Potential and utilization level of giant tiger prawn (*Penaeus monodon*) in Rokan Hilir Regency, Riau Province

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Abstract. Prawns are a type of crustacean and are included in marine fisheries commodities that hold significant economic value. They are currently being widely hunted by fishermen. Rokan Hilir Regency, being one of the largest fish-producing areas in Riau Province, boasts a diverse range of fishery resources, including prawns. Various types of prawns are caught by Rokan Hilir fishermen, but giant tiger prawns (*Penaeus monodon*) have the highest production compared to other prawn species. The aim of this research is to determine the potential and level of utilization of the giant tiger prawn caught. The survey method is used in this research to analyze the potential maximum sustainable yield (MSY) and the total allowable catch (TAC) of giant tiger prawn based on primary and secondary data. The analysis results show that the sustainable potential of prawn catch using trawl nets in Rokan Hilir Regency. The MSY value of giant tiger prawn is 397 tons year^{-1} and the TAC value is 287.17 tons year^{-1}. Additionally, the giant tiger prawn utilization rate is calculated to be 313%, indicating symptoms of over exploited. Therefore, government attention is needed in the utilization of giant tiger prawn by implementing restrictions on additional fishing gear, determining the timing and season for prawn fishing, designating specific prawn fishing areas, and regulating the types of fishing gear used.
Key Words: giant tiger prawn, MSY, sustainable, trawl net, utilization level.

Introduction. Indonesia, a maritime country, boasts a wealth of biodiversity and marine resources. The fisheries sector holds immense importance in the nation's development. With its abundant potential in capture fisheries, Indonesia is poised as a leading sector in the national economy (Adlina et al 2019; Halim et al 2019; Kusdiantoro et al 2019; Stacey et al 2021). The vast potential of fisheries remains largely untapped and not optimally managed. Hence, it is imperative to establish regulations and policies that promote the attainment of efficient resource utilization. Presently, the management of fisheries resources primarily revolves around economic considerations. This phenomenon is characterized by the overexploitation of fisheries resources, surpassing their carrying capacity or sustainable production potential. Consequently, it can disrupt the long-term sustainability of these resources (Akoit & Nalle 2018; Dewi 2018).

Rokan Hilir Regency, located in Riau Province, is renowned for being one of the largest fish-producing regions in the area. The region boasts a diverse range of fisheries resources, including prawns, which are highly valuable crustacean. These prawns are currently being harvested by local fishermen and considered to be economically significant marine fisheries commodities. Prawns typically inhabit shallow waters, ranging in depths from 2 to 70 meters. They are commonly found in areas near mangroves (Basri et al 2020; Ihsan & Tajuddin 2020). The exploitation of prawn resources in the waters of Rokan Hilir is mainly conducted by traditional fishing enterprises. Fishermen utilize boats with a size ranging from 2 to 3 gross tonnage and employ trawl nets for their fishing activities. The fleet and fishing gear used by fishermen are still relatively basic, thus necessitating the introduction of modernization concepts in fisheries to ensure long-term sustainability (Syahrul et al 2022).

According to the Rokan Hilir District Fisheries Office's data for 2022, the prawns production in 2021 reached a total of 201,854 tons. This production comprised of 126,211 tons of giant tiger prawn (*Penaeus monodon*), 29,719 tons of giant harpiosquillid mantis shrimp (*Harpiosquilla raphidea*), 23,217 tons of banana prawn (*Penaeus merguiensis*), and 22,707 tons of southern velvet shrimp (*Metapenaeopsis palmensis*). Based on the available production data, giant tiger prawn outperforms other prawn species in terms of production. There are concerns that the excessive production of giant tiger prawn may lead to overfishing or a decline in the number of catches in the upcoming year. Overfishing and the extinction of fish stocks are undoubtedly significant challenges in the development of fisheries (Kristiana et al 2021; Arief et al 2023). Therefore, effective management is essential to ensure the sustainable utilization of these resources (Apriliani et al 2020).

The objective of this study is to examine the extent of sustainable production or maximum sustainable yield (MSY) of giant tiger prawn in Rokan Hilir Regency. This includes analysing the production levels, utilization rates, and the number of catches. The findings of this research will offer valuable insights into MSY, optimum effort (E_{opt}) and utilization level, which can inform the management of giant tiger prawn in Rokan Hilir Regency.

Material and Method. The data utilized in this study consists of both secondary and primary data. The collection of secondary data involved gathering information on the production of giant tiger prawn and the number of fishing gear over the past 12 years (2011-2022). These data were obtained from various sources, including the Department of Fisheries Rokan Hilir Regency, BPS of Rokan Hilir Regency, as well as desk studies involving documents, literature and research reports relevant to this research. On the other hand, primary data was acquired through direct interviews conducted with fishermen who employ trawl net fishing gear to catch giant tiger prawn.

Study location and time. The research was conducted in Rokan Hilir Regency from June to July 2023. Figure 1 shows a map of the research location.

Figure 1. Study location map.

Data analysis. The analyzed and evaluated estimation models include the Fox model, Walter-Hilborn, Clarke Yoshimoto Pooley (CYP), Schnute, and Schaefer. The formula is used to estimate the parameters (coefficients) of these models. Based on the statistical evaluation results, specifically the R^2 value, validation value, and significance of the model regression coefficient, the optimal model as an estimator will be achieved. The MSY value and utilization rate of giant tiger prawn can be calculated using this model. This research encompasses model formation, parameter estimation and model testing. The formula for each model that will be analyzed is as follows:

a. Fox (1970):

$$X = E_t$$
$$y = U_t$$

Then, a regression analysis was conducted to estimate the biological parameters r, q and K.

$$r = \frac{Kq^2}{\beta}$$
$$q = \left[\prod_{t=1}^{n} ln\left(\frac{\frac{x}{y}}{z}\right)\right]^{1/t}$$
$$K = \frac{\alpha}{q}$$

b. Walter-Hilborn (1992):

$$X_1 = U_t$$
$$X_2 = E_t$$
$$y = \frac{U_{t+1}}{U_t} - 1$$

Then, a regression analysis was conducted to estimate the biological parameters r, q and K.

$$r = a$$
$$q = \gamma$$
$$K = \frac{r}{\beta q}$$

c. Clarke Yoshimoto Pooley (CYP) (1985):

$$X_1 = LnU_t$$
$$X_2 = E_t + E_{t+1}$$
$$y = LnU_{t+1}$$

Then, a regression analysis was conducted to estimate the biological parameters r, q and K.

$$r = \frac{2(1-\beta)}{(1+\beta)}$$
$$q = -\gamma\ (2+r)$$
$$K = \frac{e^{\frac{\alpha(2+r)}{(2r)}}}{q}$$

d. Schnute (1977):

$$X_1 = \frac{U_t + U_{t+1}}{2}$$
$$X_2 = \frac{E_t + E_{t+1}}{2}$$
$$y = ln\left(\frac{U_{t+1}}{U_t}\right)$$

Then, a regression analysis was conducted to estimate the biological parameters r, q and K.

$$r = a$$
$$q = \gamma$$
$$K = \frac{r}{\beta q}$$

e. Schaefer (1954):

$$X_1 = E_t$$
$$X_2 = E_t^2$$
$$y = U_t$$

Then, a regression analysis was conducted to estimate the biological parameters r, q and K.

$$r = a$$
$$q = \gamma$$
$$K = \frac{\alpha}{q}$$

f. Utilization rate (Deeng et al 2020; Umar et al 2020; Yanto et al 2020):

$$\mathrm{TP} = \frac{C_i}{\mathrm{MSY}} \times 100$$

where: r = intrinsic growth rate;
q = catchability coefficient (ton $unit^{-1}$);
K = carrying capacity (ton $year^{-1}$);
α = intercept;
β = slope 1;
γ = slope 2;
E_t = fishing effort in year-t (unit);
U_t = catch per fishing effort in year-t (kg);
TP = utilization rate (%);
Ci = catch in period-i (kg);
MSY = maximum sustainable yield (ton $year^{-1}$).

Results and Discussion. The production of catches in Rokan Hilir Regency has been the focus of fishermen for the past twelve years, with variations occuring annually. Data on giant tiger prawn catches in Rokan Hilir Regency over a span of twelve years is shown in Figure 2.

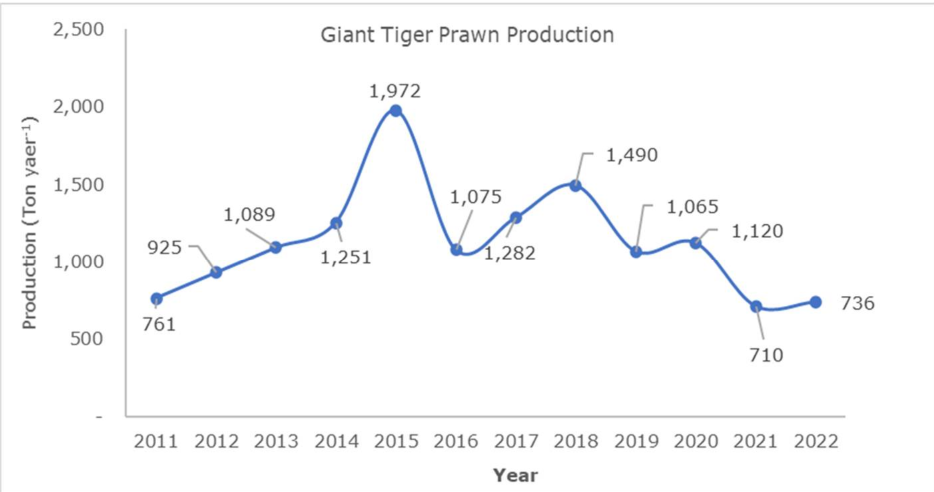

Figure 2. Giant tiger prawn production in Rokan Hilir Regency.

According to Figure 2, the production of giant tiger prawn has shown fluctuations over a span of twelve years. Notably, the highest catch within this period was recorded in 2015, reaching a total of 1,972 tons. The rise in giant tiger prawn production is a result of the growing consumption, leading to an increase in consumer demand for prawns (Akbar 2022). In addition to that, the rise in the number of ships also plays a rule in boosting prawns production (Puansalaing et al 2021). If fishing continues unchecked and without proper management, the capacity for population growth will steadily decrease, posing a significant threat to long-term sustainability of the resource population (Desiani et al 2019).

Fishing effort. Fishing effort is a crucial factor that significantly impacts the catch of fishermen targeting giant tiger prawn. This essential metric is typically measured in units. The fishing method employed in this study was trawl nets, which refers to a collection of rectangular-shaped lifting nets. These nets are constructed using trawl material, and are typically utilized in muddy or sandy water regions (Sarianto et al 2019). The fishing effort carried out by fishermen in Rokan Hilir Regency is shown in Figure 3.

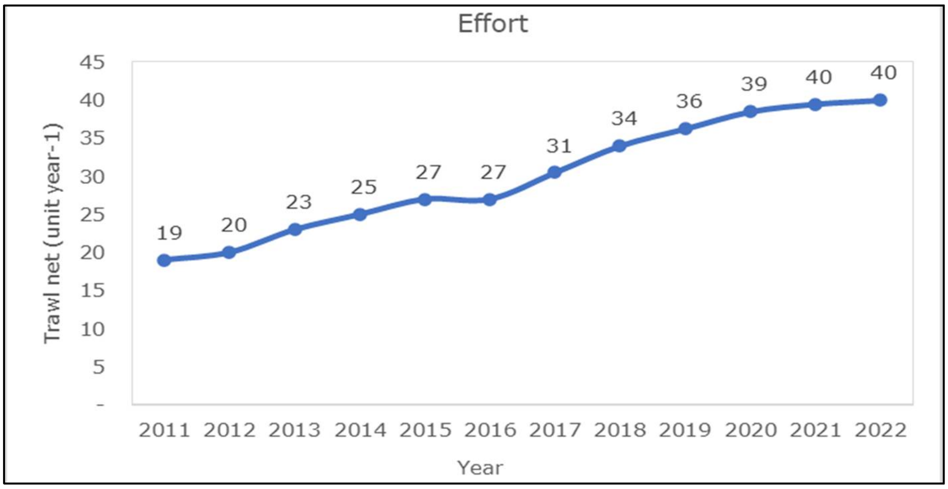

Figure 3. Fishing effort of giant tiger prawn in Rokan Hilir Regency.

Based on Figure 3, it can be seen that the effort to catch giant tiger prawns in Rokan Hilir Regency from 2011 to 2022 has increased. When analyzing the correlation between giant tiger prawn production and the quantity of fishing gear employed, it becomes evident that there exists an inverse relationship. In other words, as the number of fishing gear increases, the production of giant tiger prawn decreases. Consequently, it becomes imperative to regulate the utilization of fishing gear by controlling the frequency of fishing attempts, specifying fishing locations and times, and establishing limits on fishing quotas (Alhuda et al 2016; Damayanti 2020; Hermawan & Nurlaila 2023).

Relationship between CPUE and effort. The catch per unit effort (CPUE) value describes the condition of a stock of giant tiger prawn resources in the waters, while effort refers to the amount of effort put into catching giant tiger prawn. This has reinforced the statement by Baset et al (2017) that the CPUE is commonly utilized in fisheries stock assessment. The relationship between CPUE and effort is inversely proportional, meaning that as fishing effort increases, the CPUE value decreases. This decline in CPUE can have detrimental effects on the population and lead to economic losses. To safeguard both the ecosystem and the livelihoods of fishermen, it is crucial to implement regulations and controls on fishing efforts. This will help maintain a healthy biological balance and prevent financial losses for fishermen (Kartika et al 2020). The relationship between CPUE and effort of giant tiger prawn is shown in Figure 4.

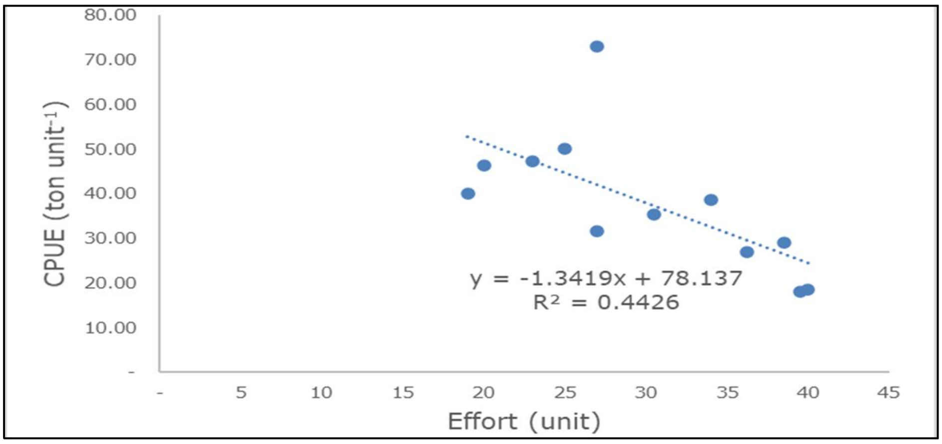

Figure 4. The relationship between CPUE and effort using the CYP model approach.

According to Figure 4, the linear regression analysis provides estimated values for the intercept (a) and slope (b) parameters, which describe the relationship between CPUE and effort. The results of linear regression calculations indicate that the equation Y= -

1.34x + 78.14 and R^2 = 0.44. This equation shows that for every one unit increase in fishing effort, the CPUE will decrease by 1.34 tons. The coefficient values for a and b are 78.14 and -1.34 respectively. According to the regression equation, it is evident that 44 percent of the decrease in giant tiger prawn production (y) can be attributed to fishing effort (x). The remaining 56 percent of the decline in giant tiger prawn production (y) is influenced by various factors, including natural and biological factors. The coefficient of determination, symbolized as R^2, is used as an indicator of the suitability of a model. It is referred to as the coefficient of determination because it quantifies the extent to which the variations in CPUE can be explained by the effort, as determined by a linear regression of Y on X. The coefficient of determination has a value ranging from 0 to 100. A higher R^2 value indicates a stronger influence of effort on CPUE (Desiani et al 2019).

Production surplus model. The surplus production model is important in assessing the stock of aquatic species. Estimated reference points on biomass and harvest rule which are described here can be applied depends on reliable estimates of r, q and K (Mohsin et al 2017; Barua et al 2021). Table 1 and Table 2 display the comparison of biological parameters and regression results obtained from the application of five production surplus model for estimating the biological parameters of giant tiger prawn in Rokan Hilir Regency.

Table 1

Estimation of biological parameters using five models

Production surplus model	*r (ton year^{-1})*	*q (ton year^{-1})*	*K (ton year^{-1})*
Fox	135.05	2.2454	35.32
Walter-Hilborn	1.3432	0.0297	3,681.67
CYP	0.9035	0.0064	1,589.20
Schnute	0.7050	0.0209	9,239.80
Schaefer	1.3185	0.1859	418.07

Table 2

Regression results for estimating biological parameter using five models

Production surplus model	*Sig F*	*Uji F*	*R^2*
Fox	0.0185	7.8892	0.4410
Walter-Hilborn	0.0808	3.5021	0.4668
CYP	0.0045	11.4172	0.7405
Schnute	0.5185	0.7138	0.1514
Schaefer	0.0034	11.3678	0.7164

According to the values presented in Table 1 and Table 2, the r, q and K parameters of the Fox, Walter-Hilborn, CYP, Schnute and Schaefer models exhibit variations. It is not possible to prove that one of the five models is superior to the others. Hence, it is feasible to choose a model that aligns with the available data in Rokan Hilir Regency. The appropriateness of the model can be determined by the coefficient of determination (R^2). The model with the highest R^2 value is the most suitable for analyzing the collected data. The R^2 value is a coefficient that quantifies the extent to which the independent variable X can explain the variation (diversity) in the dependent variable Y. The regression results show that the CYP model has the largest coefficient of determination (R^2) compared to other models, namely 74.05%. This is supported by the statement made by Ghozali (2016) that a higher R^2 value indicates a more accurate research prediction. Therefore, in this study, the most suitable model for analyzing sustainable production of giant tiger prawn resources is the CYP production surplus model. The objective of establishing this model is twofold: to achieve improved results and to prevent the direct application of a single model in analysing the surplus production model in a body of water (Kekenusa & Paendong 2020).

Maximum sustainable yield. Maximum sustainable yield (MSY) was introduced for a fishery based on an isolated fish population whose growth follows a logistic dynamics (Legović et al 2010). Sustainable potential value, also known as MSY, is an approach used to calculate the potential data of fishery resources. It aims to determine the optimal utilization value of these resources (Umam et al 2021). The estimation of fishing activity on a fishery resource requires the determination of the MSY value. The estimated values for the intercept (a) and slope (b) parameters in the CYP model were obtained based on the results of linear regression analysis calculations between CPUE and effort. Once the intercept (a) and slope (b) values are obtained, the subsequent calculation involves searching for similarities in the relationship between CPUE and effort in the CYP model. The MSY value for catching giant tiger prawn in Rokan Hilir Regency has been calculated and the results are presented in Table 3.

Table 3

Regression results and maximum sustainable yield value of giant tiger prawn in Rokan Hilir Regency

Criteria	*Value*
Intercept (a)	3.3238
X_1	0.3776
X_2	0.0184
Maximum sustainable yield (ton year^{-1})	397
Effort optimum (unit year^{-1})	71

According to Table 3, the data reveals that sustainable production (MSY) of giant tiger prawn can be determined for a twelve-years period using the surplus production method derived from CYP model. This calculation aims to determine the sustainable potential value and optimal efforts for giant tiger prawn. According to the CYP model, the optimal effort (E_{opt}) value is 71 unit year^{-1}, indicating that the effort exerted by the trawl nets fishing equipment has not yet reached the maximum fishing effort limit. Nevertheless, the production of giant tiger prawn has surpassed the sustainable limit for giant tiger prawn management, which is set at 1,123.60 ton year^{-1}.

Utilization rate*.* The utilization rate is a percentage that indicates the extent to which giant tiger prawn have been utilized. The level of utilization of giant tiger prawn in Rokan Hilir Regency can be seen in Table 4.

Table 4

Utilization of giant tiger prawn in Rokan Hilir Regency

Year	*Production (ton)*	*Total allowable catch (ton)*	*Utilization (%)*
2011	761.44	287.17	212
2012	925.17	287.17	258
2013	1,088.91	287.17	303
2014	1,251.43	287.17	349
2015	1,971.80	287.17	549
2016	1,074.82	287.17	299
2017	1,282.17	287.17	357
2018	1,489.52	287.17	415
2019	1,065.43	287.17	297
2020	1,120	287.17	312
2021	710	287.17	198
2022	736	287.17	205
Average	1,123.06		313

According to Table 4, the utilization level of giant tiger prawn in Rokan Hilir Regency has fluctuated between 2011 and 2022, expressed as a percentage. Fluctuation in utilization levels can be attributed to various factors, such as a decline in catches. The decrease in catches was a result of a decline in population size due to excessive fishing effort. On the other hand, an increase in catches can be attributed to a rise in population size due to reduced fishing effort or an escalation in fishing effort prompted by a surge in fish prices. The average utilization rate of giant tiger prawn is 313%. According to Desiani et al (2019), the utilization of giant tiger prawn is deemed excessive or over-exploited, surpassing 100%. This is attributed to the excessive catch of giant tiger prawn, which exceeds the sustainable potential (MSY). Further fishing efforts will inevitably lead to the extinction of the giant tiger prawn resource. In order to address this issue, one possible solution is to implement ecosystem-based management strategies. These may include identifying specific fishing zones, imposing restrictions on production levels, and regulating the number of giant tiger prawn fishing activities.

Conclusions. The estimated sustainable potential (MSY) of giant tiger prawn in Rokan Hilir Regency from 2011-2022 is 397 ton year^{-1} with an optimum fishing effort of 71 unit year^{-1}. The permitted catch of giant tiger prawn in Rokan Hilir Regency is 287.17 ton year^{-1} while the average utilization rate of giant tiger prawn from 2011-2022 is 313%, indicating over-exploitation.

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

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