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Short Communication: Population dynamics of double-spined rock lobster (*Panulirus penicillatus* Olivier, 1791) in Southern Coast of Yogyakarta

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Abstract. *Larasati RF, Suadi, Setyobudi E. 2018. Short Communication: Population dynamics of double-spined rock lobster (*Panulirus penicillatus *Olivier, 1791) in Southern Coast of Yogyakarta. Biodiversitas 19: 337-342.* The southern coast of Yogyakarta, Indonesia, near to the Indian Ocean borders is a preferable habitat for lobster. Double-spined rock lobster (*Panulirus penicillatus*) is one of the prevalent species caught by fishermen. However the increased number of capture activities had an effect on the sustainability of global lobster fisheries. In order to sustain these fisheries resource, the preservation management of lobster should include wild stock assessments. Currently, the effect of fishing pressures on populations of *P. penicillatus* is limited. The objective of this research was to identify several factors affecting lobster population in terms of growth (carapace length (CL) and mass), recruitment, mortality rates, and exploitation rates in this species. Results showed that double-spined rock lobster had a longer size (CL) (45.2-55.1 mm) than that of females (55.2 mm-65.1 mm). While the growth rate (K) of males lobster is 0.85 year^{-1} and its CL reached an asymptotic point at 125 mm (12 years old). Growth rate of females double-spined rock lobster was 0.55 year^{-1} and its CL reached an asymptotic point at 125.5 mm (15 years old). The total estimation of mortality rates of double-spined rock lobster was 2.46, wherein 2.56 year^{-1} for males and females, respectively. The estimated values of M were 1.08, 0.81 year^{-1} for males and females, respectively while the respective values of F were 1.38 year^{-1} and 1.75 year^{-1} for males and females. The exploitation rate of males was 0.56 and females was 0.68. It has exceeded the optimal level (0.5) and reached overfishing value. Based on these results, it suggest that the time management of fishing activities such as by several approaches including the restricted time of fishing activity in spawning and recruitment season, the management of catching effort by the development of environment-friendly fishing gear, and the development of the lobster hatchery to reproduce and maintain their population naturally.

Keywords: growth parameter, overfishing, *Panulirus penicillatus*, population, Yogyakarta

INTRODUCTION

Decapod lobsters inhabit all oceans (Cockcroft et al. 2011), which geographically ranging from New Zealand in the South Pacific Ocean, to Norway in the North Atlantic Ocean. The Palinuridae lobster fishery had the highest economic value of many global lobster fishery. It is also a promising target species for commercial fisheries (Bakhtiar et al. 2013; Kusuma et al. 2012). The high nutritional value of lobster has driven the high demand in the global market and becomes one of the most prestigious cuisines. This high demand of lobster is in line with the needs of other sectors i.e tourists, hotels, and restaurants (Vijayanand et al. 2007). Global production of lobster is estimated to reach 77,000 metric tonnes per year, with a value of around US $500 million (Phillips and Kittaka 2000). Therefore, the high demand of lobster cause the rates of fisheries capture increases leading to the existence of lobster population under high pressure (Balkhair et al. 2012).

Ernawati et al. (2014) reported that high levels of lobster exploitation (E = 0.59) has occured in the North Sea region of Sikka Regency and adjacent waters. Similarly, it also happened in Cilacap, Central Java (E = 0.57) (Bakhtiar et al. 2013) and in Oman Beach as an an international beach which the value of lobster exploitation reached 3.16 and 3.81 for males and females, respectively (Mehanna et al. 2012). The declining number in Catch Per Unit Effort (CPUE), yield, and profitability leading to over-exploitation have been also reported in Galapagos Islands, Ecuador (Szuwalski et al. (2016). These highlighted that the sustainable management and monitoring of lobster fisheries to ensure their future economic value and biological viability is necessary.

The southern coast of Yogyakarta in Indonesia, along with border of Indian Ocean is a significant region for lobster habitat. More than half of the coastline consisting of rocky coastal terrain and reef areas. Previous studies reported that six species of lobster inhabit in the southern coast of Yogyakarta, i.e., *Panulirus homarus*, *Panulirus penicillatus*, *Panulirus longipes*, *Panulirus ornatus*, *Panulirus versicolor,* and *Panulirus polypagus* (Wirosaputro 1996). Of those species, *P. penicillatus* and *P. homarus* are the prevalent species caught by fishermen (Aisha and Triharyuni 2010). Most of *P. penicillatus* lives inshore rocky reefs in shallow water (< 10 m) than offshore because water turbidity would be consistently higher than that on the deeper (Steyn and Schleyer 2011).

The Ministry of Marine Affairs and Fisheries has issued the Regulation of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 1 the Year 2015 on fishing of lobster (*Panulirus* spp.), crab (*Scylla* spp.), and blue swimming crab (*Portunus pelagicus* spp.). This regulation was revised with the Regulation of the Minister of Marine Affairs and Fisheries Number 56 the Year 2016 on Prohibition of the arrest of lobster (*Panulirus* spp.), crab (*Scylla* spp.), and blue swimming crab (*Portunus* spp.) from the territory of the Republic of Indonesia. In line with implementation of various regulation from the goverment which is aimed to prevent the over-exploitation and sustainability of lobster, the availability of data through the assessment of lobster stocks is needed. Biological information in the forms of basic data and information on fish species is essential to employ the best practices of fisheries management (Wahyudin et al. 2017). Therefore, the objective of this research was to identify several factors affecting lobster population in terms of growth (carapace length (CL) and mass), recruitment, mortality rates, and exploitation rates in this species.

Research area and sampling sites

This study was conducted between February and August 2017. Samples were collected at four locations in the southern coast of Gunung Kidul Regency, Yogyakarta (7°46´8°09´ South Latitude and 110°21´110°50´ East Longitude) at four research sites: (1) Ngrenehan, (2) Baron, (3) Drini and (4) Tepus (Figure 1). The range of seawater temperature was 28° C during the period of February until August 2017 (Litbang KKP 2017).

Sampling locations were selected based on the data of commercial fisheries rates at each site by selecting the high presence of catched lobster in order to limit the repetition of sample measurements. Gunungkidul has more commercial fisheries rates than two other districts in Yogyakarta as shown in Table 1.

Most *P. penicillatus* occupy inshore rocky reefs in shallow water (< 10 m) where the water turbidity is consistently higher than that in the deeper, offshore reefs where *P. homarus* live (Steyn and Schleyer 2011). In total, 546 samples were collected from each of the 4 sites simultaneously and *krendet* (trap net) was used to catch lobster (Figure 2). *Krendet* is a passive fishing gear used to catch lobster. This trap net is put on rocky water from the top of the cliff or put it in long lines. Construction of this trap net consists of looped iron with gillnet installed in the midle. In the center of trap net also mounted transverse straps of PE material monofilament to place the bait. Monofilament is a net that only consist of one single fiber. *Krendet* has a diameter around 80-100 cm and mesh size 4.5-5 inch. The carapace length of each sample was measured from the edge of the orbit to the posterior to the end of the carapace using a digital caliper (±0.1 mm), and mass using digital scales (± 0.1 g).

Table 1. Volume of commercial fisheries rates in Yogyakarta (ton)

District	2012	2013	2014	2015
Kulon Progo	638,971	446,900	542,834	422,500
Bantul	541,350	546,800	364,863	391,800
Gunungkidul	2,912,813	2,400,300	4,480,542	3,103,300
Total	4,093,134	3,394,000	5,388,239	3,917,600

Source: Departement of Maritime Affairs and Fisheries Yogyakarta (2015)

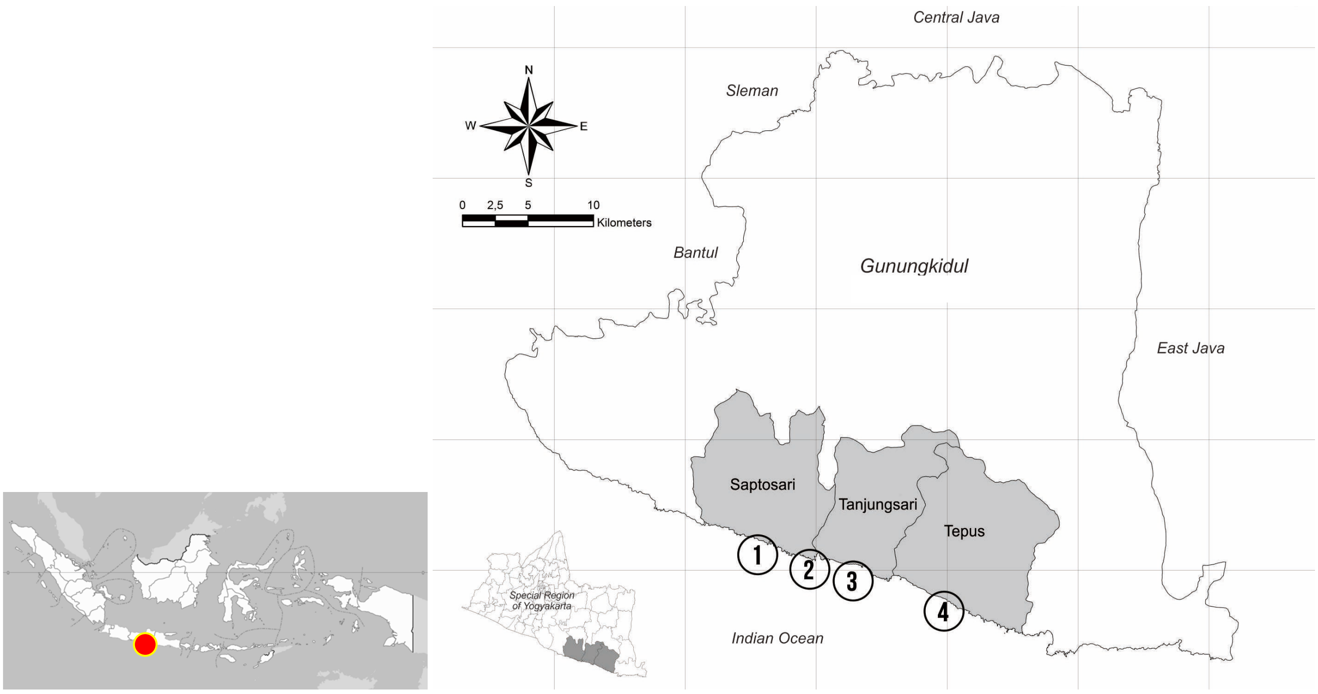

Figure 1. Location of four research sites used to capture double-spined rock lobster (*Panulirus penicillatus*) in the southern coast of Yogyakarta, Indonesia. 1. Ngrenehan beach; 2. Baron beach; 3. Drini beach and 4. Tepus beach

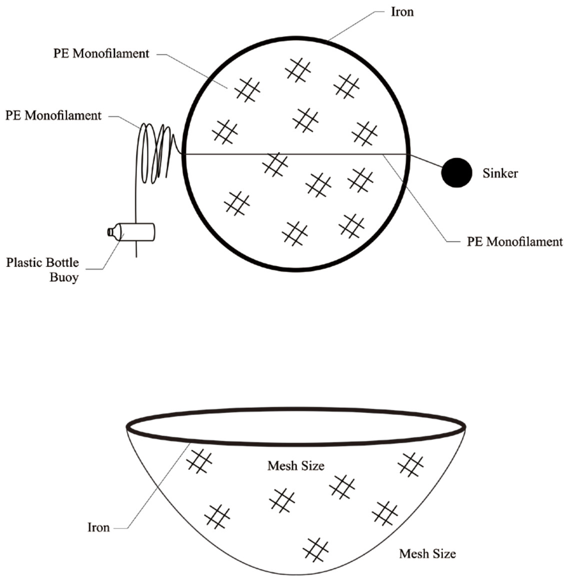

Figure 2. Schematic representation of a *krendet* trap used to capture lobster

Growth rate

The estimation of growth coefficient value of $CL\infty$ and K was calculated using the electronic length frequency analysis method (ELEFAN I) using the FAO-ICLARM Stock Assessment Tool (FISAT II) program (Gayanilo et al. 2005). The pattern of lobster growth was then calculated using the following von Bertalanffy equation as described in Sparre and Venema 1999:

$$L_t = L\infty\ (1 - \exp[-^{K(t - t0)}])$$

Where: L_t is the carapace length at age t; $L\infty$ is the asymptotic length of carapace length when reach t years old; K is growth coefficient; t is lobster age and t_0 is theoretical age when the length of carapace is zero.

The mortality rate and exploitation

The mortality rate and exploitation was completed by FISAT II program. The natural mortality rate (M) is measured by the empirical equation of Pauly (1983) using the water surface temperature's annual mean (T = 28°C) as follows:

$$\text{Log } M = -0.0066 - 0.279 \log L\infty + 0.6543 \log K + 0.463 \log T$$

The estimation of catching mortality mark (F) was calculated using the following equation (Sparre and Venema 1999): $F = Z - M$, and the rate of exploitation (E) was obtained from fishing mortality rate (F) and total mortality rate (Z) = F / Z. $E > 0.5$ represents high exploitation (overfishing); $E < 0.5$ represents low exploitation (under fishing) and $E = 0.5$ shows optimal fishing levels (Sparre and Venema 1999).

Recruitment pattern

Recruitment pattern analysis was completed by FISAT II program. The predicted result is obtained by entering the values of $CL\infty$, K, and t_0.

RESULTS AND DISCUSSION

Carapace length

A total number of 546 double-spined rock lobster (289 males and 257 females) were successfully caught from four research sites in Gunungkidul Regency, Yogyakarta with sizes (CL) ranged between 35.2 mm and 120.5 mm for males and from 35.6 mm to 90.6 mm for females. The mass (g) weight of samples ranged between 44 g and 1110 g for males and from 46 g to 505 g for females. Of the carapace length, it shows that the highest proportion of males carapace length was 26.99 % (78 lobsters) ranged between 45.2 mm and 55.1 mm (Figure 3) while the highest proportion of females carapace length was 25.68 % (66 lobsters) ranged between 55.2 mm and 65.1 mm (Figure 4). Results showed that males double-spined rock lobster had the longer size (CL) than females lobster. It could be caused by several factors affecting the lobster growth such as biology factor and ecology factors. Biology factors included sex, gene, the level of gonad maturation, growth phase, and feeding habit (Froses 2006; Tarkan et al. 2006). While ecology factors were weather, water qualities (temperature, pH, salinity), and geographic position (Jenning et al. 2001).

Tropical lobsters had a complex life cycle with an extended pelagic larve phase (> 6 mo: Philips et al. 2006) and post-settlement phases occupying different habitats and depths (Haywood and Kenyon 2009). The long larval phase means that larvae can potentially disperse in long distances from their coral reefs. During this extended larval phase, they are exposed to the range of environmental conditions that affect their survival rate and subsequent recruitment (Caputi et al. 2001).

Growth rate

Growth rate (K) of double-spined rock lobster males was determined using data from CL distribution (Figure 5). Results showed that the growth rate reached of 0.85 year^{-1} and the CL distribution reached an asymptotic point (growth-limited) at 125 mm (12 years old). The theoretical age at which CL equals zero was -0.89 for males and -0.70 for females. Theoretical age is important to measure the asymptotic length. The growth rate of female's double-spined rock lobster was determined using data from CL distribution (Figure 6). Results showed that the growth rate of 0.55 year^{-1} and that CL reached an asymptotic point (growth-limited) at 125.5 mm (15 years old). In addition, the theoretical age at which CL equals zero was -0.70. It means that double-spined rock lobster has fast growth rate in the 1^{st} year with the growth rate values (K) for males were higher than females.

The growth of double-spined rock lobster appeared to be similar to other lobster species in tropical and subtropical waters. For example, *P. homarus* in Arabia has a similar growth rate, with K values of 0.71 $year^{-1}$ and CL_∞ of 143.16 mm (Mehanna et al. 2012). However, the growth rate of *P. homarus* in Central Java (K male = 0.31 $year^{-1}$, CL_∞ = 110 mm and K female = 0.26 $year^{-1}$, CL_∞ = 95.62 mm) (Bakhtiar et al. 2013) and in West Aceh (K = 0.39 $year^{-1}$ and CL_∞ = 119.5 mm) (Kembaren and Nurdin 2015) were slow. Ernawati et al. (2014) determined the K value of *Panulirus versicolor* in north Sikka and adjacent waters at 0.44 $year^{-1}$ with a CL_∞ of 146.7 mm. In other species, *P. penicillatus* caught in Central Java had K values of 0.15 $year^{-1}$ and CL_∞ of 136 mm (male), and 0.19 $year^{-1}$, CL_∞ of 123 mm (female) (Zaenuddin and Putri 2017).

The growth rate value (K) of double-spined rock lobster was less than 1, which indicates that this species has a slow growth (Sparre and Venema 1999). It means that this species needs much more time to grow for reaching the commercial size standard of consumption. According to the Regulation of The Ministry of Maritime Affairs and Fisheries Republic of Indonesia No. 1 Year 2015, fishing lobster (*Panulirus* spp.) was permitted with carapace length > 8 cm. It means that most of catched double-spined rock lobsters were still under permitted size; therefore, the capture activities of this species should be limited and waited for 1 or 2 years to enable their carapace length grow > 8 cm. Therefore, our model provides valuable data in supporting the development of resource management strategy including an optimal catch strategy to maintain the sustainability of both the species and economical benefits.

Mortality rate and exploitation

Total mortality rates of double-spined rock lobster were estimated 2.46 $year^{-1}$ and 2.56 $year^{-1}$ for males and females, respectively. The estimated values of natural mortality (M) were 1.08 $year^{-1}$ for males and 0.81 $year^{-1}$ for females. Meanwhile, the respective values of mortality by fishing activities (F) were 1.38 $year^{-1}$ and 1.75 $year^{-1}$ for males and females, respectively. The exploitation rate of this species were 0.56 and 0.68 for males and females, respectively. Moreover, the excessive capture of lobster in fishing activities highly contributed to lobster mortality. The same study reported by Bakhtiar (2013) in Central Java, which influences the rate of exploitation is fishing activities. This research confirmed the impact of exploitation rate on the high mortality rates of lobster, which is commonly occurred in Indonesia. Concisely, the main cause of lobster mortality was fishing activities. The high fishing pressure increasing the exploitation number of lobster stock was also reported in India (Vijayanand et al. 2007). Mehanna et al. (2012) highlighted that in the international scale, the lobster exploitation value in the Oman Beach due to intensive fishing activities were 3.16 for males and 3.81 for females, respectively. Therefore, in this study, the overexploitation of double-spined rock lobster also occured in the southern coast of Yogyakarta. According to Pauly (1983), in order to ensure the sustainability, the exploitation rate of fisheries stock was recommended around 0.5 (E opt = 0.5). The use of E = 0.5 as the optimal value for exploitation rate was based on the assumption that the mortality due to fish capture and natural mortality are in balance condition (F = M). Mortality curve of *P. penicillatus* in both males and females was presented at Figure 7 and Figure 8 with the black point indicated as mortality by fishing activities and the yellow point is mortality caused by old ages.

Environmental factors influence on catching activities such as a sharp increase in rainfall during the wet season increased turbidity leading to the more active activity of lobsters, especially *P. penicillatus*. On the other hand, increase in rainfall had less effect on *P. homarus* catch than that on *P. penicillatus*. Most *P. penicillatus* occupied inshore rocky reefs in shallow water (< 10 m) where the water turbidity is consistently higher than that found in deeper offshore reefs where *P. homarus* life (Steyn and Schleyer 2011). Implementation various fishing management is needed to provide an opportunity for lobster to reproduce and maintain their population naturally.

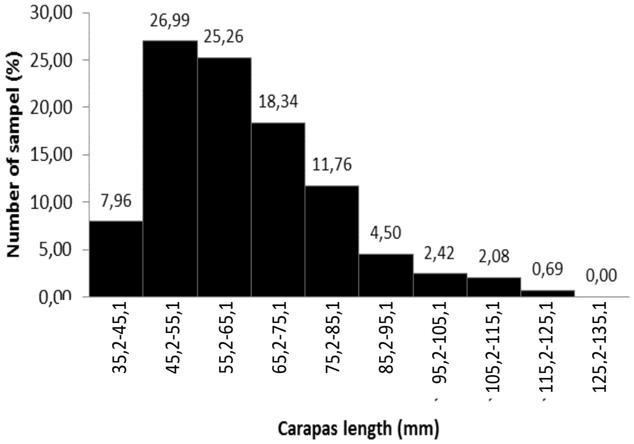

Figure 3. Distribution of carapace length of males double-spined rock lobster (*Panulirus penicillatus*)

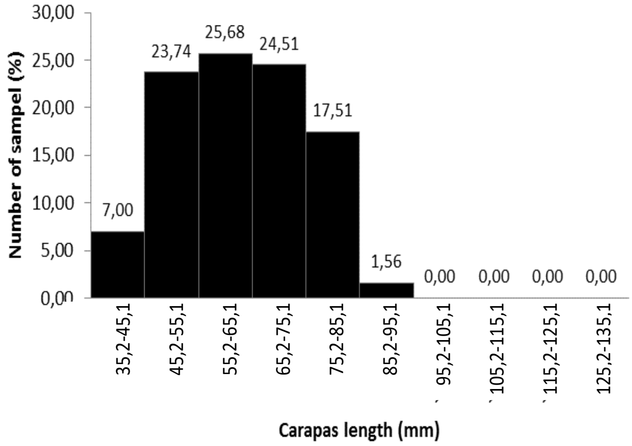

Figure 4. Distribution of carapace length of females double-spined rock lobster (*Panulirus penicillatus*)

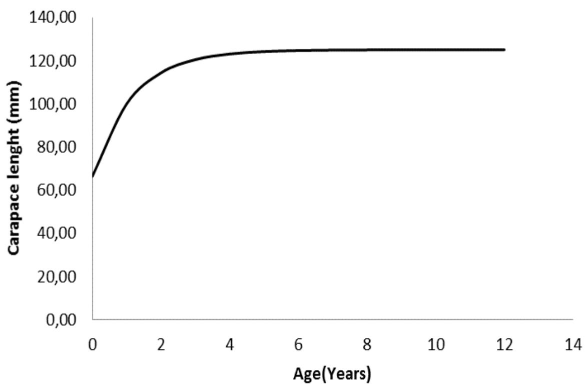

Figure 5. Growth curve of double-spined rock lobster (*Panulirus penicillatus*) males

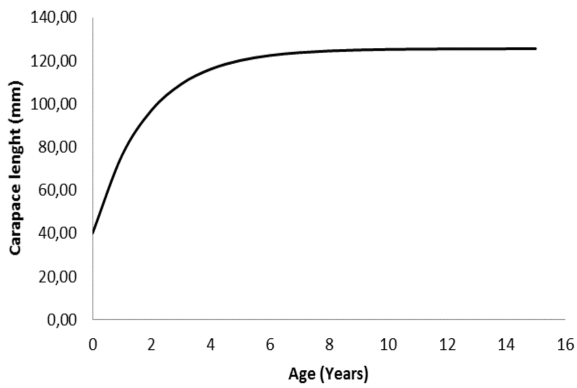

Figure 6. Growth curve of double-spined rock lobster (*Panulirus penicillatus*) females

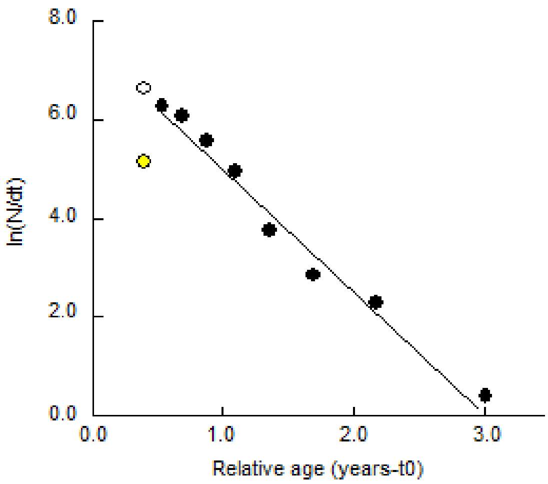

Figure 7. Males mortality curve of double-spined rock lobster (*Panulirus penicillatus*)

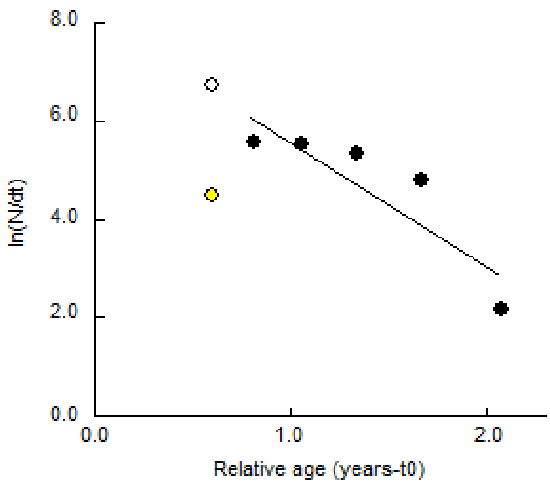

Figure 8. Females mortality curve of double-spined rock lobster (*Panulirus penicillatus*)

Recruitment pattern

Descriptive statistics were used to estimate monthly recruitment patterns for double-spined rock lobster. The peak of recruitment occurred in January and August (Fig. 9). This differed to peak recruitment of *P. homarus* in Central Java, which occurred in June and October (Bakhtiar et al. 2013). Interestingly, recruitment patterns of *P. penicillatus* at the southern coast of Yogyakarta was strikingly similar to *Panulirus versicolor* in the northern sea of Sikka District with peak recruitment occurring in August and September for both species (Ernawati et al. 2014). Differences in recruitment rates are likely caused by differences in patterns and efforts of fishing activities in each area, as well as environmental factors such as weather patterns. Besides the result, it is necessary to manage fishing time by not fishing in spawning and recruitment season as an effort to keep the sustainability of lobster resources.

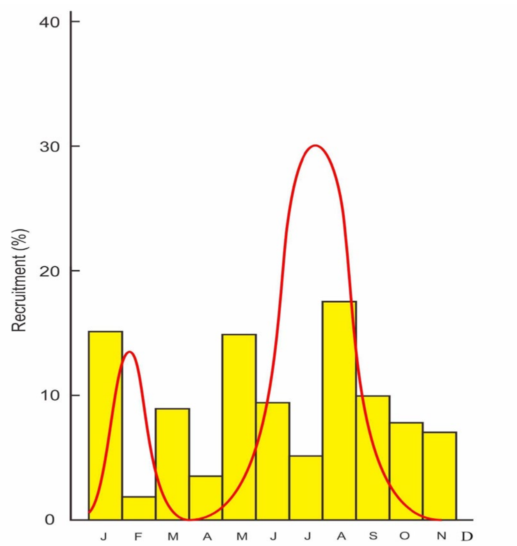

Figure 9. Recruitment pattern of double-spined rock lobster *Panulirus penicillatus* in southern coast of Yogyakarta

The conclusion of this research are males double-spined rock lobster has longer size than that in females. The growth rate (K) of males double-spined rock lobster is more quickly than females lobster. The exploitation rate of males was 0.56 and females was 0.68. Fisheries exploitation of this species has exceeded the optimal level (0.5) and reached overfishing value. The peak of recruitment occurred in January and August. Overfishing of undersize lobsters was the threat for sustainability of lobster resources. So that, it is necessary to regulate the fishing activities, especially during spawning and recruitment season. Moreover, the development of eco-friendly fishing gear and habitat protection are important to ensure their population will increase naturally.

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