The exploitations status of the orange mud crab (*Scylla olivacea* Herbst, 1796) in Aru Islands and adjacent waters, Maluku, Indonesia

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**Abstract.** The increasing exploitation and fishing of the orange mud crab (*Scylla olivacea*) are threats against the sustainability of the crab resources. Therefore, it is critical to carry out a scientific study that can serve as the basis of the fisheries management. This study was carried out from March to November 2019 several crab landing sites in Aru Islands (Dobo). It employed survey and monthly data collection methods, assisted by an enumerator. The results revealed that the capace width orange mud crab was of 110–185 mm in size where 135 mm was the dominant size and 137.8 mm was the capace width at first capture (CWc). Its growth rate ($K$) was 0.59 per year and its asymptotic capace width was 191.5 mm. The recruitment of the species occurred all year long, peaking in February at 18.53%. Its fishing mortality ($F$) was 0.74 per year, while its natural mortality ($M$) was 0.77 per year. The exploitation rate ($E$) of the orange mud crab was 0.49% (moderate state). To ensure the sustainability of the crab resource in Aru Islands, people should be advised to maintain the sustainability of the crab habitats, i.e. the mangrove forests, and not to capture the orange mud crabs below 120 mm in size.

1. **Introduction**
Indonesia is one of the countries producing and exporting highly valuable crabs. According to the Statistics Indonesia, in 2017, the crabs and blue swimmer crabs exported by the country reached USD152,739,729 [1]. The data indicate that crabs are highly potential to be exploited in the country. Moreover, the country has numerous mangrove forests as the habitats. [2] stated that crabs live well in healthy mangrove forests. They need mangroves to provide them with litters and benthos as their food sources [3]. In addition to be the habitats for adult crabs, the mangrove ecosystems also serve as crabs’ spawning, nursery, and feeding grounds [4].

Aru Islands is one of the regions in Indonesia with vast mangrove forests. The region consists of several islands in Maluku Province and is a part of the FMA 718 Arafura Sea. The mangrove forests in the region reach 111,177 Ha in size (Decree of the Minister of Marine Affairs and Fisheries No. 64 Year 2014). The coastal areas are muddy beaches with mangrove vegetations *Rhizophora* sp. and *Bruguiera* sp. dispersed in Benjina (Warkam Island), Dobo (Wamar Island), Ujir Island, and others [5]. [6] stated that Aru Islands waters have 2 out of the 4 crab species in Indonesia, i.e. giant mud crab (*Scylla serrata*) and orange mud crab (*Scylla olivacea*). The crab *S. olivacea* are locally known as ‘kepiting merah/oranye’ (literally means red/orange crabs) in Eastern Indonesia as their claws are red-
orange [7]. However, some of them are brownish-red or blackish red, depending on the habitats [8]. They are most commonly captured traditionally in mangrove forests using hooks, more tolerant against lower salinity and, therefore, found abundant near the edge of the mangrove forests that are the furthest from the sea [9]. [6] also stated that the orange mud crabs are capable of associating with mangrove forests in coastlines with lower salinity.

According to the Decree of the Minister of Marine Affairs and Fisheries No. 50 Year 2017, the crab potential resources in the FMA 718 Arafura Sea is 1,498 tons and the total allowable catch (TAC) is 1,198 tons. However, the data from the Fish Quarantine and Inspection Agency (FQIA) of Aru Islands revealed that in 2018, the total exported crabs were 1,047,624 kg, or around 1,324,071 crabs, while in 2019, the number declined by around 15.2%, i.e. to only 769,850 kg or 919,996 crabs. Therefore, based on the data, the crab fishing activity in Aru Islands waters have almost exceeded the TAC even though there are a number of areas in the FMA 718 that potentially have crab resources.

The crab population will change as the result of intensive crab fishing activities driven by high demands [10]. Therefore, it is critical to have proper management efforts to maintain the sustainability of the crab populations in Aru Islands, particularly the orange mud crab (*S. olivacea*). Determining the most suitable management efforts requires scientific studies on the exploitation status of the orange mud crabs. The results of these studies are expected to serve as the bases for determining the policy measures to keep the species population sustainable.

2. Materials and methods
2.1 Data collection
The study was carried out using survey method at several crab landing sites in Dobo and nearby islands in Aru Islands (Figure 1) from March to November 2019. The data were collected monthly by the researchers and an enumerator. A total of 1,245 crabs were used as the samples. The carapace width was measured using calipers with 0.01 mm accuracy.

![Figure 1](image-url). The mud crab fishing grounds in Aru Islands waters and adjacent areas. (Source: [11])

2.2 Data analysis
Carapace width at first capture (CWc) was determined by analyzing the relation between the distribution of the carapace width class and the frequency (n). The class interval used for the carapace width was 5 mm. The number of the crabs was recorded by the interval, and the frequency was then
calculated. [12] stated that the CWc is the intersection between 50% cumulative frequency curve and the carapace width.

The growth coefficient (K) and the asymptotic carapace width were determined using the FAO ICLARM Stock Assessment Tools II program (FiSAT II) [13] that shows the time required for crabs to reach their asymptotic length. The estimation of the age of the orange mud crab was calculated using a formula by Pauly (1980) in [14]. Based on the data on the width of the crab carapace and the frequency of crab captured by fish, the recruitment was analyzed using FiSAT II. Using the same program, the total mortality (Z) was calculated using a length converted catch curve method, while the natural mortality (M) was calculated using the empirical formula by [15]. In addition, the fishing mortality (F) was analyzed by subtracting the natural mortality (M) from the total mortality (Z). At the end, the crab exploitation status (E) was determined by calculating the proportion between the fishing mortality (F) and the total mortality (Z) [14].

3. Results and discussion

3.1 The size structure and the carapace width at first capture

The carapace width of the orange mud crab in Aru Islands was 110–185 mm with 135 mm being the dominant size. See Table 1 for the range of the carapace width of the crabs caught in the islands. A total of 99.3% of the crabs were of minimum 120 mm in size. Such size is in compliance with the Regulation of the Minister of Marine Affairs and Fisheries No. 12 Year 2020 stating that crabs’ minimum size for trade is 120 mm.

Table 1. The range of and the dominant carapace width of the orange mud crabs (S. olivacea) in Aru Islands in 2019

| Month | The range of the carapace width (mm) | The dominant carapace width (mm) |
|-------|-------------------------------------|---------------------------------|
| Mar   | 115-185                             | 130, 135                        |
| Apr   | 120-165                             | 130                             |
| May   | 120-185                             | 130                             |
| Jun   | 110-185                             | 135                             |
| Jul   | 120-185                             | 145                             |
| Aug   | 120-170                             | 135                             |
| Sep   | 120-165                             | 155                             |
| Oct   | 120-185                             | 135                             |
| Nov   | 120-185                             | 145                             |

Figure 2. The size structure of the orange mud crabs (S. olivacea) in Aru Islands waters
Based on the data, the carapace width of the species in the Aru Islands waters in 2019 was smaller than in 2017–2018 (90–200 mm) [7], but bigger than in Thailand (50–135 mm [16] and 40–155 [17]; Central Tapanuli, Indonesia (90–116.1 mm) [18]; Malaysia (47–134 mm) [19], Terengganu, Malaysia (66–128 mm) [20]; Semarang, Indonesia (47.05–132.56 mm) [21]; India (45–148 mm) [22]; and Merauke, Indonesia (70–165 mm) [23]. Such difference in the carapace width is influenced by sex, food, capture site, and habitat. The lush mangrove forests as the crab habitats in the Islands help the carapaces grow. Djunaidah et al. in [24] stated that the water substrate is also a determining factor for carapace width as muddy substrate accelerates the increase in the carapace width. In addition, the water bed’s substrate is extremely related with the condition of the mangrove forests where dense forests produce abundant mangrove litters. The litters serve as the food sources for macro-zoobenthos that in turn become the food for crabs [2]; [25].

The species’ carapace width at first capture (CWc) was 137.8 mm (Figure 3). This was bigger than the species’ CWc in Merauke, Indonesia, i.e. 111.62 mm (2017) and 112.5 mm (2018) [23], and in the same Aru Islands waters (133.7 mm) [7]. The difference in CWc was presumably due to the difference in the food availability, the condition of the habitat, and the size structure of the analyzed carapace width. Abundant food in the mangrove forests accelerate the growth of the carapaces. The orange mud crabs are carnivorous as they eat crustaceans, chunk of clams, and mollusks [26].

![Figure 3. The carapace width at first capture (CWc) of orange mud crabs (S. olivacea) in Aru Islands waters](image)

3.2 The population dynamics and the status of exploitation

The growth rate (K) of the orange mud crabs in the islands waters was 0.59 per year, while its asymptotic carapace width (CW∞) was 191.5 mm. The equation was $L_t=191.5\left[1-e^{-0.59(t-1.165)}\right]$. See Table 2 and Figure 4 respectively for the population dynamics and the length distribution curve. The growth rate was of fast growth category as [27] stated that $K > 0.3$ per year indicates fast growth. The faster the growth, the faster the crabs reach their mature size. Growth rate (K) and asymptotic carapace width (CW∞) of the species in the waters in India were respectively 0.762 per year and 148.05 mm for male and 0.856 per year and 138.80 mm for female. Such different growth rate (K) of the species is due to the different molting time during their life cycle that eventually results in different time required to increase the carapace width.
Table 2. The parameters of the orange mud crab (*S. olivacea*) population in Aru Islands waters

| Parameter                                    | Unit  | Value   |
|----------------------------------------------|-------|---------|
| Carapace width at first capture (CW<sub>c</sub>) | mm    | 137.8   |
| Asymptotic carapace width (CW<sub>∞</sub>)     | mm    | 191.5   |
| Growth rate (K)                               | year  | 0.59    |
| Time when carapace width equals zero (t<sub>0</sub>) | year  | -1.165  |
| Total mortality (Z)                           | year  | 1.51    |
| Natural mortality (M)                         | year  | 0.77    |
| Fishing mortality (F)                         | year  | 0.74    |
| Exploitation rate (E)                         | %     | 0.49    |

The natural mortality (M) of the species (0.84 per year) was higher than its fishing mortality (F) (0.78 per year). Natural mortality (M) is crab death due to non-fishing reasons such as age, changing environment, and food shortage [28]. In addition, crabs’ lives depend on the water quality aspects such as salinity, dissolved oxygen, pH, and nitrite [29]. On the other hand, the fishing mortality (F) was low due to the nature of the crabs that hide themselves in their holes in the morning and look for food in the evening [30]. The orange mud crabs (*S. olivacea*) prefer to submerge themselves in the mangrove forest more than the other mud crabs, i.e. *Scylla serrata* and *Scylla paramamosain*, (Lewis et al., 2008 in [31]). The crabs’ natural mortality (M) also depends on the condition of the mangrove forests because [32] stated that the quality of the mangrove significantly affects the crabs’ survival.

![Figure 4](image)

**Figure 4.** The distribution of the frequency of the carapace width of the orange mud crabs (*S. olivacea*) in Aru Islands waters

The size of the orange mud crab in the Aru Islands waters is 60.4 mm at 6 months old, 92.7 mm at 1 year old, and 120 mm at around 18 months old, while the asymptotic size (191.5 mm) is reached at 9 years old or 108 months old (Figure 5). Based on these findings, it is known that the species in the Aru Islands waters grows fast during young age and the growth slows down along the age. Factors affecting the crab growth are among others the food and the environment. However, young crabs are in general use energy from their foods to grow (Azis, 1989 in [24]).
Figure 5. The growth of the orange mud crabs (*S. olivacea*) in Aru Islands waters

Based on the data on the species size structure and the frequency of the capture, the recruitment process was analyzed. Recruitment is a process where new crabs enter the exploitable crab population. This process is highly related to the crab survival from the spawning period until they reach their mature size. [33] also stated that reproduction processes affect the number of individuals entering a water environment that eventually can be exploited. The recruitment of the orange mud crabs in the Aru Islands waters occurred all year long, peaking in February (recruitment 18.53%) (Figure 6). The process declined in March and April, i.e. at 15.02% and 12.05% respectively (Table 3). The peak of the recruitment in this study was different from the data acquired in India waters where the recruitment also occurs all year long but the peak is between June and September, particularly in August [22]. Recruitment is affected by reproduction processes that are influenced by the salinity of the environment [32].

Figure 6. The pattern of orange mud crabs (*S. olivacea*) in Aru Islands waters

This process is also influenced by the crab survival as they migrate to deeper waters to spawn and go back to coastal waters and mangrove forests for food, to take shelter, and to grow into adult crabs. [34] and [35] also stated that crabs only go to the sea during spawning season and they go back to mangrove ecosystems to grow and take shelter.

The exploitation rate (E) of the orange mud crabs is 0.49%, indicating a moderate exploitation state. According to [36], an optimum exploitation rate (E = 0.5) is reached when the fishing mortality (F) is equal with the natural mortality (Z). The species’ moderate exploitation state in Aru Islands waters does not necessarily mean that there is no resource management. When the crabs are exploited extensively without giving them a chance to reproduce themselves, the population will surely decline.
Therefore, proper management efforts and policies are critical to keep the orange mud crabs protected and sustainable in Aru Islands waters.

**Table 3.** The recruitment of orange mud crab (*S. olivacea*) in Aru Islands waters

| Month    | Recruitment (%) |
|----------|-----------------|
| January  | 7.14            |
| February | 18.53           |
| March    | 15.02           |
| April    | 12.05           |
| May      | 13.41           |
| June     | 11.6            |
| July     | 8.85            |
| August   | 2.22            |
| September| 4.86            |
| October  | 2.86            |
| November | 3.47            |

A number of management efforts that can be carried out are disseminating the Regulation of the Minister of Marine Affairs and Fisheries No. 12 Year 2020 stating that crabs to catch should be of minimum 120 mm in size, no female crabs with eggs outside their body are allowed to catch, and only passive fishing methods are permitted. Traditional fishing methods can be used to capture crabs in allowed size for trade that eventually allows young crabs to continue to reproduce. In addition, studies on the species spawning grounds are also important to carry out so as the fishermen do not capture crabs in the spawning grounds and eventually allow the crab population to grow.

The other efforts can come from the government. The Regional Government can implement intensive surveillance on the mangrove forests and rehabilitate degraded lands. Highly dense mangrove forests that are in good condition stimulate crabs to grow and expand their population size. Mangrove forests do not only serve as feeding grounds but also as the place where young crabs or zoea grow into adult crabs. In addition, the government can also promote the development of crab aquaculture to wean off their dependence on natural resources that surely will extinct if they are continuously exploited.

**4. Conclusion**

The carapace width of the orange mud crabs (*Scylla olivacea*) was 110–185 mm and 99.3% of them are above 120 mm. The average carapace width at first capture (CWc) was 137.8 mm. Their growth rate was 0.59 per year and their asymptotic carapace width (CW∞) was 191.5 mm. Their fishing mortality (F) was lower than their natural mortality (Z). Their exploitation rate (E) was 0.49%, indicating moderate exploitation. A number of management efforts are critical as the exploitation was already close to optimum (E=0.5) as well as to keep the crab population sustainable. The efforts are among others regulating that no crabs under 120 mm and no crabs with eggs are allowed to capture; no fishing activities in crab spawning grounds are permitted; and safeguarding and rehabilitating the mangrove forests in Aru Islands.

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