Resource domain assessment of the mud crab (*Scylla* spp.), based on an ecosystem approach to the fisheries located within the Mojo mangrove ecosystem, Pemalang Regency, Central Java, Indonesia

[1,2]Trisnani D. Hapsari, [2]Azis N. Bambang, [3]Abdul Ghofar, [2]Aristi D. P. Fitri

[1] Coastal Resources Management, Faculty of Fisheries and Marine Sciences, Diponegoro University, Tembalang, Semarang, Central Java, Indonesia; [2] Department of Capture Fisheries, Faculty of Fisheries and Marine Science, Diponegoro University, Tembalang, Semarang, Central Java, Indonesia; [3] Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Diponegoro University, Tembalang, Semarang, Central Java, Indonesia. Corresponding author: T. D. Hapsari, trisnanihapsari@live.undip.ac.id

Abstract. Fishing activity for mud crabs in Pemalang Regency has immensely increased since the mud crab fattening farming business and soft-shell crab culture activities were extensively developed in Mojo Village in 2005. The implementation of proper management practices needs to be conducted for the sustainability of mud crab fishery. The purpose of this study was to assess the resource domain status of the mud crab fishery performance using the Ecosystem Approach to Fisheries Analysis (EAFA) and to determine the tactical decisions in order to improve their management. The results indicated that the status of the mud crab fisheries in Mojo Village mangrove ecosystem is in a moderate condition. There are 4 management indicators that need improvement: CPUE, exploitation rate, size of mud crabs and range collapse of mud crab resources. Management improvement actions include: 1) documenting, applying regulations and controlling mud crabs fishing activity; 2) educating fishermen about the minimum size of mud crab that is allowed to be caught, encouraging them to comply with the Ministry of Marine Affairs and Fisheries regulation No. 12 Year 2020 and activating the role of a Community Surveillance Group; 3) establishing a mud crab conservation area and proceeding to a habitat rehabilitation.

Key Words: sustainability assessment, EAFA indicators, mangrove crab, fisheries management.

Introduction. Mud crab/mangrove crab (*Scylla* spp.) is a fishery product with high economic value. Indonesian mud crab fishery products are exported to various countries in the world, including: China, United States, Europe, Japan, Singapore, Taiwan, Hong Kong and Malaysia (Central Bureau of Statistics 2018). A total of 25,345,749 mud crabs were exported from Indonesia in 2018, increasing in 2019 to 26,982,759.20 crabs (Fish Quarantine Agency, Quality Control and Safety of Fishery Products 2020).

Pemalang Regency is one of the areas situated along the north coast of Central Java which has the potential for mud crabs, since it has a mangrove ecosystem. Mojo Village in Pemalang Regency is the center of the soft-shell crab culture. There are 6 ponds with an average area of 0.5 ha pond^{-1} and the production of crabs is of 2,000 kg month^{-1} pond^{-1} on average in this village (Farhaby 2017). The total volume of the mud crabs caught by fishermen in Mojo Pemalang Village is estimated to 44.1 tons year^{-1} with USD 784,512,029.81 total annual income and the contribution value of the Mojo Village mangrove ecosystem from soft-shell crab culture is USD 5,595,985.34 year^{-1}, as stated by Purnamawati et al (2015).

The high demand for mud crab resources to meet domestic and foreign market needs causes the exceedingly increasing exploitation of mud crab resources in the

nature. According to the Ministry of Marine Affairs and Fisheries Decree No. 79 of 2016 concerning the Fisheries Management Plan for the Fisheries Management Area/FMA 712 of the Republic of Indonesia, the crab resources in FMA 712 have been over exploited with a utilization rate of 1.28. Such a pressure will harm the sustainability of mud crab resource (Partelow et al 2018; Côrtes et al 2019).

Most mud crabs exploitations in the mangrove ecosystem of Mojo Village do not respect the Regulation of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia No. 12 of 2020. The regulation states that mud crabs can be captured if the carapace width of the crabs caught is >12 cm, but the catch of mud crab in the Mojo mangrove ecosystem is mostly for the needs of soft-shell crab culture with ≤12 cm carapace width and an egg-bearing female mud crab (Hapsari et al 2020). Another problem causing the vulnerability of the mud crab resources is the abrasion, which has shrunk the mangrove area in the Mojo Village (Renta et al 2016; Muali et al 2020). The mud crab population depend on mangrove forests in good condition, thus the damage to the mangrove forest areas will affect the habitat of the mud crab populations.

Based on the Regulation of the Minister of Marine Affairs and Fisheries No. 9 of 2015, the Ecosystem Approach to Fisheries Management (EAFM) is formulated as a management approach focusing on the importance of governance linkages in the aspects of bioecology, fisheries technology, social, economy and institutions. This study aimed to evaluate the Mojo Village resource domain's sustainability status mud crab fisheries located within the mangrove ecosystem. The results obtained by conducting the study assessing the current condition of the resources are expected to formulate the management and improvement action plan for the sustainability of mud crab fishery in Mojo Village.

Material and Method

Description of the study sites. This research was conducted from October 2018 to March 2019 in the mangrove ecosystem area of Mojo Village, Ulujami Subdistrict, Pemalang Regency, Central Java Province, Indonesia. The location of this study is presented in Figure 1.

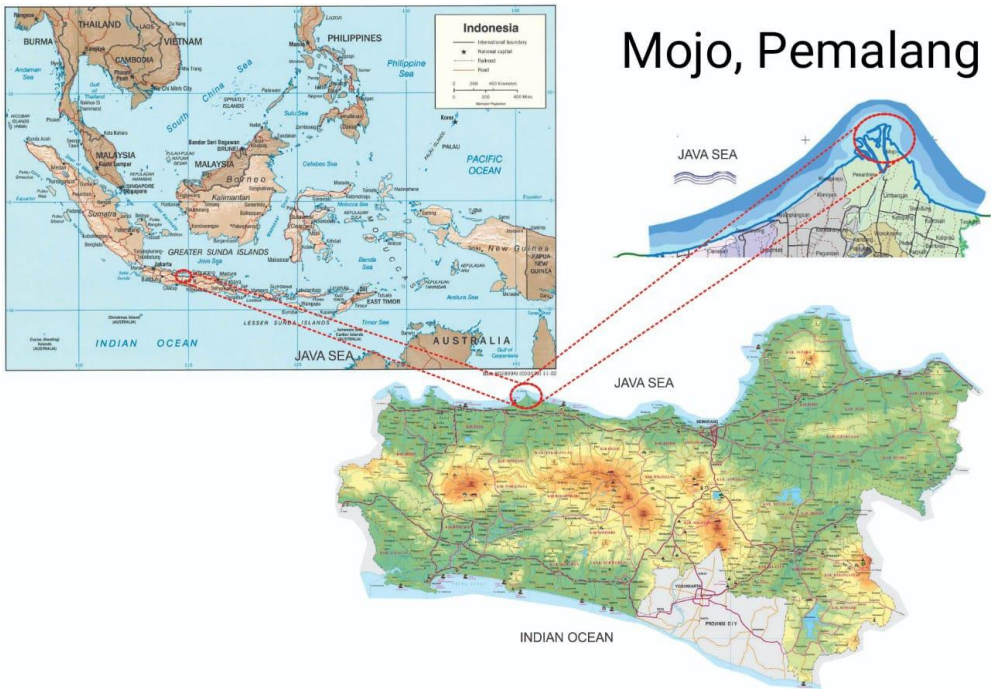

Figure 1. Mangrove ecosystem area in Mojo Village, Pemalang, Indonesia.

Data collection. The current study used primary and secondary data. Primary data were obtained through surveys, direct observation and in-depth interviews. Moreover, data of mud crab production were obtained from purchasing data given by mud crab collective

traders. The data collected in this study included Catch Per Unit Effort (CPUE) trends, exploitation rate, trends in mud crab size and proportion of juveniles caught, catch species composition, range collapse (reduction of marine ecosystem spatial space in mud crab resource stocks), and Endangered, Threatened and Protected (ETP) species. The indicators, criteria and data collection methods for the Ecosystem Approach to Fisheries Analysis (EAFA) from the resource domain are shown in Table 1.

Table 1

Indicators, criteria and data collection methods

Indicators	*Criteria*	*Data collection methods*
CPUE standards	1 = sharply decreasing (average decline >25% year^{-1}) 2 = slightly decreasing (average decline <25% year^{-1}) 3 = stable or increasing	Production data from the data of mud crabs sales to collector traders and from the results of previous studies
Exploitation rate	1 = value of E>0.5 2 = value of E=0.5 3 = value of E<0.5	The exploitation rate is calculated based on the carapace width data of the mud crabs. The calculation uses the FISAT II program
Trend of mud crab size	1 = trend of average size caught becomes smaller 2 = trend of size is relatively constant 3 = trend of size becomes bigger	Interview and sampling on sizes of mud crabs caught
Proportion of juveniles caught	1 = abundance (>60%) 2 = a large amount (30-60%) 3 = a small amount (<30%)	Interview and observation
Composition of species caught	1 = proportion of target is less (<15% of the total volume) 2 = proportion of target is similar to non-target (16-30% of the total volume) 3 = proportion of target is greater (>31% of the total volume)	Interview and observation
Range collapse	1 = mud crabs get more difficult to find 2 = relatively constant 3 = mud crabs get easier to find	Interview
ETP Species	1= caught some ETP species individuals but not released 2 = caught but released 3 = no ETP species were caught	Interview

Analysis. The sustainability status of mud crab fisheries was analyzed using EAFA indicators assessment. The data collected refer to National Working Group of Ecosystem Approach to Fisheries Management module (National Working Group EAFM 2014). The analysis in this study is focused on fish resource domain. The evaluation of EAFA indicators uses a multi-criteria approach which leads to a composite index related to the achievement level of a fisheries management based on EAFM principles (Adrianto et al 2014; Elvarsson et al 2020). In addition, a flag modeling technique is carried out using multi-criteria analysis (MCA), where a set of criteria is defined as the basis for analyzing the performance of fisheries management in an area using EAFA, through the development of a composite index with the following stages (MMAF 2014; Pregiwati et al 2015; Edwarsyah et al 2017; Rehatta et al 2020):
1) Defining criteria for each indicator in the fish resource domain;

2) Providing score (scoring) for each indicator's performance using the Likert scale based on 3 ordinal categories;
3) Determining the weight of each indicator.

The CPUE standard is the most important of the six indicators in fish resource domain with 25% weight value. Then, it is followed by the other indicators respectively, i.e. exploitation rate (20%), the trend of mud crab size (15%), the proportion of juvenile caught (15%), species composition (10%), range collapse of mud crab resources (10%) and ETP species (5%). For the composite assessment, for each of the j domain (C_{at-1}), the following formula was used (Adrianto et al 2014; Rehatta et al 2020):

$$Cat - 1 = Sai \; x \; Wi \; x \; Di$$

Where:
C_{at-1}- total EAFM value of one attribute in the domain;
S_{ai} - score of the i attribute;
W_i - weight of the i attribute;
D_i - density of the i attribute.

An aggregate composite index is developed for all domains in the evaluated fishery unit. The total of each assessed indicator is then analyzed using a simple composite analysis based on the arithmetic mean. This composite index is the conversion value of the total value of each EAFA domain. The composite value is determined from the mean value of all the domains studied in the EAFM area. The multiplication of the attribute score and the density score will give the value or weight of each attribute as a whole. These results are then inputted into the attribute aggregate value. The aggregate composite value can be formulated as follows (Adrianto et al 2014; MMAF 2014):

$$Nk - i = \frac{\frac{\text{Cat} - 1}{Cat - imax} x100}{N}$$

Where:
Cat_{-I} - total EAFM value of one attribute in the domain;
Cat_{-imax}- maximum value of one attribute in the domain which is obtained when all attributes has score of 3;
N- the number of domains in EAFA.

The aggregate attribute value is then converted into a value with a scale of 1-100. The aggregate with 100 value is categorized as the highest aggregate or it shows the best condition in the area and the lower values are classified as the least/the worst conditions in the area. The previously mentioned aggregate scores are described into 3 categories. These three categories represent 3 levels of status from the EAFA domain of an area and are presented in the form of a flag model as shown in Table 2.

Table 2
Composite index value classification and flag model visualization for EAFM assessment

Score	*Composite value*	*Flag model*	*Description*
1.00–1.50	33.33-55.55		Poor
1.51–2.50	55.56-77.77		Moderate
2.51-3.00	77.78-100		Good

Modification from Adrianto et al (2014); Muis et al (2020).

Results and Discussion

CPUE standard. CPUE analysis was conducted on data obtained from traders who received the crabs from mud crab collector/fishermen, documented from January 2017 to

December 2019. The data of catch production used were data of mud crab purchasing from fishermen. The average CPUE each month is shown in Figure 2.

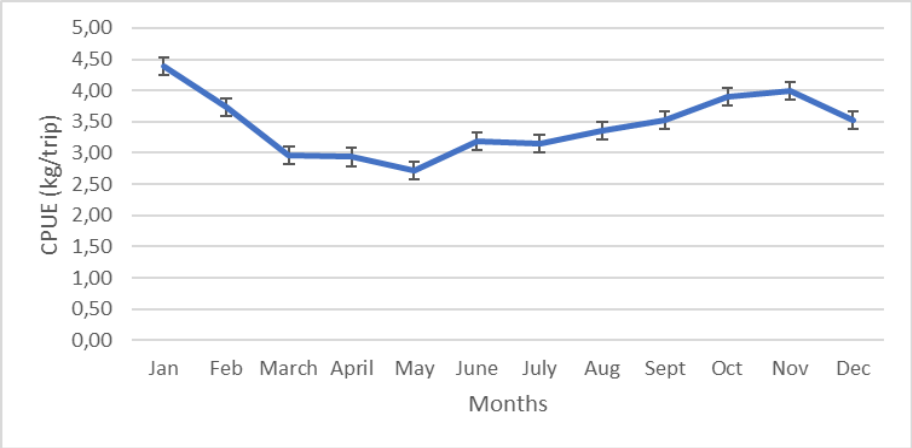

Figure 2. Monthly average changes in mud crab CPUE score.

The score of the CPUE indicator obtained was 2. This shows that there has been a slight decrease (<25%) in the CPUE of mud crabs in the mangrove area of Mojo Village. In addition, this score was obtained for the CPUE calculations from 2015 to 2019 when there was a decrease in CPUE by 19% in 2016 and 11% in 2017. Moreover, there was a slight increase in CPUE in 2018 by 7% due to a 7.8% decrease in fishing effort (Figure 3 and Figure 4) and there was another 8% decline in 2019.

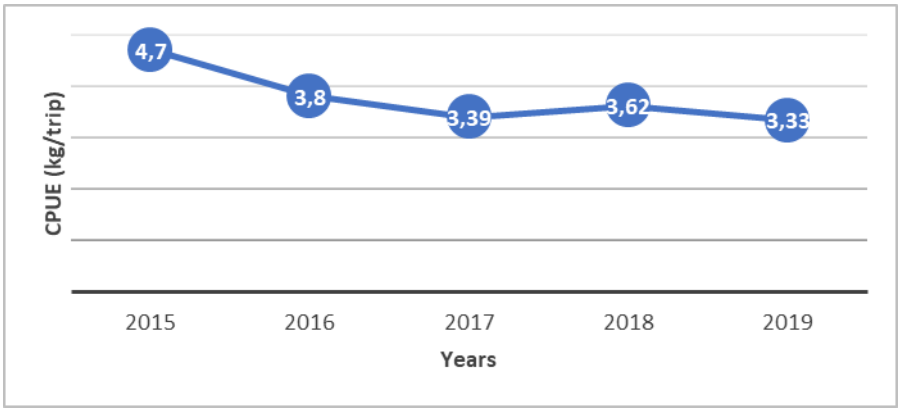

Figure 3. Average CPUE from 2015 to 2019. CPUE 2015 (Purnamawati et al 2015); CPUE 2016 (TAKA Fondation 2016).

Mud crab production data for the period 2017-2019 show fluctuation over months (Figure 4). Fishing effort began to increase in December along with the start of monsoon (western wind) season. Besides, anthropogenic pressure on mud crab resources in Mojo mangrove ecosystem increases during the western season (rainy season), since the mud crabs are in reproductive phase during the rainy season (Viswanathan et al 2019; Ali et al 2020). In addition, during the western season, the number of fishermen catching mud crabs in mangrove ecosystems and ponds increases due to high rainfall accompanied by strong winds and storms the sea fishing (Hapsari et al 2020). In February 2018, during the mud crab harvest season, there was a 22% decline in production, compared to the previous year, due to the tidal flooding that often hit the northern coastal waters, especially during the peak of rainy season. The total fishing effort decreased by 7.81% in 2018 and 6.48% in 2019. Catches also decreased by 10.39% in 2018 and 9.96% in 2019. These data show that there has been a degradation in the mud crab fishery in Mojo Village, over the last few years, which has caused a decrease in CPUE, as well as a

decrease in effort (number of trips) in the last 2 years, particularly from August to December.

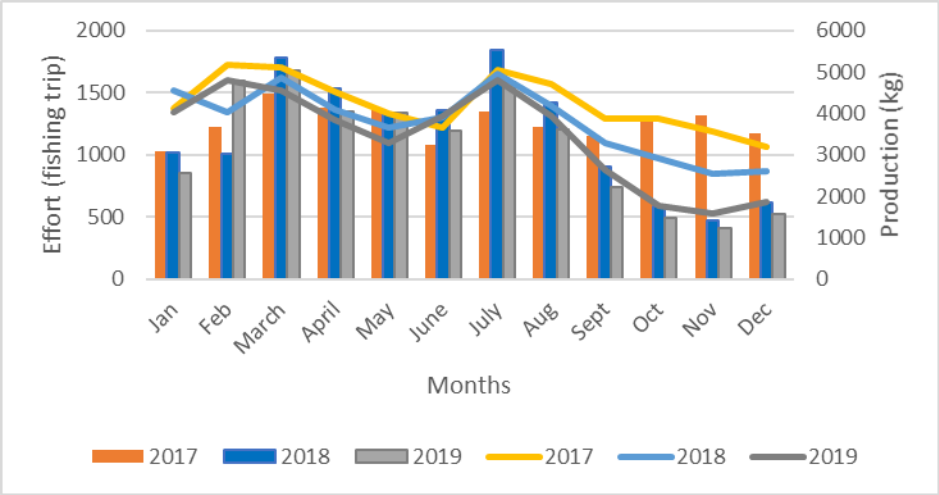

Figure 4. Total effort and production from year 2017 to 2019.

Exploitation rate (E). The value of the exploitation rate (E) of the mud crabs was obtained from the mortality analysis based on the size of the mud crabs caught. The exploitation rate limit is 0.5 (Pauly 1987; Sparre & Venema 1999). E>0.5 means that the mud crabs caught exceeded its sustainability limit. The exploitation rate indicator assessment score is: 1 for E>0.5, 2 for E=0.5 and 3 for E<0.5. The exploitation rate of male crabs is 0.6 year^{-1} and for female crabs it is 0.56 year^{-1}. Based on the value of the rate of exploitation, it is known that male and female crabs exceed the optimal exploitation value, which means that the mud crabs in the Mojo mangrove ecosystem have indicated an over exploitation, with an indicator score of 1.

Trends in fish size. The sample of mud crabs measured in this study consisted of 1,109 male crabs and 1,009 female crabs. More males than females were found probably due to migration patterns after mating. Female crabs migrate to the sea to lay eggs, while male crabs tend to settle in the mangrove area, thus the chance of being caught is greater (Sara et al 2014; Yudiati et al 2020; Ali et al 2020). According to the measurement results, the carapace width (CW) of mud crabs caught ranged from 50-136 mm (male) and 52-130 mm (female), with weights ranging between 60-417 g (male) and between 75-328 g (female). In 2013 the mud crabs caught from Mojo Mangrove Ecosystem had a minimal weight of 106 g (Faraby et al 2013) and the mud crabs caught in 2015 by Mojo Village fishermen had a carapace width ranging from 75 to 134 mm and a minimal weight of 82 g (Faraby 2017). Based on the data and information obtained, it can be noticed that there is a decreasing trend in the catch size of mud crabs. Thus, this indicator's score was 1.

Based on the assessment/identification guidelines on the types of fish with restricted capture (*Scylla* spp.), it is stated that female crabs reach maturity when the carapace width is between 80–120 mm, while male crabs become physiologically mature at a 90–110 mm carapace width (Fish Quarantine Agency, Quality Control and Fishery Products Safety 2016). Sianturi et al (2016), in his study conducted in Sicanang Mangrove Forest Area, Belawan, North Sumatra, stated that mud crabs are said to be sexually mature if they have more than 100 mm carapace width and mud crabs on the North Coast of Java are physiologically mature at carapace widths between 91 and 100 mm (Tiurlan et al 2019). The carapace width of the mud crabs at the research location was dominated by sizes ranging from 71 to 77 mm (females) and from 78 to 83 mm (males). Therefore, it can be concluded that the majority of mud crabs caught were in the category of functionally immature genitals. However, there are type differences depending on the geographic area (Meynecke & Richards 2014; Hubatsch et al 2016; Indarjo et al 2020).

According to Yudiati et al (2020), the smaller size in the waters around Java Island is thought to be due to the low availability of food in nature and to the greater fishing pressure on the mud crab resources.

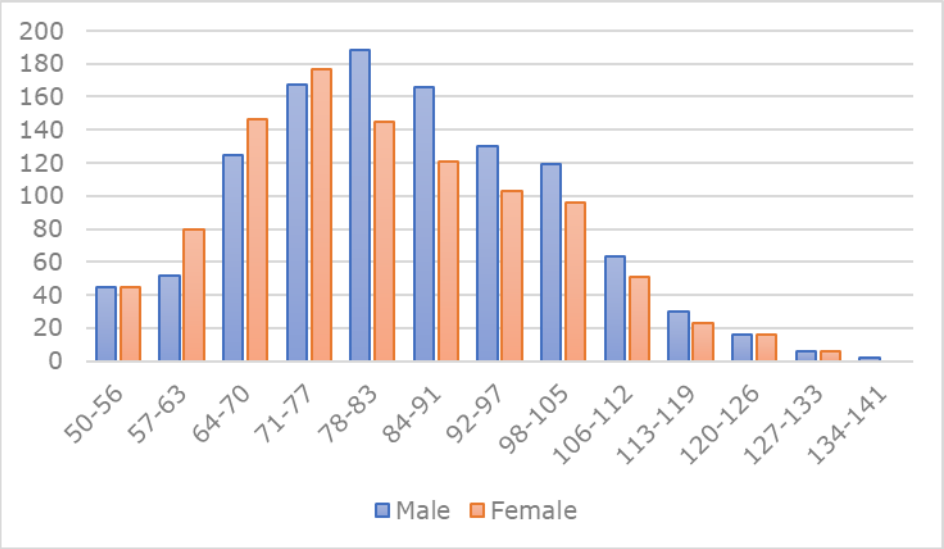

Figure 5. Frequency distribution of the size of carapace width of *Scylla* spp.

Juvenile proportion caught. The frequency of carapace width in this study is also classified based on three phases, i.e. juvenile, young crabs and adult crabs (Sara et al 2007; FAO 2011; Fitri et al 2018). As stated by Sara (2010), the carapace width in the juvenile phase is <70 mm, in the young phase it is from 70 to 120 mm and >120 mm in the adult phase. From the results of the classification into these 3 phases, it was found that the mud crabs (*Scylla* spp.) caught in the Mojo Village mangrove ecosystem in the adult phase were 1% males and 2% females, with a maximum carapace width of 136 mm and 130 mm, respectively. Moreover, 81% of the males and 74% of the females caught were in their young phase. Meanwhile, the juvenile individuals caught were 18% (male) and 24% (female) (Figure 6). Based on these findings, the score for this indicator was 3. Nevertheless, the results of the analysis show that only a small portion of the caught crabs cab be categorized as tradable (1-2% of the population has a carapace width >120 mm for both male and female crabs) (Figure 7).

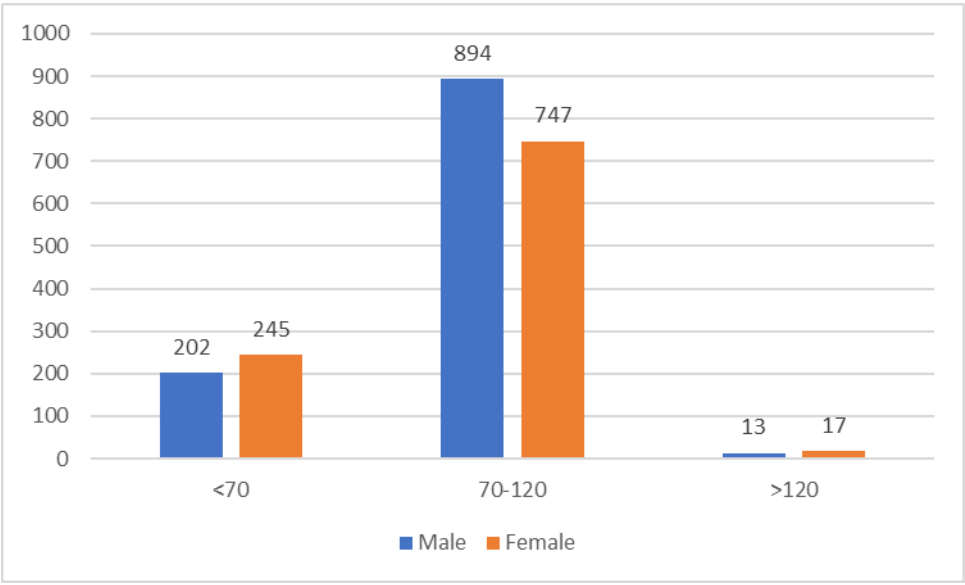

Figure 6. Frequency of *Scylla* spp. carapace width based on a 3 phases size classification.

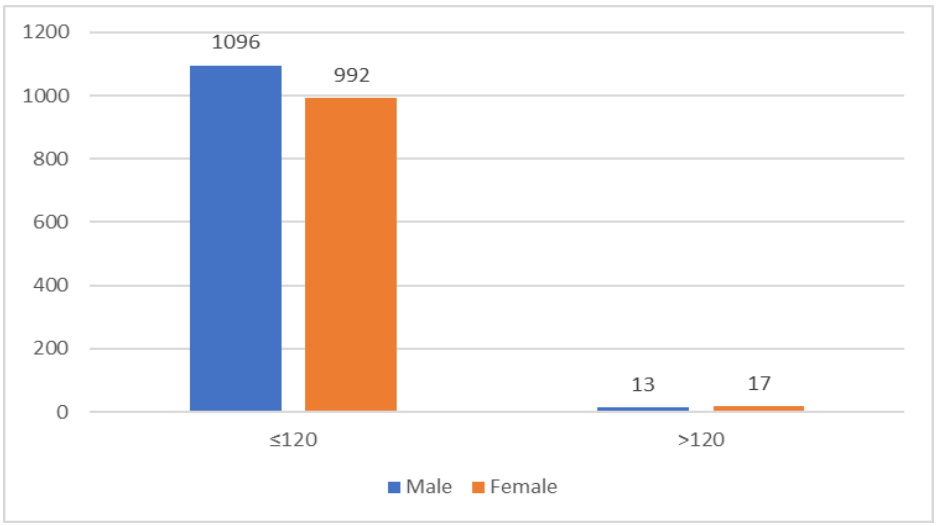

Figure 7. Frequency distribution of *Scylla* spp. carapace width based on the tradable size.

The regulation of the Minister of Marine Affairs and Fisheries No. 12 of 2020 (revision of the Regulation of the Minister of Marine Affairs and Fisheries No. 1 Year 2015 and of the Regulation No. 56 Year 2016) concerning the management of the lobster, mud crab and small/swimmer crab within the territory of the Republic of Indonesia state that mud crabs fishing can be done with the provision that the carapace size is above 12 cm wide or above 150 g weight head^{-1}. In addition, they should not be in laying eggs condition (except for the period of December to the end of February) and they should use static or passive fishing gear.

The majority of mud crabs caught does not meet the provisions (carapace width size ≤120 mm or under 150 g weight and mature female mud crabs) because 70% of the total catch of mud crabs only is to meet the needs of soft-shell crab culture and mud crab processing business (meat crab and baby crab) which are quite smaller in size and the price is much lower (Hapsari et al 2020). If only a small percentage of fishermen's catch is included in the tradable size fishermen tend to disobey these size regulations in order to preserve their income. Another factor discouraging the compliance with the rules is the fact that the standard market price of the crab does not refer to the carapace width, but it rather refers to the weight of the crabs. Therefore, the fishermen do not pay attention to the carapace width yet. Instead, the fishermen have the principle that as long as the weight is still marketable, they still sell the crabs they catch.

Species composition of the catch. Species composition of the catch can be defined as the size of a particular species biomass which become the target and other bycatch species which are not the target of the total catch obtained by a fishing gear during fishing activities (Adrianto et al 2014). The types of fishing gear used by artisanal fishermen and crab collectors in the Mojo Village mangrove ecosystem waters include folding traps, trammel net and crabbing with a line and scoop net. Folding traps fishing gear can be operated at any time because it is considered as passive fishing gear. In addition, trammel net is operated at night, from evening until dawn. Meanwhile, crabbing with a line and scoop net (crab fishing line with bait and handpicking using iron rod/wooden stick with scoop net) is usually operated during the day, but when used at night, most of them are equipped with flashlight.

Based on the results of interviews conducted with 64 fishermen as respondents (8 traps fishermen, 11 trammel net fishermen and 45 respondents using crabbing with a line and scoop net method), it was showed that almost all mud crab fishing activities done in the Mojo mangrove area used selective fishing gear, i.e. crabbing with a line and scoop net method, with mud crabs as a specific catch target. Meanwhile, there are bi-catches in addition to mud crabs when using traps and trammel net fishing gears. Based on a report from TAKA foundation (2016), fishing activities using crabbing method with a

line and scoop net (crab fishing line with bait and handpicking use iron rod/wooden stick with scoop net) only catch mud crabs (100%). The use of traps fishing gear to capture mud crab obtained 36% of the total catch, with other species caught including *Portunus pelagicus*, *Channos chanos* and *Babylonia spirata*. Moreover, the use of trammel net fishing gear produced 15% of the total mud crabs caught. Besides, the catch of trammel net was dominated by *Periophthalmus modestus*, *Mugil dossumieri*, *Lithopenaeus vannamei* and *P. pelagicus*. Based on the description above, the indicator score of catch species composition was 3.

Range collapse of fish resource. Range collapse is a common phenomenon in fish stocks when the fish stock is under overfishing constraints (Adrianto et al 2014; Gibson-Reinemer et al 2017). Fish resources that are in range collapse condition will be increasingly difficult to capture due to the spatial shrinkage of the fish stock biomass. Mud crab fishermen claim that the population of mud crabs is currently reduced by 50%. Based on interviews with mud crab collectors and traders (who collect the crab from the mud crab fishermen), it was found that the number of mud crabs caught from the waters of the Mojo Mangrove Ecosystem decreased drastically. In 2015 the quantity of mud crabs which were sold to them was 200 kg on average day^{-1}, but only 40 kg day^{-1} in 2019. Fishermen respondents stated that catching mud crabs is now increasingly difficult because the number of crabs is decreasing. Consequently, the time needed for mud crabs fishing activities is much longer and it is increasingly difficult to get large mud crabs. The occurrence of massive fishing without strict rules, the occurrence of abrasion and the damage to Mojo mangroves are assumed to cause the degradation of the mud crab resources. Fishing intensification targeted in particular the young crabs, used for soft shell crab seeds and also by the home-based food businesses producing crispy baby crab chips, as well as the female mud crabs laying eggs, due to high demand from restaurants. Based on these data and information, the indicator score of range collapse of fish resource was 1.

Endangered, threatened and protected (ETP) species. ETP species indicator is used to see the impact of fishing activities on ETP species by using certain tools in an area (Adrianto et al 2014). The fishing gear used to catch mud crabs in Mojo Village is static and has a low negative impact on the sustainability of the protected species (Hapsari et al 2020). Based on the information obtained through interviews with fishermen in the Mojo Village, specifically for mud crab fishery, no ETP species were caught. Therefore, mud crabs fishing activities do not have a negative impact on ETP species. Based on the NWAF EAFM indicators module, this indicator got a score of 3.

Aggregate assessment. Assessment results of the domain in mud crab (*Scylla* spp.) resources consist of several indicators: (1) standard catch per unit effort, (2) exploitation rate, (3) size of mud crab, (4) proportion of juvenile caught, (5) catch species composition, (6) range collapse of mud crab resources, and (7) endangered, threatened or protected species, are presented in Figure 8.

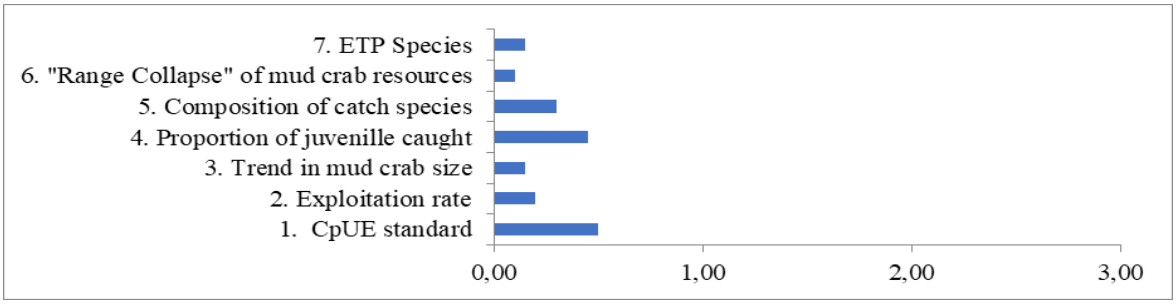

Figure 8. Score of *Scylla* spp. fishery condition assessment in the resources domain.

Indicators of the proportion of juveniles caught, species composition and ETP species show maximum scores; while CPUE standards show moderate scores. In addition, exploitation rate, mud crab size and range collapse of mud crab resources show minimum

scores. Thus, the result of the assessment, based on these 7 indicators, indicated a moderate status of the mud crab fishery from the resource domain of the mangrove ecosystem located around the Mojo Village, with an aggregate value of 66.67 (Table 3).

Table 3

Composite analysis of resource domain

Indicators	*Score*	*Weight*	*Density*	*Value*	*Maximum value*	*Composite value*
CPUE standards	2	25	28	1,300	2,100	66.67
Exploitation rate	1	20	28	560	1,680	33.33
Mud crab size	1	15	25	1,125	1,125	33.33
Proportion of juvenile caught	3	15	25	1,125	1,125	100.00
Species composition	3	10	22	660	660	100.00
Range of collapse	1	10	25	750	750	33.33
ETP species	3	5	20	300	300	100.00
Total		100		4670	7740	66.67
Description						Moderate

Recommendation for management improvement. Recommendations are compiled based on the results of the EAFA indicators assessment, which has been carried out to improve the condition of mangrove crab fishery resource domain, according to the recommendation for management improvement (NWG EAFM 2014; Adrianto et al 2016; Salmarika et al 2019; Yuliana et al 2019). Improvements were implemented to indicators that have not met the reference point values or had scores 1 and 2 in the assessment of the mud crab fishery condition. This tactical step is necessarily carried out to increase the score or to improve the fisheries conditions from poor to moderate (from a score 1 to 2), and from a moderate to good category (from a score 2 to 3). The steps which can be taken for mangrove crab fishery management in Mojo Village are described in more details in Table 4.

Table 4

Actions for management improvement based on EAFA indicators

Indicators	*Actual value*	*Reference point*	*Management actions*
CPUE trends	2 Slight decrease (<25%)	3 Stable or increasing	Reduces fishing pressure through licensing policy, regulate the fishing effort in accordance with Regulation of the Minister of Marine Affairs and Fisheries No. 12 Year 2020 and controlling mud crab fishing activities and/or efforts
Exploitation rate	1 Suffer from over exploitation (E>0.5)	2 Sustainable (E<0.5)	
Size of mud crabs	1 It gets progressively smaller	2 Relatively constant	Educating the fishermen about the minimum size of crabs which can be caught; adjustment of mesh size according to the carapace width of the target crab; encouraging fishermen to obey the Regulation; and activating the Community Surveillance Group
Range collapse	1 It is more difficult to obtain the target	2 The condition of resources is relatively stable	Establishing mud crabs protection area and conducting habitat rehabilitation

A decreasing CPUE value and exploitation rate value >0.5 indicate that the mud crab in the Mojo mangrove ecosystem is over-exploited. Recommendations concerning the management improvement are provided for better applying the regulations and controlling the mud crab fishing efforts, in order to prevent an increase in the number of mud crab fishermen during the peak season/rainy season. The regulation starts from documenting or collecting data of fishermen conducting fishing activities related to the mud crabs, along with the data about their catch results. However, one of the obstacles in disseminating information is the lack of specific data collection for fishermen who carry out mud crab fishing activities so that it becomes an obstacle in the process of conveying information to target groups.

Based on the interview, it could be concluded that the majority of mud crab catchers are mainly part-time fishermen and additionally part-time fishermen. Mainly part-time fishermen are those who do mud crab fishing as their main profession but have other jobs as supplemental income, while additionally fishermen are those whose other jobs are the main source of income and jobs as mud crab seekers are only done for additional income. Data collection on catches results has not been carried out yet until today since. The majority of fishermen sell their mud crab catches directly to crab collectors and traders. Therefore, it is necessary to create a synergy among fishermen, collectors, Fish Auction Place and Marine Affairs and Fisheries Office of Pemalang Regency to conduct the data collection and/or documentation of mud crab landings. Documenting data of mud crab production needs to be continuously done, as a database for informing the management activities.

Improvements to the mud crab catch size indicator, which is decreasing gradually over a period of time, are conducted by educating fishermen about the minimum size of mud crab that can be caught and by encouraging fishermen to comply with the Minister Regulation of Marine Affairs and Fisheries No. 12 of 2020. The effectiveness of the regulation can be successfully implemented if it is actively supported by community participation (Quimby & Levine 2018; Aheto et al 2016; Damastuti & Groot 2017). Thus, it is necessary to do some efforts to determine the business groups of mud crab fishermen to be actively involved. The main function of the community surveillance group is to enforce the implementation of the Minister Regulation of Marine Affairs and Fisheries No. 12 of 2020. Through a community-based surveillance system, mud crab fishermen can discipline themselves as well as become a model for other fishermen.

Improvements that are intended to solve the range collapse of the mud crab fisheries in Mojo Village can be carried out by establishing a mud crab protection area and by conducting their habitat rehabilitation. The sustainability of fish resources as a fishery system is shown by the availability of preserved areas, so that they can maintain the ecosystem and avoid the stocks' decline (Adrianto et al 2016; Seary et al 2020). The mangrove area is the main habitat for mud crabs to grow and to develop (nursery and feeding ground). Therefore, the wider the mangrove waters area, the better the feeding and living opportunities. Mud crab populations are typically associated with a good quality status of the mangrove ecosystems (Le Vay 2001; Santos et al 2017; Karniati et al 2021).

Conclusions. The results of the evaluation according to 6 indicators of EAFA in the domain of the resource show that the status of the mud crab fishery in the mangrove ecosystem of Mojo Village is in moderate condition with an aggregate value of 66.67. This indicates that the status of the mud crab fishery in the Mojo mangrove ecosystem, Pemalang Regency, is in the medium category. In addition, there are 4 indicators in the management which need to be improved, including CPUE standard indicators, exploitation rate, mud crab size and range collapse of mud crab resource. This study proposes some recommendations for management actions as an effort to increase CPUE, as well as to control exploitation levels, i.e. by applying licensing policies, regulating and controlling mud crab fishing activities. Improvements to the indicator of mud crab catch, which is now much smaller, can be done by educating fishermen about the minimum size of mud crab that can be caught, encouraging the fishermen to comply with the Ministerial Regulation of Marine Affairs and Fisheries No. 12 of 2020 and activating community

surveillance groups (Pokmaswas). Moreover, a management act to overcome the range collapse of the mud crab fishery in Mojo mangrove ecosystem can be carried out by establishing a mud crab protection area and conducting habitat rehabilitation.

Acknowledgements. The authors would like to acknowledge the Directorate General of Indonesian Higher Education for providing scholarships via BPPDN and helping to fund this research. Gratitude is also given to the undergraduate students research team (Maulana Ihsan, Ilfhad Armanda, Labaika Ilusi Wulandari and Michelia Fitrianing Setyawan) for their collaborative effort during data collection.

Conflict of interest. The authors declare no conflict of interest.

References

Adrianto L., Habibi A., Fahrudin A., Azizy A., Susanto H. A., Musthofa I., Kamal M. M., Wisudo S. H., Wardiatno Y., Raharjo P., Nasution Z., 2014 [Module of indicators assessment for Ecosystem Approach Fisheries Management (EAFM)]. National Working Group II EAFM. Direktorat Sumberdaya Ikan, Kementerian Kelautan dan Perikanan RI, Jakarta, 205 p. [In Indonesian].

Adrianto L., Ruchimat T., Habibi A., 2016 [Building integrated reference indicators and knowledge management system for the implementation of EAFM in Indonesia]. National Working Group Ecosystem Approach to Fisheries Management, Ministry of Marine Affairs and Fisheries, Republic of Indonesia, 30 p. [In Indonesian].

Aheto D. W., Kankam S., Okyere I., Mensah E., Osman, Jonah F. E., Mensah J. C., 2016 Community based mangrove forest management: implications for local livelihoods and coastal resource conservation along the Volta estuary catchment area of Ghana. Ocean & Coastal Management 127:43-54.

Ali M. Y., Hossain M. B., Sana S., Rouf M. A., Yasmin S., Sarower M. G., 2020 Identifying peak breeding season and estimating size at first maturity of mud crab (*Scylla olivacea*) from a coastal region of Bangladesh. Heliyon 6(6):e04318.

Côrtes L. H. de O., Zappes C. A., Di Beneditto A. P. M., 2019 Sustainability of mangrove crab (*Ucides cordatus*) gathering in the southeast Brazil: A MESMIS-based assessment. Ocean & Coastal Management 179:104862.

Damastuti E., Groot R. D., 2017 Effectiveness of community based mangrove management for sustainable resource use and livelihood support: a case of study of four villages in Central Java, Indonesia. Journal Environmental Management 203:510-521.

Edwarsyah, 2017 Lobster fishery management in the marine ecosystem approach at Simeulue Island Waters (WPP-NRI 572). Jurnal Ilmu dan Teknologi Kelautan Tropis 9(2):795-804.

Elvarsson B. Þ., Agnarsson S., Guðmundsdóttir S., Viðarsson J., 2020 Using multi-criteria analysis the assess impacts of change in ecosystem-based fisheries management: the case of the Icelandic cod. Marine Policy 116:103825.

Faraby A. M., Hutabarat J., Suprijanto J., 2013 [The potential of mud crab in the waters of ponds' surrounding in Mojo Village, Pemalang Regency]. 10th Annual National Seminar on Marine and Fisheries Research Results, Gadjah Mada University, Yogyakarta, Indonesia, 6 p. [In Indonesian].

Faraby A. M., 2017 [A study of mud crab (*Scylla* sp) biometric characteristics in Pemalang Regency: A case study in Mojo Village, Ulujami Subdistrict]. Akuatik Jurnal Sumberdaya Perairan 1(1):48-53. [In Indonesian].

Fitri A. D. P., Boesono H., Sabdono A., Nugraheni F., 2018 Different eye physiology of mud crab (*Scylla serrata*) in different life stage found in Semarang territorial waters. American Journal of Animal and Veterinary Sciences 13(1):27-35.

Gibson-Reinemer D. K., Chick J. H., Van Middlesworth T. D., Van Middlesworth M., Casper A. F., 2017 Widespread and enduring demographic collapse of invasive common carp (*Cyprinus carpio*) in the upper Mississippi River system. Biological Invasions 19(6):1905-1916.

Hapsari T. D., Bambang A. N., Ghofar A., Fitri A. D. P., 2020 Fishing pattern and environmentally friendly analysis on mud crab (*Scylla* spp.) fishery in Mojo mangrove ecosystem, Pemalang Regency, Central Java, Indonesia. E3S Web of Conferences 202:02003.
Hubatsch H. A., Lee S. Y., Diele K., Nordhaus I., Wolff M., Meynecke J. O., 2016 Life-history, movement, and habitat use of *Scylla serrata* (Decapoda, Portunidae): current knowledge and future challenges. Hydrobiologia 763:5-21.
Indarjo A., Salim G., Zein M., Septian D., Bija S., 2020 The population and mortality characteristics of mangrove crab (*Scylla serrata*) in the mangrove ecosystem of Tarakan City, Indonesia. Biodiversitas 21(8):3856-3866.
Karniati R., Sulistiyono N., Amelia R., Slamet B., Bimantara Y., Basyuni M., 2021 Mangrove ecosystem in North Sumatran (Indonesia) forests serves as a suitable habitat for mud crabs (*Scylla serrata* and *S. olivacea*). Biodiversitas Journal of Biological Diversity 22(3):1489-1496.
Le Vay L., Lebata J. H., Walton M., Primavera J., Quinitio E., Pitogo C. F., Estepa, Rodriguez E., Nghia, Sorgeloos P., Wille M., 2008 Approaches to stock enhancement in mangrove-associated crab fisheries. Fisheries Science 16:72–80.
Meynecke J. -O., Richards R. G., 2014 A full life cycle and spatially explicit individual-based model for the giant mud crab (*Scylla serrata*): A case study from a marine protected area, ICES Journal of Marine Science 71(3):484–498.
Muali, 2020 [Management strategy of mangrove forests in Mojo Village, Ulujami Subdistrict, Pemalang Regency, Central Java]. Jurnal Matematika, Sains, dan Teknologi 21(1):35-47. [In Indonesian].
Muis, Kurnia R., Sulistiono, Taryono, Azhari, Risfandi, Ariyanto D., 2020 The evaluation of reef fisheries management in the Spelman Strait coastal waters of Central Buton Regency, Indonesia. Plant Archives 20(2):5169-5176.
Pauly D., 1987 A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. ICLARM Conference Proceeding 13(232):7-34.
Partelow S., Glaser M., Solano A. S., Barboza R. S. L., Schlüter A., 2018 Mangroves, fishers, and the struggle for adaptive co-management: applying the social-ecological systems framework to a marine extractive reserve (RESEX) in Brazil. Ecology and Society 23(3):19, https://doi.org/10.5751/ES-10269-230319.
Pregiwati L. A., Wiryawan B., Baskoro M. S., Wisudo S. H., Satria A., 2015 Linking indicators for ecosystem approach fisheries management and management of marine protected area effectiveness in Anambas Island, Indonesia. AACL Bioflux 8(6):1048-1063.
Purnamawati A., Saputra S., Wijayanto D., 2015 [The economic value of mangrove forests in Mojo Village, Ulujami Subdistrict, Pemalang Regency]. Management of Aquatic Resources Journal (MAQUARES) 4(3):204-213. [In Indonesian].
Quimby B., Levine A., 2018 Participation, power, and equity: examining three key social dimensions of fisheries comanagement. Sustainability 10(9):3324.
Rehatta B. M., Kamal M. M., Boer M., Fahrudin A., Zairion, 2020 [Fisheries management strategy of small pelagic fish using an ecosystem approach in Belu Regency, East Nusa Tenggara]. Journal of Natural Resources and Environmental Management 10 (3):446-460. [In Indonesian].
Renta P. P., Pribadi R., Zainuri M., Angraini M., 2016 Mangrove community structure in Mojo Village, Pemalang Regency, Central Java. Jurnal Enggano 1(2):1-10.
Santos L., Gasalla M. A., Dahdouh-guebas F., Dantas M., 2017 Socio-ecological assessment for environmental planning in coastal fishery areas: A case study in Brazilian mangroves. Ocean Coast Management 138:60–69.
Sara L., Aguilar R. O., Laureta L. V., Baldevarona R. B., Ingles J. A., 2007 The natural diet of the mud crab (*Scylla serrata*) in Lawele Bay, Southeast Sulawesi, Indonesia. The Philippine Agricultural Scientist 90(1):6-14.
Sara L., 2010 Study on the size structure and population parameters of mud crab *Scylla serrata* in Lawele Bay, Southeast Sulawesi, Indonesia. Journal of Coastal Development 13(2):133-147.

Sara L., Aguilar R. O., Ingles J. A., Laureta L. V., 2014 Habitat characteristics and relative abundance of the mud crab *Scylla serrata* (Forskal, 1775) in Lawele Bay, Southeast Sulawesi, Indonesia. Journal of Fisheries and Aquatic Sciences 31:11-18.
Salmarika, Taurusman A. A., Wisudo S. H., 2019 [Management status of little tuna in Indian Ocean waters based on purse seine fishery landed in Lampulo Ocean fishing port: an ecosystem approach]. Jurnal Penelitian Perikanan Indonesia 24(2):263-272.
Seary R., Spencer T., Bithell M., McOwen C., Ota Y., 2021 Defining mangrove-fisheries: A typology from the Perancak Estuary, Bali, Indonesia. Plos One 16(4):e0249173.
Sianturi A., Basyuni M., Apandy Z., 2016 [Gonad maturity level of mud crab (*Scylla serrata*) in the Sicanang mangrove forest area, Medan Belawan Subdistrict, North Sumatra]. Aquacoastmarine 12(2):38-47. [In Indonesian].
Sparre P., Venema S. C., 1999 Introduction of tropical fish assessments. Manual Book 1. FAO, Rome, 438 p.
Tiurlan E., Djunaedi A., Supriyantini E., 2019 [Analysis of mud crab (*Scylla* sp) reproduction aspects in Kendal waters, Central Java]. Journal of Tropical Marine Science 2(1):29-36. [In Indonesian].
Viswanathan C., Pravinkumar M., Suresh T. V., Elumalai V., Raffi S. M., 2019 Reproductive biology of the orange mud crab *Scylla olivacea* (Herbst, 1796) from the Pichavaram mangroves of south-east India. Indian Journal of Fisheries 66(1):26-33.
Yudiati E., Fauziah A. T., Irwani I., Setyawan A., Insafitri I., 2020 Growth analysis, mortality and exploitation level of mud crab *Scylla serrata*, Forskal 1775, (Malacostraca: Portunidae) in Mangkang Wetan waters, Semarang, Central Java, Indonesia. Jurnal Kelautan Tropis 23(1):136-144.
Yuliana E., Boer M., Fahrudin A., Kamal M. M., Pardede S. T., 2019 Using ecosystem approach indicators for assessing the ecological status of reef fisheries management in a marine protected area. Biodiversitas Journal of Biological Diversity 20(7):1802-1810.
*** Central Bureau of Statistics, 2018 Export import data 2012-2017. Jakarta, Indonesia.
*** Food and Agriculture Organization, FAO, 2011 Mud crab aquaculture. FAO, Rome, 78 p.
*** Fish Quarantine Agency, Quality control and fishery products safety of the Ministry of Marine Affairs and Fisheries, 2016 Decree No. 67 Year 2016 about The guidelines for inspection/identification of restricted fish species (*Scylla* spp.) in cooperation with Bogor Agricultural University.
*** Fish Quarantine Agency, Quality control and fishery products safety of the Ministry of Marine Affairs and Fisheries, 2020 Performance report of 2020. Jakarta, Indonesia, 70 p.
*** Ministry of Marine Affairs and Fisheries, MMAF, 2014 Assessment of indicators of ecosystem approach to fisheries management. Direktorat Sumber Daya Ikan, Kementerian Kelautan dan Perikanan, Jakarta.
*** Ministry of Marine Affairs and Fishery of the Republic of Indonesia, 2016 Decree No. 79 year 2016 about Fishery management plan for fisheries management area. State of the Republic of Indonesia 712.
*** Ministry of Marine Affairs and Fishery of the Republic of Indonesia, 2015 Regulation of Minister of Marine and Fishery no. 9 Year 2015 about Competency standard specific work management fisheries with the ecosystem approach.
**** Ministry of Marine Affairs and Fishery of the Republic of Indonesia, 2016 Regulation of Minister of Marine and Fishery No. 56 of 2016 about The catching of lobster (*Panulirus* spp.), mangrove crab (*Scylla* spp.), and blue swimming crab (*Portunus* spp.).
*** Ministry of Marine Affairs and Fishery of the Republic of Indonesia, 2015 Regulation of Minister of Marine and Fishery No. 1 Year 2015 about The catching of lobster (*Panulirus* spp.), mangrove crab (*Scylla* spp.) and small crab (*Portunus* spp.).
*** Ministry of Marine Affairs and Fishery of the Republic of Indonesia, 2020 Regulation of Minister of Marine and Fishery No. 12 of 2020 about Management of lobster

(*Panulirus* spp.), mangrove crab (*Scylla* spp.), and Rajungan (*Portunus* spp.) in the territory of the Republic of Indonesia.
*** National Working Group on Ecosystem Approach to Fisheries Management, NWG, 2014 Module of fisheries management indicators using EAFM (Ecosystem Approach to Fisheries Management. Direktorat Sumber Daya Ikan, Kementerian Kelautan dan Perikanan Republik Indonesia, Jakarta, 174 p.
*** TAKA Foundation, 2016 [Risk based assessment for mud crab in Ulujami District, Pemalang]. Semarang, Indonesia, 14 p. [In Indonesian].

Received: 20 June 2021. Accepted: 28 July 2021. Published online: 12 August 2021.
Authors:
Trisnani Dwi Hapsari, Diponegoro University, Faculty of Fisheries and Marine Sciences, Coastal Resources Management, Jl. Prof. H. Soedarto, S.H., Tembalang, Semarang 50275, Central Java, Indonesia, e-mail: trisnanihapsari@live.undip.ac.id
Azis Nur Bambang, Diponegoro University, Faculty of Fisheries and Marine Science, Department of Capture Fisheries, Jl. Prof. Soedarto, S.H., Tembalang, Semarang 50275, Central Java, Indonesia, e-mail: azis_undip2013@yahoo.com
Abdul Ghofar, Diponegoro University, Faculty of Fisheries and Marine Science, Department of Aquatic Resource Management, Jl. Prof. Soedarto, S.H., Tembalang, Semarang 50275, Central Java, Indonesia, e-mail: aghofar099@gmail.com
Aristi Dian Purnama Fitri, Diponegoro University, Faculty of Fisheries and Marine Science, Department of Capture Fisheries, Jl. Prof. Soedarto, S.H., Tembalang, Semarang 50275, Central Java, Indonesia, e-mail: aristidian.undip@gmail.com

How to cite this article:
Hapsari T. D., Bambang A. N., Ghofar A., Fitri A. D. P., 2021 Resource domain assessment of the mud crab (*Scylla* spp.), based on an ecosystem approach to the fisheries located within the Mojo mangrove ecosystem, Pemalang Regency, Central Java, Indonesia. AACL Bioflux 14(4):2134-2148.