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Assessment on demersal fisheries status in the FMA 573 under data-limited situation: A combination of statistic and CPUE data as inputs for bayesian surplus production model

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Abstract. Demersal stock potential, total allowable catch (TAC), and exploitation level status in the FMA 573 were assessed and determined by the National Commission of Stock Assessment (KOMNASKAJISKAN) through Ministerial Decree No. 19/2022. However, the fisheries status, i.e., the biomass level concerning the BMSY and the effort level compared to FMSY, was not completely determined. This study demonstrated the alternative approach to determining fisheries status under limited data. Statistical time series production and existing CPUE data were used to perform the Bayesian Surplus Production Model (cMSY). Based on the results, the stock of demersal fisheries in FMA 573 is overexploited, whereas the F/FMSY and B/BMSY are>1 and <1, respectively. The situation needs concern from all stakeholders. Rebuilding the stock formulation scheme through harvest strategy development for demersal fisheries in FMA 573 must be prioritized to ensure the sustainability of the stock and the fisheries business.

Keywords: Demersal fisheries, FMA 573, cMSY model, sustainability

1. Introduction

The Republic of Indonesia's fishery management area is divided into 11 water areas based on the Decree of the Ministry of Marine Affairs and Fisheries Number 18/2014. This division aims to facilitate management because most of Indonesia's territory consists of seas. One of them is the Fisheries Management Area (FMA) 573. FMA 573 is fertile waters, so it has abundant fish resources. Apart from that, there is another potential in FMA 573 waters, namely demersal fisheries and other commodities.

Demersal fisheries in FMA have an estimated fish resource potential of 269.640 tonnes/year [1]. The level of utilization of demersal fish is currently in a healthy condition, not experiencing overexploitation

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and overfishing. Such a situation is different from the case with demersal fish stocks, which from 2005 to 2021 have consistently been in the red zone; thus, their utilization status is classified as overexploited and overfishing. Fisheries status, i.e., the biomass level concerning the BMSY and the effort level compared to the FMSY, was not entirely determined.

Developing a harvest strategy to rebuild the stock of demersal fisheries in FMA 573 must be prioritized. The development involves setting sustainable catch limits, implementing effective fishing regulations, and promoting responsible fishing practices to allow the stock to recover. Using a combination of statistics and CPUE data, we can determine the current status of Demersal fish in FMA 573.

2. Method

2.1. Data Sources

Data on demersal fish catch and the number of fishing vessels in FMA 573 were collected from the Center for Data and Information of the Indonesian Ministry of Marine Affairs and Fisheries (PUSDATIN KKP) in 2022 [2]. Catch-per-unit-of-effort (CPUE) data were obtained from reference journals from 2005 to 2019.

2.2. cMSY Model

The cMSY method is used to estimate biomass, exploitation rate (F/FMSY), relative stock size (B/BMSY), and reference points for fisheries (MSY, r, k) from time series of catches, resilience, and qualitative stock status information at the beginning and end of the time series [3], [4]. The results of the cMSY method can be reinforced with the BSM method when relative abundance, specifically CPUE data, is available in addition to catch data. The dynamics of biomass using the cMSY and BSM methods follow Equation (1):

$$B_{t+1}=B_t+r(1-\frac{B_t}{k})B_t-C_t \quad (1)$$

Bt and Bt+1 is the biomass in year t and the following year, respectively; r is the intrinsic rate of population increase; k is the carrying capacity; and Ct is the catch in year t. A linear decline of surplus production is incorporated in Equation (2) when stock size is strongly depleted, i.e., the biomass falls less than 0.25 k.

$$B_{t+1}= B_t + 4\ \frac{B_t}{k}\ r\ \left(1 - \frac{B_t}{k}\right)\ B_t-C_t \mid \frac{B_t}{k} < 0.25 \quad (2)$$

Resiliency estimates were obtained from FishBase to establish the initial values of the resilience range (r-range) for demersal stock. The value of r for demersal stock was determined based on the r-value of the main catch species for each commodity. The initial range for k was derived from three empirical rules in [1] using Equation (3) for stocks with low initial biomass at the end of the available catch time series and Equation (4) for stocks with high initial biomass at the end of the time series:

$$k_{low}=\frac{max(C)}{r_{high}},k_{high}=\frac{4max(C)}{rlow} \quad (3)$$

$$k_{low}=\frac{2max(C)}{r_{high}},k_{high}=\frac{12max(C)}{rlow} \quad (4)$$

*k*low and *k*high are the lower and upper bounds of the initial range k, max(C) is the maximum catch in the time series, and rlow and rhigh are the lower and upper bounds of the r range to be explored by the Monte-Carlo method of cMSY. The range of r values was previously obtained from the resilience estimated by FishBase for each fish species with 4 types of resilience as follows: high r = 0,6–1,5; mid r = 0,2–0,8; low r = 0,05–0,5; and very low r = 0,015–0,1 tahun1.

3. Results and Discussion

3.1. Demersal Fisheries Production in FMA 573

Demersal fish is a commodity with one of the potential fishery resources in FMA 573. Based on the PUSDATIN KKP in 2021 [2], the dominant fish production in FMA 573 was small pelagic (47%), demersal (33%), and large pelagic (7%). Demersal fish (101,600.8 tons) was the third highest production, indicating that this species group is one of the major catches in FMA 573 (Figure 1).

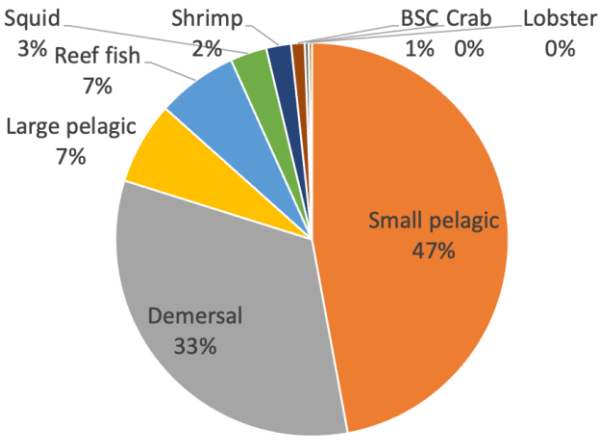

Figure 1. Fish production in FMA 573 of 2021

The production of demersal fish in FMA 573 tends to increase, ranging from 42,463 to 126,205 tons annually, with an average of 68,848 tons per year (Figure 2). The catch of demersal fish is dominated by various species, including mackerel (Caranx spp.), large head hairtail (Trichiurus spp.), threadfin bream (*Nemipterus* spp.), silver sillago (*Leiognathus* spp.), silver pomfret (*Pampus argenteus*), goldband goatfish (*Upeneus vittatus*), snappers (*Lutjanus* spp.), rabbitfish (*Nibea albiflora*), black pomfret (*Parastromateus niger*), and emperor fish (*Lethrinus* spp.) [2].

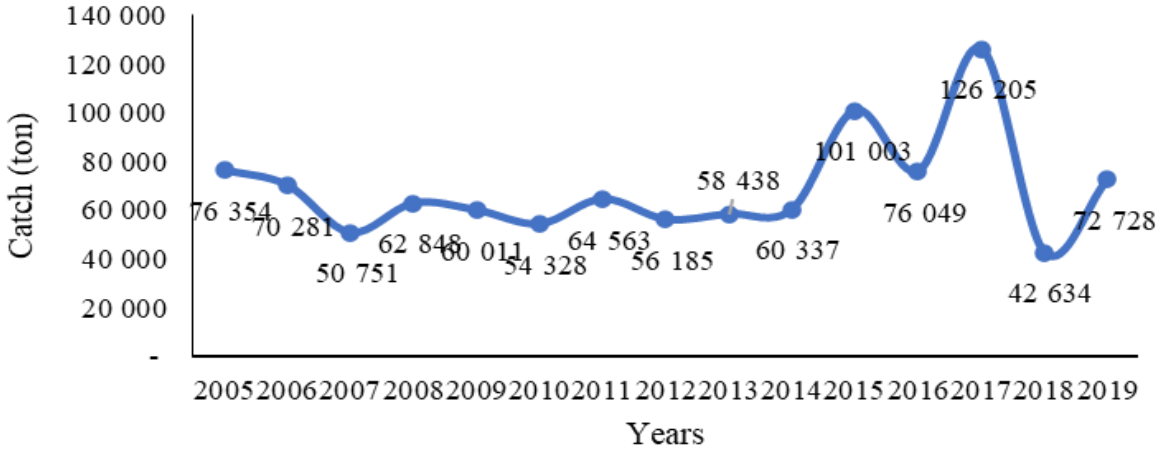

Figure 2. The development of demersal fish production from 2005 to 2021 in FMA 573.

Using a combination of statistics and CPUE data, we can determine the current status of the demersal fish in FMA 573. We used the CPUE proxy from the largehead hairtail [5], [6] related to the dominant catches from the demersal group in FMA 573 (10% of the total catches) [2] (Figure 3).

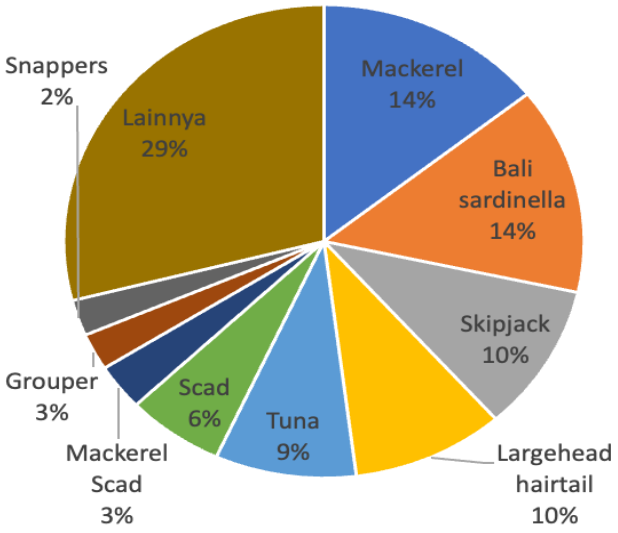

Figure 3. Species composition in the FMA 573 in 2021 (PUSDATIN KKP)

3.2. Biomass relative (B/BMSY) and fishing mortality relative (F/FMSY)

Demersal fish is one of the potential fishery commodities in FMA 573 because FMA 573 can serve as the primary habitat for demersal fish. Small-scale fishermen mainly engage in demersal fishing activities in FMA 573, using gear such as trammel net, gill net, drag net, trap, purse seine net, mini purse seine, and cantrang [2] . Over the years, there has been a continuous increase in fishing efforts for demersal fish, including an increase in the number of fishing vessels and trips. This condition has led to increased fishing pressure and exploitation of demersal fish in the Java Sea, which may result in overfishing conditions.

Analysis of the utilization level was conducted using the Monte Carlo method (cMSY) to estimate the conditions of the capture fishery based on production (catch) data and resilience. The output of the model is shown in Figure 4. Additionally, the Bayesian state-space implementation of the Schaefer Model is used to predict the values of r, k, and MSY using catch data and biomass or CPUE.

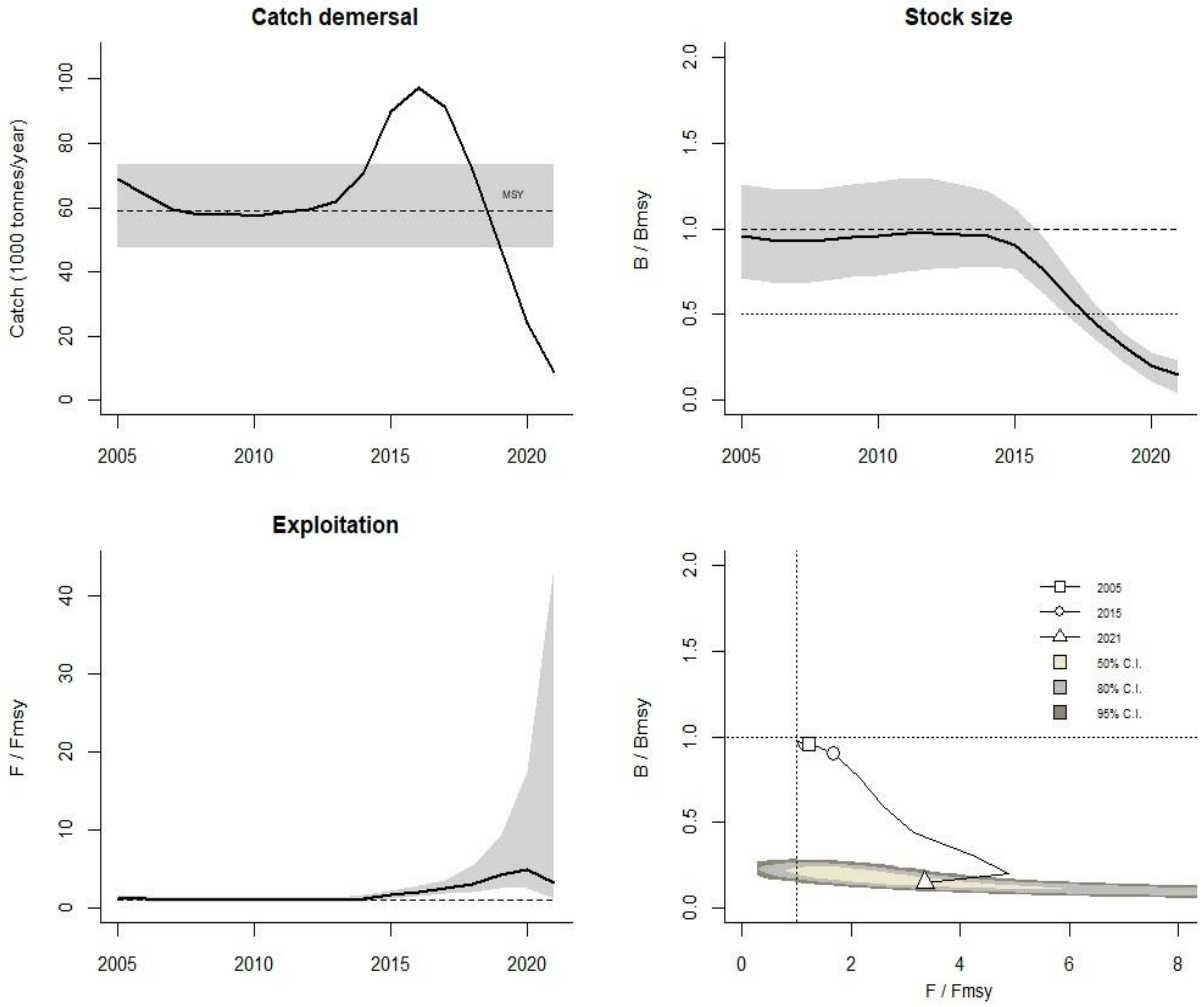

Figure 4. The catch, stock size, and exploitation rate of the demersal fish in FMA 573 from the cMSY model

The graphs provide information on the stock status. The catch graph showed the catches relative to MSY (dashed line) as estimated by cMSY with an indication of 95% confidence limits in light grey. The stock size graph showed the time series of predicted total biomass relative to Bmsy, which has decreased since 2015, and the exploitation showed relative exploitation over the years. The cMSY and BSM analysis results are shown in Table 1 and Figure 5.

Table 1. The utilization levels, MSY (Maximum Sustainable Yield), F/FMSY (Fishing Mortality Rate relative to FMSY), B/BMSY (Biomass relative to BMSY), and the status of demersal fisheries in FMA 573 based on the BSM/CMSY method and Ministerial Decree No. 19 of 2022 [1].

Stock	Potency (ton/year)	MSY	F/F_{MSY}	B/B_{MSY}	Status cMSY	Status*
Demersal	269,640	135,000	2.35	0.65	Overexploited, overfishing (red)	Moderate (green)

*Source: Minister of Marine Affairs and Fisheries Decree No. 19 of 2022 concerning the Estimation of Fishery Resource Potential, Allowed Fish Catch, and Utilization Rate of Fishery Resources in the Fisheries Management Area of the Republic of Indonesia.

The analysis results of the demersal fish stock using the BSM method show a B/BMSY value of 0.65 and a F/FMSY value of 2.35, with an MSY (Maximum Sustainable Yield) of 135,000 tons. These results indicate that the demersal fisheries in FMA 573 are still experiencing overfishing, with high fishing pressure and a biomass condition considered overfished. According to Palomores et al., [7], a fish stock with B/BMSY values between 0.8 and 1.0 indicates slightly overfished biomass. On the other hand, a F/FMSY value greater than or equal to 1 indicates overfishing in the fishing activities for that particular fish commodity [8]. According to Costelo et al., [8], a stock condition with B/BMSY less than 1 and/or F/FMSY greater than 1 indicates that the stock is either fully exploited or overexploited.

It can be observed that the trajectory of the demersal fish stock condition based on biomass and fishing mortality in FMA 573 has been in an overfished and overfishing state since 2005 (Figure 5). It may be assumed that this continuous overexploitation for a long period would severely deplete the stock, resulting in the poor condition of the existing biomass of the demersal fish [9]. A Kobe phase plot represents the time series of pressure (F/FMSY) on the Y-axis and of state (B/BMSY) on the X-axis. According to [4], the red area indicates that the fish commodity has experienced overfishing, with the biomass being too low to achieve the maximum sustainable yield. A decrease in fish biomass likely causes this condition due to increased fishing activities.

Drawing from the Minister of Maritime Affairs and Fisheries Decree No. 19 of 2022, which deals with the Estimation of Fishery Resource Potential, Allowable Fish Catch, and Utilization Rate of Fishery Resources in the Indonesian State Fishery Management Area [1], it's noteworthy to point out that the utilization rate of demersal fish within the FMA 573 area has been set at a cautious 0.2. This indicates a clear intention to manage and preserve the fishery resources effectively. However, the application of the cMSY model introduces an interesting layer of complexity to the discussion. The assessment reveals that the demersal fisheries in the FMA 573 are undergoing a more complex situation. Specifically, the cMSY model suggests that the demersal fisheries have fallen into a state of overfishing.

These observations invite a broader discussion on the effectiveness of the existing management strategies and their alignment with the actual ecological dynamics of the FMA 573 area. It's evident that while regulatory measures have been established to limit the utilization rate, the application of these measures might not be sufficient to combat the ongoing challenges faced by the demersal fisheries.

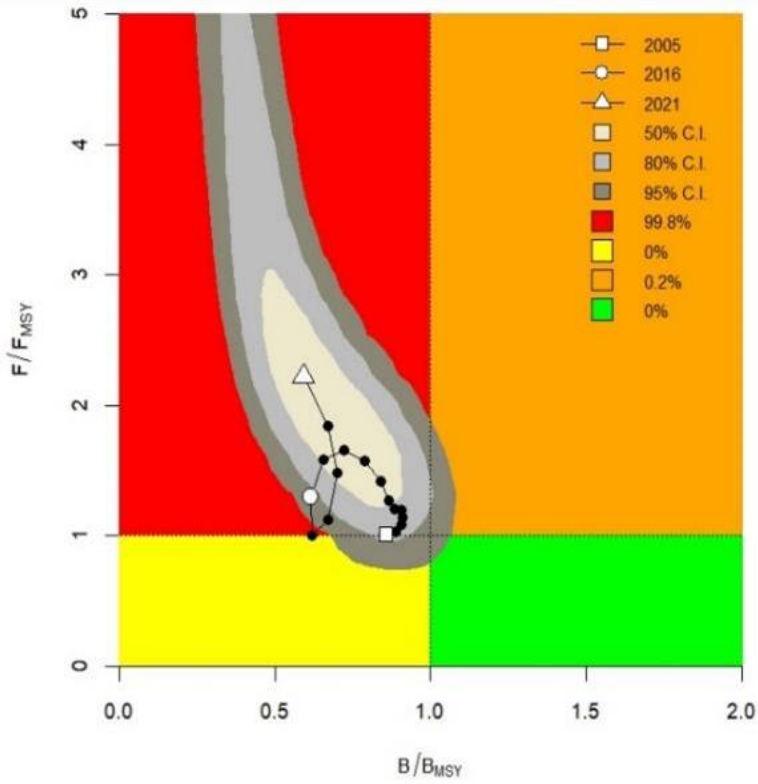

Figure 5. Estimation of fish biomass trajectory and demersal fish catch mortality (Kobe Plot) (2005 - 2021)

4. Conclusion and Recommendation

The condition of demersal fish stocks based on biomass in FMA 573 since 2005 indicated that the stocks were overexploited and overfished. This situation is shown by the B/BMSY value of demersal fish less than 1 since 2005 and the F/FMSY value of more than 1. So the condition of demersal fish stocks has been in the red zone since 2005. Given that the demersal fisheries in FMA 573 are overexploited, urgent attention is required from all stakeholders, including government agencies, fishers, and conservation organizations. Besides that, developing a harvest strategy to rebuild the stock of demersal fisheries in FMA 573 must be prioritized. The development involves setting sustainable catch limits, implementing effective fishing regulations, and promoting responsible fishing practices to allow the stock to recover.

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