Stock assessment of pelagic fish in the eastern part of Java Sea: A case study in offshore Regency of Rembang and Tuban, Indonesia

Zairion1,2,*, A Hamdani1, Y Rustandi1, A Fahrudin1,2, M N Arkham1, A Ramli1 and A Trihandoyo1

1Center for Coastal and Marine Resources Studies (CCMRS), IPB University (Bogor Agricultural University), Kampus IPB Baranangsiang, Jl. Raya Pajajaran No. 1, Bogor 16127, West Java, Indonesia
2Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia

*E-mail: zairion@apps.ipb.ac.id

Abstract: Total annual landing of pelagic fish resources from the eastern part of Java Sea tend to be increased, but the stock status is not known well. This study was aimed to analyse optimal exploitation and stock status of pelagic fish in the eastern part of Java Sea and enlighten overfishing issues. Monthly catch of pelagic fish and effort data (trips) based on fishing gear during the period 2010 to 2016 were collected from four representative fish landing base or fishing port (i.e. Tasik Agung, Sarang, and Karang Anyer of Rembang Regency, and Bulu of Tuban Regency). Analyses were carried out using a surplus production model, and the best fit estimation was the Schaefer Model with Fox algorithm approach. Estimated bio-technique parameter of pelagic fish stock such as intrinsic growth rate (r) was 0.27 ton per year, catchability coefficient (q) was 0.000017 ton per unit, and environmental carrying capacity (K) was 622,614.72 ton per year. Result also showed that optimal production (h), effort (E) and profit (π) at Maximum Sustainable Yield (MSY) level 42,553.58 ton per year, 8,138 trips per year, and 263,783 billion rupiah (IDR), respectively. Meanwhile, those three variables at Maximum Economic Yield (MEY) were 41.670,87 ton per year, 6,966 trip per year, and 271,468 billion rupiah. However, the average of actual production, effort, and profit were 40,409.83 ton per year, 6,972 trips per year, and 260,408 billion rupiah. Moreover, total production and effort in 2016 were 42,009 ton and 10,114 trips. The status of pelagic fish stock in this area tends to be economic overfishing due to increased effort and less effective of fishing cost. Reducing fishing effort must be applied in fisheries management.

Keywords: catch per unit effort (CPUE); fisheries management; fish stock assessment; Schaefer model; Java Sea.

1. Introduction
The Java Sea is included in Fisheries Management Area (FMA 712) of the Republic of Indonesia, and it has the potential of various groups of fish resources (i.e. small pelagic fish, large pelagic fish, demersal fish, reef fish, and some other of fish resources). Based on the Decree of the Minister of...
Marine Affairs and Fisheries of the Republic of Indonesia No. 50 the year 2017 concerning potential estimation, total allowable catch, and level of fish resources utilization in FMA of Indonesia, the potency fish resources in FMA 712 is 1,341,632 ton per-year. The highest potential of fish resources in FMA 712 is a demersal fish group, which is 657,525 ton per year and followed by small pelagic fish that is 364,663 ton per year. Other potential fish resources are squid, large pelagic fish (non-tuna and skipjack), penaeid shrimps, reef fish, blue swimming crabs, mud crabs and lobster. Some of those fish resources groups are fully and over exploited, except small and large pelagic fish, blue swimming crabs, and mud crab.

Stock assessment of pelagic fish has been conducted in FMA 712 with the objectives are to identify their potency and exploitation level. However, this assessment is general in a wide area. The dynamic of fish stock in the marine area is influenced by several factors, such as growth, recruitment, migration, and total catch or yield in every year [1-5]. Yield is also influenced by standing stock and fishing effort [6]. Consequently, the maximum sustainable yield (MSY) also varies in each year as well as it has a dynamic in the wide area [7].

Fishery resources which are state-owned as a representative of public ownership, have the nature of open access and are often regarded as common property resources. As a result, there is often expansion and stability in its use. The above conditions cause a decrease in the quality of fish resources and a decrease in economic rent due to biological and economical overfishing [1, 8-9]. The utilization of fisheries resource must be based on the biological factors of fish and the socioeconomic aspects, sustainability and environmental conditions to support the activities of sustainable use. Thus, the necessary thing about fisheries resource management is how the activities of utilizing these resources to produce high economic benefits for users, but its sustainability are maintained [10-11].

Although the pelagic fish stock (multi-species fish stock) in the Java Sea (FMA 712) has been assessed, little is known about their condition in the eastern part of Java Sea. Knowing fish stock condition in this area is very important due to the large numbers of fishers in Rembang and Tuban Regency who catch pelagic fish in this marine area. The total annual landing of pelagic fish resources from this area tend to be increased, but the stock status is not known well. Thus, this study was aimed to analyses multi-species stock status, optimal exploitation of pelagic fish in the eastern part of Java Sea and enlightens overfishing issues.

2. Materials and methods

2.1. Data collection

The study was conducted from March-June 2017 in the eastern part of Java Sea with data base at four fish landing locations or fishing port in Rembang and Tuban Regency. These four fish landing locations have chosen in the area as a main fishing base for multi-species pelagic fish, there are Tasik Agung, Sarang, and Karang Anyer of Rembang Regency, and Bulu of Tuban Regency (Figure 1). The main fishing gear used for capturing pelagic fish is mini-purse seine. The length of mini-purse seine is range from 250-360 m and depth from 40-50 m with body and bag mesh sizes are 1.5 and 1.0 inch, respectively. The fishing ground of mini-purse seine fishing gear at a distance of 20-50 miles from the fishing base or coastline. The type of fishing fleet is a motor boat with a size of 10-30 gross tonnage (GT), and fishing trip duration is 1-5 days.

This study was using the survey method through quantitative and descriptive analysis. The type of data collected includes primary and secondary data. Primary data obtained through direct observation of fishing activities and interviews with fishers based on a questionnaire. Determination of the number of samples was using a formula developed by Isaac and Michael in [12] with a confidence level of 85%. Secondary data for completing catch per-unit of effort (CPUE) analysis, optimal utilization of resources was collected time series data for seven years in the period 2010-2016, from both monthly catch fisheries statistics at each fish landing location and capture fisheries statistics data of each regency. Secondary data also are taken included input used (effort), price per unit of output (fish price per kg or ton), consumer price index (CPI) and Gross Regional Domestic Product (GRDP).
2.2. Data analyses

2.2.1. Standardization of fishing effort
Estimation of optimal utilization of fish resources was using a surplus production model with a bio-economic approach. Given that fishing gear in an area varies in types, size of similar fishing gear and trip duration, it is necessary to standardize fishing gear (effort). According to [3-4, 7, 10], fishing gear input that will be standardized is the multiplication of the fishing power index (FPI) with the input (effort) of the standardized fishing gear, with the following formulation:

\[ E_{std} = \varphi_i E_i; E_{std} = \frac{U_i}{U_{std}} \]

Whereas \( E_{std} \) is effort standard, \( E_i \) is effort of fishing gear-i, \( U_i \) is CPUEi or catch per unit of effort of fishing gear-i, \( U_{std} \) is CPUE\textsubscript{std} or catch per unit of effort of fishing gear that is used as standard.

![Figure 1](image_url)  
Figure 1. Study area of pelagic fish stock assessment in the eastern part of Java Sea. The red and blue star on the map indicating a fishing port for data collection.

2.2.2. Bio-technical parameter analyses
Since the CPUE of each species data did not record well, we used average data in almost biological and economic variables of the fishery. The bio-technical analysis uses a surplus production approach from the Schaefer model [13-14], can be estimated by the following equation:

\[ h = qK - \frac{q^2K}{r}E^2 \]

Whereas \( h \) is production or total landed of catch, \( q \) is catchability coefficient, \( r \) is the intrinsic growth rate of fish biomass, \( K \) is carrying capacity of the aquatic environment, and \( E \) is a fishing effort (trip).
The value of \( r, q, \) and \( K \) was obtained from supporting estimation models, such as Fox algorithm, Schnute, Walter-Hilbon (WH), and Clark-Yoshimoto and Pooley (CYP) models [4, 6, 15-16]. The best fit model was used in the subsequent estimation.

2.2.3. Bio-economic analyses

The bio-economic analysis is done by adding economic factors in the form of price and cost factors to the bio-technique aspects through the Gordon-Schaefer mathematical model [9, 17], as follows:

\[
\pi = TR - TC
\]
\[
\pi = p * h - c * E
\]
\[
\pi = p\left(qK - \left(\frac{q^2K^2}{r}\right)E^2\right) - cE
\]

\( TR \) is total income (Rupiah, Rp), \( TC \) is total cost (Rp), \( \pi \) is economic margin or rent (Rp), \( p \) is the average price of fish (Rp), \( h \) is total catch (kg), \( c \) is fishing cost per unit of effort (Rp), and \( E \) is fishing effort (trip).

Based on various conditions, the pattern of fish resource utilization can be statically estimated using formulas as listed in Table 1.

**Table 1.** The calculation formula for the optimal static of resources utilization.

| Variable | Equilibrium Condition of Gordon-Schaefer Model |
|----------|-----------------------------------------------|
|          | MEY                                           | MSY                                           | Open Access                              |
| Biomass (x) | \[
\frac{K}{2} \left(1 + \frac{c}{p.q.K}\right)
\] | \[
\frac{K}{2}
\] | \[
\frac{c}{p.q}
\] |
| Catch (h) | \[
\frac{r.K}{4} \left(1 + \frac{c}{p.q.K}\right) \left(1 - \frac{c}{p.q.K}\right)
\] | \[
\frac{r.K}{4}
\] | \[
\frac{r.c}{p.q} \left(1 - \frac{c}{p.q.K}\right)
\] |
| Effort (E) | \[
\frac{r}{2q} \left(1 - \frac{c}{p.q.K}\right)
\] | \[
\frac{r}{2q}
\] | \[
\frac{r}{q} \left(1 - \frac{c}{p.q.K}\right)
\] |
| Economic Rent (\( \pi \)) | \[
q.K.E \left(1 - \frac{q.E}{r}\right) - c.E
\] | \[
p.\left(\frac{r.K}{4}\right) - c.\left(\frac{r}{2q}\right)
\] | \[
p - \frac{c}{p.x} \times F(x)
\] |

3. Result and discussion

3.1. Fish species and production

The dominant fish species caught by the mini-purse seine in the study area include scads (mackerel scads and round scads), longtail tuna, fringescle sardinella, indian mackerel and short mackerel, trevally, etc. Total catch data of each dominant species was available, but it was hard to connect with the unit of effort. Thus, we combine all pelagic volume data as pelagic fish wild catch production. Total catch or total pelagic fish landing at each fishing port during 2010-2016 were varied varied among landing site, but the lowest and the highest production occured in Bulu and Tasik Agung fishing port, respectively (Table 2). Total production for all landing site was also fluctuated among observed year, whereas the lowest and the highest production were in 2010 and 2012, respectively. Production at Tasik Agung fishing port increase from 2010-2013 and then decrease, while at Karang Anyar and Sarang tend to be increased. However, little fluctuation on production occurs at Bulu.
landing site during 2010-2016. Meanwhile, total pelagic fish production increase from 2010-2013 and then tend to decrease from 2014-2016. This fluctuation of production or yield might influence the stock status in each year [1-5, 7]

Table 2. Production of pelagic fish that landed at four fishing port from 2010-2016.

| Year | Pelagic fish production at each fishing port (ton) |
|------|--------------------------------------------------|
|      | Tasik Agung | Sarang | Karang Anyar | Bulu | Total |
| 2010 | 11,852      | 8,266   | 5,864        | 5,696| 31,678 |
| 2011 | 15,307      | 11,429  | 7,753        | 5,505| 39,994 |
| 2012 | 20,479      | 12,901  | 7,915        | 4,731| 46,026 |
| 2013 | 20,550      | 10,868  | 8,868        | 5,146| 45,433 |
| 2014 | 13,085      | 16,391  | 9,105        | 5,471| 44,052 |
| 2015 | 11,680      | 10,614  | 4,659        | 6,722| 33,675 |
| 2016 | 11,517      | 16,544  | 6,885        | 7,063| 42,009 |
| Total| 104,470     | 87,013  | 51,049       | 40,334|

Source: 1) [18], 2) [19]

3.2. Fishing effort and standardization of fishing gear

The numbers of fishing efforts (trips) using mini purse seine fishing gears at four fishing ports are presented in Table 3. The lowest and the highest number of fishing effort were in Sarang and Bulu, respectively. There was a little variation of the number of fishing effort in Sarang and Tasik Agung during 2010-2016. However, the number of fishing effort in Bulu tends to decrease, while at Karang Anyar tend to increase during 2010-2014 and then decrease. This annual variation in fishing effort will be affected by stock status and economic of fishing [8-9]

Table 3. Number of pelagic fishing efforts with mini purse seine fishing gear at four fishing port in 2010-2016.

| Year | Number of mini purse seine fishing effort at each fishing port (trip) |
|------|--------------------------------------------------|
|      | Tasik Agung | Sarang | Karang Anyar | Bulu |
| 2010 | 3,254        | 1,670   | 11,920       | 36,788|
| 2011 | 5,557        | 2,181   | 11,183       | 29,295|
| 2012 | 4,729        | 1,666   | 12,077       | 20,478|
| 2013 | 4,064        | 1,632   | 13,045       | 18,232|
| 2014 | 3,343        | 2,180   | 15,478       | 18,643|
| 2015 | 2,776        | 1,901   | 9,311        | 13,442|
| 2016 | 3,264        | 3,983   | 9,162        | 19,153|

Source: 1) [18], 2) [19]

Based on the comparison of the catch per-unit of effort (CPUE) from the mini purse seine fishing gear in each fishing port, it is known that the mini purse seine fishing gear in “Sarang fishing port” has the highest productivity, so that it is used as a standard tool in pelagic fishing efforts in the study area. The fishing power index (FPI) value of mini purse seine fishing gear at four fish port is presented in Table 4. The FPI of mini purse seine at Tasik Agung range between 0.52-0.85 and it is higher than FPI of mini purse seine in Karang Anyar and Bulu fishing ports, which were range from 0.08-0.18 and 0.03-0.09, respectively.

The total fishing effort of mini purse seine by various fishing units in four fishing port is the sum of the fishing effort of each standardized fishing gear. Thus, the number of pelagic fishing effort with mini purse seine that has been standardized in four fishing port can be seen in Table 5. The standardized fishing effort in four fishing port tends to increase in the year 2010-2012 or 2010-2013 and then decrease but increase again 2015-2016. Consequently, this pattern followed by the total effort of the standardized mini purse seine. The total effort of standardized mini purse seine in 2016 was
almost 1.6 of the total effort in 2010 and its mean increasing sharply. This sharp increase in effort could have reduced the economic efficiency of pelagic fishing in the study area [10-11].

Table 4. Fishing power index according to mini purse seine at four fishing port in 2010-2016.

| Year | Fishing Power Index (FPI) mini purse seine at each fishing port |
|------|---------------------------------------------------------------|
|      | Tasik Agung\(^1\) | Sarang\(^1\) | Karang Anyar\(^1\) | Bulu\(^1\) |
| 2010 | 0.74              | 1.00        | 0.10               | 0.03        |
| 2011 | 0.53              | 1.00        | 0.13               | 0.04        |
| 2012 | 0.56              | 1.00        | 0.08               | 0.03        |
| 2013 | 0.76              | 1.00        | 0.10               | 0.04        |
| 2014 | 0.52              | 1.00        | 0.08               | 0.04        |
| 2015 | 0.75              | 1.00        | 0.09               | 0.09        |
| 2016 | 0.85              | 1.00        | 0.18               | 0.09        |

Source: \(^1\)[18], \(^2\)[19]

Table 5. Standardized of fishing efforts at other locations based on FPI mini purse seine of Sarang fishing port in 2010-2016.

| Tahun | Standardized of fishing effort (Trip) | Total Effort of Standardized Mini purse seine (Trip) |
|-------|--------------------------------------|-----------------------------------------------------|
|       | Tasik Agung | Sarang | Karang Anyar | Bulu |                       |
| 2010  | 2,394       | 1,670  | 1,185        | 1,151| 6,400                  |
| 2011  | 2,921       | 2,181  | 1,480        | 1,050| 7,632                  |
| 2012  | 2,645       | 1,666  | 1,022        | 611  | 5,944                  |
| 2013  | 3,086       | 1,632  | 1,332        | 773  | 6,822                  |
| 2014  | 1,740       | 2,180  | 1,211        | 728  | 5,859                  |
| 2015  | 2,092       | 1,901  | 834          | 1,204| 6,031                  |
| 2016  | 2,773       | 3,983  | 1,658        | 1,700| 10,114                 |

The relationship between CPUE and the effort to standardize mini purse seine fishing gear in four fishing port during 2010-2016 showed a decreasing trend. This condition can be seen in the equation of “\(y = 10.458 - 0.0006x\)” with a determinant coefficient (\(R^2\)) = 0.5175 (Figure 2). The declining tendency of CPUE toward fishing effort is one indication of overfishing of pelagic fish resources in the study area, especially related to fishing effort [4, 11].

3.3. Estimation of bio-technical parameters

Based on the values of biological and statistical parameters, it can be seen that the best fit estimation model that can be used to describe and predict the condition of pelagic fish resource utilization is an estimation model using the Fox algorithm approach. The results of the analysis obtained bio-technical
parameters as follows: (1) intrinsic growth rate \( r \) of 0.27 tons per year; (2) catchability coefficient \( q \) of 0.000017 tons per trip; and (3) and environmental carrying capacity \( K \) of 622,614.72 tons per year.

3.4. Estimation of sustainable yield and bio-economic optimization

Schaefer’s estimation model approach is used to describe the condition of pelagic fish resource utilization in the study area. The relationship of sustainable yield with the effort (effort) of mini purse seine fishing gear resulted of standardization based on databases at four fishing port is shown in Figure 3, while the optimal values for pelagic fish resource utilization at Maximum Sustainable Yield (MSY) are listed in Table 6. It can be seen that the optimal production at MSY level was 42,553.50 ton. Pelagic fish production in 2012-2014 was higher than MSY level, even though fishing efforts were under MSY level. In 2016, fish production almost equal to the MSY level, but the fishing effort was very high, which is made an increasing fishing cost, and it is more in-efficient. It can be also seen that the actual production has been reached 94.96% of MSY. Although the actual fishing effort reached 85.67% of the effort at MSY level, this pelagic fish utilization was high and 14.96% higher than the precautionary approach. The precautionary production approach based on the agreement of the experts or total allowable catch (TAC) is generally 80% of MSY level.

Table 6. Comparison of Actual and Optimal Utilization of Pelagic Fish Resource Utilization with Schaefer Model.

| Resources Utilization | Actual        | MSY           | Actual to MSY |
|----------------------|---------------|---------------|---------------|
| Biomass \( (x) \) (ton) | -             | 311,307.36    | -             |
| Production \( (h) \) (ton) | 40,409.83     | 42,553.58     | 94.96%        |
| Effort \( (E) \) (trip) | 6,971.81      | 8,137.72      | 85.67%        |

Figure 3. Relationship curve of sustainable production, actual production and efforts to utilize pelagic fish resources.
The bio-economic analysis is carried out to determine the optimum utilization of fisheries resources. Thus, the optimization of pelagic fish resource utilization is analyzed in several management conditions, namely sole owner or maximum economic yield (MEY), maximum sustainable yield (MSY) and open access (OA). The three management conditions are also compared to the actual condition. The result showed that there was a little variation of stock estimated under MEY and MSY, as well as production and effort among actual condition, MEY and MSY (Table 7). Based on the actual conditions, the actual profit or rent was 260,408 million rupiahs per year. This profit is much lower than the 271,468 million rupiahs per year, and it caused by the amount of production and the level of effort have not been optimal. The difference in the amount of profit is due to a decrease in the volume of catch production and a higher level of effort so that the costs to conduct pelagic fishing resources were less efficient. In such above condition shows that there is an indication of economic overfishing (economically overfishing).

| Resource utilization variables | Actual Condition | Management Model |
|-------------------------------|------------------|------------------|
|                               |                  | MEY              |
|                               |                  | MSY              |
| Biomass (x) (ton)             | -                | 356,143.70       |
| Toning                        | 311,307.36       | 89,672.68        |
| Production (h) (ton)          | 40,409.83        | 41,670.87        |
| Toning                        | 42,553.58        | 20,984.45        |
| Effort (E) (trip)             | 6,972            | 6,966            |
| Toning                        | 8,138            | 1,3931           |
| Economic Rent (π) (billion Rupiah) | 260,408      | 271,468          |
| Toning                        | 263,783          | 0                |

Note: MSY = Maximum Sustainable Yield; MEY = Maximum Economic Yield; Open access = without management.

4. Conclusions
The optimal production (h) and profit (π) at Maximum Economic Yield (MEY) were above the average of actual production and profit, while effort in contrary as well as effort in 2016. The status of pelagic fish stock in the area tends to be economic overfishing due to increased effort and less efficient of fishing cost. Reducing fishing effort and increasing fishing cost effectiveness must be considered in fisheries management.

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