster gonad maturity stage of each month observation. The study show that the male and female mature gonads can be found in every month of observation (August, September and October) both in Pabean Ilir and Pagirikan Subdeltas. Based on this, it can be stated that *C. gigas* spawning occurs during the study. Figure 7 shows that the male *C. gigas* are present in the length class interval of 16 mm to 65 mm, and at the following length class interval of 65 mm to 100 mm, the *C. gigas* undergo sex change into females (protandri hermaphrodite). The first length of mature males and females of Pacific oyster gonads was measured using the Spearman Karber method is 33 mm and 68 mm, respectively (Udupa 1986). Both male and female Pacific oysters whose gonads are mature can be found in every month of observations (August, September, and October 2014) (Figure 7) both in Pabean Ilir and Pagirikan Subdeltas.

For the sustainable management of pacific oysters, analysis of Lm 50 % had to be conducted. The analysis was done to identify the trend of the size of the oysters when they become mature for the first time so that with this size, 50 % of the total population of gonads have been mature. Pacific oyster is a protandri hermaphrodite type where at their early life they are male but at a certain size, they change into female. The intersection of the lines in the graph indicate that Lm 50% means that as much as 50% of male gonads of the Pacific oysters are mature with the sizes of 48.43 mm (Pabean Ilir) and 47.46 mm (Pagirikan). Furthermore, the oysters will turn into female (hermaphrodite protandri) and as much as 50% of them are mature female gonads with the sizes of 75.27 mm (Pabean Ilir) and 75.50 mm (Pagirikan) (Figure 8).

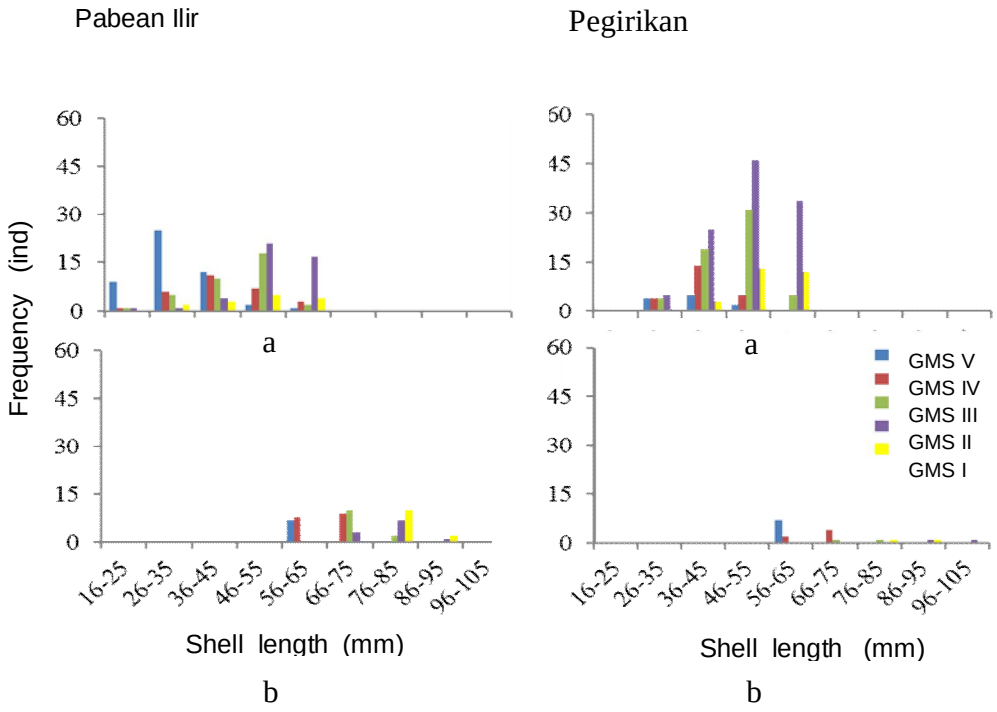

Figure 7. Gonad maturity stage (GMS) of *C. gigas* on monthly in Pabean Ilir (a.male, b.female), Pagirikan (a. male, b.female)

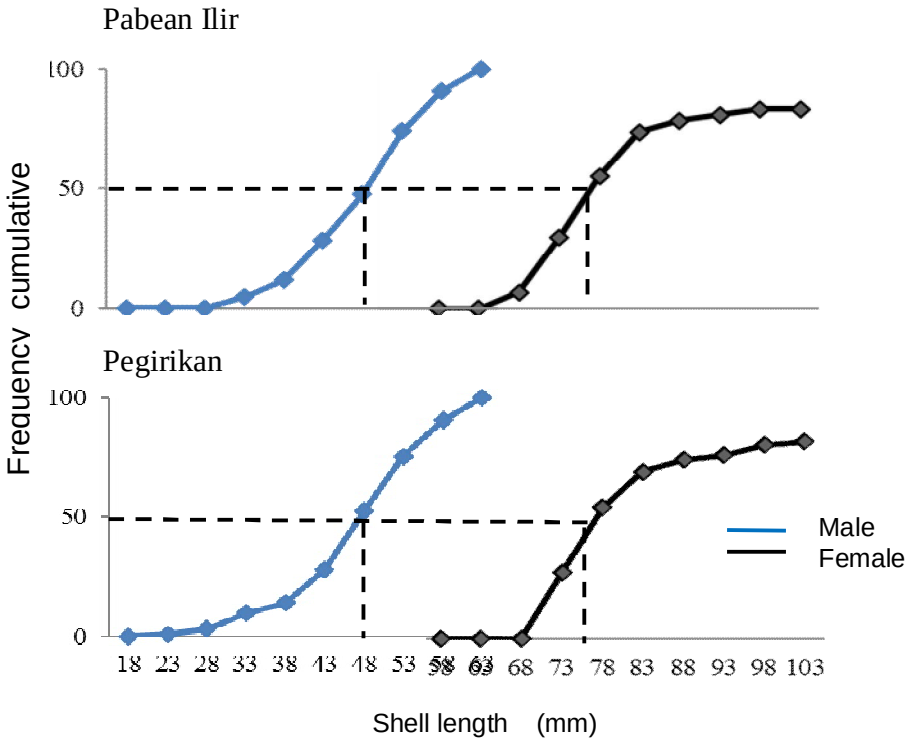

Figure 8. Shell length of first mature gonad (Lm) of pacific oysters (*C. gigas*) collected in Pabean Ilir and Pagirikan

Discussions

The *C. gigas* in Cimanuk Delta are a sedentary organism type and have a clump distribution pattern. This is in accordance with the results of study conducted by Suryono and Retno (2002) which show that the distribution pattern of *C. cuculata*, *C. enchinata* and *C. Forskalli* is clumped. This pattern might be influenced by various factors including the waters environmental condition, suitable substrates for life and food supply. The pacific oysters live by attaching themselves to the hard substrates.

Cimanuk Delta is ecosystem with a mud substrate, but the *C. gigas* still can live by settling themselves on hard substrates derived from oyster shells that are already dead or still alive. The availability of hard substrates such as the former shells and mangrove roots and water environmental condition might influence the distribution pattern of the *C. gigas*.

The results of the condition factor analysis show that there are differences in the conditions of fattiness among *C. gigas* that live in the Pabean Ilir and in Pagirikan Subdeltas. The condition factor of the oysters living in Pabean Ilir is greater than that of oysters living in Pagirikan. The value of the condition factor of Pabean Ilir can reach 1.63 while that in Pagirikan can only reach 1.26. According to Effendie (1997), the value of the condition factor depends on the number of present organisms and their condition, the availability of environment and condition of the waters environment. The results of water quality analysis show that there are differences in water quality at the two locations, and this environmental condition may affect the condition factor of the oysters in Pabean Ilir and Pagirikan Subdeltas and so the difference habitats (estuary, coastal and brackishwater ponds) in Cimanuk Delta. Environmental parameters have relation with condition factor of *C.gigas* (Villalba et al. 2007)

In addition, according to Descasari (2014) and Pieterse et al. (2012) the condition of mangrove in these areas was different which will lead to different food availability, thus affecting the condition factor. This is supported by the statement of Sukardjo (2010) stating that the production of debris (manure) derived from mangrove was important of the food web of aquatic organisms. Suwignyo et al. (2005) stated that the type of bivalvia was generally a ciliary feeder. Based on this condition, the food availability for Pacific oysters is also related to the condition of mangrove density.

Pacific oysters are hermaphrodite protandri organism (Dheilly et al., 2012), hence they have sexual change (Reynoso et. al,. 2006). Based on this research they will mature as male in 47,46-48,43 mm then they will change their sexual to female and mature in 75,27-75,50 mm. Crassostrea an organism that could spawn throughout the year (Octaviana et al., 2013). This is consistent with the observation, during the observation periods for three consecutive months (August, September and October 2014) mature Pacific oyster gonads always existed. This is in accordance with the results of study conducted by Gomes et al. (2014). According Jaramillo et al. (2017) maturation, spawning periods and resting phase of tropical oysters occured most of the year and have several several spawning peaks.

The Lm analysis result of 50% of the Pacific oysters in Cimanuk Delta shows that the male and female mature gonads was of 33 mm and 68 mm shell leght, respectively (Figur 8). Results of the study conducted by Oates (2013) in Oregon, Martinez et al. (2012) in Mexico, and Octaviana Sionaloa et al. (2013) in the waters of Kuala Gigieng, Aceh Besar show that the length could reach 30 mm. In addition, Santoso (2010) stated that the length of the gonads of *Crassostrea* in Kupang reach maturity stage around 50 mm. Differences in the size of the first ripen gonads (Lm) can be influenced by the geographical location and the waters where the oysters live (Octaviana et al., 2013) as well as by the exogenous and endogenous factors (Batista 2007). The exogenous factors include temperature, salinity and food availability while the endogenous factors include the cycle of neuroendocrine and genotypes. In addition, the value of Lm 50% can be used as one of the suggestions for the *C. gigas* minimum size which may be caught with the assumption that 50% of the *C. gigas* population have mature gonads so that Pacific oysters have a chance to spawn before being caught.

4. Conclusion

Based on the study of the Pacific oysters (*Crassostrea gigas*) conducted from August to October 2014, at the Cimanuk Delta, Indramayu, West Java, Indonesia, it can be seen that the oysters have clumped distribution patterns. Higher condition factor of the Pacific oysters was found in the waters around the brackish water pond and estuary. Pacific oyster is reconformed

as a hermaphrodite protandry. The Pacific oyster was found in gonad maturity stage (GMS) I – IV. The oyster was hermaprodit protandry and had length of first mature gonad (Lm 50%) of 47,46-48,43 mm (male) and 75,27-75,50 mm (female).

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