Risk based framework analysis for sustainable management of mud crab *Scylla* sp of Kotania Bay, Western Seram, Indonesia

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**Abstract.** The mud crab *Scylla* sp. fishery of Kotania Bay, Western Seram District has been conducted for many years starting from 1980 with almost no management. Mud crab is one of the economic important fish resources from this area. The mud crab is harvested by local fishermen that are classified as artisanal fishermen. The fishermen depend on the mud crab as their source of income. Economic pressure, available market, and no proper fisheries management create the fishery under extensive exploitation. A study on risk potency and stock parameter of mud crab *Scylla* sp. was conducted from June to August 2019. The objectives of this study were to analyze the risk potency and stock parameters of this fishery. The productivity Susceptibility Analysis (PSA) approach was used to analyze the risk potency of the mud crab, while Schaefer dynamic model was used to analyze stock parameters of the fishery. The result showed that the risk potency from fishing gear towards *Scylla* sp., bait-fish, and habitat was unconditionally passed according to MSC criteria with a score of 89, 95, and 85 consecutively. The result on stock parameters showed that there is a strong and negative relationship between effort and CPUE ($r = 0.8997$), the mud crab production has exceeded MSY as a reference point and tends to decrease, whereas average fishing effort was 198 units and already passed the fMSY of 130. All these stock parameters suggested that the mud crab fishery of Kotania Bay was in overfishing condition.

1. Introduction

The mud crab of genus *Scylla* spp. has been harvested by many small-scale coastal fisheries in the tropics and sub-tropic of the Indo-Pacific region. This mud crab represents a valuable component for many fishermen living in the coastal area that mostly artisanal fishermen [1, 2, 3]. Mud crab production on the global scale has been increasing as a result of the development of hatchery production. In Asia and African countries, in 2008 the production amounted to 18,000 t and has been predicted to increase [3].

Despite an increase in mud crab production reported, an attempt has also been made to increase the sustainability of this fishery. This is because in some parts reported have shown the indication of over-exploitation towards mud crab resources [4, 5]. On the north coast of Java [6], Western Seram District [7, 8], Southeast Maluku [9, 10], a sign in mud crab production decline was also reported. Mud crab fishery from Kotania Bay area has been exploited by local fishermen since 1980 (personal communication) with almost none management regulation. The decline in the number of mud crab harvested and individual body size reduction was also reported in this area [11, 12].

Sustainable fisheries management through the ecosystem approach requires a substantial and good quality of data [13, 14]. In the case of mud crab fisheries management in Kotania Bay and its surrounding area, the availability of good quality data for sustainable management is lacking. Qualitative analysis such as Ecological Risk Assessment for the Effects of Fishing (ERAEF) [15, 16], Rapfish analysis [17] and Risk-Based Framework analysis [17, 18] was developed to assess sustainability condition of...
fisheries resources of poor data situation. The objectives of this study, therefore, to analyze the risk potency and some population parameters of mud crab *S. serrata* of Kotania Bay.

2. Material and Methods
The study was conducted between June to August 2019 at Kotania Bay waters covers the villages of Kotania, Wael, and Taman Jaya (Figure 1). The sustainable status of *Scylla* sp. was analyzed based on some fish stock parameters using the Schaefer according to [19, 20, 21]. Data on mud crab production was obtained from local marine and fishery agencies, mud crab trade collectors, and interviews with local mud crab fishermen. The risk potency analysis of the mud crab fishery, the bait fishery, and habitat arise from the fishing activity was conducted using the Productivity Susceptibility Analysis (PSA) approach [18, 22, 23, 24, 25, 26] of the MSC Ver. 2.1 which was running under Microsoft Excel [23]. Data for PSA was obtained from secondary data and other relevant literature.

![Figure 1. Map of Kotania Bay showing study site.](image)

3. Results and Discussion

3.1. Risk potency analysis

3.1.1. Risk potency for mud crab. PSA was developed to analyze the ecology risk potency of fishing gear towards target species, baitfish, and habitat. Variables that assess the ecological risk incorporate productivity parameter covering average age of maturity, average maximum age, fecundity, average maximum size, average size at maturity, reproductive strategy, and trophic level, whilst susceptibility covers availability, encounterability, gear selectivity, and post-capture mortality [19, 27].

In this analysis, species target is mud crab of the genus *Scylla* sp., non-target species (baitfish) i.e. lethrinid, snappers (*Lutjanus* sp.), mullets (*Mugil* sp.), and rays fish, and the habitats are mangrove ecosystem and bait fishes habitat. Traditional mud crab pot called *bubu* is the only fishing gear used in this fishery, whilst gear used for baitfish is gill net and hand line.

From PSA for risk category of mud crab fishery of Kotania Bay shows low-risk category (Tabel 1). This analysis suggests that the risk potency from fishing gears towards mud crab fishery was considered low [27, 28]. Table 1 shows that final MSC score was 89 which was greater than MSC scoring guidepost [23]. Low risk category from collapsible mud crab trap was also reported from a study in Australia [29, 30]. This suggests that the risk potency from fishing gears towards mud crab fishery was considered low.
3.1.2. Risk potency for bait fishery. The risk potency analysis (PSA) for these four baitfish species shows that the risk potency category for those species was considered low (Table 2). Very little information on the status of baitfish in mud crab concerning gear effect. A study by Fikri et al [10] at Southeast Maluku, Indonesia, and Banks and Leadbitter [30] at Philippine, however, shows low and medium risk respectively to bait fishes used related to gear used.

Table 2. Final recapitulation of PSA results for bait fish risk potency from hand line and gill net used in mud crab fishery.

| Component                        | Gill net | Hand line |
|----------------------------------|----------|-----------|
|                                   | Lethrinus sp | Lutjanus sp | Mugil sp | Dasyatidae | Lethrinus sp | Lutjanus sp | Mugil sp | Dasyatidae |
| MSC PSA-derived score            | 94       | 95        | 96       | 92         | 94          | 94          | 95       | 93         |
| Risk category name               | Low      | Low       | Low      | Low        | Low         | Low         | Low      | Low        |
| MSC scoring guidepost            | ≥80      | ≥80       | ≥80      | ≥80        | ≥80         | ≥80         | ≥80      | ≥80        |
| Finas MSC score (per scoring element) | 89       | 89        | 89       | 89         | 89          | 89          | 89       | 89         |

3.1.3. Risk potency for habitat. Risk potency analysis for habitat covers mangrove area as mud crab habitat and coastal area for baitfish habitat. Table 3 shows CSA (Consequence Spatial Analysis) results for risk potency on mangrove habitat and coastal area of Kotania Bay of Western Seram. From this table, it was clear that mud crab pot (bubu) has a low impact on mangrove habitat. In mud crab harvesting with pot trap (bubu), fishermen deploy the trap in the creek area within the mangrove ecosystem and covered it with some mangrove leaves. This kind of harvesting technic do very little impact on the mangrove ecosystem. Bait fishing using hand lines and gill net also has a low impact on coastal areas.

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Table 3. Final recapitulation of CSA results for fishing gear risk potency towards habitat in mud crab fishery.

| Component                        | Bubu | Gill net | Hand line |
|----------------------------------|------|----------|-----------|
|                                   | Mangrove | Coastal area |           |
| MSC CSA-derived score            | 89   | 88       | 90        |
| Risk category name               | Low  | Low      | Low       |
| MSC scoring guidepost            | ≥80  | ≥80      | ≥80       |
Table 4 shows the conclusions from Risk-Based Framework using PSA and CSA approach to assessing Performance Indicator (PI) of species target (PI 1.1.1.), species non-target, in this case, baitfish, (PI 2.2.1.) and effect of fishing gear on habitat (PI 2.4.1.) at Kotania Bay waters. This table reveals that performance indicator (PI) for species target, baitfish, and impact of fishing gear on the habitat of mud crab at Kotania Bay was unconditional pass according to MSC standard [28].

Table 4. Final result of risk potency analysis for mud crab fishery of Kotania bay, Western Seram

| PI       | Automated MSC score | Status  | Explanation         |
|----------|----------------------|---------|---------------------|
| 1.1.1    | 89                   | Unconditional pass | Species target      |
| 2.1.1    | FAIL                 | FAIL    | Species primer 1)   |
| 2.2.1    | 95                   | Unconditional pass | Species non-target  |
| 2.3.1    | FAIL                 | FAIL    | Species ETP 2)      |
| 2.4.1    | 85                   | Unconditional pass | Habitat             |

1) Retain species (not analyzed);  
2) ETP (not analyzed).

3.2. Stock status
Mud crab Scylla sp fishery in Kotania Bay waters has been conducted from 1980 according to local mud crab fishermen. From an interview with local mud crab fishermen, the number of mud crab fisher at that time was very few with only a small amount of mud crab pot, locally called bubu. As time pass, the number of mud crab fisher and bubu increased quite substantially. Using secondary data from Western Seram Marine and Fishery agencies, mud crab trade collector, and interviewed with local mud crab fisher, the production of mud crab Scylla sp. from 1990 to 2018 is shown in Figure 2. This figure shows that mud crab production (kg) tends to decline with fluctuating effort but tends to increase over time. No data was available for the beginning of this fishery but according to local mud crab fisher, the production was higher in early 1980. One mud crab pot can catch 2-3 individuals in the early 1980 and the fisher deployed the trap twice a day some time, but this is rarely happening right now.

![Figure 2. Mud crab production and number of effort](image)

Based on data obtained, an analysis was conducted to see the CPUE for this fishery over time. Figure 3 shows the CPUE of mud crab fishery from Kotania Bay from 1990 to 2018. The CPUE of this fishery decreased from time to time. Condition, where the CPUE decrease even though there is an increase in effort, is a sign of overfishing [20, 21, 24]
The Schaefer model was performed to analyze the relationship between effort and CPUE of this fishery and Figure 3 shows the result of that relationship. This figure shows that there is significant relationship between number of crab pot (effort) with CPUE ($F_{calc} = 114.75 > F_{crit} = 0.0000$) with high correlation coefficient ($r = 0.8997$). This relationship suggests that overfishing in this fishery has occurred since the increase in effort causes a decrease in CPUE [20, 24].

![Figure 3. CPUE of mud crab fishery over time](image)

Based on the relationship equation between effort and CPUE (Figure 4), the MSY of this mud crab, therefore, was 45,642.32 kg yr$^{-1}$. In the harvest control rule, the MSY is used as a reference point and fish production should not exceed the reference point [25, 26]. Data obtained from this study show that in 1990, mud crab production was 59,920 kg yr$^{-1}$ and already exceed the reference point.

![Figure 4. Relationship between effort (trap) and CPUE](image)

The analysis on optimum fishing ($f$ MSY) shows that the $f$ MSY is 129.63 and from data obtained concerning the effort (Figure 1), it was found that by 1994 the effort was 138 units and already exceed the $f$ MSY. Results on the relationship between effort and CPUE, reference point and mud crab production as well as optimum fishing indicate clearly that the fishery of mud crab Scylla sp. at Kotania Bay is already under overexploitation condition.
4. Conclusion.
From this study, it can be concluded that risk potency from risk potency that arises from fishing activity had a low impact on mud crab, bait-fish, and habitat with MSC score 89, 95, and 85 respectively. A study on mud crab stock parameter shows that CPUE had decreased with an increase of effort, the production had declined, and the average fishing effort (198 unit) had pass f MSY (130 unit) and these findings suggested that the mud crab fishery at Kotania Bay already at overfishing status.

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