The fishing season and the exploitation status of mud crab (Scylla serrata) in Asahan Sea, North Sumatera, Indonesia

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Abstract. Crab is one of the resources that can be found in almost all areas in Indonesia, and its export increases every year. However, increase in its exploitation and mangrove forest damage affect crab availability. Scylla serrata is one of the crab commodities for export in Asahan sea, North Sumatera. Scientific studies are necessary to determine the fishing season and the exploitation status of crabs in the area. Therefore, this study was carried out for 3 years, i.e. in April–December 2018, February–December 2019, and March–December 2020, at one crab landing site in Asahan. The fishing season for S. serrata in this area occurred all year long, with peak seasons in April–June and September–December. The crab’s carapace width (CW) was 65–175 mm, where 71.2% of which were below 120 mm. Its carapace width at first capture (CWc) increased from 103.2 mm to 112.1 mm. Its fishing mortality (F) was 1.40 per year, higher than its natural mortality (M) (0.84 per year). Therefore, its exploitation rate (E) was 0.63, indicating that the species was already overfished. Suggested measures to control the fishing activity include limiting the crab size for capture in accordance with the Regulation of the Minister of Marine Affairs and Fisheries No. 12 Year 2020 and improving the environment of mangrove habitats.

1. Introduction
Mud crab is a fishery commodity favored by people and widely consumed, both in seafood restaurants and street vendors. The reason is mud crab has a tasty meat and, although its cholesterol level is high, it contains low levels of saturated fat, vitamin B12, zinc, and selenium highly beneficial for the body [1]; [2]. Karim (2005) in [3] stated that crab meat contains 47.5% protein and 11.2% fat, and therefore it is favored by people. It is also an export commodity in overseas markets such as China, Malaysia, and Singapore. According to the Fish Quarantine Inspection Agency (FQIA) of the Ministry of Marine Affairs & Fisheries of the Republic of Indonesia, in 2018, a total of 25,351,249 mud crabs were exported, and in 2019 the number slightly increased to 27,007,144 mud crabs (by 3.2%) and in 2020 it was 28,791,824 mud crabs, meaning that in 2020 there was a 6.2% increase in the mud crab export from the year 2018. In addition, in 2020, there was a 4.5% increase from the year 2018 in the export to the 3 biggest countries (China, Malaysia, and Singapore). The exported crabs are shipped alive as dead crabs have lower taste and price. One of the most traded mud crabs is the species Scylla serrata as it has higher post-capture survival rate as well as distinctive aroma and taste [4].

Market opportunities with high prices have led to many mud crab-related business in Indonesia, such as in Kalimantan (East Kalimantan, South Kalimantan, and North Kalimantan), Sulawesi (South Sulawesi, Southeast Sulawesi, and Central Sulawesi), Java (Subang, Indramayu, Cilacap, Pemalang, Gresik, and Sidoarjo), Sumatera (Riau, Jambi, North Sumatera, and Lampung), Papua, West Papua,
and others [5]. The abundance of the mud crabs in Indonesian seas is supported by the presence of mangrove forests scattered in coastal areas. Mangrove forest is a transitional ecosystem between the land and marine ecosystems, and it becomes the habitat for mud crabs. Almost all of the provinces in Indonesia produce mud crabs, with the exception of Jakarta Province, and the biggest mud crab-producing province is North Sumatera (SATU DATA KKP, 2021). Based on the data, the province produces 40.4% of all the mud crab productions in Indonesia. On the other hand, Central Kalimantan produces 5.9%, East Java 5.5%, and Riau Islands 5.4%. The data suggested that the mud crab exploitation in North Sumatera is high (SATU DATA KKP, 2021).

North Sumatera Province has a total area of 103,415 Ha mangrove forest (1977), while Asahan District has 18,785 Ha or 18.2% of the total mangrove forest and the area continued to decrease by 87.73% to only 2.305 Ha (2006) [6]. However, according to [7] the area of mangrove forest in the district’s coastal area is 4,624.41 Km² or approximately 30.6% of the total area. In addition to intensive exploitation, the decrease in mangrove forest area also affects the life and sustainability of mud crabs. Mangrove forest litters produce detritus that fertilizes soil and serves as the source of phytoplankton lives [8]. Mud crabs favor mangrove forests that still have great roots as they provide shelters and foods for them [9].

The most abundant mud crab species in these seas are the blackish green mud crab (Scylla serrata) and the orange mud crab (Scylla olivacea), and the local fishers often call them the sea and the land crabs. They call S. serrata as the sea crabs because the crabs are more often caught using fish nets around the seafronts. In general, according to [10]. S. serrata characteristics include high, thin, slightly blunt, and round-edged spines at the frontal area as well as two sharp spines at the carpus area. In addition, Purwati et al. (2009) in [2] stated that the species is green with a pair of sharp spines at the ‘elbow’. The species prefers higher salinity compared to S. olivacea. The species S. serrata is able to tolerate high salinity of around 15–30 ppt [11]; [12]. As they prefer estuary area, the species is often caught in mangrove forest areas adjacent to the sea [13].

The sustainability of the crabs in North Sumatera seas, particularly in Asahan, faces challenges that emerge due to fishing activity and the decreasing mangrove forest area. According to [14], uncontrolled fishing and decreasing mangrove forest area lead to a decrease in mud crab population. To keep the resource sustainable, scientific studies are necessary to inform the ecosystem improvement efforts and the mud crab fishing activities. Exploitation without management will only lead to a change in the population structure and it economically affects the mud crab fishers. This study discusses the estimated fishing season and the exploitation status of the mud crab in Asahan sea to inform the management efforts. The estimated fishing season can be used as an insight on when is the optimum fishing time, while the exploitation status can be used as a reference in crab population management efforts. It is expected that the results of this study can provide solutions in the management of the mud crab (S. serrata), particularly in Asahan sea, North Sumatera.

2. Materials and methods

2.1 Data collection

This study was carried out in Asahan sea for 3 years, i.e., in April–December 2018, February–December 2019, and March–December 2020. See Figure 1 for the mud crab’s fishing grounds. The researcher was assisted by an enumerator who collected a time series data from one of the crab collectors. On the other hand, the fishers’ catch data were collected by direct observation of the number and the composition of the catch.

A total of 2,593 mud crabs (S. serrata) were sampled and measured for their carapace width using a caliper with 0.1 mm accuracy. See Figure 2 for the method of measuring the mud crab carapace.
2.2 Data analysis
The catch data were tabulated to determine the fluctuation of the catch and the dominant composition of the catch, including the bycatch. Based on the data, the crab fishing season can be estimated. The catch per unit effort (CPUE) was analyzed by comparing the catch production with the number of fisher trip. On the other hand, the fishing season was analyzed using the moving average method by Dajan (1983) in [15]. The crab fishing season was also calculated using the Fishing Season Index (FSI) by Zulkarnaen (2012) in [16] who stated that FSI < 50% indicates low season, 50% < FSI < 100% indicates moderate season, and FSI > 100% indicates peak season.

The data on the mud crab (S. serrata) measurements were tabulated to determine the distribution of the carapace width structure and the size class interval used was 5 mm. The size of the crabs caught was measured each month to determine the dominant carapace width of the crabs. The distribution of the size structure was used as the basis for determining the carapace width at first capture (CWc). The CWc was analyzed by determining the intersection between 50% cumulative frequency curve and the carapace width of the crabs caught [17].

The growth coefficient (K) and the asymptotic carapace width (CW∞) were determined using the ELEFAN I method assisted by the software FAO ICLARM Fish Stok Assessment Tool (FISAT II). The fish theoretical age when the length is 0 was estimated separately using Pauly empirical equation [18]. In addition, natural mortality rate (M) was calculated using Pauly empirical formula (1980) in [19] and the mean sea surface temperature used was 29°C.

The total mortality rate (Z) was calculated using the catch curve method which was the slope (b) between Ln N/t and the relative age [19]. In addition, according to [19], the fishing mortality (F) was determined by subtracting the natural mortality (M) from the total mortality (Z) (F = Z – M). Finally, the exploitation (E) was compared with the E_{optimum} = 0.5 [20].
3. Results and discussion

3.1 Production and fishing season

The production of the crabs caught in this area was found fluctuating as in 2018 the production was 5,697.811 grams and the number decreased by 37.3% in 2019 to 3,733.224 grams. The production increased in 2020 to 8,586.141 grams (by 56.9%) (Table 1). However, based on the catch composition, the highest production of the *Scylla serrata* was in 2018 (75.5%) and the number decreased in 2019 to 46%, while in 2020 the crab was only 0.6% of the total catch. The decrease in *S. serrata* production was followed by the decrease in *S. olivacea* production. The findings suggested that there has been a decline in *S. serrata* population.

Table 1. The production of the crabs caught in Asahan sea, 2018–2020

|   | Mugilidae spp. | Scienidae spp. | Cynoglossus spp. | Scylla olivacea | Scylla serrata spp. | Eleutheronema spp. | Total   |
|---|----------------|----------------|------------------|----------------|---------------------|-------------------|---------|
| 4 | 13             | 21.35          | 21.55            | 494.4          | 424.15              | 71                | 1045.45 |
| 6 | 2.7            | 15.14          | 23.805           | 102.1          | 533.7               | 16.79             | 694.235 |
| 7 | 8.23           | 19.8           | 35.98            | 46.84          | 707.2               | 31.2              | 849.25  |
| 8 | 9.83           | 25.58          | 38.817           | 43.03          | 449.3               | 31.45             | 598.007 |
| 9 | 13.06          | 15.33          | 23.38            | 29.22          | 699.4               | 25.24             | 805.63  |
| 10| 13.32          | 12.522         | 22.998           | 34.164         | 603.4               | 21.799            | 708.203 |
| 11| 10.81          | 10.15          | 22.154           | 25.026         | 431.48              | 24.85             | 524.47  |
| 12| 6.779          | 7.311          | 16.721           | 13.773         | 341                 | 86.982            | 472.566 |
|   | Total          | 77.729         | 127.183          | 205.405        | 788.553             | 4189.63           | 5697.811 |
| 2 | 10.4           | 14.184         | 32.544           | 80.722         | 236.8               | 32.794            | 407.444 |
| 3 | 13.2           | 13.15          | 16.55            | 64.3           | 95.5                | 16.25             | 218.95  |
| 4 | 13.8           | 13.967         | 25.268           | 141.4          | 237.4               | 18.814            | 450.649 |
| 5 | 11             | 11.611         | 25.767           | 127            | 201.6               | 17.062            | 394.04  |
| 6 | 9.4            | 6.474          | 18.983           | 28.5           | 77                  | 12.855            | 153.212 |
| 7 | 14             | 13.551         | 23.86            | 47.4           | 106.6               | 20.969            | 226.38  |
| 8 | 11.676         | 14.871         | 21.47            | 62.8           | 108.61              | 22.097            | 241.524 |
| 9 | 11.2           | 10.574         | 272.167          | 64.6           | 81.4                | 15.612            | 455.553 |
| 10| 10.8           | 9.792          | 17.957           | 73.6           | 130.2               | 17.866            | 260.215 |
| 11| 10.8           | 14.873         | 19.082           | 179.5          | 239.6               | 22.359            | 486.214 |
| 12| 8.8            | 13.48          | 17.96            | 168.9          | 204.3               | 25.603            | 439.043 |
|   | Total          | 125.076        | 136.527          | 491.608        | 1038.722            | 1719.01           | 3733.224 |
| 3 | 11.08          | 13.71          | 27.85            | 954.8          | 10.51               | 27.41             | 1045.36 |
| 4 | 7.98           | 10.66          | 20.69            | 697.4          | 5.99                | 18.26             | 760.98  |
| 5 | 10.87          | 12.1           | 21.92            | 1124.8         | 6.211               | 14.93             | 1190.831|
| 6 | 10.91          | 45.56          | 21.07            | 1127.8         | 1.26                | 19.65             | 1226.25 |
| 7 | 9.57           | 9.97           | 15.98            | 764.23         | 4.52                | 13.41             | 817.68  |
| 8 | 6.78           | 7.69           | 10.45            | 473.3          | 7.41                | 9.87              | 515.5   |
| 9 | 6.69           | 7.94           | 10.76            | 451            | 2.14                | 8.92              | 487.45  |
| 10| 14.02          | 13.82          | 28.09            | 989.1          | 2.42                | 22.11             | 1069.56 |

[9]
On the other hand, based on the production data, _S. serrata_ decreased significantly, i.e. from 4,189.63 kg in 2018 to only 50.881 kg in 2020. However, as the number of fishing trips was still around 99–170 trips/month (Table 2), the CPUE of _S. serrata_ resource decreased each year. _S. serrata_ exploitation without control changed the population structure, indicated by the CPUE that began to decrease. Such decreasing number of catch can be due to several factors, such as the fishers do allow appropriate timeframe for the mud crabs to survive [21].

### Table 2. Catch per unit effort (CPUE) of _S. serrata_ in Asahan sea, 2018–2020

| Month | Production (kg) | Effort (trip) | CPUE (Kg/trip) | Production (kg) | Effort (trip) | CPUE (Kg/trip) | Production (kg) | Effort (trip) | CPUE (Kg/trip) |
|-------|----------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|
| 2     | 236.8          | 129           | 1.8            | 10.51          | 170           | 0.06           | 5.99           | 159           | 0.04           |
| 3     | 95.5           | 144           | 0.7            | 6.211          | 145           | 0.04           | 1.26           | 119           | 0.01           |
| 4     | 424.15         | 145           | 2.9            | 237.4          | 136           | 1.7            | 6.211          | 145           | 0.04           |
| 5     | 201.6          | 119           | 1.7            | 10.51          | 170           | 0.06           | 6.211          | 145           | 0.04           |
| 6     | 533.7          | 110           | 4.9            | 77             | 95            | 0.8            | 1.26           | 119           | 0.01           |
| 7     | 707.2          | 155           | 4.6            | 106.6          | 150           | 0.7            | 4.52           | 141           | 0.03           |
| 8     | 449.3          | 145           | 3.1            | 108.61         | 145           | 0.7            | 7.41           | 99            | 0.07           |
| 9     | 699.4          | 141           | 5.0            | 81.4           | 137           | 0.6            | 2.14           | 69            | 0.03           |
| 10    | 603.4          | 133           | 4.5            | 130.2          | 142           | 0.9            | 2.42           | 124           | 0.02           |
| 11    | 431.48         | 128           | 3.4            | 239.6          | 145           | 1.7            | 6.65           | 123           | 0.05           |
| 12    | 341            | 99            | 3.4            | 204.3          | 106           | 1.9            | 3.77           | 108           | 0.03           |
| Total | 4189.63        | 1056          | 4.0            | 1719.01        | 1448          | 1.2            | 50.881         | 1257          | 0.04           |

_S. serrata_ fishing season occurred all year long, with peak seasons in (119.7%) to June (142.5%) and September (125.9%) to December (123.5%) (Table 3). The fishing seasons were indicated by the higher number of catch compared to any other time [16], meaning that the catch of the crab fishers during these months was higher than in other months. April–June and September–December were determined as the most optimum months for catching _S. serrata_. However, the size of the caught crabs must be also taken into account to allow them to reproduce.

### Table 3. _S. serrata_ fishing season in Asahan sea, 2018–2020

| Month | FSI (%) | Season     |
|-------|---------|------------|
| 2     | 24.7    | Low        |
| 3     | 59.9    | Low        |
| 4     | 119.7   | Peak       |
| 5     | 90.1    | Moderate   |
| 6     | 142.5   | Peak       |
| 7     | 99.9    | Moderate   |
| 8     | 86.0    | Moderate   |
| 9     | 125.9   | Peak       |
| 10    | 123.4   | Peak       |
| 11    | 104.5   | Peak       |
| 12    | 123.5   | Peak       |
3.2 Size structure and the length at first capture
In general, the size of the mud crab (*S. serrata*) caught in 2018 to 2020 was 65–175 mm, and 95 mm was the dominant size (Table 4). The crab’s dominant size in 2018 was 95 mm, while in 2019–2020 it was 105 mm. The difference in the crab size affected the carapace width at first capture (CWc). The distribution of the carapace width (CW) was relatively similar to the data in 2016, i.e. 85–175 mm [22].

| Month | Range (mm) | Dominant (mm) | Range (mm) | Dominant (mm) | Range (mm) | Dominant (mm) |
|-------|------------|---------------|------------|---------------|------------|---------------|
| 2     | 70–155     | 105           | 90–155     | 110           |
| 3     | 80–160     | 100, 115      | 65–170     | 95–155        | 105–170    | 110           |
| 4     | 80–115     | 100           | 65–170     | 95–140        |
| 5     | 65–165     | 90            | 70–145     | 105–140       | 110–140    |
| 6     | 80–165     | 90            | 90–140     | 95–140        | 110–140    |
| 7     | 90–145     | 90, 120       | 70–145     | 95–145        | 110–145    |
| 8     | 90–160     | 105           | 85–120     | 95–120        |
| 9     | 80–165     | 100           | 95–140     | 120–140       |
| 10    | 80–160     | 115, 120      | 95–150     | 130           |
| 11    | 80–155     | 95            | 95–150     | 140–150       |
| Total | 65–175     | 95            | 65–170     | 105–170       | 105–170    |

The size of the mud crabs caught by gillnets in Kutai National Park waters was 70–142 mm, in Cilacap 32.5–122.5 mm, Pamurbaya, Surabaya 55–135 mm, Pasaman 62–175 mm, and Mayangan, Subang 43–133 mm [23]; [24]; [25]; [26]; [27], and those crabs were smaller than those caught in Aru Islands waters (100–200 mm), Kendari (85–205 mm), and Mahakam (62–183 mm) [21]; [28]; [29]. A total of 71.2% crabs caught in the area in 2018–2020 were below 120 mm although according to the Regulation of the Minister of Maritime Affairs and Fisheries (PERMEN KP) No. 12 Year 2020, the minimum size of crab for consumption is 120 mm. In 2020, the number of mud crabs caught between 120 mm in size was still 10.9%. The mud crabs were caught and passed the Fish Quarantine Station inspection because their weight already met the standard (150 grams) (PERMEN KP No. 12 Year 2020). Although there a regulation is in place on crab weight, crab size should also still be evaluated to avoid young crabs from being caught. The reason was crab weight is also influenced by sex. Male crabs weigh more than the female ones despite having the same carapace width (Chakrabarti, 1981) in [30].

The size of the mud crab (*S. serrata*) at first capture changed, i.e., 103.2 mm in 2018, increased to 112.2 mm in 2019 and decrease slightly to 112.1 mm in 2020 (Table 5). However, the size was still smaller than those caught in the same area (118.6 mm) with the carapace width at first gonad maturity (CWm) 120.6 mm [22]. In addition, [13] stated that the gonad maturity of the crab *S. serrata* is 120–240 mm. Therefore, based on the analysis, in general, the crabs *S. serrata* caught still had immature gonads. If this continues, the crab population would decline as the crabs had yet to contribute to the aquatic environment. Even though in another area the species was found to have its gonad maturity at 109.8 mm [21], it was only due to the difference in the life habitat and food, hence the difference in the gonad maturity. The crab living habitats, i.e. high density and litter-producing mangrove forests, provide abundant macro zoobenthos that help the crabs to have sufficient food [31].

The mud crab’s reproduction takes time as they only spawn after adult female crabs finished molting [30]. This condition affects the production as there is a possibility of adult female crabs but
have not yet spawned being caught. Young crabs up to 80 mm carapace width inhabit intertidal areas, while adult crabs in subtidal [13]. However, according to Sara (1994) in [32], crabs prefer intertidal area with mud substrates. Adult female crabs migrate to a deeper water to spawn, and the juveniles migrate to the upstream of estuary and into mangrove forests to grow into adult crabs [13]; [2]; [25]. This life stage is disrupted due to the destruction of mangrove forest area, leaving young crabs without shelters and unable to protect themselves.

### Table 5. The carapace width at first capture (CWc) of the mud crabs (Scylla serrata) in Asahan, 2018–2020

| Year | CWc (mm) |
|------|----------|
| 2018 | 103.2    |
| 2019 | 112.2    |
| 2020 | 112.1    |

#### 3.3 The population dynamics and the exploitation status

The growth rate (K) of mangrove crabs in this area was 0.66 per year, and their asymptotic size was 183.1 mm. The total length (TL) frequency distribution of the mud crab (S. serrata) in Asahan Sea presented in Figure 3 below indicated that although the crabs have a fast growth rate, over time it will eventually slow down.

![Figure 3. The total length (TL) frequency distribution of the mud crab (S. serrata) in Asahan sea](image)

The time required by the crabs to reach their adult size and asymptotic size was analyzed based on the growth rate. The carapace widths of 1, 2, and 3 years old crabs were 97.3 mm, 138.8 mm, 160.2 mm (Figure 4). To reach the asymptotic carapace width (CW∞ = 183.1 mm), they need to reach 12.5 years old. The age of S. serrata caught in Asahan sea with the maximum carapace width of 175 mm was 1,645 days or 4.57 years. The data suggested that young crabs grew faster than adult crabs. The growth rate of S. serrata in Asahan sea were higher than those in other areas, i.e. at 1.1 year old the carapace width of the crabs caught in Mayangan Subang was 71.88 mm while in Pasaman 87.2 mm [26]; [27]. According to [28], mud crabs have high growth rate when they are young and the rate slows down to reach their asymptotic length.

Growth rate is affected by other aspects, in addition to food, sex, and aquatic environment. This species generally feeds on mollusks and they usually stay still, according to Hill (1976) in [12]. This causes the crabs to stay in their burrows more often and are affected by their environment to survive. In general, the temperature in Asahan sea was 29.27–31.09°C, a suitable temperature for the crabs as the best temperature for S. serrata to grow fast from stadia into young crabs is 28–30°C [33]; [34]. On the other hand, Cholik (1999) in [35] stated that crab growth is slow in a temperature below 20°C. In addition, Zacharia et al. (2004) in [31] also stated that temperature is a determining factor for the oxygen and food consumption activities of every aquatic biota.
In addition to temperature, salinity is also closely related to mud crab growth rate as stated by Gunarto et al. (1987) in [36] that salinity of 30–32 ppt will slow the growth rate. However, according to [32], S. serrata is able to tolerate salinity >28 ppt. As stated by [37], the salinity in Asahan sea was only 21–25.4 ppt, unsuitable for ideal growth. Salinity is also a determining factor for the survival of crab as an aquatic organism [3].

Based on the growth rate (K) and the asymptotic width (CW∞) of S. serrata, its natural mortality (M) was 0.84 per year with total mortality (Z) 2.23 per year. Natural mortality is also caused by the environment of the living habitat because unsupportive environment forces the crabs to migrate or die. According to [19], natural mortality (M) is not related to death due to old age only, but also more related to the carrying capacity of the environment. [12] added that it is crabs’ nature to create burrow and hide in the mud where they live permanently when sufficient food is available, otherwise they will search another location. Natural mortality rate (M) indicates the ability of an environment in allowing mud crabs to survive.

From the analysis, the fishing mortality (F) was 1.40 per year, higher than the natural mortality (M). High fishing mortality (F) is due to the intensive fishing by the fishers to meet the market demands. The fishing mortality (F) was then used to analyze the exploitation status. In Asahan sea, the exploitation status (E) of S. serrata was 0.63%, meaning that the crabs were already overfished. The overfishing was already 13% compared to [20] E = 0.5.

The management efforts that can be carried out include reducing the current efforts by 26% by putting in place a limitation on fishing gears and fishing ground as well as improving the ecosystem. The fishing gears can be limited by reducing mesh size as well as reducing the number of the crab fishers. However, reducing the number of crab fishers should be followed by providing solution, i.e. other fishing gears used to change their activities from the crab fishers to fish- or small crab fishers. Fisher’s adherence to policies is closely related to their socio-economic aspects, their perception of ideal fishing gears, and resource availability [38]. This means, information should be disseminated to fishers, elaborating that the policies are in place to improve the resources because the decline in the crab catch is closely related to their small size and young age and therefore the crabs have yet to contribute to the environment.

Maintaining the sustainability of mud crabs means maintaining their population by regulating the fishing activities as well as maintaining mangrove forests to continue as their habitats [39]. The sustainability of mangrove forests is maintained as they serve as nursery, feeding, and shelter areas for young crabs to maintain their population [24]. In Asahan sea, the mangrove forest changed from 15,563 Ha in 1997 to completely vanished in 2006, changing it from a primary mangrove forest to a secondary one [6]. This change surely affected the population of the mud crab because their habitat was damaged and the mangrove area declined. Although S. serrata has a large movement area to the sea [36], they still require mangrove forest as their rearing area.
A sustainable fisheries management requires all elements to work together to sustain the resource. The government as the fisheries managing party can disseminate the information to and involve fishers in conservation efforts. Such management also requires evaluating the fishers’ responses because they must be able to understand the policies in place [38]. The participation of the communities around the mangrove forests in maintaining the sustainability of the forests will increase their productivity without compromising their local wisdom [14]. Maintaining the sustainability of the mangrove forest in Asahan sea is imperative as the fishers depend on the forest as the habitat for the mud crabs. The forest can be revitalized to increase economic benefits for the communities around the forest, particularly the crab fishers [40]. A sustainable fisheries resource management requires synchronous biological, fishing, environmental, and economical aspects to develop policies to control the exploitation. The sustainability of the mud crab S. serrata can be maintained by exploiting it without exceeding the carrying capacity of the resource and environment.

4. Conclusions
The fishing seasons for the mud crab Scylla serrata in Asahan sea were April–June and September–December. The crab’s carapace width (CW) was 65–175 mm, where 71.2% of which were below 120 mm. Its carapace width at first capture (CWc) increased from 103.2 mm to 112.1 mm. Its fishing mortality (F) was higher than its natural mortality (M), causing the exploitation status (E=0.63) high (overfishing). The suggested management effort includes reducing the fishing efforts by approximately 26% to improve the mangrove ecosystem.

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