# Maximum sustainable yield of bombay-duck (*Harpadon nehereus*) in the waters of Dumai City, Riau Province

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**Abstract**. Bombay-duck (*Harpadon nehereus*) is one of the local superior commodities that are quite important in the waters of Dumai City. The catch of Bombay duck is substantial and tends to increase each year. The capturing of bombay-duck is commonly done by traditional fishing businesses using boats with a gross tonnage of 2-3 and gill net fishing gear. The aim of this study is to assess the potential and utilization level of bombay-duck catches in the waters of Dumai city. A survey method was employed, involving the analysis of the maximum sustainable yield (MSY) and the total allowable catch (TAC) for bombay-duck using both primary and secondary data. The analysis revealed that the sustainable potential of bombay-duck in Dumai City yielded a MSY of 79 ton year$^{-1}$, with an optimal effort ($E_{opt}$) of 94 unit year$^{-1}$. The TAC was calculated at 63 ton year$^{-1}$, with a utilization rate of 110 percent, indicating that the bombay-duck stock is overexploited. Therefore, effective management steps are needed to reduce overexploitation of the bombay-duck. Some steps that can be taken include setting lower catch quotas, tightening fisheries regulations, closing certain fishing seasons, as well as educating and socializing fishermen. In addition, the development of alternative livelihoods and efforts in restocking and habitat conservation are also needed to ensure the sustainability of bombay-duck populations and the well-being of fishermen who depend on this resource.

**Key Words**: bombay-duck, maximum sustainable yield, traditional fishing, utilization.

**Introduction**. The coastal area is a potential region to be developed as a source of regional income through fishing activities (Kumaat et al 2013). In terms of fish supply, capture fisheries play an important role in maintaining food security in Indonesia. The rising per capita fish consumption has led to a surge in the demand for fish, consequently increasing fishing activities (Guillen et al 2019; Shamsuzzaman et al 2020). There are many fishing activities, one of which takes place in the waters of Dumai City.

As a coastal area, Dumai City has enormous fishing potential. Dumai's strategic location on the east coast near the Strait of Malacca makes it an important international shipping route (Ramadhan et al 2021). The state of fisheries in Dumai City shows that almost all of its production comes from marine fisheries, accounting for approximately 75.45 percent of the total production. The remaining percentage is from aquaculture. The fisheries production in Dumai City has increased from 1,020.3 tonnes in 2022 to 1,057 tonnes in 2023 (BPS-Statistics Dumai 2024).

One type of fishery resource found in the waters of Dumai City is the bombay-duck (*Harpadon nehereus*). Bombay-ducks live in the muddy coastal areas, river estuaries, with a total length of up to 40 cm, and typically ranging from 10 to 25 cm in size (Salim et al 2023). They are found in tropical regions of the Indo-Pacific, India, Somalia, Papua New Guinea, Japan, and Indonesia (Djunaidi 2021). In Indonesia, bombay-duck is commonly found in the sea waters of Tarakan City under the name 'Nomei' and in the waters of Dumai under the name 'Lomek' (Anita et al 2023). This fish is one of the local superior commodities that are quite important in the waters of Dumai City. This is due to the significant amount of fish caught, which tends to increase every year.

BPS-Statistics Dumai recorded that the production of bombay-duck for the period 2022-2023 increased from 201 tonnes in 2022 to 261 tonnes in 2023 (BPS-Statistics Dumai 2024). The utilization of bombay-duck is commonly done by traditional fishing businesses using boats with a gross tonnage of 2-3 and gill net fishing gear. The fleet and fishing gear used by fishermen are still relatively simple, so modernization concepts in fisheries are needed to achieve sustainability (Syahrul et al 2022; Arief et al 2023b). The bombay-duck is being intensively exploited in the waters of Dumai City without any control, which is feared to threaten the sustainability of fish resources in its habitat. Utilization efforts without considering the ability to recover have caused fisheries resources in some water areas to become extinct (Brown et al 2018). In order to ensure the continued existence of the bombay-duck, initial data on the biological aspects of the bombay-duck are needed to assist in the proper utilization and conservation of the species for future generations. Therefore, effective management is necessary to ensure the sustainable utilization of the fish.

This research aims to analyze the level of maximum sustainable yield (MSY) of bombay-duck in Dumai City, including production, utilization rate, and catch quantity. This research is expected to provide information on MSY, optimum effort ($E_{opt}$), and utilization rate as information for the management of bombay-duck in Dumai City.

**Material and Method**. Data were collected at the Dumai Fish Landing Base (PPI) and the Department of Fisheries Dumai City. The collected data was categorized into primary and secondary data. Primary data was obtained through direct observation and interviews. Secondary data was obtained from relevant parties related to the research problem. These parties come from the Department of Fisheries Dumai City and the BPS-Statistics Dumai, providing data on fishermen, fish production, the number of fishing gear, and the fleet of boats.

***Study location and time***. The research was conducted in June-July 2024 at the Dumai Fish Landing Base (PPI). It is assumed that all fishermen in the Dumai City area land their catch at PPI Dumai. The map of the research location is shown in Figure 1.

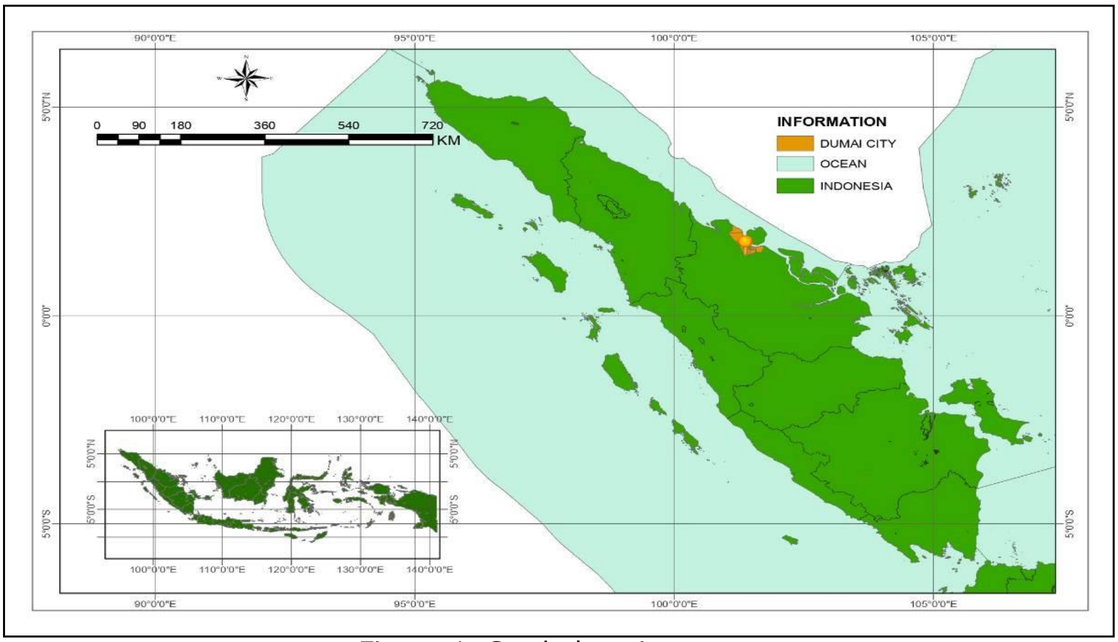

Figure 1. Study location map.

***Data analysis***. The utilization rate of bombay-duck is estimated using a surplus production model approach. This model is commonly used to assess fish stocks based on catch data and fishing effort data, which are generally available. The estimated models analyzed consist of five models: Schaefer, Fox, Walter-Hilborn, Schnute, and Clarke Yoshimoto Pooley (CYP). The parameter estimation procedure for these models follows a formula. Based on the statistical evaluation results, such as the $R^2$ value, validation value, and significance of the regression coefficient, the best model will be selected as an estimator (Fauziyah et al 2020a; Arief et al 2023a). From that model, the value of MSY and the level of exploitation of bombay-duck can be calculated. This research includes the formation of models, parameter estimation, and model testing. Here are the formulas for each model that will be analyzed.

1. Catch per unit effort (CPUE). CPUE is the value calculated between total production (ton $year^{-1}$) and total effort (unit) (Kristiana et al 2021). The CPUE value is obtained by the formula:

$$CPUE = \frac{Catch}{Effort}$$

2. Biological parameters

a. Schaefer (1954):

$$E_{opt} = -\frac{a}{2\beta}$$

b. Fox (1970):

$$E_{opt} = -\frac{1}{\beta}$$

$$C_{MSY} = -\frac{1}{\beta}\ \exp(a-1)$$

c. Walter-Hilborn (1992):

$$E_{opt} = -\frac{a}{2\beta} = -\frac{r}{2q}$$

$$C_{MSY} = \frac{a^2}{4\beta} = \frac{rK}{4}$$

d. Schnute (1977):

$$E_{opt} = -\frac{a}{2\beta} = -\frac{r}{2q}$$

$$C_{MSY} = \frac{a^2}{4\beta} = \frac{rK}{4}$$

e. Clarke Yoshimoto Pooley (CYP) (1992):

$$E_{opt} = \frac{r}{q}$$

$$C_{MSY} = \frac{rK}{e}$$

f. Utilization level:

$$TP(i) = (Ci/MSY) \times 100$$

where: CPUE = catch per unit effort (ton $unit^{-1}$);
Catch = production of bombay-duck (ton);
Effort = fishing gear (unit);
e = effort;
r = intrinsic growth rate;

ɑ = intercept;
β = slope 1;
q = catchability coefficient (ton unit$^{-1}$);
K = carrying capacity (ton year$^{-1}$);
$E_{opt}$ = effort (unit);
$C_{MSY}$ = maximum sustainable yield (ton unit$^{-1}$).

**Results and Discussion**. The fisheries sector is one of the contributing sectors to the regional economic growth of Dumai City. Bombay-duck is a type of fish with high economic value that has a significant production value due to various factors, such as high market demand and favorable habitat conditions. This is supported by Shalichaty et al (2021), who stated that bombay-duck has a high production amount and is in high demand. Bombay-duck is a typical species found in the waters of Dumai City. Data on bombay-duck catches for the past 10 years are presented in Figure 2.

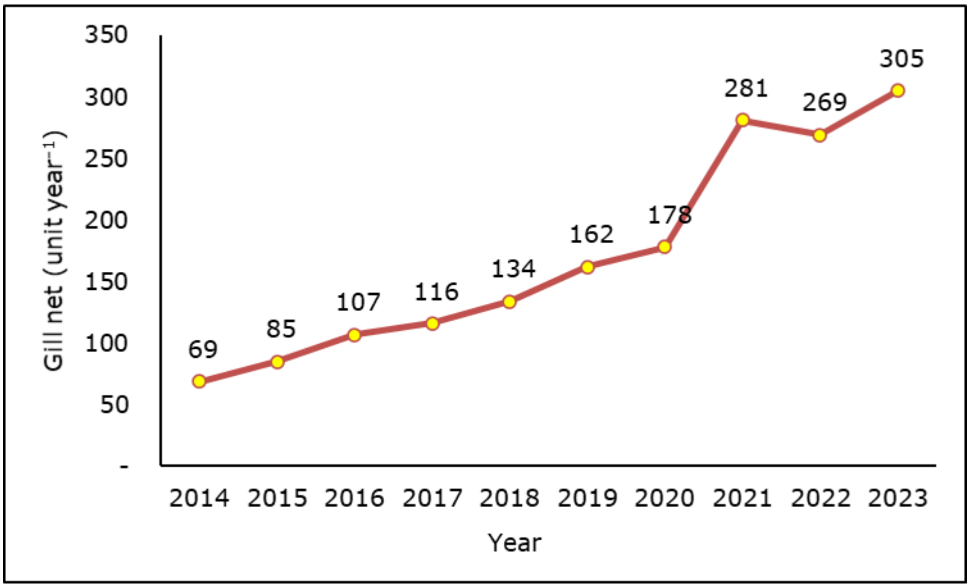


Figure 2. Bombay-duck production in Dumai City.

Figure 2 shows that over a ten-year period, bombay-duck production in Dumai City fluctuated with an increasing trend. The largest increase occurred between 2014 and 2017, when production increased from 17 tonnes to 86 tonnes. After reaching an initial peak of 91 tonnes in 2018, production decreased in 2019, but increased again to reach 97 tonnes in 2023. This data indicates the potential for increased production, but also reflects fluctuations that may be influenced by environmental factors or varying fishing efforts (Prusty et al 2023). This is also consistent with the research of Akoit & Nalle (2018) that increased production is influenced by seasons, weather, fishing technology, and the availability of fish in the waters.

***Fishing effort***. The fishing effort is measured in units. The fishing gear used to catch bombay-duck is gill net. The gill net is a passive fishing gear. The mesh size used by the fishermen is 2.5 inches. The fishing effort of the fishermen in Dumai City is shown in Figure 3.

Based on Figure 3, the rise in fishing efforts in the waters of Dumai City is attributed to the increase in the number of active fishing gear in operation. This phenomenon can occur at any time because fisheries resources are open access and common property, which means that no one has exclusive rights to own or prevent others from exploiting the resources (Wilen 2018). In actuality, the development of effort has increased over time (Rousseau et al 2019). This increase is mainly due to the local government's program in the field of infrastructure, which assists fishermen groups in Dumai City in procuring fishing equipment.

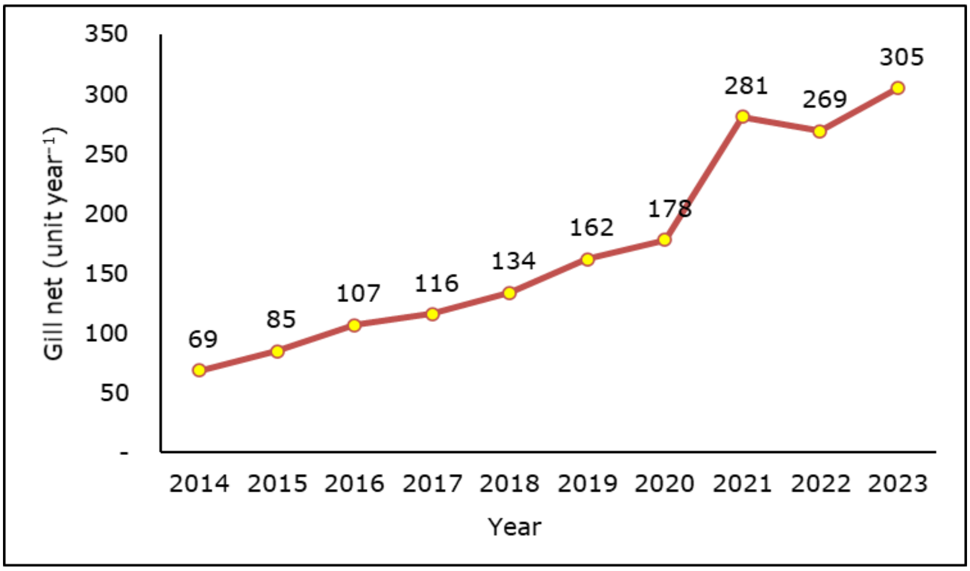


Figure 3. Fishing effort for bombay-duck in Dumai City.

***Catch per unit effort***. CPUE is one of the indicators of the level of fishing effort and the catch level in obtaining fishery resources. The CPUE value can be used to assess the ability of resources to be exploited at a given time (Froese et al 2020). The catch of bombay-duck in Dumai City waters is mostly landed at PPI Dumai. The results of CPUE calculations in the last ten years can be seen in Table 1.

Table 1

CPUE value of bombay-duck in Dumai City Waters

| *Year* | *CPUE (ton unit$^{-1}$)* |
|---|---|
| 2014 | 0.630 |
| 2015 | 0.819 |
| 2016 | 1.363 |
| 2017 | 1.889 |
| 2018 | 1.736 |
| 2019 | 1.133 |
| 2020 | 1.108 |
| 2021 | 0.747 |
| 2022 | 0.866 |
| 2023 | 0.815 |

The CPUE value of bombay-duck in Dumai City waters showed fluctuations from 2014 to 2023. CPUE increased significantly from 0.630 ton unit$^{-1}$ in 2014, reaching a peak in 2017 at 1.889 ton unit$^{-1}$, indicating high fishing efficiency or a large fish population at that time. However, after 2017, the CPUE value experienced a gradual decline, with the lowest point in 2021 at 0.747 ton unit$^{-1}$, reflecting pressure on fish stocks. In subsequent years, CPUE values stabilised, although they were lower than the peak, indicating the need for more careful management to maintain the sustainability of bombay-duck stocks. An increase or decrease in CPUE can illustrate the level of utilization of fish resources. An increase in CPUE values indicates that fishing can still be developed, CPUE values that tend to stagnate indicate fishing is approaching the saturation point of the business and a decrease in CPUE values indicates fishing leads to overfishing if no control is taken. Both increasing and decreasing CPUE values affect fish stocks in the waters (Arkham et al 2021).

***Relationship between CPUE and effort***. The relationship between CPUE values and fishing effort is used to determine trends in the productivity of fishing gear in catching fish species. The relationship between CPUE and effort was calculated using simple linear regression analysis. The relationship between CPUE and effort of bombay-duck can be seen in Figure 4.

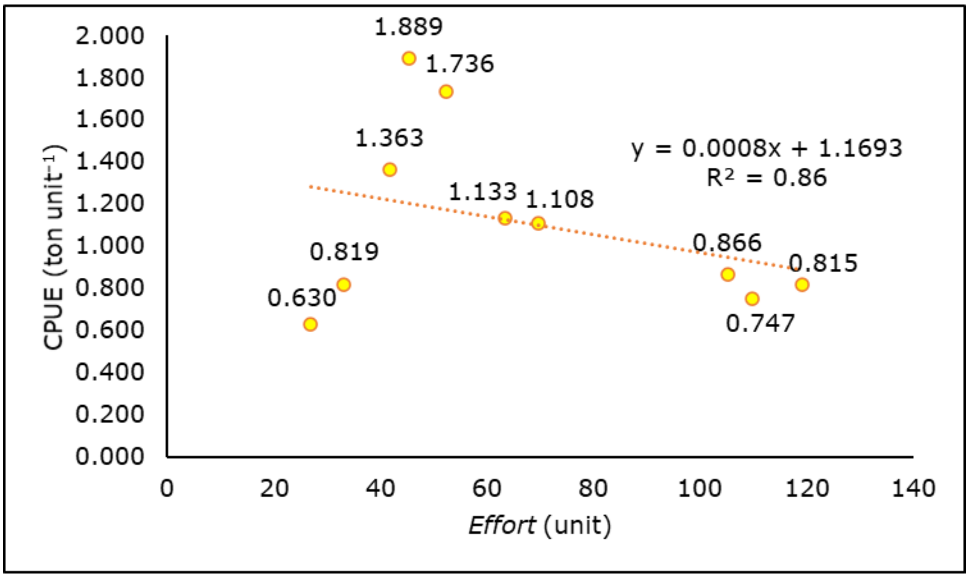


Figure 4. The relationship between CPUE and effort of bombay-duck from 2014-2023.

Based on Figure 4, the relationship between CPUE and effort of bombay-duck with parameters intercept (a) and slope (b) through linear regression shows the equation Y = 0.0008x + 1.1693 with values of a = 1.1693 and b = 0.0008. This means that if there is an increase in fishing effort by one unit of fishing gear, it will reduce CPUE by 0.0008 ton unit$^{-1}$. The value of $R^2$ = 0.86 means that 86 percent of the decrease in production was caused by fishing effort (x) while 14 percent of the decrease in catch production was caused by other parameters not included in the study. The value of the coefficient of determination ranges from $0 \leq R^2 \leq 100$, meaning that if $R^2$ approaches 100 percent, it can be said that the influence of effort on CPUE is significant (Jupitar et al 2020; Hoyle et al 2024).

***Surplus production model***. This model is used to determine the optimum effort level that can produce the MSY. The purpose of the surplus production model analysis is to determine the level of utilization of a fish resource using CPUE data (Pedersen & Berg 2016). This study uses five models in determining MSY, namely the Schaefer model, Fox model, Walter-Hilborn model, Schnute model and Clarke Yoshimoto Pooley model. Based on these five models, the best fit was selected from the other estimations. According to Kekenusa et al (2019), the formulas of surplus production models only apply when the slope parameter (b) is negative, which means that increasing fishing effort will result in a decrease in CPUE. If parameter b has a positive value, then it is not possible to estimate the size of the stock or the optimum effort, but it can only be concluded that increasing fishing effort is still possible to improve catch results.

*Schaefer model*. To obtain the MSY in the Schaefer model calculation, first perform a regression analysis between standard fishing effort as the independent variable x and CPUE as the dependent variable y. The estimated catch and sustainable fishing effort with the Schaefer model of bombay-duck can be seen in Table 2.

Table 2

Schaefer model analysis results

| *Parameter* | *Value* |
|---|---|
| Intercept (a) | 1.3990744 |
| Slope (b) | -0.0043260 |
| $R^2$ | 0.11 |
| $E_{opt}$ (unit $year^{-1}$) | 161 |
| $C_{MSY}$ (ton $year^{-1}$) | 113 |
| Total allowed catch (ton $year^{-1}$) | 90 |

Regression results of CPUE values on fishing effort showed that only 11 percent of changes in effort could be explained by changes in CPUE, while 89 percent were influenced by other variables. Based on the Schaefer model, the optimum fishing effort ($E_{opt}$) is 161 unit $year^{-1}$ with potential sustainable catch ($C_{MSY}$) of 113 ton $year^{-1}$. The allowable catch is 90 ton $year^{-1}$, meaning that if the stock of bombay-duck in Dumai waters is estimated at 113 tonnes, then the amount of bombay-duck that can be exploited is only 90 ton $year^{-1}$.

*Fox model.* To obtain the maximum sustainable potential value in the Fox model calculation, a regression analysis was first conducted between the standard fishing effort as variable x (independent variable) and the natural logarithm of CPUE (lnCPUE) as variable y (dependent variable). The estimated catch and sustainable fishing effort with the Fox model can be seen in Table 3.

Table 3

Fox model analysis results

| *Parameter* | *Value* |
|---|---|
| Intercept (a) | 0.260972 |
| Slope (b) | -0.003278 |
| $R^2$ | 0.09 |
| $E_{opt}$ (unit $year^{-1}$) | 305 |
| $C_{MSY}$ (ton $year^{-1}$) | 146 |
| Total allowed catch (ton $year^{-1}$) | 117 |

The regression result of lnCPUE against fishing effort shows that only 9 percent of the change in effort can be explained by the change in lnCPUE, while 91 percent is influenced by other variables. According to the Fox model, the optimal fishing effort ($E_{opt}$) is 305 unit $year^{-1}$ with a potential sustainable catch ($C_{MSY}$) of 146 ton $year^{-1}$. The allowable catch is set at 117 ton $year^{-1}$, which means that if the bombay-duck stock is estimated at 146 ton, only exploitation up to 117 ton $year^{-1}$ is allowed.

*Clarke Yoshimoto and Pooley (CYP) model*. The CYP model is also a model that uses calculations with multiple linear regression equations with the concept of least squares (Nam & Chu 2018). In the CYP model, multiple regression was conducted between the dependent variable (y) which is ln(Ut+1) and the independent variables (x) which are $X_1$ = ln(Ut) and $X_2$ = (Et+Et+1). The estimated results of catch and sustainable fishing effort using the CYP model can be seen in Table 4.

Table 4

Clarke Yoshimoto and Pooley (CYP) model analysis results

| *Parameter* | *Value* |
|---|---|
| Intercept (a) | 0.42925 |
| $X_1$ (b) | 0.48009 |
| $X_2$ (c) | -0.00276 |
| $R^2$ | 0.62 |
| Instrinsic growth rate (r) | 0.70255 |
| Catchability coefficient (q) | 0.00747 |
| Carrying capacity (K) | 305.76 |
| $E_{opt}$ (unit year$^{-1}$) | 94 |
| $C_{MSY}$ (ton year$^{-1}$) | 79 |
| Total allowed catch (ton year$^{-1}$) | 63 |

Based on the regression analysis results of the CYP model, with regression coefficient values a = 0.42925, b ($X_1$) = 0.20689, and c ($X_2$) = -0.00276, and an $R^2$ value of 0.62, the maximum carrying capacity of the water (K) is 305.76 tons, the catchability coefficient (q) is 0.007, and the intrinsic growth rate (r) is 0.7 year$^{-1}$. The CYP model calculates the optimum fishing effort ($E_{opt}$) at 94 unit year$^{-1}$ with a sustainable catch potential ($C_{MSY}$) of 79 ton year$^{-1}$, which is a safe limit to maintain the sustainability of the bombay-duck resources. The allowable catch limit is set at 63 ton year$^{-1}$, meaning that out of the estimated bombay-duck stock of 79 tons, only 63 tons can be exploited each year to ensure its sustainability.

*Schnute model.* Schnute model uses the least square concept to calculate multiple linear regression. From the linear regression results, regression parameters can be obtained to calculate the maximum sustainable catch value and optimum sustainable effort (Zheng et al 2020). Regression can be done by determining independent and dependent variables. The independent variable in the Schnute model is ln(Ut+1/Ut). The dependent variable $X_1$ is (Ut+Ut+1)/2 and the dependent variable $X_2$ is (Et+Et+1)/2. The estimation of sustainable catch and fishing effort using the Schnute model can be seen in Table 5.

Table 5

Schnute model analysis results

| *Parameter* | *Value* |
|---|---|
| Intercept (a) | 0.1884 |
| $X_1$ (b) | -0.0018 |
| $X_2$ (c) | -0.0027 |
| $R^2$ | 0,10 |
| Instrinsic growth rate (r) | 0.1884 |
| Catchability coefficient (q) | 0.0027 |
| Carrying capacity (K) | 37,644 |
| $E_{opt}$ (unit year$^{-1}$) | 35 |
| $C_{MSY}$ (ton year$^{-1}$) | 1,773 |
| Total allowed catch (ton year$^{-1}$) | 1,418 |

Based on the regression analysis results of the Schnute model, with regression coefficient values a = 0.1884, b ($X_1$) = -0.0018, and c ($X_2$) = -0.0027, and an $R^2$ value of 0.10, the intrinsic growth rate (r) obtained is 0.1884 ton year$^{-1}$. This indicates that if there are no disturbances from natural factors or human activities, the bombay-duck population will naturally grow by 0.1884 ton year$^{-1}$. The catchability coefficient (q) of 0.0027 indicates that each increase of one unit of fishing effort will result in an additional catch of 0.0027 tons. The environmental carrying capacity (K) of 37,644 tons indicates that the waters of Dumai can support the production of bombay-duck up to 37,644 ton year$^{-1}$. The Schnute model also calculates the optimum effort ($E_{opt}$) at 35 unit year$^{-1}$, with a sustainable catch potential ($C_{MSY}$) of 1,773 ton year$^{-1}$, which is a safe limit to ensure the sustainability of the bombay-duck stock in the area.

*Walter-Hilborn model.* The Walter-Hilborn model is a model that uses the least square concept for multiple linear regression calculations. Regression can be performed by including CPUEt+1/CPUEt data as independent variables. The independent variables of $X_1$ and $X_2$ are CPUE and effort. The estimated catch and sustainable fishing effort with the Walter-Hilborn model can be seen in Table 6.

Table 6

Walter-Hilborn model analysis results

| *Parameter* | *Value* |
|---|---|
| Intercept (a) | 0.9962 |
| $X_1$ (b) | -0.5414 |
| $X_2$ (c) | -0.0019 |
| $R^2$ | 0.49 |
| Instrinsic growth rate (r) | 0.9962 |
| Catchability coefficient (q) | 0.0019 |
| Carrying capacity (K) | 940 |
| $E_{opt}$ (unit year$^{-1}$) | 254 |
| $C_{MSY}$ (ton year$^{-1}$) | 234 |
| Total allowed catch (ton year$^{-1}$) | 187 |

Based on the analysis of the Walter-Hilborn regression model, the regression coefficients obtained are a = 0.9962, b ($X_1$) = -0.5414, and c ($X_2$) = -0.0019, with an $R^2$ value of 0.49. The intrinsic growth rate (r) of the bombay-duck population is 0.9962 ton year$^{-1}$, which means that the natural population of bombay-duck will grow by 0.9962 ton year$^{-1}$ if there are no disturbances from natural factors or human activities. The catch coefficient (q) of 0.0019 indicates that for every one unit increase in fishing effort, the catch will increase by 0.0019 tons. The carrying capacity (K) of 940 tons indicates that the waters of Dumai can support the production of bombay-duck up to 940 ton year$^{-1}$. From the Walter-Hilborn model, an optimum effort ($E_{opt}$) of 254 unit year$^{-1}$ and a sustainable catch potential ($C_{MSY}$) of 234 ton year$^{-1}$were obtained, which is the safe limit to maintain the sustainability of the bombay-duck resources in the area.

***Evaluation of surplus production model***. The built surplus production model needs to be verified and validated in order to increase the confidence that the model represents the real system in fisheries, in particular the dynamics of fish populations (Zottoli et al 2020; Kokkalis et al 2024). Verification is carried out by checking the suitability of the relationship between the variables described in the model. In the surplus production model, verification is done by checking the sign of the regression coefficients (intercept (a) and slope (b)) and the biological parameters (r, q and K) (Fauziyah et al 2020b). The validation results of bombay-duck surplus production model can be seen in Table 7.

Table 7

Bombay-duck surplus production model validation results

| | *Schaefer* | *Fox* | *CYP* | *Schnute* | *Walter-Hilborn* |
|---|---|---|---|---|---|
| Matching signs | as requested | as requested | as requested | as requested | as requested |
| | a = 1.399 | a = 0.261 | r = 0.702 | r = 0.188 | r = 0.996 |
| | b = -0.004 | b = -0.003 | q = 0.007 | q = 0.002 | q = 0.002 |
| | | | K = 305.706 | K = 37.644 | K = 940 |
| $R^2$ | 0.11 | 0.09 | 0.62 | 0.10 | 0.49 |

Based on Table 7, the formulas of surplus production model only apply when the slope parameter (b) is negative, which means that increasing fishing effort will result in a decrease in catch per unit effort. If the slope parameter (b) is positive, it cannot be concluded that increasing fishing effort is still possible to improve catch results. Meanwhile, the biological parameters (r, q, and K) must be positive for the CYP, Schnute, and Walter-Hilborn models. Based on the verification results of the five surplus production models that have the corresponding signs presented in Table 7, in this study, the surplus production model used to describe the condition of managing bombay-duck resources is the CYP surplus production model. The regression model of CYP has the highest $R^2$ value. According to Pradini et al (2021), the coefficient of determination or $R^2$ value is typically used to measure the goodness of fit of a regression model and compare the valid regression results of independent variables in the model, indicating that the model will be better if the $R^2$ value is larger.

***Maximum sustainable yield***. Bombay-duck is a typical fish that is commonly found in the Riau Province region, one of which is in the waters of Dumai City. The fishing gear used to catch bombay-duck is gillnet. The MSY is a limit value at which the resources of bombay-duck can still be utilized without compromising their sustainability for regrowth. The MSY value of bombay-duck in the waters of Dumai City is determined using the CYP model. The optimum fishing effort value ($E_{opt}$) for bombay-duck in the waters of Kota Dumai is 94 unit year$^{-1}$, with a maximum sustainable catch ($C_{MSY}$) of only 79 ton year$^{-1}$, as shown in Figure 5. The $C_{MSY}$ value is a limit where the resources of bombay-duck can still be utilized without compromising their sustainability for reproduction. In the calculation of the allowable catch, the result obtained is 63 ton year$^{-1}$, which means if the estimated stock of bombay-duck in the waters of Dumai is 79 tons, then the amount of bombay-duck that can be exploited is only 63 ton year$^{-1}$. The MSY curve of bombay-duck can be seen in Figure 5.

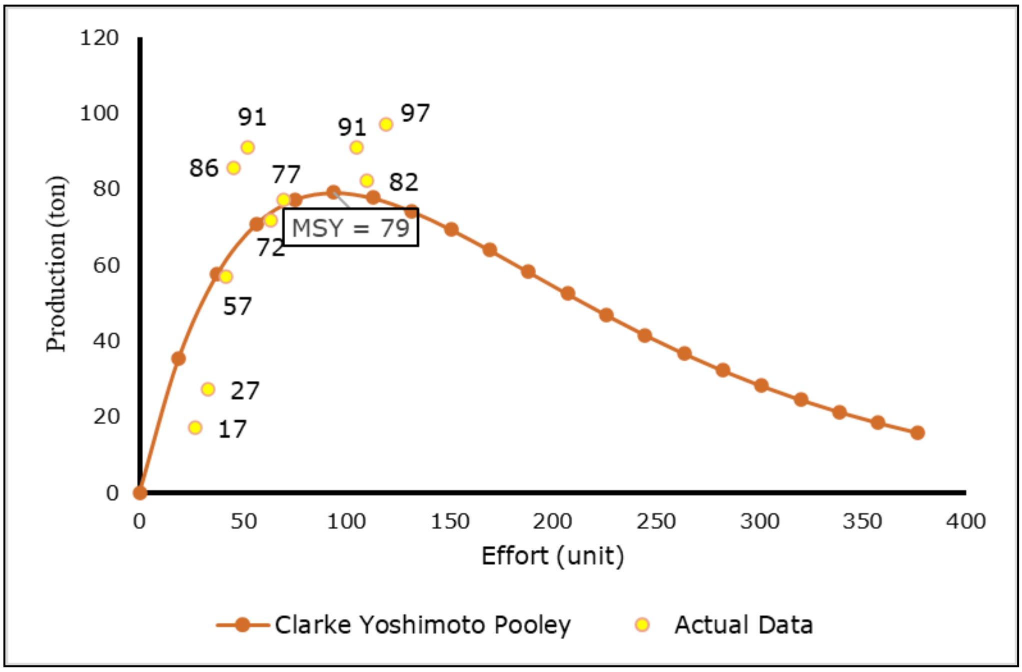


Figure 5. Maximum sustainable yield curve of bombay-duck

Figure 5 shows that the catch and fishing effort of bombay-duck in the waters of Dumai City over a period of ten years (2014-2023) has reached overfishing. According to Saimona et al (2021), overfishing occurs when the fishing rate exceeds the optimum level to produce MSY. One of the consequences of overfishing is the depletion of the availability of bombay-duck resources, resulting in the remaining fish being undersized and threatening the stock regeneration in the waters of Dumai. If more small and immature gonad fish are caught, it may lead to overfishing.

***Utilization level***. The value of the utilization level can be used to assess the condition of fish stocks in the waters of Dumai City that have been exploited. The utilization level can be estimated by comparing the average catch results of the last ten years with the allowed catch amount and then multiplied by 100 percent. The utilization level of bombay-duck can be seen in Table 8.

Table 8

The utilization level of bombay-duck in Dumai City

| *Year* | *Production (ton)* | *Total allowable catch (ton)* | *Utilization (%)* |
|---|---|---|---|
| 2014 | 17 | 63 | 27 |
| 2015 | 27 | 63 | 43 |
| 2016 | 57 | 63 | 90 |
| 2017 | 86 | 63 | 135 |
| 2018 | 91 | 63 | 144 |
| 2019 | 72 | 63 | 114 |
| 2020 | 77 | 63 | 122 |
| 2021 | 82 | 63 | 130 |
| 2022 | 91 | 63 | 144 |
| 2023 | 97 | 63 | 154 |
| Average | 70 | | 110 |

Based on the results (Table 8), bombay-duck has an average utilization level of 110 percent, which is in the overexploited status (100-150 percent), meaning that the bombay-duck stock has decreased due to being exploited beyond MSY. Fishing efforts need to be reduced because the sustainability of bombay-duck resources has been disrupted. To reduce overexploitation, there is a need for management strategies or policies such as changing the fishing pattern with the pressure not to catch immature gonad fish through regulating the selectivity of fishing gear to provide opportunities for spawning and reproduction for the sustainability of bombay-duck.

**Conclusions**. The surplus production model that can be used to analyze the catch of bombay-duck in the waters of Dumai City is the Clarke Yoshimoto Pooley model. The maximum sustainable catch of bombay-duck ($C_{MSY}$) is 79 ton year$^{-1}$ obtained at the fishing effort level ($E_{opt}$) of 94 units. The utilization level is 110 percent, which is categorized as overexploited status. To prevent the extinction and overexploitation of bombay-duck, various mitigation measures are needed to be implemented immediately by involving policymakers, fishermen, and other relevant actors.

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**Conflict of interest**. The authors declare that there is no conflict of interest.

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