Some consequences of unreported fishing on the results of simple fish stock assessment

M F A Sondita*

Fisheries Resources Utilization Department, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University (IPB University), Bogor, Indonesia

*E-mail: mfasondita@ipb.ac.id

Abstract. Unreported fishing received less attention than illegal fishing but the later contributed the problem of data availability. Among various data needed for fish stock assessment, catch and fishing effort are popular for some preliminary analysis to describe annual trends of catch, fishing effort and catch per unit effort. Surplus production models can be used to determine the status of fish stock, maximum sustainable yield (MSY) and optimum annual fishing effort. Fisheries authorities then can determine some management measure promoting sustainability of the fisheries, such as total allowable catch. This study exercised some consequences of unreported fishing effort and catch data on the outputs of the assessment by a simulation with different levels of data using the model. The estimates of both MSY and optimum fishing effort were lower when catch and fishing effort were not fully reported. When the authority should firmly use the best available but limited data, their decision on the maximum annual catch and fishing effort will be more conservative. In contrast, their decision can be risky if over-estimated catch and fishing effort were used. If fishers expected fair levels of catch and fishing effort, the authorities can firmly ask them to provide data completely.

Keywords: assessment, fishing effort, unreported fishing

1. Introduction

Unreported fishing received less attention than illegal fishing but later contributed the problem of data availability (Agniew et al 2009, Doumbouya et al 2017). Unreported fishing will have some implications on incompleteness of published catch and fishing effort data. Incompleteness in data is a common problem among the fisheries globally. Calculation of estimates of missing data from fisheries statistics using reconstruction approach indicated significant portion of unreported catch (Pauly and Zeller 2015, Derrick et al 2017). Among various data needed for fish stock assessment, catch and fishing effort are popular for preliminary analysis to describe annual trends of catch, fishing effort and catch per unit effort or abundance index (Chen et al 2003, IOTC Secretariat 2014, Chang et al 2017). Surplus production model can be used to determine the status of fish stock, maximum sustainable yield or MSY and optimum annual fishing effort or f_MSY (Mace 2001). Fisheries authorities then can determine some management measure promoting sustainability of the fisheries, such as total allowable catch (National Research Council 2000, King 1995). Concern on availability
of good quality data has been increasing with growing awareness and literacy of stakeholders on the importance of effective sustainable fisheries management (e.g. Jacquet et al 2010, Tesfamichael 2014, Apriliani and Nugroho 2016, Stobberup 2012, FAO 2017). Evans (2003) provides nine criteria of good quality data, i.e. transparent, responsive, independent and consensual, integrated, credible and quality controlled, peer reviewed process and peer reviewed results.

Indonesia is one of countries with a strong intention to manage the fisheries resources effectively. The Government of Indonesia has been establishing eleven units of fisheries management area called wilayah pengelolaan perikanan (WPP NRI), under the Regulation of Ministry of Fisheries and Marine Affairs No. 18/PERMEN-KP/2014. Subsequently, a guideline for developing fisheries utilization strategies was published by Government of Indonesia Directorate General Capture Fisheries Regulation (DGCFR) No. 17/PER-DJPT/2017). The guideline provides an outline for establishing some harvest strategies. Here, fisheries management authority should provide estimate of references points for fisheries management, for example an index of fish abundance i.e. catch per unit of effort (CPUE). Since illegal fishing activities characterized the fisheries of Indonesia (Poernomo et al 2011), relevant fisheries data were likely incomplete. Therefore the use of existing fisheries statistics for fish stock assessment may not reflect the actual status of the exploited fish resources. Before going too far, the authorities and stakeholders should be aware of the limitation of the existing data.

This study exercised some consequences of unreported fishing effort and catch data on the outputs of the assessment by a simulation with different levels of data using the model. The results is expected to be a foundation for the fisheries management authorities in Indonesia and other countries where fisheries data are not necessarily complete, especially in determining the status of fish stocks which can be used as a baseline for setting-up reference points of fisheries management (as presented by Helias 2019).

2. Materials and methods

2.1. Materials

This study used a set of data obtained from the Annual Report of National Fishing Port of Palabuhanratu, West Java. The data were monthly fishing trips and production of fishing units locally called jaring rampus which operated bottom gillnets for demersal fish (including shrimps) for a period of 6 years (2010-2015) (table 1). In the first three years (2010-2012) the fishing fleets consisted of boats with outboard engine, inboard motorized fishing boats (i.e. size groups of less than 10 GT and 11-20 GT). Then, the last three years (2013-2015) the fishing fleets included larger fishing boats (i.e. size group of 21-30 GT). The annual reports provide data of monthly fishing trips for each size group of fishing boat. The reports, however, provide data of monthly fish production for outboard engine boats, but the monthly fish production for the motorized fishing boats was grouped in one number. This study was not intended to review or criticized the statistics or data collection program carried by the management of Palabuhanratu Fishing Port. This was merely an exercise to identify some consequences of incomplete data due to unreported fishing.

Since each type of fishing units had different features that determined the capture capacity, calculation of total annual fishing effort was started by calculating the mean catch per trip for each type of fishing unit. The averages were then used for estimating relative fishing power for each type of fishing units. The relative fishing powers were established by taking more optimistic catch, i.e. less than the calculated average. Since larger boats were assumed to possess higher fishing power, the fishing power of larger boats should be higher even the mean catch per trip of larger boat was smaller than the mean catch per trip of smaller boat (table 1). The fishing power index (FPI) for outboard engine boat was equal to that of inboard motorized boat of 5-10 GT (i.e. FPI = 1). The FPI for inboard motorized boat of 11-21 GT was 15 and that for boats of 21-30 GT was 20 because the later was significantly
greater than the former (table 2). The estimation of the FPI in this study was carried out with oversimplification.

**Table 1.** Brief description of data used for identifying some consequences of unreported fishing on the results of a simple fish stock assessment.

| Sources of data | Annual Report on Statistics of Capture Fisheries by National Fishing Port of Palabuhanratu (for 2010-2015) |
|-----------------|-----------------------------------------------------------------------------------------------------|
| Details of data | 1) fishing effort (*i.e.*, fishing trips) and catch (*i.e.*, production, kg) data of fishing boats that operate bottom gillnet for demersal fish and shrimps  
2) monthly fishing trips for outboard engine boat and each of three size categories of inboard motorized fishing boats (5-10 GT, 11-20 GT and 21-30 GT)  
3) monthly fish production (kg) for outboard engine boats and combined fish production of the three inboard motorized fishing boats (5-10 GT, 11-20 GT and 21-30 GT) |

**Table 2.** Average catch per trip (kg) and fishing power index for 4 types of fishing boat operated bottom gillnet for demersal fish and shrimps.

| Types of fishing boat | Outboard engine boat | Inboard motorized of 5-10 GT | Inboard motorized of 11-20 GT | Inboard motorized of 21-30 GT |
|----------------------|----------------------|------------------------------|------------------------------|------------------------------|
| n                    | 8                    | 5                            | 14                           | 2                            |
| Mean (kg/trip)       | 38.8                 | 27.0                         | 561.1                        | 239.3                        |
| SD (kg)              | 33.8                 | 10.6                         | 257.7                        | 151.0                        |
| Mean - 0.25 SD (kg/trip) | 30.3              | 24.3                         | 496.7                        | 201.5                        |
| Fishing power index (FPI) | 1                  | 1                            | 15                           | 20                           |

Annual fishing effort made by all fishing fleets was calculated with the following formula:

\[
F = \sum_{i=1}^{4} [f_i \times FPI_i] 
\]  

(1)

where *F*: total annual fishing effort, *f*: fishing effort recorded in fisheries statistics, *i*: type of fishing unit or boat, *FPI*: fishing power index (table 2). The results of data processing are presented in table 3.

**Table 3.** Results of data processing for the simulation of the effect of unreported fishing on the output of stock assessment.

| Year | Production (kg) | Fishing effort (standardized trip) | Catch per unit effort (kg/trip) |
|------|-----------------|------------------------------------|--------------------------------|
| 2010 | 84907           | 1465                               | 58.0                           |
| 2011 | 76833           | 1198                               | 64.1                           |
| 2012 | 97627           | 1348                               | 72.4                           |
| 2013 | 37524           | 2290                               | 16.4                           |
| 2014 | 21771           | 2290                               | 9.5                            |
| 2015 | 37301           | 3149                               | 11.8                           |

This set of data was then used to calculate the annual fishing effort and yields for a situation when
fishing trips were not completely reported or catches were not recorded or reported. In this study, it was arbitrarily assumed 5% of either catch and fishing effort were not reported. This may had happened when some fish were not landed in the for sale at the port but directly transferred to their warehouse. Some fish may not be reported because some fish is distributed among the crews for their meal on board or take-away for their family or perhaps sold without record. The calculation for each situation (either under reported or over reported) a uniform coefficient was applied for each annual data, i.e. the annual catch or effort were deducted 5%. For example, for situation when fishing effort (or catch) was 5% less reported then the annual fishing efforts (or annual catch) in year 1 to year 6 became 95%. A worse situation was also exercised by applying 10% deduction of annual catch and fishing effort.

2.2. Methods
This study applied two surplus production models, i.e. Schaefer (1954) and Fox (1970) models. The main difference between the models is the relationships between the catch per unit effort (CPUE, C/f) and fishing effort (f) (table 4). The calculation for the maximum sustainable yield (MSY) and level of fishing effort to reach the MSY (F_MSY) for each model is presented in table 3. Calculation of model parameters, such as a and b, were carried out using linear regression analysis with the help of R program.

| Table 4. Parameters for two surplus production models and calculations or estimating the maximum sustainable yield (MSY) and optimum fishing effort to produce the MSY (f_MSY). |
|-----------------|-----------------|-----------------|-----------------|
| Model           | CPUE and f relationships | MSY             | f_MSY           |
| Schaefer (1954) | C/f = a + bf     | b               | b^2             |
| Fox (1970)      | \ln (C/f) = a + bf | \frac{-1}{b}e^{(a-1)} | \frac{-1}{b}  |

3. Results and discussion

The simulation using each surplus production models for 2 fishing situation with different status of data of catch (C_095% - C_099%) and fishing effort (F_095% - F_099%) resulted 5 sets of values of model parameters, i.e. coefficients a and b. For both Schaefer and Fox models, the coefficient was higher for reported lower fishing effort. For both models, the coefficient b was lower for reported lower fishing effort but higher for reported reported lower catch. The main difference in coefficient b between the models was noticeable. The coefficient b was lower for lower fishing effort but the value was similar among different levels of catch.

These coefficients determined the values of MSY and f_MSY. For Schaefer's model, when data of lower fishing effort were used, the fishing effort to achieve the MSY (or f_MSY) was also lower but not much different for different levels of reported catch. Similar pattern, i.e. lower b for lower fishing effort, was also identified for the f_MSY calculated from Fox's model. For both models, the MSY was not different among different level of fishing effort data but higher MSY was resulted from higher catch data.

Different levels of input to the surplus production models indicate a pattern of responses, i.e. outputs of the MSY, f_MSY and fishing productivity when MSY was reached with f_MSY. In general, lower inputs, either lower annual catches or annual fishing effort, will produce lower MSY and lower f_MSY (table 5, figure 1). In the simulation of Schaefer model for fishers or fishing companies with their catch 10% lower than the actual catch (or F_099%) but their fishing effort was correct (or C_100%), the MSY was 10% lower than the MSY calculated from correct figures of fishing effort and catch (i.e. F_100% and C_100%). Similarly, if they reported annual fishing trips 5% less than the actual efforts (or F_095%) but they reported their catch correctly (or C_100%), the f_MSY was also lower than F_MS from a calculation with
correct figures (i.e. $F_{100\%}$ and $C_{100\%}$). Similar consequences were also found in the simulation of Fox model for incomplete reporting of fishing effort ($F_{90\%}$) and catch ($C_{90\%}$). Therefore, it is clear that lower values of annual catch and fishing effort due to incomplete recording or reporting will produce lower estimates of MSY and $f_{MSY}$.

Table 5. MSY, $f_{MSY}$ and maximum fishing productivity for 6 situations of unreported fishing based on Schaefer and Fox surplus production models.

| Reported Catch (%) | Reported Fishing Effort (%) | Schaefer’s model | Fox’s model |
|--------------------|------------------------------|------------------|-------------|
|                    |                              | MSY (kg/year)    | $f_{MSY}$ (trips/year) | Maximum Productivity (kg/trip) | MSY (kg/year) | $f_{MSY}$ (trips/year) | Maximum Productivity (kg/trip) |
| 100%               | 90%                          | 81,920           | 1,381       | 59.3                               | 81,414       | 814                   | 99.98                        |
| 100%               | 95%                          | 81,918           | 1,458       | 56.2                               | 81,440       | 860                   | 94.71                        |
| 100%               | 100%                         | 81,921           | 1,535       | 53.4                               | 81,471       | 903                   | 90.19                        |
| 95%                | 100%                         | 77,830           | 1,535       | 50.7                               | 77,357       | 905                   | 85.48                        |
| 90%                | 100%                         | 73,736           | 1,535       | 48.0                               | 73,286       | 905                   | 80.98                        |

Figure 1. Comparison in the effects of unreported fishing effort while the catch was correctly reported (above: A.1 and A.2) and the effects of unreported catch while the fishing effort was correctly reported (below: B1 and B2) on the maximum sustainable yields (MSY) and fishing effort for the MSY based on Schaefer’s model (1954) (left) and Fox’s model (1970) (right).

If the outputs of the models are used by fisheries management authorities as one of the bases in governing the fisheries, lower quota of annual catch and effort may be applied. To them, this decision is more conservative because the risk of overfishing becomes lower. To fishers, however, such lower quotas means their business was being restricted to a condition of low opportunity to make income. If
law enforcement is weak, however, some fishers may have an intention to catch more fish while ignoring the quota regulation. The situation stimulated by limited communication, *i.e.* incomplete reporting and trust, will then encourage them to commit illegal fishing.

On the other hand, if the authorities used excessive data submitted by the fishers, *e.g.* data with extra catch and/or fishing effort, the recommended annual catch and fishing effort will have a higher risk of overfishing. The simulations of both models showed either extra fishing effort or annual catch will produce higher MSY and higher $f_{MSY}$. Such decision means that the authority allow the fishers to catch fish more than the actual MSY and volume of fishing effort exceeds the actual $f_{MSY}$. Fishers may be happy with such higher quota and will not feel guilty as long as they comply with the quota regulation. However, the authority still needs to be conservative because of the uncertainty of data, unknown dynamics of the fish stock *etc.* (Hilborn and Walters 1992, Ulltang 2003).

Fishing efforts is not only determined by number of fishing trips made by the fishers, but also specification of fishing gear and mode of fishing operation. It means record of fishing trips may not be sufficient to correctly determine the MSY and $f_{MSY}$, for a fisheries involving various types of fishing units that operate different types of fishing gear and/or different specification. More effective fishing gear should have higher fishing effort than the less effective fishing gear. Since a longer gillnet is most likely more effective in catching fish than the shorter one, ten fishing trips of boats which operated longer gillnet may be equal to more than ten fishing trips of similar boats operate shorter gillnet. Therefore, fisheries statistics should be provided sufficient details for the authorities to determine technical variability among the fishing fleets that reflects variability in factors determining fishing effort. In developing countries, such as Indonesia, this kind of information should have been available in the low level management of fisheries association.

The simulation clearly describes the importance of openness of the fishers or fishing companies in sharing their catch data and fishing efforts. Any existing fisheries monitoring system should convince the fishers or fishing companies that their reports will be considered with respect by the authorities and some types of information are confidential. The issue of confidentiality is less for fisheries that involved large numbers of fishing boats, fishers or business units than small number of participants (National Research Council 2000). Some fishers may want to keep locations of productive fishing spots secretly (FAO 1998) but information on spatial distribution of fishing effort is also important to fisheries management authority. As reported by Leroy *et al.* (2016), less effective fishing fleets that belong to coastal communities were mostly concentrated in their coastal waters (*i.e.* within 12 nm from the shore) while large purse seiners were allocated fishing areas offshore (*i.e.* outside 12 nm from the coastline).

Reduction of fishing effort or annual catch are usually advised if the latest fishing effort or catch exceeded the estimate of $f_{MSY}$ or MSY. If the incoming fishing effort should be less than the $f_{MSY}$ then the advised fishing effort may be still higher than the actual $f_{MSY}$ when the assessment was made on the bases of excessive fishing effort. In contrast, when the assessment was made on the bases of under reported fishing effort, the advised fishing effort may be still lower than the actual $f_{MSY}$. Similar results were also found for assessment that used under-reported and over-reported catch. This means outputs of the assessment using data from unreported fishing may be more conservative than the assessment using complete data of fishing.

Once fishers participated in catch monitoring, *e.g.* sharing data, they should be informed how the data are used, processed, analyzed and return the results to them. To encourage fishers or fishing companies submitting actual data, fisheries management authorities should provide a system that accommodate confidentiality of information submitted by the fishers or fishing companies. At the same time, results of data processing and analysis should also be distributed to the fishers or fishing
companies to access the results fairly. However, above all, awareness on the importance of having good quality data should be built among them. This concept will promote participation of the resource users in reporting the information of their fishing activities, especially when fishers or fishing companies given a proper incentives promoting fisheries sustainability, *i.e.* rights to control their activities and responsibility (Grafton *et al* 2006).

When the authority should firmly use the best available but limited data, their decision on the maximum annual catch and fishing effort will be more conservative. In contrast, their decision can be risky if over-estimated catch and fishing effort were used. If fishers expected fair levels of catch and fishing effort, the authorities can firmly ask them to provide data completely. Therefore, a wisdom for such uncertainty should be, as quoted from Jacquet *et al* (2010): "*When it comes to managing fish, as well as compiling fisheries catch data, it is better to be vaguely right than precisely wrong*". This can be one of the principles of precautionary approach.

4. Conclusion

The estimates of both MSY and optimum fishing effort to reach the MSY ($f_{\text{MSY}}$) were lower when catch and fishing effort were not fully reported by fishers or fishing company. On one hand, such estimates can be classified more conservative since it will promote low level of fish resource exploitation. On the other hand, such estimates may reduce the opportunity of fishers or fishing companies to utilize its capital optimally. In contrast, if catch and fishing effort data were reported excessively, the estimates of the MSY and the $f_{\text{MSY}}$ will be higher than they are supposed to be. Such higher figures will jeopardize the fisheries into a risky situation, *i.e.* overfished resources. To address this uncertainty, the fisheries management authorities should take precautionary approach, even the fishers or fishing companies reported their data correctly.

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