Bioeconomic analysis of spiny lobster catching activity in Pangandaran Coast, West Java Province, Indonesia

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Abstract. This research was conducted to analyse the performance of the lobster-fishing industry on the Pangandaran coasts, to analyze the conditions, efforts, and actual production of lobster-fishing activity in Pangandaran and to determine if it is sustainable and optimal, from the bioeconomic Gordon-Schaefer model, and in addition to provide correct input and output on lobster-fishing activity in Pangandaran. The data gathered for this research has been collected from October 2022 to February 2023 through field surveys. Primary and secondary data furthermore processed through the descriptive-quantitative method of analysis were used. The primary data was gathered through interviews with 90 respondents, and the secondary data was gathered from a relevant regional service office. The result of this research shows that 2020 was the best year for lobster-catching activity in Pangandaran. The species with the highest number of captured specimens was the spiny lobster (*Panulirus homarus*). The sustainable production catches (MSY) of this type of lobster is 7,423 kg with the catching trip (MSY) of 336,142 trips. The highest efficiency was obtained on MEY condition with 331,215 trips (MEY) and the catches (MEY) are 7,423 kg. The lowest efficiency was obtained on open access conditions, with trip estimated 662,429 trips, which resulted in 428 kg of lobster catches (OA). The optimum profit from the lobster fishing in Pangandaran on MEY condition generated 51,261.37 USD of profit, whilst on maximum sustainable condition MSY generated around 51,118.36 USD of profit. And the profit generated from the open access condition equals zero (OA)=0.

Key Words: bioeconomics, lobster, management, Pangandaran.

Introduction. Spiny lobster is a highly prized crustacean, with a strong and increasing demand throughout Asia, Europe, and America (Hart 2009), mainly due to their size and excellent meat (Davidson & Jaine 2006). Almost all spiny lobster production originates from capture fisheries, while capture rates are at or over their maximum sustainable yield (Phillips 2000). The spiny lobster fishery is an important source of income, employment, and to a lesser extent, food for many. However, historically detailed economic information and, by extension, assessments are not readily available. As a result, it has been generally difficult to determine the financial profitability and economic viability of the fishery (Riel & Wesley 2005). This is proven by the rise of lobster demand from the domestic and international markets (Setyono 2006). The lobster demand in the international market has reached around 2,500 tonnes year^{-1}, with export destinations to Hong Kong, Taiwan, China, Singapore, and Japan (ACIAR 2008). The rise in demand and lobster utilization in Indonesia would cause overfishing. According to the Head of Regional Fisheries and Marine Service Office of Pangandaran Regency in West Java Province says that the level of lobster fishing in Pangandaran waters has exceeded the level of over-exploitation.

There are nine lobster fishing spots in Pangandaran waters, West Java Province, Indonesia: Madasari, East Pangandaran Coast, Majingklak, Bojongsalawe, Palatar Agung, Nusawiru, Batukaras, Legok Jawa, and Muaragatah. According to the data that was provided by the Regional Fisheries and Marines Service Office of Pangandaran Regency, there are 3 locations with the highest catch of lobster fishing. Those locations are Madasari Coast, the East Pangandaran Coast, and Majingklak, with a total annual catch that could reach 17 tonnes. The rising yield of lobster fishing has become an important concern. Is commonly known that lobster is an open-access and common resource that every individual has the right to harvest it. This could lead to a decline in the number of lobster catches and a decrease in the economic rent due to overfishing. The use of fisheries resources shall be based on the socioeconomic and biological aspects to support their use sustainably (Zuzy 2003).

The planning for sustainable lobster harvest must be carried out in order to preserve the availability of lobster stock and the stability of lobster fishermen's income. This issue was at the origin of this research on lobster bioeconomic analysis in Pangandaran Waters. In order to study and analyze how to have a sustainable lobster resource in Pangandaran, this research uses the bioeconomic analysis Gordon Schaefer bioeconomic modelas a basis for policy analysis of sustainable fisheries development.

Material and Method

The general description of the research location. The Pangandaran Regency is one of the regencies of West Java Province with its capital located in the district of Parigi. The Pangandaran Regency is geographically situated at the coordinates of 108-41-109 East latitude and 07-41-0750 South longitude (Dwipayana et al 2018). On the map of West Java, the Pangandaran Regency is situated in the extreme Southeast. The North borders the Ciamis Regency and the Regency Tasikmalaya, the West also borders the Ciamis Regency and the Tasikmalaya Regency, the East borders the Province of Central Java, and to the South, lies the Indian Ocean. Generally, the Pangandaran Regency has two seasons. These are the dry season (east monsoon season) and wet season (west monsoon season).

Description of the study sites. This research was conducted from October 2022 until February 2023 in Pangandaran Waters. The study area or locations consisted of 3 sites (Figure 1) Site 1 Madasari Beach (Jl. Pantai Wisata, Masawah Village, Cimerak District) at coordinates 7° 47' 29.076" S, 108° 29' 47.2158" E, Site 2 Pangandaran East Beach (Jl. Pantai Timur, Pananjung Village, Pangandaran District) at coordinates 7° 42' 4.8198" S, 108° 39' 30.0168" E, and Site 3 Majingklak (Pamotan Village, Kalipucang District) at coordinates 7° 40' 23.1888" S, 108° 47' 58.7646" E. The determination of these locations was based on the highest lobster catch production according to the data from the Fisheries and Marine Service of Pangandaran Regency.

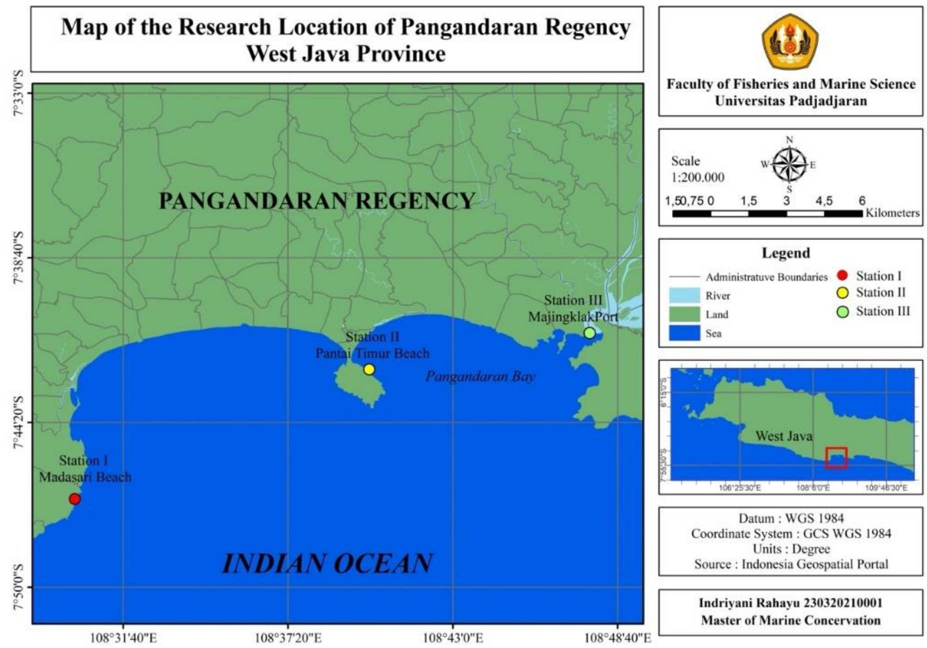

Figure 1. Research location.

Research methods. The research method used is a survey method. Sugiyono (2009) stated that the survey method is used to obtain data from natural (non-artificial) settings, but the researcher intervenes in data collection, for example, by distributing questionnaires, conducting tests, structured interviews, and other means. The gathered information is from local Pangandaran lobster fishermen from three stations, which are Madasari (ST. 1), East Pangandaran Coast (ST. 2), and Majingklak (ST. 3) in Pangandaran Regency, Province of West Java, Indonesia.

Data source. The type of data that is being used in this research is primary and secondary data. The primary data was gathered directly from qualified respondents lobster fishermen in Pangandaran by filling in a questionnaire. The secondary data is data gathered from past reports and research from a relevant institution or literary study, which was gathered from annual reports of a regional office or institution concerned in this research, such as the annual report on fisheries production data from the Regional Fisheries and Marine Service Office of Pangandaran Regency from 2015 until 2022, and including other relevant agencies report that were directly involved in this research. The analysis method that is used in this research is the descriptive-quantitative method. The quantitative method is the scientific approach to the reality in which the data can be classified, concrete, observable, and measurable in a structured way, determining causal variable relationships based on numerical dataand statistics (Sugiyono 2009).

Analysis of standardization of fishing gear. The standardization of fishing efforts needs to be carried out before conducting the Catch Per Unit of Effort (CPUE) calculation by comparing the catch per fishing effort of each fishing unit (Noordiningroom et al 2012). The standard fishing gear that is used to capture lobster in Pangandaran waters is the trammel net, whose productivity is used as calculation basis to determine the lobster yield of each fishing effort (Catch Per Unit Effort or CPUE). This analysis is performed to discover the abundance and the utilization rate based on the division between the total catch and fishing effort through an equation according to Sparre et al (1999):

$$\text{CPUE} = \frac{c}{f}$$

Where:
CPUE - catch per unit effort (kg trip^{-1});
Catch (C) - total catch (kg);
Effort (F) - total fishing effort (trip).

Sustainability potential estimation analysis. The functional analysis of the maximum sustainable production of fisheries or Maximum Sustainable Yield (MSY) has long been used for the production purpose of many fisheries industries all over the world (Mace 2001), by using the production surplus method by Schaefer that is a linear relation between Catch Per Unit Effort (CPUE) and the fishing effort (effort) (Sparre et al 1999). The analysis of Maximum Sustainable Yield (MSY) is used in this research to determine the lobster population condition in Pangandaran.
The Schaefer formula (Schaefer 1954; Listiani et al 2017) steps for processing the data are:

- Plot the F value to C/F and estimate the intercept value (a) and slope value (b) with linear regression
- Calculate the estimation of sustainable potential (CMSY) and optimum effort (EMSY)

The linear regression equation formula (Schaefer 1954; Listiani et al 2017):

$$y = a - bx$$

Where:
y - dependent variable (CPUE) in kg trip^{-1};
x - independent variable (effort) in trip;
a and b - regression parameters.

Furthermore, the a and b parameters can be determined through the formula (Schaefer 1954; Listiani et al 2017):

$$a = \sum\frac{Xi}{n} - \sum\frac{yi}{n}$$

$$b = \frac{n.\sum((xi)(yi))-(\sum Yi)}{n.\sum(xi^2)(xi)^2}$$

Where:
a - intercept (constant);
b - slope;
xi - fishing effort on period i;
yi - fishing catch per effort unit on period i;
n - sample size.

The estimation of sustainable potential (MSY) and optimal effort level (f_{opt}) can be conducted using the Schaefer and Fox model (Pauly 1983; Nugraha et al 2012; Istikasari et al 2016) as follows:

a. The relationship between CPUE and effort can be formulated as:

$$CPUE = a + bf$$

b. The relationship between catch and effort formulated as:

$$C = af + b(f)^2$$

Where:
CPUE - the total catch per fishing effort unit (kg $trip^{-1}$);
C - catch;
a - intercept;
b - regression coefficient/variable;
f - fishing effort (trip) on period i.

According to Wahyudi (2010), the Schaefer model only applies if the parameter value (b) is negative, which means that an increase in fishing effort will lead to a decrease in CPUE. If the coefficient (b) is found to be positive in the calculations, there is no need to proceed with the estimation of potential and optimum fishing efforts, as it indicates that increasing fishing effort is still likely to increase the catch.
Once the values of "a" and "b" are known, the next step is to calculate the optimal catch and optimal fishing effort using the following formulas (Sulistiyawati 2011):
Optimal fishing effort (E_{MSY}):

$$E_{MSY} = \frac{a}{2b}$$

The maximum sustainable yield (C_{MSY}) or the optimal catch:

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

Where:
a – intercept;
b - regression coefficient or f variable;
E_{MSY} - optimal fishing effort;
C_{MSY} - optimal catch.

The Gordon-Schaefer bioeconomic analysis. Bioeconomic analysis is a combination of the biological dynamics of fishery resources and the economic factors influencing fishing activities (Fauzi 2010). This study is necessary to determine the magnitude of economic rent generated from a lobster fishing enterprise. Economic factors that influence the calculation analysis include fishing costs (c) and fish price (p). Economic rent is the difference between revenue and costs in fishing operations. According to Fauzi & Zuzy (2005), the foundation of fisheries resource management is how to utilize the resources in a way that generates high economic benefits for users while ensuring its sustainability. This statement contains two meanings is economic and conservation or biological aspects. Thus, the optimal utilization of fishery resources should accommodate both of these disciplines. Therefore, a bioeconomic approach to fisheries resource management is essential for every stakeholder involved in fisheries resource management. The field of fisheries is one of the most significant areas that extensively applies bioeconomic principles. The Gordon-Schaefer Bioeconomic Model was developed by Schaefer using the logistic growth function originally developed by Gordon. The logistic growth function model is combined with economic principles by incorporating factors such as price per unit of catch and cost per unit of fishing effort into the function equation. There are three conditions of stability according to the Gordon-Schaefer model, these are Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access Equilibrium (OAE) (Hutagalung et al 2015). This analysis is used in the research to understand the conditions of the lobsters' population in Pangandaran waters. The formulas of Gordon-Schaefer's three conditions of stability are provided in Table 1 (Wijayanto 2008).

Table 1

The Gordon-Schaefer's formulas of three conditions of stability

	MSY	*MEY*	*OAE*
Catch (C)	$a^2/4b$	$aE_{MEY} – b(E_{MEY})^2$	$aE_{OAE} – b(E_{OAE})^2$
Effort (E)	A / 2b	(pa-c) / (2pb)	(pa-c) / (pb)
Total revenue (TR)	C_{MSY} x P	C_{MEY} x P	C_{OAE} x P
Total cost (TC)	c x E_{MSY}	c x E_{MEY}	c x E_{OAE}
Economic profit (π)	$TR_{MSY} - TC_{MSY}$	$TR_{MEY} - TC_{MEY}$	$TR_{OAE} - TC_{OAE}$

Where:
a – intercept;
b - regression coefficient or f variable;
E_{MSY} - optimal fishing effort;
C_{MSY} - optimal catch;
E_{OA} - open access;
P – price;
C – cost;
TR - total revenue;
TC - total cost;
π - economic profit.

The sustainable production function is determined using the Schaefer surplus production model. The data used in this research are time series data on lobster catch and fishing efforts from 2015-2022, which were obtained from relevant regional service offices or agencies. The equation for the sustainable production function being acquired is $h = \alpha E - \beta E^2$. The values of coefficients α and β are obtained through linear regression analysis.

Results

Characteristics of respondents. As many as 90 Lobster fishermen act as respondents and they came from 3 different stations, which are Madasari (ST. 1), East Pangandaran Coast (ST. 2), and Majingklak (ST. 3). The lobster fishermen characteristics for observation include age, education level, and work period. Here are the socio-demographics of the respondents from 3 stations.

From the interview, it is concluded that the majority of lobster fishermen in all three stations are within the age groups of 43-52 years old (34%) and 33-42 years old (30%) with only a 4% difference. This is because age influences a person's attitude in choosing their occupation. According to Simanjuntak & Payaman (2005) and Putra & Kartika (2019), a person's age will affect their job selection, which not only significantly impacts the quality of work they perform but also their attitude towards future retirement. Older individuals have reasons to continue their work, driven by factors such as economic needs or genuine enjoyment of their profession (Saihani 2011; Rahayu et al 2014), believes that age is one of the significant factors influencing a person's way of thinking and decision-making process, especially when making crucial decisions. The percentage is shown in Figure 2.

From Figure 2, it can be concluded that the highest level of education of the majority of fishermen in all 3 stations is junior high school, with a percentage of 48%, while the lowest is primary school, with a percentage of 10%. The lack of education among the lobster fishermen is caused by the poor economic conditions; fisherman is an inherited profession; it is considered that it does not need formal education. The lobster fishermen also consider that skills and ability are needed to generate the maximum volume of catches. According to Rahman (2016), the lack of education is caused by the poor economic conditions in the past which made long-term education inaccessible.

According to the identification results, the majority of fishermen who fish lobsters have 11-20 years of fishing experience, with a percentage of 34%; those who have about 41-50 years of fishing experience are only 3%. According to Ananda (2014), one of the factors for fishermen to develop their effort in fishing is experience. The more experience the fishermen have, the bigger the ability of fishermen to understand fishing techniques. The percentage is shown in Figure 2.

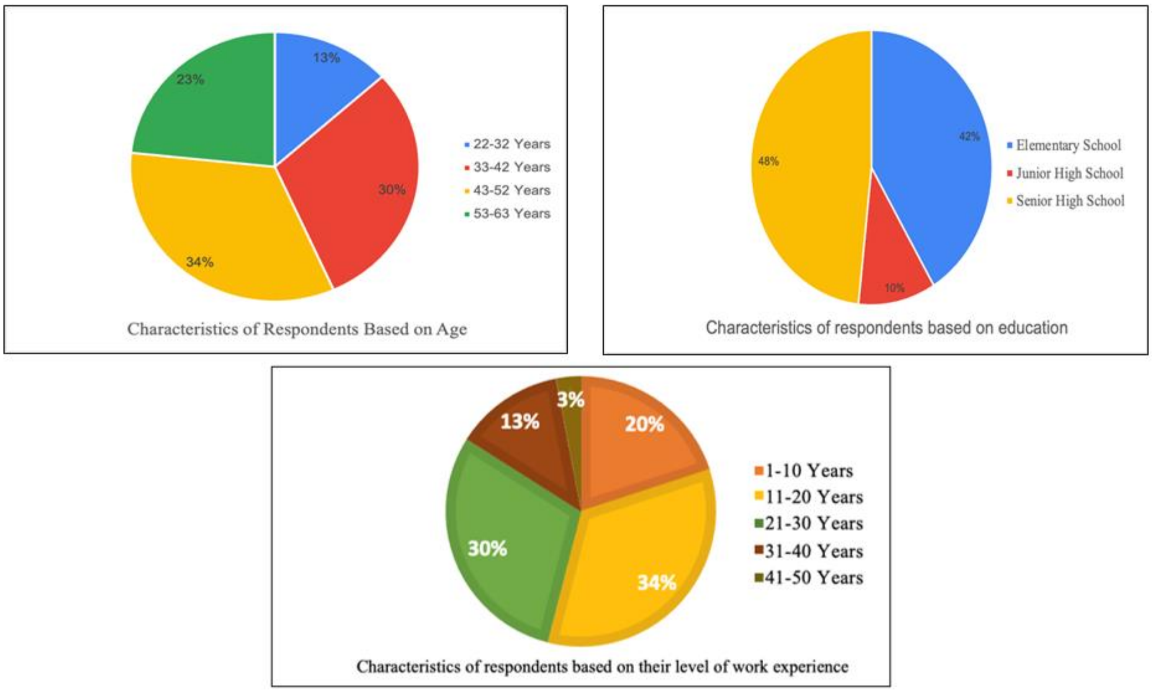

Figure 2. Respondents characteristics.

Production and volume of lobsters caught in the waters of Pangandaran. The data on the production of lobsters over the last 8 years (2015-2022) in Pangandaran waters can be seen in the Figure 3 (Ministry of Marines and Fisheries 2022).

According to Figure 3, the production of lobsters from 2015 to 2022 saw a fluctuation, which is caused by natural factors. Lobster fishermen in this research stated that lobster-catching seasons and the weather affect them. This is understandable since the places where lobsters are commonly caught are located within the reefs, and when the tides are high, it would be difficult for fishermen to catch lobsters. The highest production of lobsters in Pangandaran was in 2020, with an amount of 17,251.58 kg year^{-1}. This happened, as stated by the Head of the Regional Fisheries and Marine of the Pangandaran Regency, because prior to 2020, there were releases of lobster seeds in the waters of Pangandaran, conducted by the Ministry of Maritime Affairs and Fisheries, BKIPM and KHP (Badan Karantina Ikan, Pengendalian Mutu, dan Keamanan Hasil Perikanan - Board of Fishery Containments, Quality Control, and Security of Fishing Products) and other related boards, and by so, in 2020, all the lobster seeds were ready to be harvested.

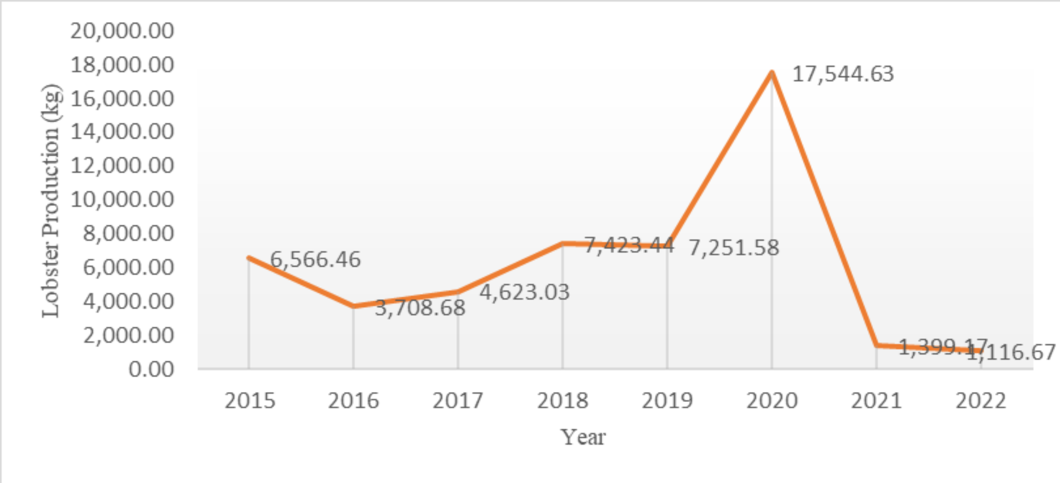

Figure 3. Production of lobsters in the Regency of Pangandaran from 2015 to 2022.

The highest lobster production in Pangandaran in the year 2020 was also attributed to a new policy by the Ministry of Marine and Fisheries (2020) regarding the management of lobster (*Panulirus* spp.), crab (*Scylla* spp.), and cuttlefish (*Portunus* spp.). This regulation allowed for the export of lobster seeds from the territory of the Republic of Indonesia. Such activities were previously prohibited under the Ministry of Marine and Fisheries (2015). As a result, in the year 2020, *Panulirus* spp. production in Pangandaran was significantly higher compared to previous years.

The lowest production of lobsters was recorded in 2021 and 2022, with the amount of 1,399.17 year^{-1} due to the prohibition of the cultivation of lobster seeds by the Ministry of Marines and Fisheries, as stated by the Ministry of Marines and Fisheries (2021). Despite the ban on exports, cultivation of lobster seeds is still allowed under certain conditions. This indicates that the regulations issued by the ministry are obeyed by fishermen in Pangandaran Regency. In Figure 4 are presented the percentages of cultivation in 3 stations - Madasari (ST. 1), East Pangandaran Coast (ST. 2), and Majingklak (ST. 3).

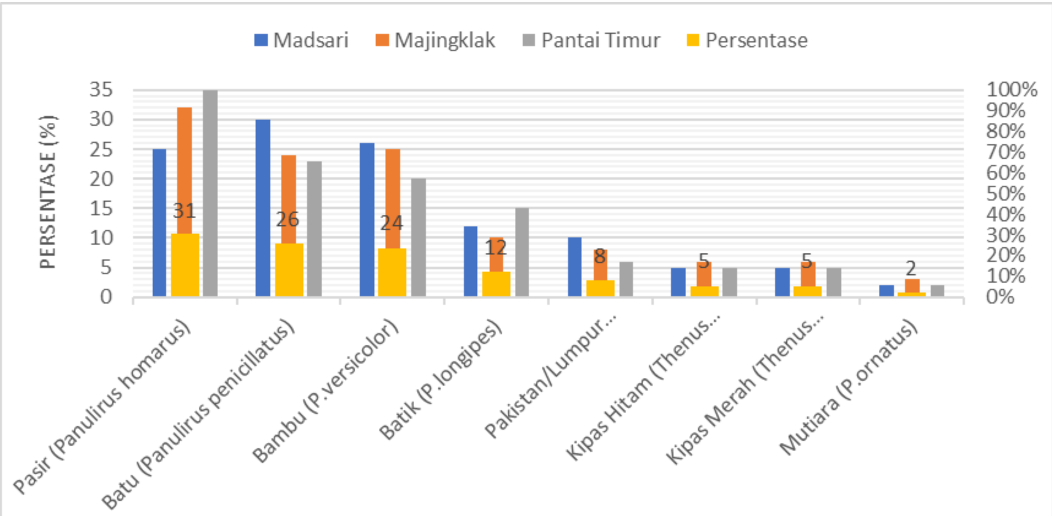

Figure 4. The percentages of cultivation of lobsters by types in Pangandaran waters.

Figure 4 shows the percentage of grounded lobsters caught at all 3 locations: Madasari (ST. 1), East Pangandaran Coast (ST. 2), and Majingklak (ST. 3), with the highest amount of catches (31%) being spiny lobsters (*Panulirus homarus*). The *Panulirus penicillatus* type coexists with the *P. homarus* type (Suadi et al 2001), which caused the *P. penicillatus* type to also get caught in a big amount. From all 3 locations, the most difficult type of lobsters to catch are ornate spiny lobsters (*Panulirus ornatus*). During the research's interviews, the fishermen agreed that ornate spiny lobsters are one of the scarcest critters, but also the most favoured lobsters among seafood consumers, with a high economic value, due to its soft and thick meat.

Catch per Unit Effort (CPUE). The Catch per Unit Effort (CPUE) is obtained by dividing the lobster catch production (h) by the fishing effort (E). The CPUE describes the productivity value of the Trammel Net fishing gear in catching lobsters. The CPUE value is presented in the Table 2:

Table 2

Catch per unit effort value of the Schaefer model

Year	*Volume (kg)*	*Trip year* $^{-1}$	*CPUE*	*LN CPUE*	*U* $_{est}$	*Y* $_{est}$
2015	6,566.46	150	13.133	2.575	10.296	1544.4
2016	3,708.68	115	9.675	2.270	10,986	4449353.18
2017	4,623.03	110	12.608	2.534	11.084	26963728.07
2018	7,423.44	250	8.908	2.187	8.326	417406.5
2019	7,251.58	360	6.043	1.799	6.159	231033547.3
2020	17,544.63	400	13.158	2.577	5.371	5300.4
2021	1,399.17	300	1.399	0.336	7.341	3975.3
2022	1,116.67	350	0.957	-0.044	6.356	4637.85

According to the effort relations graphs and lobster's CPUE in the Pangandaran waters between 2015-2022, the linear equation was obtained y = -0,0657x + 44,169 with the R^2 = 0,2113. Based on the functional equation, the slope value (β) obtained is of -0,0657, which indicates a negative relationship between production and effort: every reduction of 1 effort trip will cause the CPUE to increase by 0.0657 kg trip^{-1} and vice versa. Based on Figure 5, the R-squared value (R^2) obtained is 0.2113 or 21.13%. This means that the variation or fluctuations in CPUE by 21.13% are caused by the fluctuations in the effort value, whereas a higher R-squared value indicates a better fit for the model.

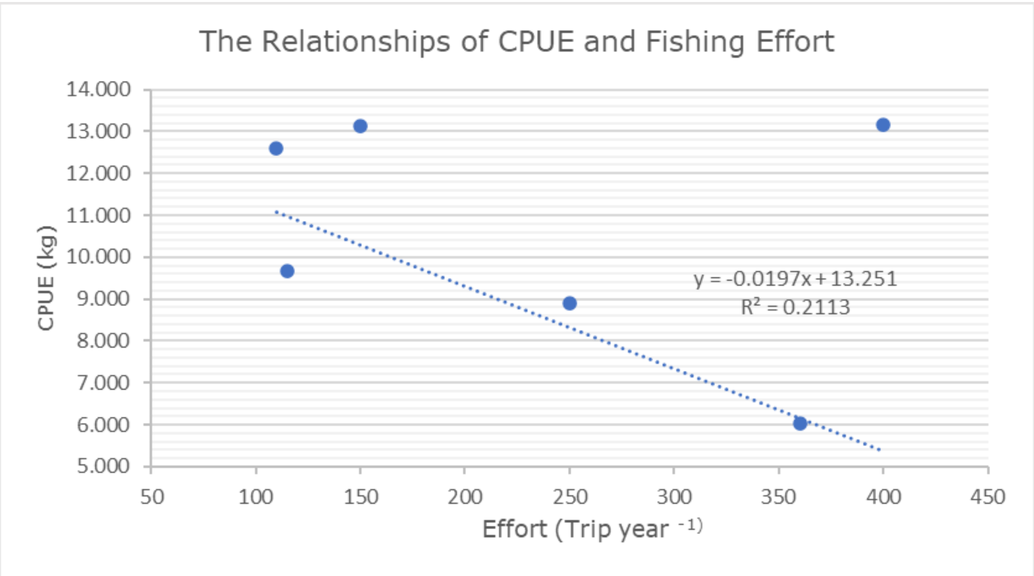

Figure 5. The Relationships between CPUE and fishing effort.

There are three categories of R-squared values grouping: strong, moderate, and weak (Hair et al 2011). Based on the CPUE values, there has been fluctuation from 2015 to 2022. The highest CPUE value was recorded in 2020 at 13.15 kg trip^{-1}, while the lowest was recorded in 2022 at 0.957 kg trip^{-1}. The high and low values of CPUE occurred due to the changes in the number of fishing trips (effort) during that period. This can be interpreted that an increase in fishing effort will decrease fishing productivity (CPUE), as observed in Figure 5. The higher the fishing effort rate, the greater the number of fish being caught, which could lead to a reduction in the fisheries' resources if not balanced with the mortality rate of the fish itself (Nurhayati 2013).

Sustainable production function. The values of coefficients α and β (in the equation for the sustainable production function $h = \alpha E - \beta E^2$), obtained through linear regression analysis, are 13.251 and -0.0197, respectively. Thus, the function for the sustainable production equation is:

$$h = 13.351\ E - (-0.0197\ E2)$$

The coefficients α and β are then used to determine the functions for sustainable fishing effort rate and sustainable catch production as follows:

$$\text{EMSY} = \frac{\alpha}{2\beta} = \frac{13.351}{2 \times 0.0197} = 336.320 \text{ trips}$$

$$\text{Hmsy} = \frac{\alpha^2}{4\beta} = \frac{13.251^2}{4 \times 0.0197} = \ 2{,}228 \text{ Kg}$$

The effort required in sustainable conditions is 336,320 trips year^{-1}. The sustainable lobster production is 2,228 kg. The fishing effort and lobster production values also represent the amount of lobster that can be caught in the Pangandaran waters within a year. The relationship between fishing effort and lobster caught in sustainable conditions can be seen in the Figure 6.

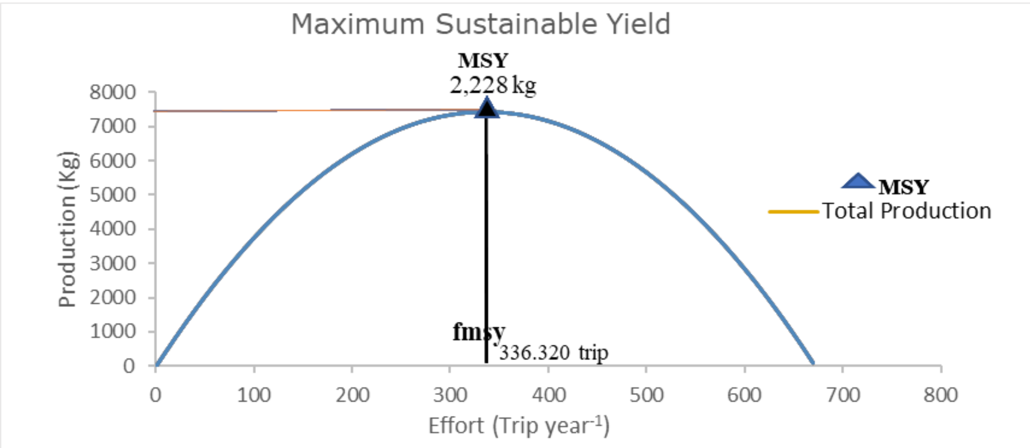

Figure 6. Quadratic relationship between lobster fishing effort and lobster production in Pangandaran waters with the Schaefer model.

Bioeconomic analysis of lobster resource utilization. The bioeconomic analysis is the integration of biological dynamics of fishery resources and economic factors that influence the capture fishery industry (Fauzi 2010). This study is necessary to determine the amount of economic rent generated by a lobster fishing business. The economic factors that affect the calculation of the analysis include the fishing cost (c) and fish price (p). Economic rent is the difference between revenue and cost in fishing activities. This bioeconomic analysis is calculated using the Gordon-Schaefer model under three conditions: Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA). The results of the lobster resource bioeconomic calculation are presented in the Table 3:

Table 3

The bioeconomic analysis results of lobster resource under various conditions (1 Year)

Variable	*Conditions*		
	MSY	*MEY*	*OA*
Effort (E) (trip)	336.320	319.888	639.776
Catches (h) (kg)	2,228	2,228	414
TC (USD)	5,540.51	5,269.04	10,536.91
TR (USD)	55,368.63	56,550.94	10,536.91
Rent (π) (USD)	51,139.87	51,280.42	0

Maximum Sustainable Yield (MSY). The Maximum Sustainable Yield (MSY) is an effort to catch fishery resources in a precise manner in order to maintain the existence of fish stocks in the sea, thus ensuring the sustainability of the stocks (Zuzy 2019). Based on Table 3, the rate of fishing effort in MSY condition is 336,320 trips. The amount of lobster catch in MSY condition is 2,228 kg. These results indicate the rate of sustainable lobster catch production, which is the highest lobster catch that can be harvested without threatening the sustainability of the lobster resource. The lobsters caught in MSY condition are higher than the catch in MEY condition, but lower than the catch in open access condition. The profit obtained from MSY condition is lower than MEY condition, which is 51,280.42 USD with a Total Revenue of 56,550.94 USD and a Total Cost of 5,269.04 USD The MSY value is the maximum value in economic and social terms (Hakim 2014).

Maximum Economic Yield (MEY). The effort required to reach the optimal point in the MEY condition is much smaller compared to the MSY condition, indicating that the effort rate at the MEY point is more conservative-minded (more environmentally friendly) (Hannesson 1993). The calculation results presented in Table 3 show that the fishing effort in the MEY condition is 319,888 trips year^{-1}, and the production yield of lobster catches is 2,223 kg. These results indicate the smallest rate of lobster fishing effort and production yield compared to the MSY and OA conditions. The total cost required to carry out lobster fishing for one year under the MEY condition is 5,269.04 USD. The total revenue obtained is 56,550.94 USD, resulting in a profit of 51,280.42 USD from the difference between the TC and TR values. The total revenue received by the fishermen in the MEY condition is not the highest, but it obtains the maximum economic rent. Maximum Economic Yield (MEY) is the highest profit received by fishermen in managing fishery resources and business sustainability by paying attention to the sustainability of fishery resources (Tamti & Hafid 2016).

Open access. Open access conditions are a balancing point of a bioeconomic analysis. Stability occurs on the effort rate of 639,776 trips annually and a total volume of of 414 kg of lobsters caught annually. This shows the highest number of trips conducted, but the volume of catch is smaller compared to the conditions of MEY and MSY. The total effort on the open access conditions could increase the total cost of outcomes for the fishermen. From Table 4, it can be seen that the total cost is 10,536.91 USD with a total revenue of 10,536.91 USD. In other words, on this condition, the lobster-catching activity in the waters of Pangandaran no longer generates profits. The loss of economic benefits is commonplace, considering that open access resource management does not pay attention to any regulations, hence allowing fishermen to catch and embark on trips as much as they wish to.

Discussion. According to Fauzi (2010), a sustainable fishery system is by limiting input and output in capture fisheries. The MEY condition is deemed to be the best condition for lobster-catching activity in Pangandaran waters, compared to the results of the management of MSY and OA. This happens because the MEY conditions give the best rent/economic benefits to fishermen without having to disturb the existence of lobsters in Pangandaran waters. The relationships between TR, TC, and economic rent on the conditions of MSY, MEY, and OA can be seen on the curve shown in Figure 7.

In a state of bioeconomic equilibrium, fishermen are free to catch lobsters, so that the extracted resources will reach the lowest point resulting in unprofitable efforts, which is referred to as economic overfishing. The extinction of lobster stocks is highly likely to occur if fishing efforts continue. At points to the right of the graph (Figure 7), the average cost per unit effort will be higher than the average revenue per unit. In this condition, it causes fishermen to exit the fishing industry, as management under the open access regime reveals that the benefits of lobster-catching activities, if continued, would have a negative value even though the production value keeps increasing. This represents wasteful use of energy and costs, and it also has negative implications for the sustainability of lobster stocks. Such management is not socially beneficial.

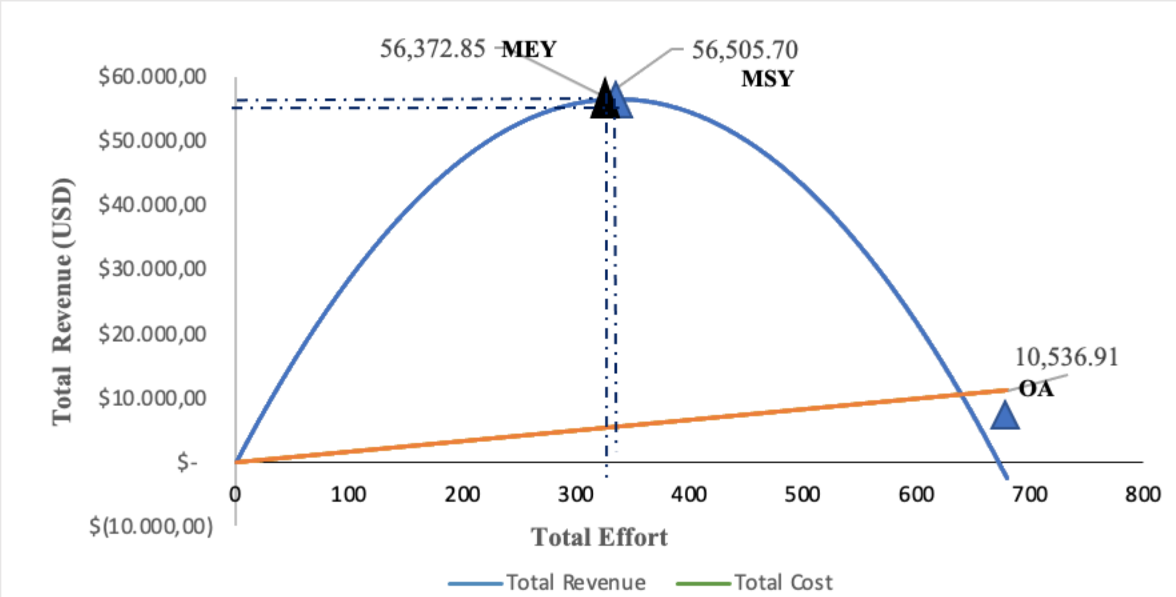

Figure 7. Bioeconomic curves for the MEY, MSY, and OA conditions.

Gordon (1954) has predicted that the open access will lead to economic overfishing. This is supported by Clark et al (1990) who stated that economic overfishing will not occur in a controlled fishery, while biology overfishing will occur anytime when the price-to-cost ratio is sufficiently high. In other words, an open access equilibrium will occur if all economic rents have been exhausted (driven to zero) so that there are no longer incentives to enter or exit, and there is no change in the existing level of effort (Fauzi 2006). An important issue related to the management of fishing effort is how to determine the limits of economically sound fish management (Suharyanto 2011). Purwanto (1989) argues that economically the optimal level of exploitation of fishery resources, regardless of the dynamics due to the time factor, is when the maximum economic yield (MEY) is achieved. The Gordon-Schaefer model uses optimal effort and catch as control variables. The value is obtained based on the bioeconomy balance solution. This alternative will provide optimal catch quotas and optimal economic benefits, so that the sustainability of lobster resources can be maintained (Pramono 2007). Based on the results of the analysis, in 2018 and 2020 the exploitation of lobster resources in Pangandaran waters was biologically and economically excessive.

Conclusions. The research consists of an analysis of biological and economic aspects of lobster-fishing effort in capture fishery industries with standard fishing gear (trammel net) in Pangandaran waters. The highest lobster catch in Pangandaran occurred in 2020 (17.251,58 kg year^{-1}) and the highest percentage of lobster species landed at the 3 stations is dominated by *P. homarus*). The graphic of effort and lobster CPUE relationships in Pangandaran waters year 2015–2022 corresponds to the linear equation y=-0,0657x+44,169, with R^2=0,2113. The MSY conditions on lobster-fishing activity in Pangandaran showed a number of 336,320 trips with a total catch volume of 2,228 kg. The MEY conditions with the total effort of 319,888 trips, and the total lobster catch volume of

2,223 kg. And lastly, in open access conditions the total effort was of 639,776 trips and the total lobster catch of 414 kg.

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