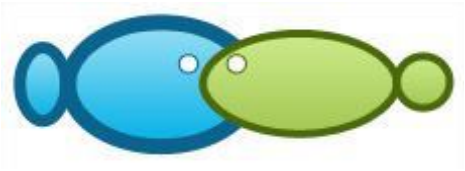

Study on the coconut crab (*Birgus latro*) *in-situ* rearing in Derawan Islands, Indonesia: feeding artificial food (part 1)

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Abstract. The coconut crab (*Birgus latro*) is an organism conserved in Indonesia. Overfishing and other human disturbant activities have led to a population decrease. Therefore it is important to manage and conserve the species to avoid extinction. This study aimed to analyze the growth, mortality and survival rates of the coconut crab reared in incubator boxes placed in the area of the coconut crab habitat. This study was conducted for 7 months, from May to November 2018. Rearing of the crabs was carried out at Maratua Island. The crabs (n = 30) were put into incubator boxes (sized 70 x 40 x 40 cm^3), with one individual per incubator box, with three different treatments (as food supplements). In the first treatment, the coconut crabs were fed pellets of formula A (wheat flour at 60%, coconut powder 30%, fish powder 5%, vitamin mix 2%, and minerals 3%). In the second treatment, they were fed formula B (wheat flour at 40%, coconut powder 50%, fish powder 5%, vitamin mix 2%, and minerals 3%). In the third treatment, they were fed formula C (wheat flour at 20%, coconut powder 70%, fish powder 5%, vitamin mix 2%, and minerals 3%). The crabs were treated with feed in the form of pellets given once a week (20-30 g) plus feed in the form of coconut twice per week. Based on the observations conducted in the field, the coconut crabs had an absolute growth of 3.7% (treatment A), 6.4% (treatment B), and 3.0% (treatment C) during 7 months period. The survival rates of the crabs were 80% (treatment A), 100% (treatment B), and 90% (treatment C).
Key Words: domestication, endangered species, East Kalimantan, coconut crab, *Birgus latro*.

Introduction. Indonesia is an archipelago with 17,000 islands, extending from the west (Sabang) to the east (Merauke). This country is filled with abundant life forms, one of which is the coconut crab (*Birgus latro*). In Indonesia, this crab can be generally found in the eastern part of the country, namely, Sulawesi, Nusa Tenggara, Maluku, North Maluku and Papua. Harvesting of the coconut crabs has been conducted intensively in several locations in Indonesia, *e.g.* in North Maluku, North Sulawesi, Central Sulawesi, Southeast Sulawesi, and even in remote islands such as Derawan Island of the East Kalimantan (Borneo) Province. This is possible because there is an attractive market (high prices of IDR. 200,000-350,000 per individual in the field, 1-2 kg in size) even up to IDR. 750,000 in some restaurants in Indonesia (Sulistiono et al 2014, 2016). The crabs are also consumed as food in some restaurants in the Indo-Pacific regions because of their delicious meat (Kessler 2006; Buden 2012).

Since 1981, the coconut crabs have been listed on the IUCN as a red list, but their status was changed to a data deficit in 1996 (Eldredge 1996). In the Republic of Indonesia, the crabs have been listed as protected animals, because the population of this biota is estimated to be sufficiently degraded, this is why it needs protection to avoid

extinction. The decrease of the coconut crab population is deemed to result from not only environmental changes (habitat, food sources, and predators), but also by human activities (deforestation, land occupancy, introduction of predators by human, and exploitation). Additionally, this biota has a relatively slow growth (Sulistiono et al 2014).

Conservation of the coconut crab was only the designation of the biota as a protected animal with the exclusion of certain areas estimated to be inhibited by this biota (PPSDAHP 1987; Anonymous 2004), and captive breeding programs through domestication have never been carried out. A smaller population and scarcity of larger crabs in several islands in Indonesia appear to require support of technology to procure and rear hatchings (Sulistiono et al 2016). In this way, a restocking program will mean transfering populations from one area to another and also enriching stock in at least one ecosystem where this animal has become extinct or has a small population. Although this biota is protected, there are still many activities carried out by people to catch the coconut crab. Some communities even illegally capture crabs outside their province areas (Sulistiono et al 2014). In order to protect the biota, various steps must be taken which include protection of the area, prohibition of catching, determination of protected areas and domestication efforts.

A number of studies on coconut crabs have been carried out by several researchers in regards to their ecology and behavior (Helfman 1973), biology (Amesbury 1980; Pratiwi 1989; Brown & Fielder 1991), adaptation to terrestrial (Greenaway et al 1988), capture activities (Boneka 1990; Sulistiono et al 2009a), bioecology (Rondo & Limbong 1990; Pratiwi & Sukardi 1995), habitat and population (Ramli 1997), breeding and domestication efforts (Sulistiono 2006; Sulistiono et al 2007), larval growth (Wang et al 2007), gonad maturity (Sulistiono et al 2008b), rearing activity (Sulistiono et al 2009b), population in Mariana Islands (Vogt & Navy 2010), gonad morphology and histology (Refiani & Sulistiono 2009), reproductive pattern (Sulistiono et al 2008a), habitat characteristics (Supyan et al 2013), crab potency in nature (Sulistiono et al 2013), population structure (Drew & Hansson 2014), growth and estimation of the size of first mature gonads (Supyan et al 2015), status of the biota in Niue (Helagi et al 2015), growth (Oka et al 2015), factors influencing growth (Drew et al 2013), foraging strategies (Krieger et al 2016), population dynamics (Widiyanti et al 2016), color polymorphism (Nokelainen et al 2018), morphometric characters (Serosero et al 2018a), spatial and temporal distribution (Serosero et al 2018b), and sex ratio and growth pattern (Serosero et al 2019).

In an endeavor to conserve the coconut crab, the present study was conducted for estimating the growth, mortality, and survival rates using food supplementation through pellets. It is expected that this study will provide solutions for the high mortality level of this biota in its natural habitat. In addition, it is postulated that this study will initiate steps to improve survival rates, so that the targetted biota can be relocated and spread to certain areas suitable for coconut crab habitat, particularly in small islands.

Material and Method

Time and location. This study was carried out for 7 months from May to November 2018 in Maratua Island of the Derawan Islands group. Sample crabs (n = 30) were taken from a number of places, including Maratua, Derawan, and Bulingisan Islands (East Kalimantan) (Figure 1), while rearing activity was conducted on Maratua Island.

Materials and equipment. The following tools and materials were used for rearing activity such as targetted biota, feed and rearing tools, consisting of water containers (2), incubator boxes made of plastic (30) with their related equipment, sea and fresh water as nurturing media, chopped coconuts, and pellets for food.

Collection of samples. Coconut crab samples (n = 30 individuals) were collected from their natural habitat. To collect the coconut crabs, coconut bait was scaterred in the habitat of the coconut crab during evening which was rocky and coastal areas. The coconut crabs were collected at night by hand.

Figure 1. The location of the rearing activity of the coconut crabs in Maratua Island of Derawan Islands, East Kalimantan Province of Indonesia.

Rearing and treatment. Captured coconut crabs were reared in an incubator box containing a sea water container and a fresh water container (Figure 2), coconut, and pellet as food source. The density was 1 animal per rearing box (0.7 x 0.4 x 0.4 m^3). Feed was given three times in a week (on Monday, Wednesday, and Friday), while water was replaced once a month. For food supplement treatments, pellets were fed once a week (*e.g.* Monday), while coconuts were fed twice a week (*e.g.* Wednesday and Friday). Schedule of the feeding coconut and supplementary food is presented in Table 1.

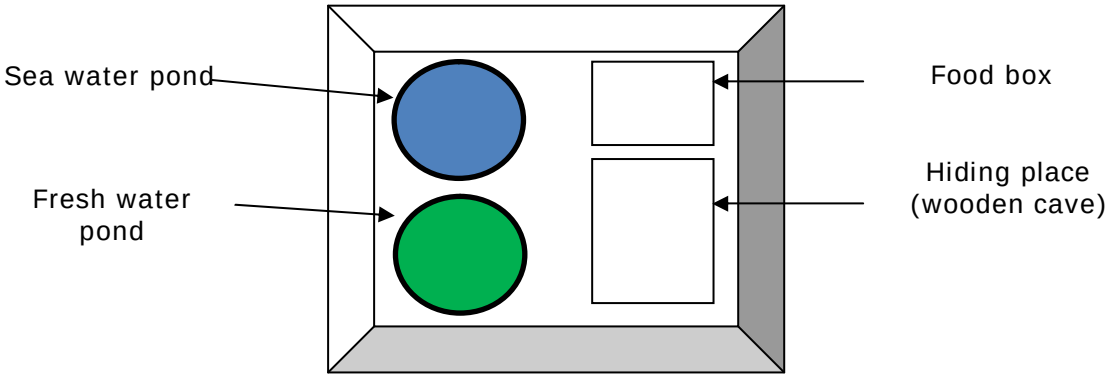

Figure 2. Design of incubator box for rearing coconut crab (top view).

Table 1

Schedule of the feeding supplementary food (once in a week) on the coconut crab

Treatments	*Days in a week*						
	Sun.	*Mon.*	*Tues.*	*Wed.*	*Thur.*	*Fri.*	*Sat.*
A		pellet		coconut		coconut	
B		pellet		coconut		coconut	
C		pellet		coconut		coconut	

pellet; coconut.

In this study, the coconut crabs collected from area near to the site (location) were put into incubator boxes, with one individual per incubator box, with three different treatments (as food supplements). In the first treatment, the crabs were fed pellets of formula A (wheat flour at 60%, coconut powder 30%, fish powder 5%, vitamin mix 2%,

and minerals 3%). In the second treatment, they were fed formula B (wheat flour at 40%, coconut powder 50%, fish powder 5%, vitamin mix 2%, and minerals 3%). In the third treatment, they were fed formula C (wheat flour at 20%, coconut powder 70%, fish powder 5%, vitamin mix 2%, and minerals 3%). The crabs were treated with feed in the form of pellets given once a week (20-30 g) plus feed in the form of coconut twice per week.

Data analysis. The parameters recorded were the survival rate (number of surviving coconut crabs per 7 months), mortality level, and growth rates (weight per month during 7 months rearing) of the biota. Measurement on the (absolute) growth (ΔW) was performed by measuring body weight (gram), compared to weight at the beginning of the study (W_0) and weight during observation (W_t), $\Delta W = (W_t-W_0)/W_0 \times 100$ (Effendie 1979). Average growth of each treatment (A, B, C) was analyzed using ANOVA ($p < 0.05$) (Walpole 1982). Survival rate (SR) was recorded by calculating the number of crabs at the beginning (N_0) and ending of observation (N_t), $SR = (N_t/N_0)$, and mortality (m) was examined by calculating the number of coconut crabs nurtured at the beginning of the study and during observation or m = 1-SR (Effendie 1979).

Results. Coconut crab is one of the economically important animals in some areas of Indonesia. Intensive fishing and other human disturbant activities in the crabs habitat, caused population of the crab beginning to decline. Therefore, it is important to domesticate the crab for conservation. In this study, we tried to domesticate the coconut crab in-situ at Derawan Island. Part of this study conducted in 2004-2013 was to make the crabs accustomed to a limited environment. Feeding pieces of coconut depicted the real condition of crabs in the nature, in which they eat only coconut (Sulistiono 2006; Sulistiono et al 2007; 2009b; 2014). In the present study, three treatments were used, namely formula A, B and C, as mentioned before. According to the study using first treatment (formula A), mortality was observed in July after being kept for 2 months, but as many as 8 individuals still survived during the study period of 7 months. In the second treatment (formula B), there was no mortality. All individuals survived over 7-month study activity. In the third treatment (formula C), there was one mortality 1 in July. The population during these observations is presented in Figures 3-5.

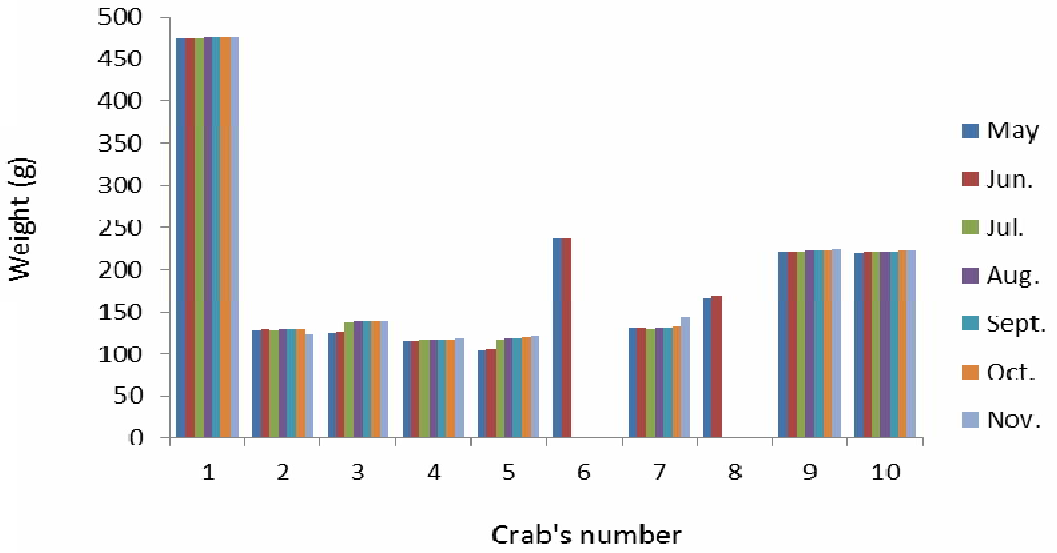

Figure 3. Condition of coconut crabs reared in incubator boxes with treatment A observed from May to November 2018 (crabs no 6 and 8 deceased after 2 months).

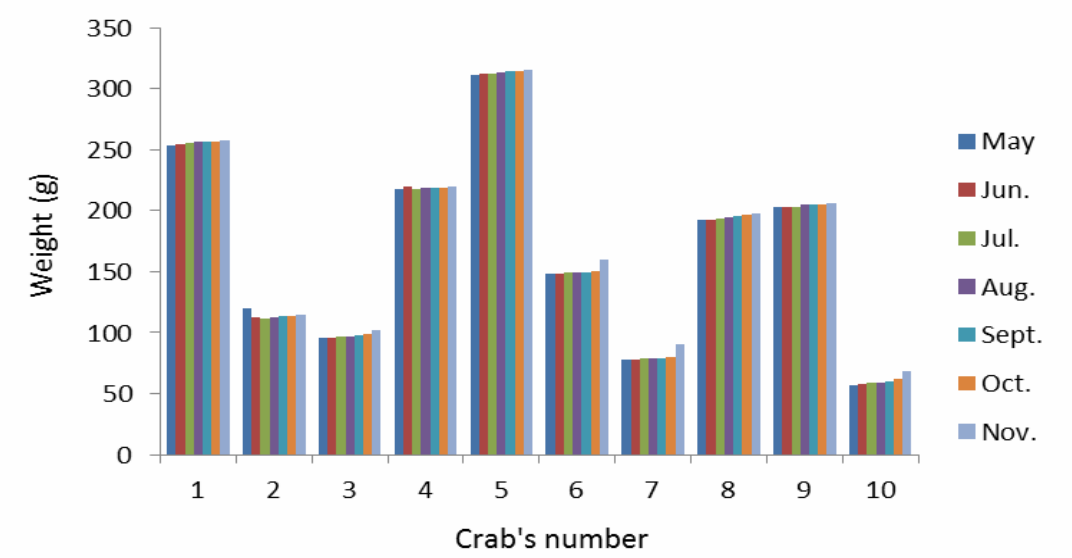

Figure 4. Condition of coconut crabs reared in incubator boxes with treatment B observed from May to November 2018.

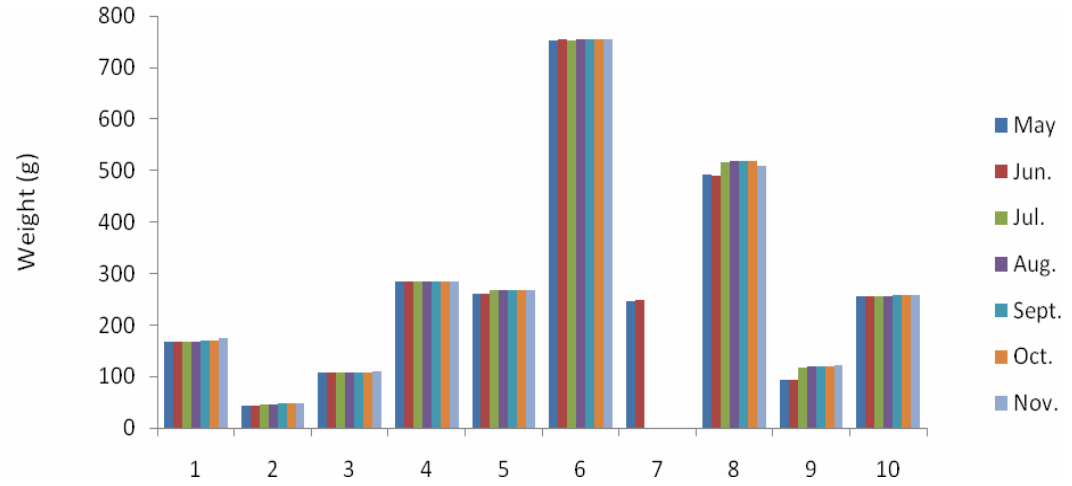

Figure 5. Condition of coconut crabs reared in incubator boxes with treatment C observed from May to November 2018 (crab no 7 deceased after 2 months).

The result shows all 3 groups crab gained weight over 7 months. During adaptation stage of these crabs, there was a positive weight gain. In the first treatment (A), body weigth of the crab (in average) was 189.22 g (May), 190.23 g (June), 193.24 g (July), 194.01 g (August), 194.44 g (September), 194.49 g (October), and 196.16 g (November 2018). The growth increased from May by 1.00 g (0.53%) in June, 3.01 g (1.58%) in July, 0.78 g (0.40%) in August, 0.43 g (0.21%) in September, 0.48 g (0.24%) in October, and 1.25 g (0.64%) in November. Average growth of the crab was 1.16 g (0.60%) per month (Figure 6). In the last measurement of body weight (Wt) conducted in November, the crab grew 3.67% (in total) compared to the first measurement of body weigth (Wo) (May).

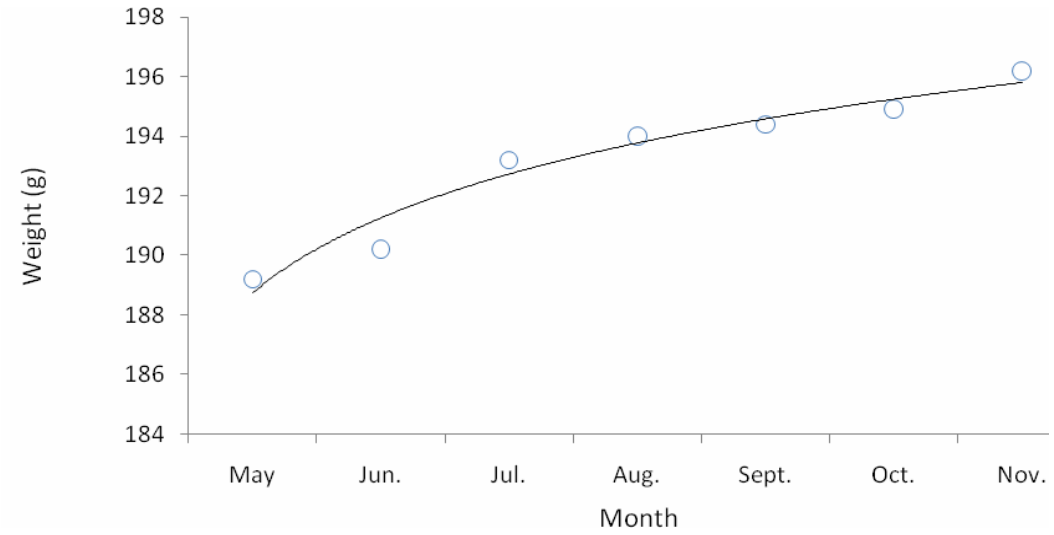

Figure 6. Coconut crabs growth reared in incubator boxes with treatment A observed from May to November 2018.

In the second treatment (B), body weight of the crab (in average) was 167.58 g (May), 167.61 g (June), 167.84 g (July), 168.40 g (August,) to 169.05 g (September), 169.83 g (October), and 173.16 g (November 2018). The growth increased from May by 0.03 g (0.02%) in June, 0.23 g (0.14%) in July, 0.56 g (0.33%) in August, 0.65 g (0.39%) in September, 0.78 g (0.46%) in October, and 3.33 g (1.96%) in November. Average growth of the crab was 0.93 g (0.55%) per month (Figure 7). In November, body weigth of the coconut crab (Wt) grew 3.33 % (in total) compared to the first measurement of body weigth (Wo) (May).

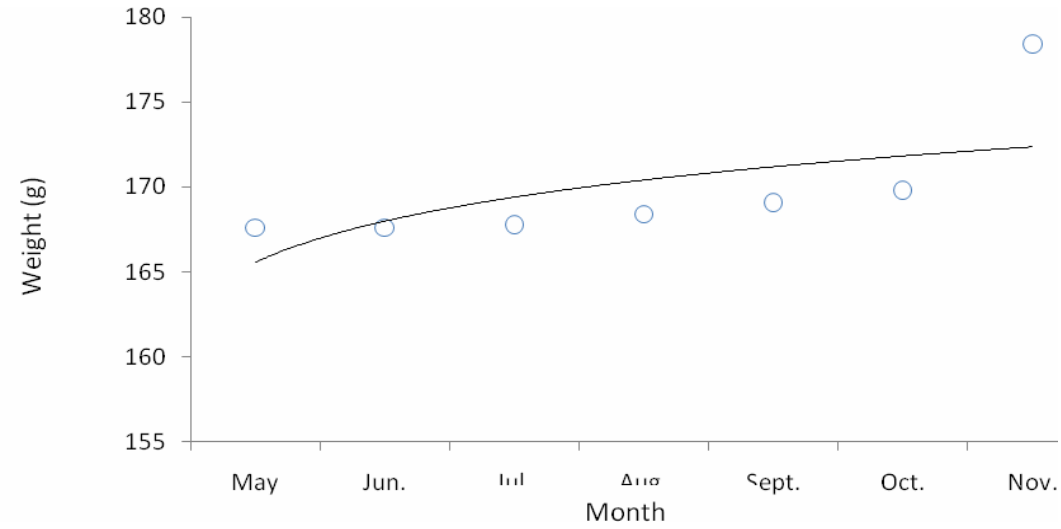

Figure 7. Coconut crabs growth reared in incubator boxes with treatment B observed from May to November 2018.

In the third treatment (C), average body weight of the crab was 273.16 g (May), 273.49 g (June), 279.61 g (July), 280.33 g (August), 280.91 g (September), 281.19 g (October), and 281.46 g (November 2018). The growth increased from May by 0.33 g (0.12%) in June, 6.12 g (2.24%) in July, 0.72 g (0.26%) in August, 0.58 g (0.21%) in September, 0.28 g (0.10%) in October, and 0.27 g (0.09%) in November 2018. Average growth of the crab was 1.38 g (0.50%) per month (Figure 8). In the last observation of body weight (Wt) (in November), the crab grew 3.04% (in total) compared to the first body weigth (Wo) (May). Based on statistical analysis, each treatment (average growth

1.16 g-treatment A, 0.93 g-treatment B and 1.38 g-treatment C) was not significantly different ($p < 0.05$).

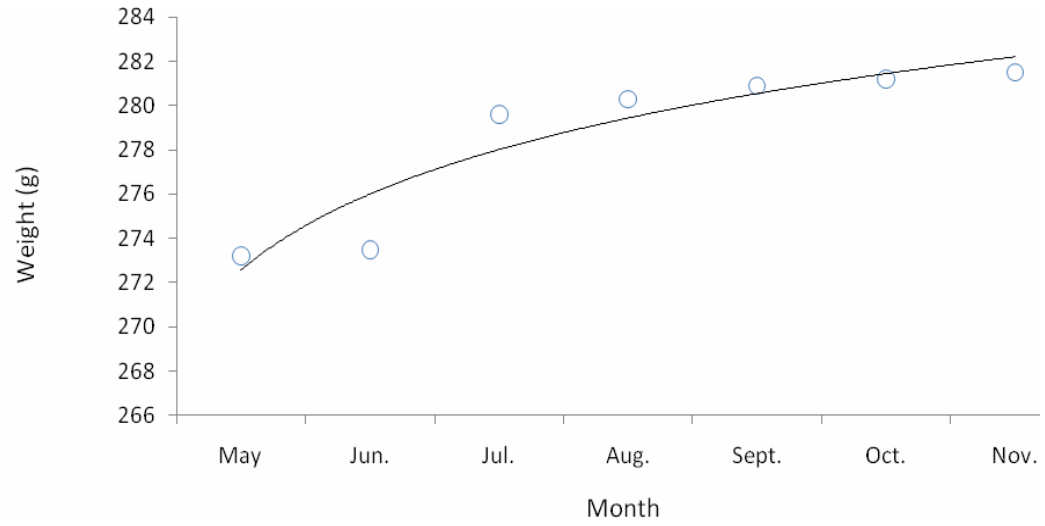

Figure 8. Coconut crabs growth reared in incubator boxes with treatment C observed from May to November 2018.

Observation on survival rate of the crab was conducted by counting a number of biota per month. Result of the observation is presented in Figure 9. From the three treatments (A, B, C), treatment B has a survival rate 100%, treatment C 90%, and treatment A 80%. Those conditions indicate that mortalities of the coconut crab reared in the incubator box were 0% (treatment B), 10% (treatment C), and 20% (treatment A), for 6 months rearing activity. Based on statistical analysis, average mortality in treatment A (0%), B (10%) and C (20%) was significantly different ($p < 0.05$).

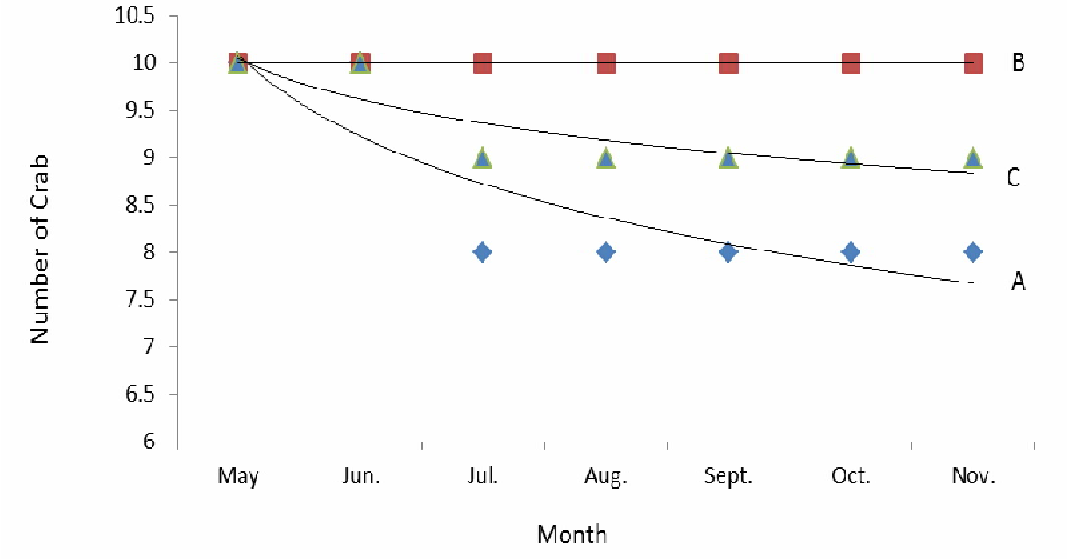

Figure 9. Coconut crabs survival rate reared in incubator boxes with treatment A, B, C observed from May to November 2018.

Discussion. Studies of coconut crabs are very limited, and little information on the coconut crab has been published. Several activities that have been published relating to this biota in Indonesia conducted by sseveral researches exist *i.e*. Pratiwi (1989), Boneka (1990), Rondo & Limbong (1990), Pratiwi & Sukardi (1995), Ramli (1997), Sulistiono (2006), Sulistiono et al (2007; 2008a; 2008b; 2009a; 2009b; 2013; 2014; 2016),

Refiani & Sulistiono (2009), Widiyanti et al (2016), Supyan et al (2013, 2015), and Serosero et al (2018a, 2018b, 2019). However, information related to the domestication, especially in the context of conservation has not been widely distributed.

Domestication is an activity of cultivating wild biota, and it is the initial activity for the breeding of wild biota. Conservation is an effort to preserve a natural resource. Conservation also means management of natural resources by sustainable use. According to IUCN, several aquatic biota in Indonesia have become targets for protection. A number of domestication and breeding program have also been carried out by the government through research institutions, universities and non-governmental organizations. A type of Asian bonytongue arowana fish (*Sclerophagus formosus*) is one example of a domestication program that is considered to have been quite successful. In addition to the observation and preservation of target organisms, conservation of habitats (lakes, rivers, and other types of waters) is also a strong foundation for the protection and preservation of endangered species (Sulistiono et al 2014).

This domestication activity is an effort to preserve the biota from extinction, as a result of increasingly intensive changes in the coconut crab is habitat which was originally an island or beach with a number of forage areas in the form of coconut trees which have been turned into plantations, or housing or industrial areas. Rearing activity at this location was also the implementation of the biota rearing system which has been carried out ex-situ (Sulistiono et al 2014).

Study conducted in 2004, 2005-2006, 2008 and 2013 was to make the crabs accustomed to a limited environment. Feeding pieces of coconut, depicted the real condition of crabs in the nature, in which they eat only coconut (Sulistiono 2006; Sulistiono et al 2007; 2009b; 2014). A preliminary study to rear coconut crabs had been carried out in Palu (Central Sulawesi) (Sulistiono et al 2007). The activity was carried out twice, from June to November 2004 and from December 2005 to January 2006. The target biota reared was taken from Pasoso Island (Central Sulawesi). Rearing equipment was a tub made of cement and provided with shade on the top. From these observations, it was shown that the survival rate was still quite low (13.8-50.0%) and the mortality rate was quite high (50.0-87.5%). In addition, the growth conditions were still very low (about 0.01 grams per month). In the *in-situ* rearing activity carried out in Yoi Island (Central Halmahera, North Maluku Province) from January to September 2008, each coconut crab was placed in a plastic tub (box) sized 56 cm x 30 cm x 35 cm. In each of these boxes, fresh water and sea water were provided. One individual was reared in each box and fed only coconut. From these observations, it was known that coconut crabs had a survival rate of approximately 80% (Sulistiono et al 2009b)

Coconut crab rearing activities in a preliminary study were also carried out externally in their habitat (ex-situ). The animal rearing activities were carried out in the Lebak area (Banten Province) from May to December 2008. The rearing medium was a cement building that was sheltered as well as rearing activities carried out in 2004 in Palu (Sulistiono et al 2007). In this activity, rearing tanks were given fresh water and sea water. In this study, the biota grew and had a survival rate of approximately 82-83% (Sulistiono et al 2009b). This study was continued at the Ecobiology Laboratory of the Department of Aquatic Resources Management of IPB. Rearing activities began from July to September 2013. From these observations, it is known that coconut crabs grew and had a survival rate of approximately 70-100%. When the activities were extended for 8 months, the survival rate was still high (60%). In rearing activities carried out in February-October 2016, the survival rate of this biota was approximately 60-79% (Sulistiono et al 2016).

Efforts to carry out a preliminary study conducted at this time involve the application of plastic box which serves as an incubator box for rearing coconut crabs in the field. Previous rearing had been carried out (Sulistiono et al 2013, 2016) quite successfully with survival rates ranging from 60 to 100% depending on the period and treatment of the study. In rearing activities with the provision of feed in the form of coconut, the crabs still had a high survival rate, compared with artificial feed. However, the rearing activity carried out with artificial feed (once a week) in Derawan also succeeded with survival rate of 80-100% (Sulistiono et al 2016).

From this study, the coconut crabs with artificial feed (pellets with various treatments) had a growth of 3.04-3.67% over 7 months. The growth of the coconut crab is slow according to Drew et al (2013). In this study, crabs with smaller sample sizes have higher growth compared to those of larger size (such as treating A, B, C). The survival rate during the study was around 80-100%. This survival rate shows a higher value compared to previous studies in 2004, 2005, 2006 (Sulistiono et al 2007). Wang et al (2007) have studied on the growth of the coconut crab larvae, and obtained a survival rate of around 5.7-95.3% (in 2004) and 16%-87% (in 2003). From these observations, it can be seen that coconut crab rearing can be carried out in a plastic incubator box system and given supplementary artificial feed in the form of pellets.

Conclusions. Coconut crabs were reared in the Maratua Island of the Derawan Islands group with three treatments namely A (wheat flour of 60%, coconut powder of 30%, fish powder of 5%, vitamin mix of 2%, and mineral of 3%), B (wheat flour 40%, coconut powder of 50%, fish powder of 5%, vitamin mix of 2%, and mineral of 3%), and C (wheat flour of 20%, coconut powder of 70%, fish powder of 5%, vitamin mix of 2%, and mineral of 3%). Based on the observations conducted in the field, the coconut crabs had an absolute growth of 3.67% (treatment A), 3.33% (treatment B), and 3.04% (treatment C) during 7 months period. The coconut crabs have survival rate of 80% (treatment A), 100% (treatment B), and 90% (treatment C). The coconut crabs can be reared *in-situ* using an incubator box system with artificial feed in the form of pellets.

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