HARVEST CONTROL RULES OF DEMERSAL FISHERIES IN BRONDONG WATER, LAMONGAN, EAST JAVA

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ABSTRACT

Multispecies demersal fisheries management in Brondong waters have been managed by conventional single-species approach for determining catch quota or annual allowable biological catch (ABC). This might be impractical since a multispecies fishery should be managed by a multispecies fisheries management approach. The feedback harvest control rule (HCR) is a harvest control rule that has been validated and might be applied for a multispecies fishery. The aim of this study is to compare the conventional single-species approach and the feedback HCR in order to estimate the annual ABC. In this study, the annual ABC was calculated by applying two HCRs, the conventional single-species approach that applying the Schaefer surplus production model into the catch and effort of the dominant demersal fisheries data series of 2011 – 2020. The results showed that the Schaefer model provided the annual ABC higher than the feedback HCR estimation. Therefore, it was safe to apply the feedback HCR than the Schaefer model to determine the annual ABC. Under data-limited conditions, the feedback HCR might be an option to manage multispecies fisheries.

Keywords: *Allowable Biological Catch, Surplus Production Model, Feedback Harvest Control Rule, Schaefer Model*

1. INTRODUCTION

Brondong waters has contributed in demersal fisheries production. Several demersal species are dominantly landed in Brondong fishing port, such as Red big eye (*Priacanthus tayenus*), Golden thredfin bream (*Nemipterus nemathoporus*) and Sulphur goat fish (*Upeneus sulphurous*) (Yaskun & Sugiarto, 2017). For years, as other multispecies fisheries, these fisheries have been managed by conventional single-species approach for determining annual total allowable catch (TAC) which refers to annual allowable biological catch (ABC) (Harlyan *et al*., 2019, 2020; Harlyan, Sari, *et al*., 2021; Harlyan, Matsuishi, *et al*., 2021; Harlyan *et al*., 2022; Sartimbul *et al*., 2016)

Several conventional single-species approach surplus production models such as the Schaefer model, the Fox model, the Walter-Hilborn model, and the yield per recruit model (YPR) (Harlyan *et al*., 2019; Hilborn & Ovando, 2014; Newman *et al*., 2018), require species-specific information for fishery stock assessment. This requirement might be strictly hard to obtain in the data-limited multispecies fishery (Cadrin & Dickey-Collas, 2015). Some argue that these conventional approaches might be impractical to be applied in a multispecies fishery (Harlyan *et al*., 2020; Harlyan, Matsuishi, *et al*., 2021; Hilborn & Ovando, 2014; Shertzer & Williams, 2008).

Brondong fisheries are characterized as multispecies fisheries that managed as single-species fisheries. This condition is relatively challenging to be accomplished since the fisheries are exploited by multi-gear that catch multispecies (Harlyan *et al*., 2020; Harlyan, Sari, *et al*., 2021; Harlyan, Matsuishi, *et al*., 2021; Harlyan *et al*., 2022; Punt *et al*., 2016). In fact, most fisheries have been managed based on the recommendations of single species model that are calculated for only a few priority species without considering other species as a part of multispecies fisheries (Harlyan *et al*., 2022; Kvamsdal *et al*., 2016; Munehara *et al*., 2021). Moreover, several limitations on technical and financial in terms of performing species aggregation occurred due to the lack of species-specific data (Yuniarta *et al*., 2017).

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The feedback harvest control rule (HCR) (Chumchuen & Chumchuen, 2019; Ohshimo & Naya, 2014; Tanaka, 1980) is the validated HCR which applied as one of tools for data-limited condition in the Japanese fisheries management since 1997 (Harlyan *et al*., 2019, 2020, 2022; Harlyan, Sari, *et al*., 2021; Ichinokawa *et al*., 2017; Makino, 2011). The feedback HCR can determine the annual ABC considering historical stock abundance (Magnusson, 1992; Tanaka, 1980). In the feedback system, fish resources are considered as a loop system with catch quotas as output and stock abundance as inputs, therefore the amount of quotas is close to the amount of stock abundance (Goethel *et al*., 2019; Harlyan *et al*., 2019; Hoshino *et al*., 2012; Ichinokawa *et al*., 2015; Ohshimo & Naya, 2014).

As conventional single-species models, the feedback HCR can provide the estimation of annual ABC along with precautionary principle. However, limited reviews demonstrated a technical comparison of the use of the feedback HCR and the surplus production model to determine annual ABC. This study determined the annual ABC for demersal multispecies fisheries in Brondong waters by applying the feedback HCR and surplus production model. Therefore, the objective of this study is to compare the use of the feedback HCR and the surplus production models to estimate the annual ABC.

2. MATERIALS AND METHODS

2.1 Source of data

The field survey was carried out in March – April 2021 and located in Brondong fishing port, Lamongan, East Java (Figure 1).

2.2. Data Analyses

The data souce was catch-effort data series collected from the fisheries statistics data from 2011 to 2020. The data was gathered under authority of Brondong fishing port which filled and validated by official enumerators and tabulators in the East Java Province. The catch data was the catch of dominant demersal species landed in Brondong fishing port. They were red big eye, golden thredfin bream and sulphur goat fish. The effort data was the number of fishing trips applied to catch three dominant demersal species. There were two gears operated for catching demersal species in the Brondong waters. They were Danish seine and bottom long line.

A set of data analyses was carried out to compare the use of the feedback HCR and surplus production model to determine the annual ABC. In this study, the Schaefer model was performed representing the surplus production model approach. The details data analyses were shown as follows:

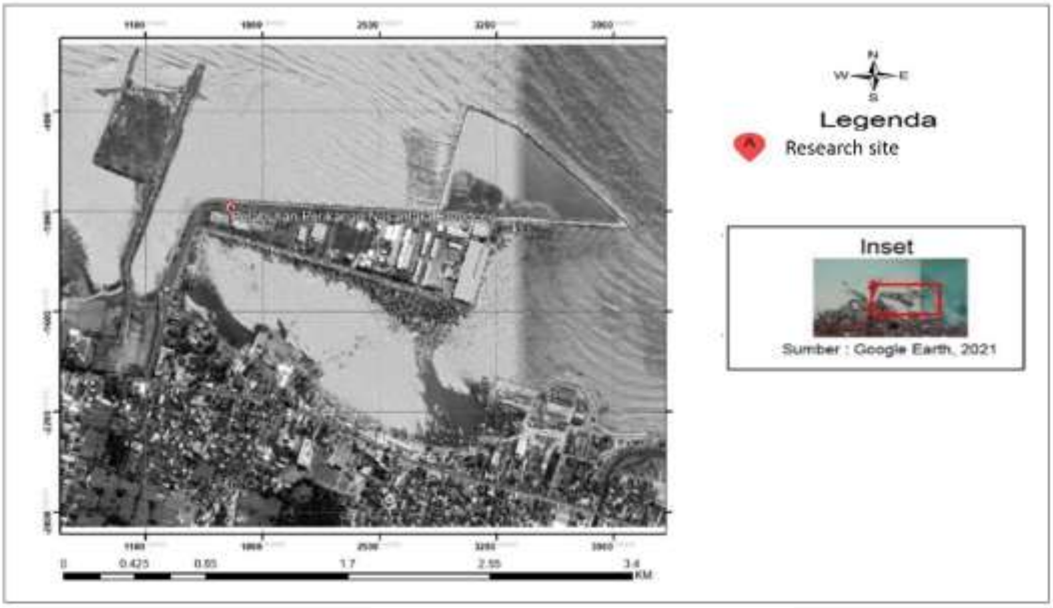

Figure 1. Brondong fishing port

2.2.1 Catch per unit effort

To present the stock abundance index for the three dominant demersal species, the catch per unit effort ratio was applied by following formula:

$$CPUE = \frac{C}{f} \quad (1)$$

where c and f indicate catch of demersal species (ton) and effort that performing as the number of fishing trips, respectively (Sparre & Venema, 1992).

2.2.2 Effort standardization

To provide the fishing effort standard of several fishing gears that may differ from one to another, the amount of fishing trip was treated by effort standardization. Practically, the method is applied to determine the standard of fishing gears that generate the highest amount of catch overall gears. The fishing power index (FPI) of all gears are compared to show the gear productivity overall gears. The standard fishing gear is indicated as if its FPI is equal to 1 (Susanti *et al*., 2020). The FPI is calculated by applying this formula:

$$FPI = \frac{CPUE \text{ of gear}}{CPUE \text{ of standard gear}} \quad (2)$$

The standardized effort for each fishing gear is calculated by the following formula:

$$\text{The standardized effort} = FPI \times \text{effort} \quad (3)$$

2.2.3 Harvest control rules

In this study, two HCRs, the surplus production model and the feedback HCR were applied into catch-effort data series of three dominant species landed in Brondong fishing port in order to determine their annual ABC.

a. The Schaefer model

In this study, the Schaefer model was applied as a representative of surplus production models to determine the value of maximum sustainable yield (MSY). Under the Schaefer model, the relationship between CPUE and effort is following a negative correlation (Sparre & Venema, 1992).

The Schaefer model applies linear regression for CPUE and effort relationship with the following formula:

$$\frac{C}{f} = a - b.f \quad (4)$$

$$f_{MSY} = -\frac{a}{2b} \quad (5)$$

$$C_{MSY} = -\frac{a^2}{4b} \quad (6)$$

The intercept and the regression coefficient are symbolized as *a* and *b*, respectively. The f_{MSY} indicates the effort or the number of fishing trips that is dependable in achieving MSY. The C_{MSY} indicates the largest amount of catch that can be exploited from the stock. In technical, the annual TAC is determined at 80% of the estimated C_{MSY} using the Schaefer model (Fuad *et al*., 2020; Sartimbul *et al*., 2016)

b. The feedback HCR

The results of the feedback HCR calculation is the annual ABC. The ABC is determined by considering the overfishing limit to take into account scientific uncertainty. Subsequently, the total allowable catch (TAC) is set at certain value that might not exceed the determined ABC.

The feedback HCR is calculated by the following formula (Harlyan *et al*., 2019):

$$ABC_y = \delta \times C_{y-2} \times \gamma \quad (7)$$

$$\gamma = 1 + k\frac{b}{I} \quad (8)$$

Where δ is the weighting coefficient and set as 1.0, 1.0 and 0.8 for high, medium and low stock level, respectively. To obtain the stock level, the stock abundance index of three dominant demersal species are observed from 2011 to 2020. The stock abundance index is corresponding to the trend of catch per unit effort (CPUE) overall dominant species. To determine stock level, it is required to calculate the upper and lower threshold that are obtained from 33rd and 67th percentile of the stock abundance index of three dominant demersal species in the period 2011 – 2020. The stock level is assumed as high level if the recent stock abundance index is higher than the upper threshold, while the stock level is assumed as lower level if the stock level is lower than the lower in between the upper and lower threshold.

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The medium level is assumed if the stock level is in between the upper and lower threshold.

The C_{y-2} defined as the catch of y – 2 (ton), the k is the feedback factor which is set as 1, while γ is the trend of CPUE of 2011 – 2020. The regression coefficient and the average of CPUE in the y – 4 to y – 2 (ton/trip) are indicated as b and I. The feedback HCR may provide simultaneous calculation for multispecies fishery. In this situation, the calculation of annual TAC of species with similar growth rate, fast and/or medium growing species in a multispecies fishery, may be managed together at once.

3. RESULTS AND DISCUSSION

Over 10 years, the demersal fisheries landed six group of species (Figure 2) which are dominated by three demersal species, Red big eye, Golden thredfin bream and Sulphur goat fish. The trend showed that there is a stable number of landings with the peak appeared in 2014, while the landing composition discover that similar species composition occurred in the period of study.

Figure 2. The demersal landing composition from 2011 – 2020

The demersal fisheries landed in Brondong waters has been exploited by two gears (Figure 3). The productivity of Danish seine was higher than bottom longline since 2014. To increase demersal fisheries productivity, fishers increased the use of Danish seine more than that of bottom longline.

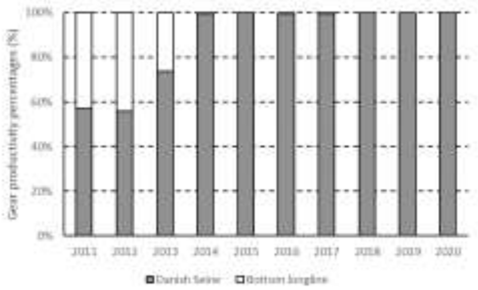


Figure 3. Gear productivity proportion from 2011 – 2020

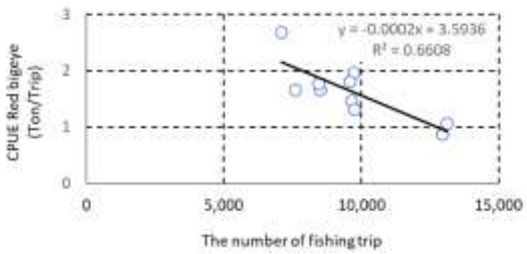
Since there were two fishing gears that employed to catch demersal fisheries, the effort standardization was conducted before further analyses (Table 1). It showed that a unit Danish seine is equal to 21 unit of bottom longline. Therefore, the number of fishing trips of bottom longline was standardized following this calculation.

Table 1. Effort standardization

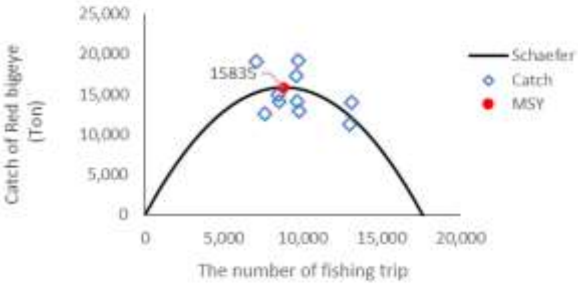
Fishing gear	Fishing productivity	FPI	Ratio
Danish seine	658,157.82	1	1
Bottom longline	31,020.83	0.05	21

3.1 The Schaefer model

For the Red bigeye species, the estimation of annual ABC in the Schaefer model performed the linear regression between the number of fishing trip and CPUE with a negative slope, which met the Schaefer model assumption (Figure 4a). The linear regression showed as $y = 3.59 - 0.0002x$. There was an increase in the number of fishing trips generated a reduced amount of the CPUE by 0.0002 tons/trips. The determination coefficient indicated that 66% was dependent on the number of fishing trips while the other was affected by other factors (Figure 4b).



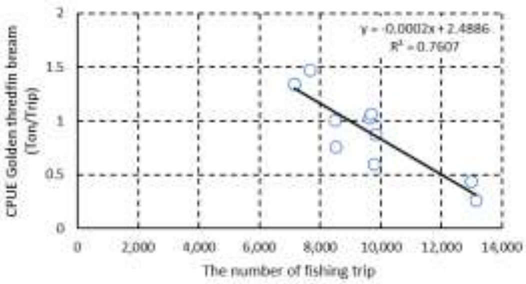
(a)



(b)

Figure 4. Linear regression relationship between CPUE and the number of fishing trip (a) and the Schaefer model curve (b) of Red bigeye in Brondong waters.

For golden thredfin bream, the estimation of the annual ABC also performed a negative slope of linear regression model with the function: $y = 2.49 - 0.0002x$ (Figure 5a). An increase in the number of fishing trips produced a decrease amount of CPUE by 0.0002 tons/trip. The determination coefficient indicated that 76% was dependent on the number of fishing trips while the other 24% was affected by other factors (Figure 5b).



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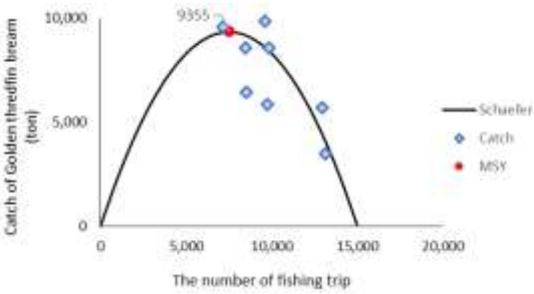
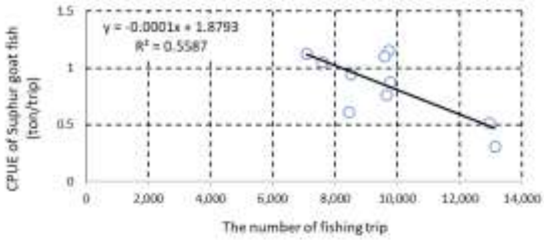


(b)

Figure 5. Linear regression relationship between CPUE and the number of fishing trip (a) and the Schaefer model curve (b) of Golden thredfin bream in Brondong waters.



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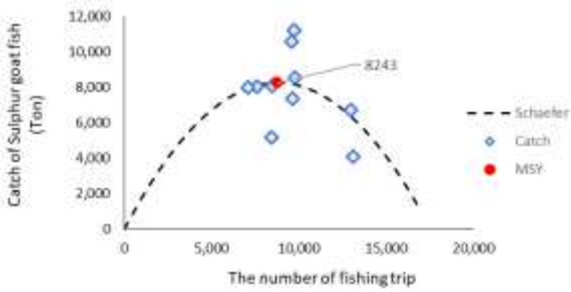

(b)

Figure 6. Linear regression relationship between CPUE and the number of fishing trip (a) and the Schaefer model curve (b) of Sulphur goat fish in Brondong waters.

The estimation of the annual ABC of Sulphur goat fish also performed a negative slope of linear regression model with the function: $y = 1.88 - 0.0001x$ (Figure 6a). An increase in the number of fishing trips produced a decrease amount of CPUE by 0.0002 tons/trip. The determination coefficient indicated that 54% was dependent on the number of fishing trips while the other 24% was affected by other factors (Figure 6b).

3.2 The Feedback HCR

In the feedback HCR, the estimation of the annual TAC was performed as allowable biological catch (ABC_y). The three dominant species are fast – medium growing species which can be managed simultaneously. Therefore, the calculation of the feedback HCR was applied for all dominant species at once.

The stock levels (δ) appear as the trend of stock abundance index (CPUE) in 2011 – 2020 (Figure 7).

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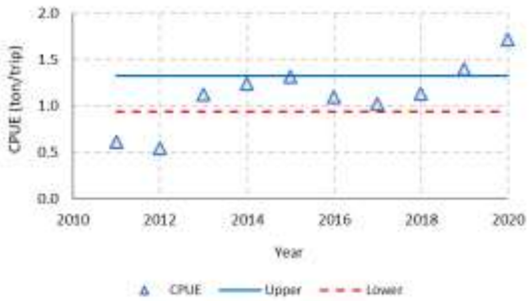

Figure 7. The stock abundance index (CPUE) of demersal fishery in Brondong waters in 2011 – 2020 with the upper and lower limits for determining stock status level in feedback HCR

The stock level showed in the high level; therefore, it was as 1.0 (Figure 7). The catch of two years before the estimated year (C_{y-2}) was 31,897 tons (Table 2). The regression coefficient of y – 4 to y – 2 was 0.29, while the average CPUE from y – 4 to y – 2 was 1.41 tons/trip. The annual TAC was 38,488 ton and the annual TAE was 27,576 trips. The results were separated by species to be compared (Table 3).

Table 2. Catch and effort data of scad fishery in 2011 – 2020

No	Year	Catch (tons)	The number of fishing trip	*CPUE*
1	2011	23,776	38,870	0.61
2	2012	21,560	39,379	0.55
3	2013	28,657	25,509	1.12
4	2014	36,216	29,214	1.24
5	2015	37,773	28,754	1.31
6	2016	31,823	28,969	1.10
7	2017	30,022	29,352	1.02
8	2018	28,700	25,361	1.13
9	2019	31,897	22,854	1.40
10	2020	36,612	21,332	1.72

3.3 Technical comparison

The results of the annual TAC estimation were compared between the Schaefer model and the feedback HCR (Table 3).

Table 3. Technical comparison of HCRs

No	Spesies	The Feedback HCR	The Schaefer model
1	Red bigeye	18.743	12.667
2	Golden thredfin bream	10.003	7.484
3	Sulphur goat fish	9.742	6.594

Without assessing biomass as a common requirement for applying surplus production model, the feedback HCR can provide the estimation of annual ABC by considering the precautionary approach (Harlyan *et al*., 2019; Ichinokawa *et al*., 2017). Following the historical data of catch – effort over 10 years, the estimation of annual ABC can be calculated. In this situation stock abundance index that was documented in the historical catch – effort data can be used for considering further fishing activities (Harlyan *et al*., 2019; Ohshimo & Naya, 2014).

The results of study that were summarized in the Table 3 showed that the feedback HCR gave higher estimation of annual ABC for three dominant demersal species than the Schaefer model. However, this does not indicate that the feedback HCR could not apply the precautionary approach since the estimation of the future annual ABC was about to adapt the recent stock abundance index (Harlyan *et al*., 2019; Magnusson, 1992; Tanaka, 1980). Since the recent stock abundance index performed an increase trend of productivity, the future estimation may follow this trend.

The historical stock abundance has a critical function to set future policies and strategies as the feedback HCR do. On the other hand, the Schaefer model as a conventional surplus production model was depended on the MSY estimation that may contain uncertainty in biomass assessment (Shertzer *et al*., 2008).

The demersal fisheries in Brondong waters are multispecies which may raise mismanagement in species separation. Therefore, the feedback HCR may provide an answer to manage these multispecies fisheries as it is applicable to manage multispecies at once.

4. CONCLUSION

The feedback HCR can provide closer and more adjustable estimation of annual ABC than the Schaefer model in terms of the historical stock abundance index. It is suggested that the feedback HCR is applicable for multispecies fisheries management where the species separation problem occurred. Therefore, it is critical to document the implementation of the feedback HCR in the real multispecies fishery which could not provide species-specific data. This might be beneficial to assess the use of this application in the fisheries with data-limited condition.

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