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ASSESSMENT OF THE RESOURCES SUSTAINABILITY USING RESOURCE UTILISATION AND CATCH PROJECTION APPROACH: CASE OF PRIGI GULF INDONESIA

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Abstract: Utilisation of fisheries resources requires good management to maintain the sustainability of fish resources. Based on these conditions, this study aims to analyse the status of fish resource utilisation and estimate fish catches in the following year. The data collection is secondary data from Prigi Fishery Port, East Java, from June to September 2023. This study evaluates biological surplus production relationships. Next, due to the time series data, the forecasting performance uses Holt-Winter's exponential smoothing. The modelling shows that the best estimation value in the Fox model is based on the highest R^2 (0,614) and the effort coefficient (0.000034). The maximum sustainable yield (C_{MSY}) and the optimum catch effort (E_{MSY}) values were 10.006 tonnes/year and 29,425 trips/year, respectively. It shows that biological overfishing has yet to occur. The average production forecasting results in 2021-2023 decreased 8.5% from the previous year. Forecasting fish catches in 2021 exceeds C_{MSY}, but in 2022 and 2023, production is still below C_{MSY}. The circumstance indicates that fishing operations are inefficient because the catch obtained is projected to be smaller with fixed effort. Possible management strategies, therefore, include creating sustainable fisheries management through improved work variation for fishers in the off-season.

Keywords: Fisheries resource utilisation, small-scale fishers, fish catch estimation.

Introduction

Marine resources are common property open to anyone (Field, 1990). Everyone can utilise marine resources with any equipment and in unlimited quantities. The ocean as a common property is the basis for explaining the crisis of marine resources (Hardin, 1968; Cahyadi, 2012). As a result of open access fisheries resources, the boundaries of everyone's responsibility in managing and utilising resources become unclear, which will cause overfishing (Akoit & Nalle, 2018). The study's results (Setyaningrum, 2018) show that the catch of mackerel (*Scomber Scombrus* spp.) in the Situbondo Regency Waters using purse seine gear was overfishing due to the catch rate exceeding the optimum fishing effort. Therefore, to avoid overfishing, the government has to make several policies, e.g., replacing fishing gear if there is a break in the fishing gear and limiting the catch rate.

The symptoms of overfishing are found in several waters in Indonesia. The utilisation of fishery resources in WPP 571 Malacca Strait has exceeded exploitation (Asmawati & Nasir, 2017). Furthermore, the condition of demersal fisheries resources around the coast in Indramayu Regency showed overfishing and resource degradation (Yulianto *et al.*, 2016). Similarly, the condition of small-scale fisheries in Semarang City is at an over-exploited utilisation level (Kristiana *et al.*, 2021). The same thing was found in Dumai waters, where the utilisation status of demersal fish fell into the overfishing category (Arkham *et al.,* 2021). Overfishing in several ocean waters in Indonesia causes the regulation and management of fisheries resources to consider the sustainability of marine aquatic life (Regulation of the Minister of Marine Affairs and Fisheries Republic Indonesia, 2016; 2021).

Moreover, to prevent the circumstance, some things that must be done to reduce the pressure on marine exploitation are limiting the use of fishing gear that is not environmentally friendly, developing alternative livelihoods, and forming marine resource management institutions (Kristiana *et al*., 2021). Not environmentally friendly fishing gear means that the gear is not harmful to the environment, or we can say that it is selective gear, e.g., longline, pool and line. Meanwhile, the need for effort regulation through government policies coupled with policies to create alternative livelihoods and manage fish habitats from destruction (Yulianto *et al.,* 2016).

Small-scale fisheries with handline nets dominate the waters of Prigi Bay in Trenggalek Regency. Handline nets are environmentally friendly and selective because they use hooks that match the size of the fish caught. The selectivity of the fishing rod is relatively high because the fish will not eat the bait if the size of the fishing rod is more prominent or smaller than the mouth of the fish (Dewi *et al*., 2020). Moreover, handline has sustainability and environmentally friendly aspects with the highest score compared to 10 other fishing gear (e.g. trowel lines, pole and line, purse seine, boat seine, lift net, longline, shrimp trawl, seine nets, beach seine, and trammel net (Nanlohy, 2013). Findings (Limbong *et al*., 2021) show that longline fishing is environmentally friendly with grouper (*Epinephelinae* spp.), red snapper (*Lutjanus campechanus* spp.), barracuda (*Sphyraena* spp.).

Small-scale fishers in Prigi Bay operate between six and eight months in a year. The average work time of small-scale fishers is 117 to 230 working days (Purwanti *et al*., 2022). Generally, small-scale fisher households have jobs outside of fishing, including forest farmers, livestock breeders, tour guides, and small traders (Susilo *et al*., 2021; Purwanti *et al*., 2023a). The business diversification activities carried out by fishers in Prigi Bay can strengthen the adaptive capacity of small-scale fishers (Susilo *et al*., 2021). Business diversification activities result in more stable income for fisher households. Thus, fisher households can fulfil basic food and non-food expenses, and small-scale fisher households are prosperous (Purwanti & Susilo, 2019). This food sufficiency will cause small-scale fishing households in Prigi Bay to have food security (Purwanti *et al.,* 2023b).

The above behaviour of small-scale fishing households indirectly benefits marine resources to recovery. In one year, resource utilisation is intensive during the four-month peak season. During the medium season, only a few do fishing activities. Most fishing rod fishers do many activities outside fishing (Purwanti *et al.,* 2022). Concerning the productive activities of fishing households in Prigi Bay, this study will examine the determination of the status of small-scale fisheries in Prigi Bay to determine the level of utilisation. In addition, it analyses the estimation of fishers' catches to see how small-scale fishing businesses can provide income for fishers' households.

Materials and Methods

This research was conducted from June to September 2023 in Prigi Bay, Trenggalek Regency. The time-series data of fish catches consists of annual landings, including their effort at the Prigi Fishery Port from 2014 to 2020 (Table 1). The weight of a catch is expressed in a well-defined unit of fishing effort called the catch per unit effort (CPUE). CPUE regulates catch data based on the volume of effort (total time or coverage) utilised. Therefore, this study requires input data from purse seine, i.e. total fish catch, number of fishing trips, and number of fishing gear, for the past six years (2014-2020). This study evaluated CPUE based on daily fishing, i.e., the amount (in weight) of fish caught per day by fishing gear (tonnes/trip).

Table 1: Fish catch-effort data based on fishing gear catch fishery of Prigi, East Java, Indonesia

Year	Effort (Trip)	Catch (Tonnes)	CPUE (Tonnes/trip)
2014	14802	10182	0.688
2015	20927	10074	0.481
2016	11744	4323	0.368
2017	14258	4873	0.342
2018	18863	9345	0.495
2019	21074	7365	0.349
2020	24575	9235	0.376

Source: data processed (2023)

Data analysis was conducted using two models, namely the Surplus Production Model (SPM) and Winter. Each analysis has a different purpose. The SPM determines the status of small-scale fisheries resources. This model is one of the simplest stock assessment models and is most easily explained and accepted by fish resource managers. The underlying assumption of this model is that the fish resource is a single entity without the not-so-simple processes that lead to the entity's formation (Karim *et al*., 2020). This model only requires catch and effort data, two types of data that have been collected and are known as fisheries statistics known as fisheries statistics (Causido-Rocha *et al*., 2022). However, at a minimum, it is necessary to know the characteristics of the fish resource, its behaviour, and the limits of its resilience to fishing pressure to fishing pressure (Zhang *et al*., 2021). Moreover, data analysis to estimate the target fish catches of small-scale fishers uses Winter. The following describes each procedure during data analysis in detail.

Analysis of Small-scale Fisheries Resource Utilisation Using the Surplus Production Model

By estimating the potential sustainable catch and optimum effort used five surplus production models. Schaefer (1954), Walter-Hilborn (1976), Schnute (1977), The Fox (1970) and CYP (1992) are models used in this paper (Tinungki *et al*., 2005). Data on the amount of production or catch and the fishing gear available at the Prigi Fishery Port were analysed to calculate CPUE, $C_{MSY,}$ and E_{MSY}. CPUE value is calculated based on the total amount of production or catch (tonnes/year) compared to the total effort (units). CPUE is needed to transform the formula equation into a linear equation. Thus, all biological parameters can use the ordinary least square regression to measure SPM. CPUE formula is mentioned as follows (Gulland, 1983):

$$\text{CPUE} = \frac{\text{C}}{\text{E}} \qquad \textbf{(1)}$$

where:
CPUE = Catch per unit effort
C = Catch
E = Fishing effort

The five models used for this analysis relate stock size, fishing effort and yield to one another. Using the same logbook data, we use those models to explain the relationship between production and fish growth to estimate resource utilisation in Prigi Bay. The five models, namely, Schaefer (1954), Walter-Hilborn (1976), and Schnute (1977), use a logistic population (linear relationship) (Clarke, 1992). Then, the Fox (1970) and CYP (1992) models used a Gompertz curve (exponential relationship) (Richards, 1959). The details of each model are presented in this section.

1. *The Schaefer model.* The model was developed in 1954 with the assumption that there is a long-term equilibrium circumstance in the production process and stock. Then, the dynamic function will be applied to the catch and sustainable fisheries. This model does not use a

concrete version of the biological model. The Schaefer model equation is as follows:

$$CPUE = \alpha - \beta E \qquad \textbf{(2)}$$

where:
CPUE = Catch Per Unit Effort
α = Constant
β = Coefficient
E = Effort

Maximum Sustainable Yield (C_{MSY}), abide by:

$$C_{MSY} = \frac{\alpha^2}{4\beta} \qquad \textbf{(3)}$$

Optimum Catch Effort (E_{MSY}), abide by:

$$E_{MSY} = \frac{\alpha}{2\beta} \qquad \textbf{(4)}$$

2. *The Fox models*. This model uses the Gompertz growth model to measure biomass growth, and CPUEt follows a negative exponential pattern. The parameter estimation is based on the equilibrium model by Schaefer model analysis in a linear-non-linear form. The Fox model equation is as follows:

$$LnCPUE = \alpha - \beta E \qquad \textbf{(5)}$$

where:
LnCPUE = Ln catch per unit effort
α = Constant
β = Coefficient
E = effort

Maximum Sustainable Yield (C_{MSY}) where *a* = constanta; and *b* = coefficient, abide by:
$C_{MSY} = E.\exp(a + bE)$

Optimum Catch Effort (E_{MSY}), abide by:

$$E_{MSY} = \frac{1}{b}$$

3. *The Walter-Hilborn model.* Found in 1976, the model uses a different approach to the Schaefer model. The model uses a discrete and concrete version of the biological models, with the regression method as the physical parameters. His method is known to be easier than others due to the way of estimation directly from the equation. Therefore, this model is linear, lag, and reciprocal. The Walter-Hilborn model equation is written in the following line:

$$\frac{U_{t+1}}{U_t} - 1 = \alpha + \beta U_t + \gamma E_t \qquad \textbf{(6)}$$

where:
U_{t+1} = CPUE current year + 1
U_t = Current year
α = Constanta
β = Coefficient
γ = Coefficient 2

4. *The Schnute model*. This model is a modification of the Schaefer model and was developed in 1977. It is a nonlinear analysis, log, and reciprocal. It also shows another redaction of the vigorous and separate in time from the Schaefer. This model answers the criticism of the Schaefer due to its nature above. The Schnute model equation is as follows:

$$Ln\left(\frac{U_{t+1}}{U_t}\right) = \propto - \beta\frac{(U_{t+1} + U_t)}{2} - \gamma\frac{E_{t+1} + E_t}{2} \qquad \textbf{(7)}$$

where:
U_{t+1} = CPUE current year + 1
U_t = Current year
α = Constant
β = Coefficient
E_{t+1} = Effort current year + 1
E_t = Effort current year
γ = Coefficient 2

5. *The Clarke, Yoshimoto, and Pooley (CYP) model*. In 1992, as a development for other surplus production models, this model used a log model to estimate biological parameters in a discrete form of logarithmic in natural logarithmic. The CYP model equation is as follows:

$$\ln U_{(t+1)} = \alpha + \beta U_t - \gamma(E_t + E_t + 1) \qquad \textbf{(8)}$$

In details:
U_{t+1} = CPUE current year + 1
U_t = current year
α = Constant
β = Coefficient
E_{t+1} = Effort current year + 1
E_t = Effort current year
γ = Coefficient 2

Analysis of Fish Catches Estimation of Small-scale Fishers' Catches Using Winter Methods

For the next step, data analysis will be used to forecast the target fish catches of small-scale fishers using Holt-Winter (Rusiman *et al.*, 2018; Pamungkas, 2021). Data analysis using this method was carried out with the help of the Minitab 17 computer program. The Holt-Winters method is a forecasting technique that can be used for time series data that exhibits both a trend and a seasonal variation. It is an extension of Holt's linear trend method, developed to capture seasonality. The method assumes that the time series can represent a linear trend with a seasonal component. It uses three smoothing equations to estimate the time series' level, trend, and seasonal components.

In this model, the level equation is used to estimate the current value of the time series, while the trend equation is used to estimate the change in the time series over time. The seasonal component equation estimates the seasonal variation in the time series. The method can handle both additive and multiplicative seasonality, depending on the nature of the seasonal variations in the data. The Holt-Winters method is widely used in various fields, including inventory forecasting, and can be applied to daily, weekly, monthly, or quarterly data (Chatfield, 1978). The Winter method consists of several stages as follows (Octora & Kuntoro, 2013):

(1) Identifying the model
(2) Determining the initial value of parameter estimates
(3) Determine the smoothing constants (α, γ, and β)
(4) Calculating the original data forecast value
(5) Forecasting the next period

The model in the Winter method can be formulated (Fani *et al.*, 2017) as follows:

$$S_t = \alpha(X_t - I_{t-L}) + (1-\alpha)(S_{t-1} + T_{t-1}) \quad \textbf{(9)}$$

$$T_t = \beta(S_t - S_{t-1}) + (1-\beta)T_{t-1} \quad \textbf{(10)}$$

$$I_t = \gamma(X_t - S_{t-1}) + (1-\gamma)T_{t-L} \quad \textbf{(11)}$$

$$\hat{Y}_{t+p} = (S_t + T_t.p) + I_{t-L+p} \quad \textbf{(12)}$$

where:

S_t = the new smoothing value of actual data
X_t = actual production value in the period
α = smoothing coefficient (0 < α < 1)
T_t = trend estimate value
β = smoothing coefficient for trend (0 < β < 1)
I_t = seasonal forecast value
γ = seasonal smoothing coefficient (0 < γ < 1)
p = the number of future production periods to be forecasted
L = length of seasonal variable
$\hat{Y}_{t+p}$ = production forecast value for future periods

Forecasting with the Winter method has three smoothing parameters (α, β, and γ) with values between 0 and 1, subsequently, many combinations must be tried to find the optimal parameter values. The best model in the Winter method is obtained by finding the minor error value from several models with different combinations of the three constants. The smoothing constants or parameters α, β, and γ are determined by trial so that minor error in the form of MAPE (Mean Absolute Percentage Error), MAD (Mean Absolute Deviation), and MSE (Mean Square Error) is obtained among the models tried (Octora & Kuntoro, 2013). The criteria for the ability of data to produce excellent forecasts is if the MAPE percentage value is considered less than 10%, good if between 10-20%, feasible between 20-50%, and poor if > 50% (Hutasuhut, 2014).

Results and Discussion

Status of Small-scale Fisheries in Prigi Bay

Prigi Fishery Port is built on an area of 30.1 hectares with a land area of 14.1 hectares and a berthing pond area of 16 hectares. Located at coordinates 111043'58" East and 08017'22" LS, precisely in Tasikmadu Village Watulimo District Trenggalek Regency East Java Province. The distance from Nusantara Port to Surabaya, a province capital city, is 200 km. Meanwhile, the distance to Trenggalek as a district capital city is 47 km. The fishing area for fishers at Prigi Fishery is the Indian Ocean Regional Fisheries Management 573. In 2019, the fisheries production volume at Prigi Fishery Port amounted to 28.822 tonnes with a production value of IDR198,339,137,750 (USD12,762,068.55).

Furthermore, in 2020, it amounted to 24.928 tonnes with a production value of IDR219,419,964,000 (USD14,118,507.59). It shows a decrease in fisheries production volume of 3.894 tonnes (3.51%) due to a significant decrease in the volume of the *Decapterus Macrosoma Bleeker* sp. by 70%. However, the condition did not affect the value since the production value increased by IDR1,080,826,250 (USD1,356,439.04) or 10.63% because fish prices tend to be stable. In 2020, weather conditions, rainfall, and oceanography tended to be suitable for fishing, so the fishing season at the Prigi Fishery Port occurs throughout the year except in December, with a significant decrease in production. In comparison, the peak fishing season occurs in October.

The number of vessels in 2020 is 664 units, consisting of vessels less than 10 Gross of Tonnage (GT): 490 units (73.8%), 11-20 GT: 81 units (12.2%), 21-30 GT: 91 units (13.7%) and more than 30 GT: 2 units (0.3%). The number of fishing trips in 2020 was recorded at 24,575 times. It consisted of one vessel purse seine used 21 times (0.1%), two vessel purse seines used 14,253 times (58%), gill net used 756 times (3.1%), traditional open fishing boat (*payang*) used 571 times (2.3%), Tonda fishing rod used 976 times (4%) and Handline used 7,998 times (32.5%).

Into the bargain, the number of fishing gear at the Prigi Fishery Port in 2020 was 664 units, which consisted of 449 units (67.2%) of Hand Line, two Vessel Ring Trawl: 130 units (18.95%), Tonda Fishing Line 67 units (9.77%), Gill Net 7 units (2.48%), traditional open fishing boat (*payang*) 7 units (1.02%) and One Vessel Ring Trawl: 4 units (0.58%). Compared to the 608 units of fishing gear and 21.074 units of fishing trips in 2019, it means an increase of 56 units (9%) in a year. Therefore, from these data, fishing trips have increased by more than 15% from 2019 to 2020.

The largest fish catches landed at Prigi Fishery Port is from pelagic fish species such as Bullet Tuna (*Auxis rochei* spp.) by 8.004 tonnes (32.12%), Indian Oil Sardine (*Sardinella longicep* spp.) by 6.185 tonnes (24.59%), Mackerel Scads (*Decapterus macrosoma bleeker* spp.) by 3.167 tonnes (13.10%), Gold stripe Sardinella (*Sardinella gibbosa* spp.) by 2.061 tonnes (8.53%), Blue Mackerel (*Scomber australasicus* spp.) by 1.199 tonnes (4.96%), Lajang Scad (*Decapterus russelli rüppell* spp.) by 1.043 tonnes (4.32%), Hairtails Nei (Trichiurus savala spp.) by 811 tonnes (3.36%), Skipjack tuna (*Katsuwonus pelamis spp.*) by 763 tonnes (3.16%), Redtail Scad (*Decapterus kurroides bleeker* spp.) by 619 tonnes (2.56%), and Yellowfin tuna (*Thunnus albacares* spp.) by 311 tonnes (1.29%).

The catches of small-scale fishers in Prigi Bay are generally Common Squid Nei (*Loligo* spp.), Hairtails Nei (*Trichiurus savala* spp.), Frigate Tuna (*Auxis thazard* spp.), and Anchovy (*Stolephorus* spp.) (Susilo *et al.,* 2021). Generally, *A. rochel* spp. is the most dominant fish catch, with an average production of 6,924.729 kilos (6,924 tonnes). At the same time, the lowest catch is *Loligo* spp. in 29,674 kilos (29 tonnes) (Figure 1); therefore, the average production of all fish from 2014-2020 is 7,913.845 kilos (7,913 tonnes).

The dominant types of fishing gear used to catch the four dominant fish species are purse seine, gill net, traditional open fishing boat (*payang*), tonda fishing, and handline fishing. The average fishing effort was 14,797 trips, with the lowest trip in 2016 is 6,128 trips and the highest trip in 2020 is 21,926 trips (Figure 2). Purse seine is the standardised fishing gear that produces the highest Fishing Power Index 1 (CPUE). The CPUE value is obtained by dividing the data between the catch and the amount of effort that has been standardised. The CPUE value in 2014-2020 (Figure 3) has decreased yearly by 6.95%, explaining that the

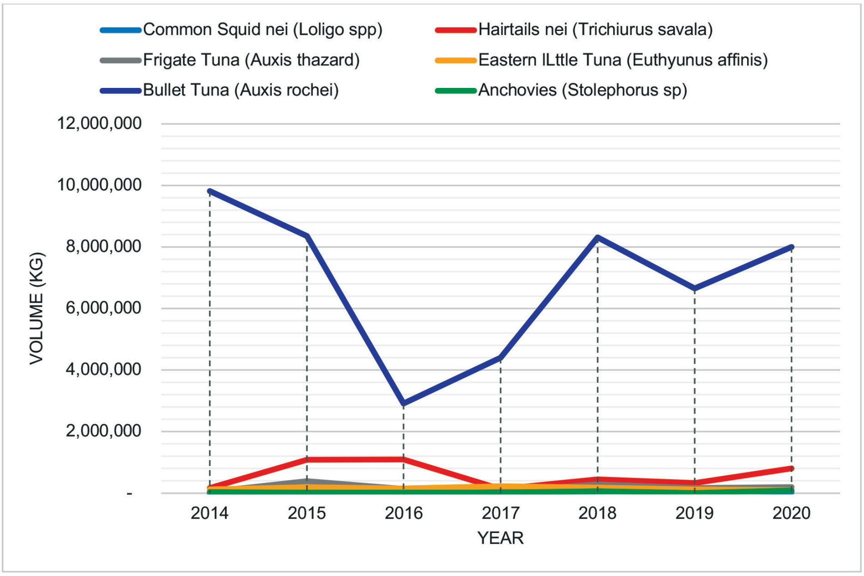

Figure 1: The catches of small-scale fishers of Prigi Fishery Port, East Java, Indonesia (2014-2020)

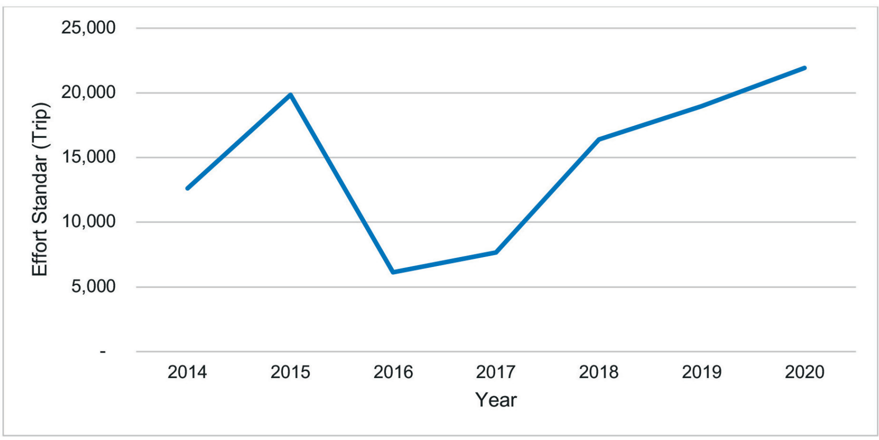

Figure 2: Number of standardised efforts of Prigi Fishery Port, East Java, Indonesia (2014-2020)

development trend or decline in CPUE value can be seen from the relationship between CPUE and effort. This CPUE trend can indicate the status of fish resource utilisation in a body of water.

The sustainable potential of fish resources caught by small-scale fishers through catch and effort is estimated using five models, namely the Schaefer, Fox, Schnute, CYP, and Walter-Hilbron approaches. As previously stated, these five models have peculiarly different biological production relationships. The Schaefer and Schnute models have a logistic relationship. It is shown in the comparison (Table 2).

The selection of equations that can produce good estimation values then meets the requirements of the sign in the equation, R square, and significant value. Based on the consideration of the suitability of the requirements, the Fox equation $Y = 6.83 - 0.000034X_1$ was chosen.

Based on Fox's approach, the C_{MSY} value is 10,006,793.87 kilos (10.006 tonnes) with E_{MSY} value of 29,424.53 trips (Figure 4). The resulting effort shows no biological overfishing because

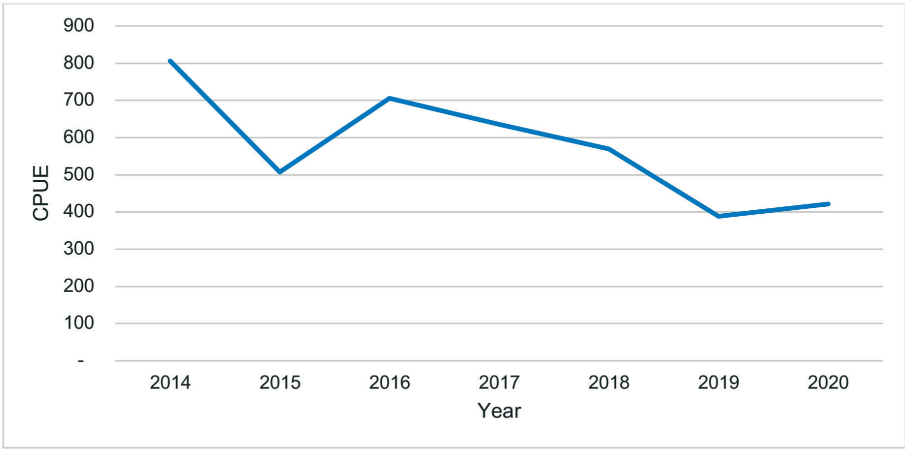

Figure 3: Catch per unit effort of Prigi Fishery Port, East Java, Indonesia (2014-2020)

Table 2: The indicator comparison for biological production

Indicator	Schaefer	Fox	Walter-Hilbron	Schnute	CYP
α	855.4	6.83	0.65	1.64	8.05
β	0.0189	0.000034	0.0012	0.00196	0.18
γ	-	-	0.000000472	0.0000437	0.000022

Source: data processed (2023)

Table 3: Appropriateness of biological equations

Indicator	Scheafer	Fox	W-H	Schnute	CYP
Sign Conformance	Suitable	Suitable	Suitable	Suitable	Unsuitable
R^2	58.99%	61.42%	42.17%	20.24%	65.89%
t	Significant	Significant	Insignificant	Insignificant	Insignificant

Source: data processed (2023)

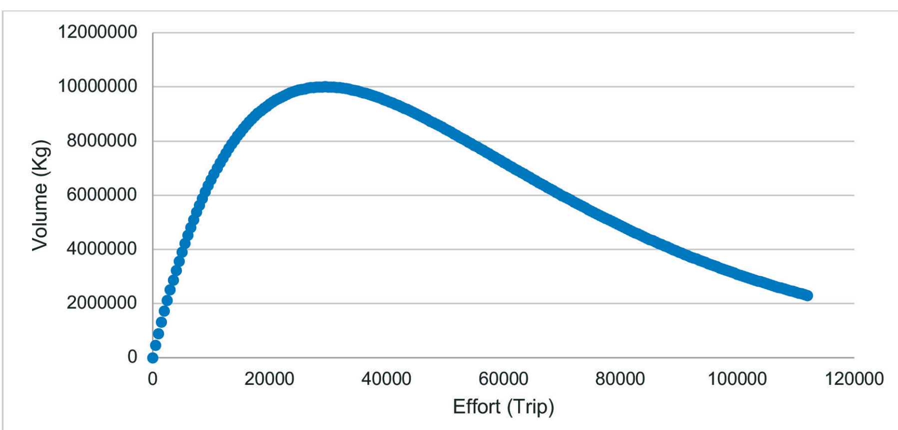

Figure 4: Relationship between effort and production quantity using Fox approach

the average fishing effort from 2014-2020 was 14,797 trips; in 2020, the standard fishing effort of 21,926 trips is still below E_{MSY}.

Fishing effort in 2020 was 21,926 trips; hence, that consideration for the next year can add a standard amount of effort of 7,498.53 trips. The fishing effort using the dominant purse seine gear per vessel is 110 trips, with a total fishing effort of 14,253 trips. As a result, if the fishers add a vessel, there will be 68 vessels. However, if the government issues a policy to increase the number of purse seine with 130 fishing gear in 2020, each fishing gear can add 58 trips of fishing effort.

Estimation of Fishers's Catch in Prigi Bay

Using Holt-Winter's model, this paper also provides the estimation of production. Demand forecasting is essential to predicting the possibility of overfishing. Demand forecasting calculations require periodic series data from the previous period so that estimates can be used to make decisions (Fattah *et al*., 2020). Fishery production results are based on quarters from 2018-2020, with the highest production value in the fourth quarter of 2018 at 7,233,558 kilos (7,233 tonnes), while the lowest production value is in the first quarter of 2019 with 348,170 kilos (348 tonnes) (Figure 5).

The model that produces the smallest forecasting error value has a combination of coefficients alpha = 0.3, betha = 0.3, and gamma = 0.3. It was chosen as the best winter method forecasting model because it is more accurate than others. Forecasting accuracy is an essential factor in deciding between various alternative forecasting meth ds. The accuracy of a forecast is based on the historical error of the forecast. To minimise the error in the analysing process, three approaches are needed: Mean absolute percentage error (MAPE), mean absolute deviation (MAD), and mean square error (MSE). Using quarterly data from 2018 to 2020, the results show the number of MAD is 4.44668E + 05, MSE is 3.31752E + 11, and MAPE is 17.8% (Figure 6).

The MAPE is the average absolute percentage error, which is particularly useful when the size of the forecasting variable is an essential factor in evaluating forecasting

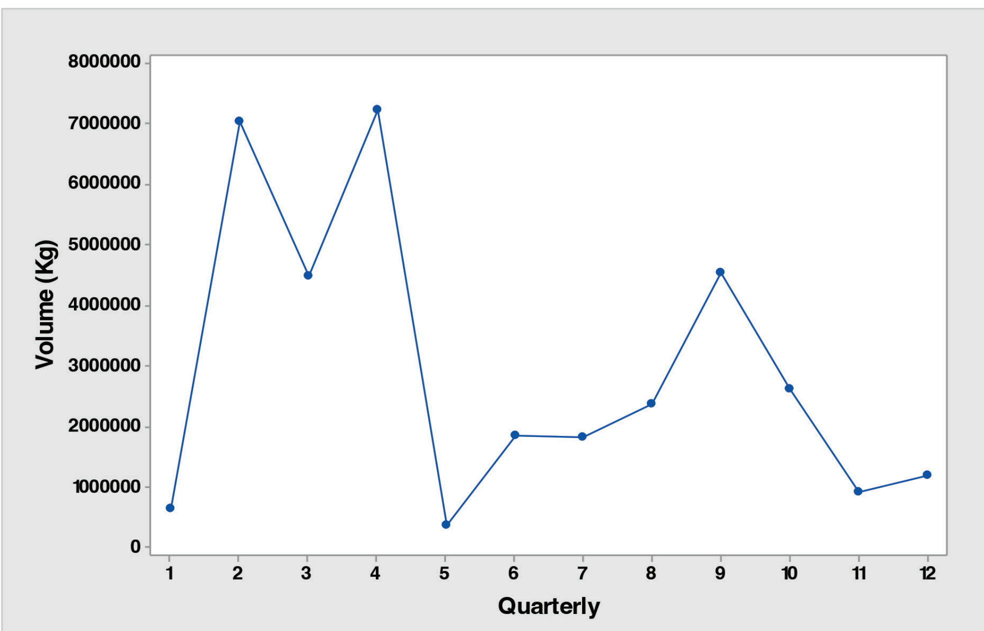

Figure 5: Targeted fish catches of small-scale fishers (quarterly)

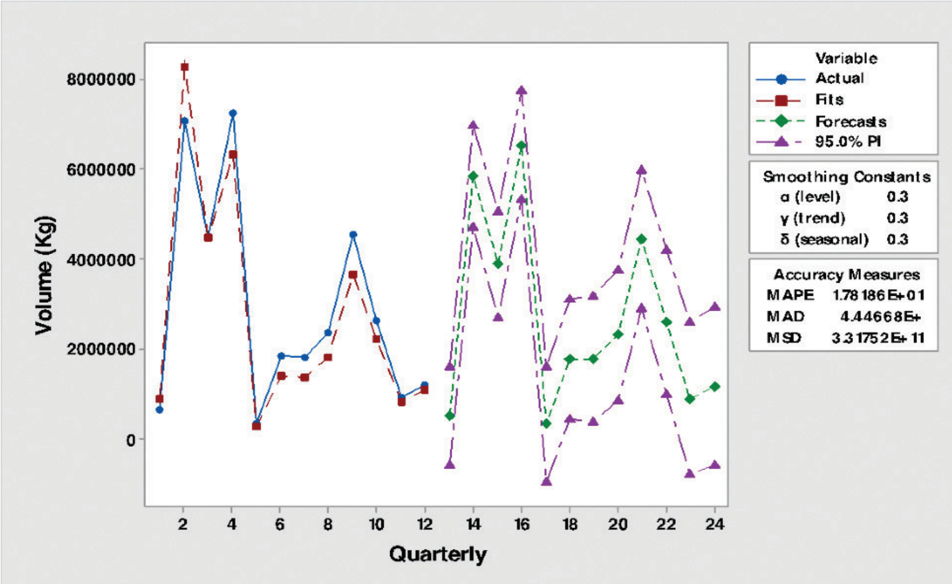

Figure 6: Accuracy and forecasting of fish catches

accuracy. MAPE yields the value of the forecasting error compared to the actual value. The smallest MAD value used to determine the forecast calculation results is close to or equal to the actual conditions. Suppose the MAD results are closer to zero, even though it is impossible to assume they are close to reality (Sarjono & Abbas, 2017). The MSE is another way to measure overall forecasting error. The MSE is the average squared difference between forecasted and observed values (Barry & Heizer, 2001). The data is suitable for forecasting if the MAPE value is 20-50% (Montaño Moreno *et al*., 2013). Then, the data based on quarters from 2018 to 2020 can be declared suitable for forecasting.

Table 4: Quarterly forecasting in 2021-2023

No.	Year	Quarter	Fish Catches Forecasting (Kilos)
1	2021	1	502.554
		2	5.837.920
		3	3.873.429
		4	6.532.188
2	2022	1	324.947
		2	1.764.512
		3	1.762.802
		4	2.301.929
3	2023	1	4.448.061
		2	2.586.829
		3	897.314
		4	1.169.527

Source: Data Processed (2023)

From the forecasting results, small-scale fishers' average target fish catches have decreased compared to the previous year's average production by 8.5% or 248,896.08 kilos. The average quarterly between 2018 to 2020 was 2,915,730 kilos (2,915.73 tonnes) to 2,666,834.33 kilos (2,666.834 tonnes) between 2021 to 2023.

Forecasting the target fish catches of small-scale fishers in Prigi Bay in 2021 amounted to 16,746,091 kilos (16,746.091 tonnes). On that account, this year exceeds the sustainable potential. However, the estimated production results in 2022 and 2023 amounted to 6,154,190 (6,154.19 tonnes) and 9,101,731 (9,101.731 tonnes), respectively. This result shows that it is still below the sustainable catch. Therefore, production can still be maximised in future years.

Conclusions

Estimating the utilisation of target fish resources of small-scale fishers produces the best estimate using the Fox approach. Actual target fish catches are 79.08% of C_{MSY}, while real effort is 48.4% of E_{MSY}. Therefore, the effort value shows that biological overfishing has not occurred. Forecasting three years after 2020 resulted in the 2021 production value exceeding 67.4% of C_{MSY}, while in 2022 and 2023, it approached the C_{MSY} value by 38.5% and 9.04%, respectively. The suggestion that can be given in this study is that the dominant fishing gear is purse sein; then, with the E_{MSY} results, there are two options: the first can add 68 vessels or add fishing effort as many as 58 trips per vessel. Another way to enhance the fishers' welfare while maintaining bioeconomic sustainability is by using several work variations. The fishers can also cultivate forest land and maximise the area to become a potential tourism destination.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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