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Stock status and supporting species of anchovy fisheries in the northern of East Java, Indonesia

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Abstract. *Wiadnya DGR, Harlyan LI, Rahman MA, Mustikarani SMI, Nadhiroh ENS, Taufani WT. 2023. Stock status and supporting species of anchovy fisheries in the northern of East Java, Indonesia. Biodiversitas 24: 4775-4782.* Anchovy, a commercial fish with high demand in local and international markets, was selected as the Unit of Assessment (UoA) of the Fisheries Improvement Project (FIP) based on the priority fisheries consultation process under the Marine Stewardship Council certification in Indonesia. One of the criteria is the availability of stock status and information about supporting species. This research was conducted from January to May 2022 at Lekok Fishing Port, Pasuruan, and Karangagung Fishing Port, Tuban, using primary data collection methods, including a fishery survey to obtain data species composition data and fishing coordinates. The secondary data were the catch-effort data from 2013 to 2021 collected from both fishing ports. Data analysis was carried out by the surplus production models, Schaefer and Fox model, to determine the total allowable catch (TAC) and the exploitation rates of anchovy fisheries. The participatory mapping method was carried out to obtain data on the distribution of fishing grounds and catch composition. The exploitation rate of anchovy (*Stolephorus commersonnii*) and large anchovy (*Encrasicholina punctifer*) landed in the Lekok fishing port was 76% and 75% (moderate), respectively. In this situation, fishing efforts can still be increased, as TAC value for anchovy fisheries' sustainability. On the other hand, the exploitation rate of anchovy in the northern waters of Tuban is 105% (over-exploited), which is necessary to reduce fishing efforts for its sustainability. The classification of supporting species resulted in 19 identified species in the Lekok fishing port, covering three target species: two endangered threatened and protected (ETP) species, two main primary species, six minor primary species, one major secondary species, and five minor secondary species. While in Karangagung fishing port, eight species were identified, consisting of 1 major primary species, five minor primary species, and two minor secondary species. The supporting species' information is required to complete FIP Anchovy fisheries.

Keywords: Anchovy fisheries, fisheries improvement project, fishery certification, supporting species, surplus production models

INTRODUCTION

Anchovy (*Engraulidae*) is a group of small pelagic fish inhabiting the northern East Java waters. This area is included in the Indonesian Fisheries Management Area (FMA)-712, which covers the Java Sea (Minister of Marine Affairs and Fisheries 2014). Several species of anchovy are distributed in this area, such as Shorthead anchovy (*Encrasicholina heteroloba*), Buccaneer anchovy (*Encrasicholina punctifer*), silver-stripe round herring (*Spratelloides gracilis*), Andhra anchovy (*Stolephorus andhraensis*), Bagan anchovy (*Stolephorus baganensis*), Commerson's anchovy (*Stolephorus commersonnii*), (Indian anchovy) *Stolephorus indicus*, Spined anchovy (*Stolephorus tri*), Baelama anchovy (*Thryssa baelama*), and Dussumier's thryssa (*Thryssa dussumieri*) (Harlyan et al. 2022b; Harlyan et al. 2022c). As a small pelagic fishery in this area, anchovy fishery is assumed to contribute to food security (Sartimbul et al. 2023). Therefore, the Department of Marine and Fisheries, Province of East Java, applies fishery certification for anchovy fisheries to ensure their sustainability.

One of the fishery certifications is the Marine Stewardship Council (MSC), which focuses on assisting the sustainable seafood trade and protecting its supply in the future (Wakamatsu and Wakamatsu 2017; Manach et al. 2020). MSC issues ecolabeling certification based on fisheries standard guidelines and CCRF (Code of Conduct for Responsible Fisheries) from the Food and Agriculture Organization (FAO). The certificate covers three principles to be accomplished: managing stock identification and availability, minimizing fishery impacts on the ecosystems, and providing good governance for fishery sustainability. For each principle, some principal indicators with the following scoring issues need to be passed. The completion of MSC certification for anchovy fishery requires four stages: pre-assessment, generating action plans, action plan implementation, and full assessment (Southall et al. 2016).

The main principle of sustainable stock focuses on the stock status and its assessment. The fish stock must present

its status relative to recruitment impairment; in other words, it must be above the point where recruitment would be impaired. Some fisheries that could not meet the requirements will get a lower MSC point range (Pierucci et al. 2022).

The second principle is minimizing environmental impacts. In this situation, the fishing operations should be managed to maintain the structure, productivity, function, and diversity of the ecosystem on which the fishery depends, including other species and habitats. Some fisheries do not have other species information available in the same area. Therefore, before certification assessment, the fisheries must categorize other species' information and their responses to the main fishery (Pierucci et al. 2022).

Recently, anchovy fishery has received its pre-assessment results for *E. heteroloba* and *Encrasicholina pseudoheteroloba* caught by seine net. One of some critical assessments stated that the fishery needs to have catch data to assess the stock status against the MSC standard (Bio inspecta 2019). Therefore, to accommodate the limitations, the fishery must conduct action plans in the framework of Fishery Improvement Projects (FIPs) that allow the fishery to improve its conditions (Pierucci et al. 2022).

One of the action plans to improve the anchovy seine fishery in the northern of East Java is conducting research on the target stock as the unit of assessment (Yusrizal et al. 2018). However, the lack of research activities in northern Java for anchovy fishery might cause problems with stock sustainability information as the completion of MSC standards. The MSC standards also ensure the certified fishery must be managed to preserve the structure, productivity, and diversity of the ecosystem the fishery inhabits, including other species and environments (Southall et al. 2016). Less information on other species performing as supporting species for anchovy fishery might raise problems in recognizing the anchovy fishery impacts on other fisheries. Therefore, the characterization of other fisheries and species as primary, secondary, and ETP species is prominent as baseline data for assessing the anchovy fishery in northern East Java to those species.

Two fishing ports, Lekok fishing port located in Pasuruan Regency and Bulu fishing ports located in Tuban Regency, are occupied as the most dominant landing sites of anchovy fishery landed in northern East Java. This study was conducted to explore the anchovy fishery in these two ports that represent the northern East Java fishery areas by assessing stock status and characterizing the supporting species of anchovy fishery. If the anchovy fishery is MSC-certified, there will be a guarantee for fishery sustainability and expansion of their market globally.

MATERIALS AND METHODS

Study area

The study was conducted out in northern East Java, two landing sites, Lekok and Bulu fishing ports (Figure 1). The field surveys were carried out to gather daily fishing and landing information from the purse seine boat owners in two landing sites by an enumerator for each landing site from January to May 2022, which was assumed to be the high fishing season. At the time of the survey, all boat owners were selected as respondents. There were 950 respondents comprising 622 owners of seine net boats who landed their anchovy catch in the Karangagung fishing ports and 328 owners of seine net boats of anchovy fishery in the Lekok fishing ports.

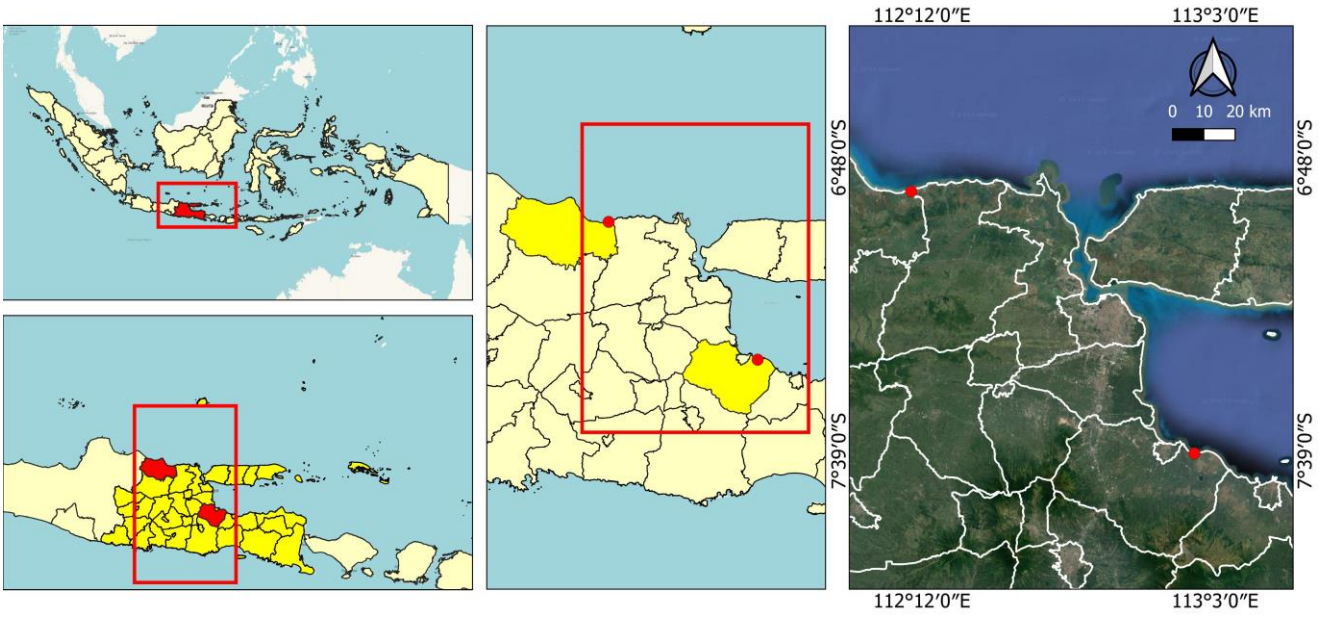

Figure 1. The northern East Java (Indonesia) waters with two fishing ports

The field surveys were performed by using a systematized questionnaire to collect landed species information, such as their fishing grounds, the fishing gear that they are caught from, and their number of landings with boat owners just after they landed their catches. It can be used to gather information about fishery profiles and histories, which might be used to support the stock status estimation. The fishing coordinates were collected from participatory mapping to assist local fishers in identifying their fishing coordinates. The Lekok fishing ports covered catch from northern East Java with coordinates 08º 17' S, 111º 42' E, while the Karangagung fishing port covered catch from coordinates 06º 53' S, 112º 10' E. The species composition of the catch data was grouped from fishing logbooks submitted to the local authorities at Lekok and Karangagung fishing ports.

The historical catch-effort data of anchovy was obtained from fishery data statistics collected from both fishing ports. The catch data are the time-series anchovy catch data caught by the seine fishery, while the effort data are the fishing trip of the seine net involved in the anchovy fishery. The catch-effort data period of anchovy fishery in Lekok fishing port is available from January 2013 - December 2021, while Karangagung fishing port is available from January 2017 - December 2021.

Data analysis

Stock status

To express the stock abundance status, the study applied the Schaefer model (1954) as a surplus production model to determine the maximum sustainable yield (MSY), total allowable catch (TAC) and stock status of anchovy fisheries in Lekok and Karangagung fishing ports. According to Pedersen and Berg (2017) the following formula is applied for calculating MSY:

Schaefer model (1954)

$$Yi = (a \times f) + (b \times f^2) \dots\dots\dots (1)$$

$$F_{MSY} = -\frac{a}{2b} \dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$Y_{MSY} = -\frac{a^2}{4b} \dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

The a and b are intercept and slope, respectively, obtained from the regression results of catch and effort data for anchovy fishery at Lekok fishing port for nine years from 2013-2021 and anchovy fisheries at Karangagung fishing port Tuban for five years from 2017-2021. F_{MSY} is an effort to catch sustainable yield (Y_{MSY}).

According to Ministry of Marine Affairs and Fisheries Decree No. 19 of 2022 in FMA 712 for small pelagic fish species, the precautionary principle determines the TAC. So, the formula for calculating TAC is as follows:

$$TAC = 90\% \times Y_{MSY} \dots\dots\dots\dots\dots (4)$$

The estimation of the exploitation rate is done by calculating the number of catches in a certain year (C_i)with MSY (Sağlam and Sağlam 2013). The equation of the exploitation rate is:

$$Exploitation\ rate = \frac{Ci}{MSY}\ x\ 100\% \dots\dots\dots\dots (5)$$

Species categorization

To categorize species, the decision tree was applied to categorize the species into target and supporting species. The supporting species were separated into primary, secondary, and ETP species. Below is the decision tree that can be applied as a guide on the designated supporting species (Figure 2).

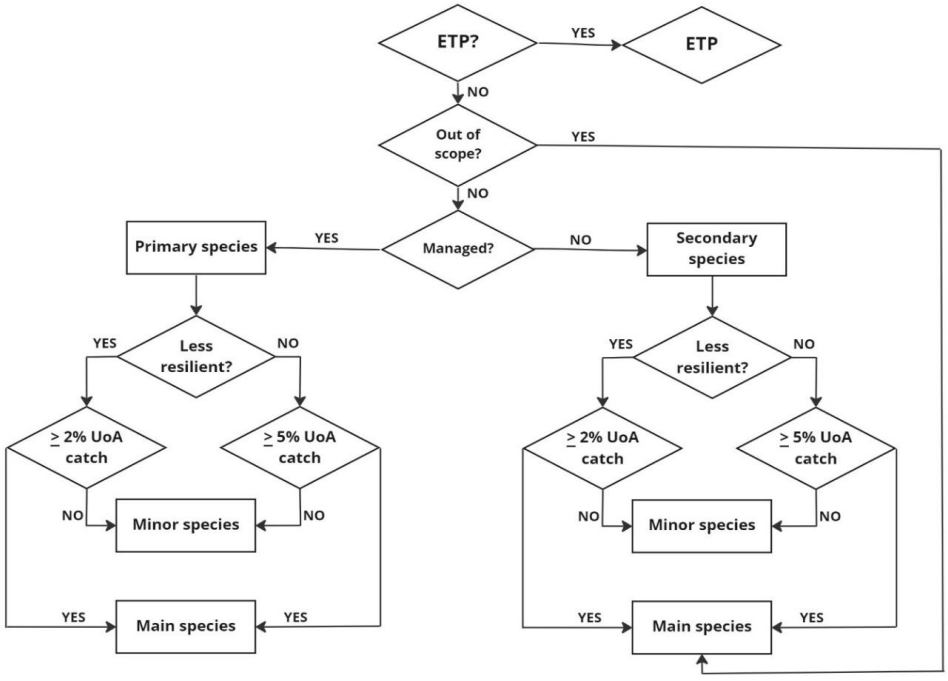

Figure 2. The MSC decision tree (Source: Southall et al. 2016)

In the decision tree, the species are categorized as ETP species if the species in scope that is recognized by national threatened and protected species legislation (Directorate General of Marine Spatial Management 2015) or species listed in binding international agreements such as the Convention on International Trade in Endangered Species (CITES) or any other organizations, if not, they are not treated as "out of scope". Species which is classified as 'out-of scope' (amphibians, reptiles, birds, and mammals) are listed in the IUCN Redlist as vulnerable (VU), endangered (EN), or critically endangered (CE) are recognized as ETP species. Those species that are not specified as out of scope are divided into the managed, which will be treated as primary species, and unmanaged species, which will be treated as secondary species. For either primary or secondary species, they will be categorized into minor species if their total landings are less than 2% of the unit of assessment (UoA) for those are indicated as a less resilient species or less than 5% of UoA for those indicated as a more resilient species. Other than those, they will be categorized as the main species (Southall et al. 2016).

To define spatial distribution of anchovy fishery and its supporting species from two landing sites in the Northern of East Java, each fishing coordinate with their species composition was digitized and distributed into a species distribution map.

RESULTS AND DISCUSSION

Species composition

The anchovy fishery dominates both landing sites (Figure 3). Three species of anchovies landed in the Lekok fishing port. The first is Tropical anchovy (*S. commersonnii*), which has a fusiform body with a reasonably transparent body color. There are silver lines on the sides with fragile lines. Buccaneer anchovy (*E. punctifer*) also had a fusiform body with a reasonably transparent body color. It also has prominent silver lines on the sides of the body. The difference between the Tropical anchovy and the Buccaneer anchovy is that the Buccaneer anchovy has a reddish color on its body, and the shape of its belly is also apparent, white to the anal area. The Indian anchovy (*S. indicus*), at first glance, is similar to the Tropical anchovy and the Buccaneer anchovy but has a slightly flat (depressed) body shape with a cloudy white body color on the belly similar to the Tropical anchovy but on the Indian Anchovy's tail there is a slight yellow color while in there is no found in the Tropical anchovies. The data collection of the Tropical anchovy and the Buccaneer anchovy is available yearly but not for Indian Anchovy due to species misidentification anchovy fisheries as mixed fish and scads. In this situation, the catch data of Indian anchovy fish cannot be calculated because it is assumed to be a part of mixed fish and scads. Species aggregation also occurs in Karangagung fishing port, where all anchovy species are assumed to be species.

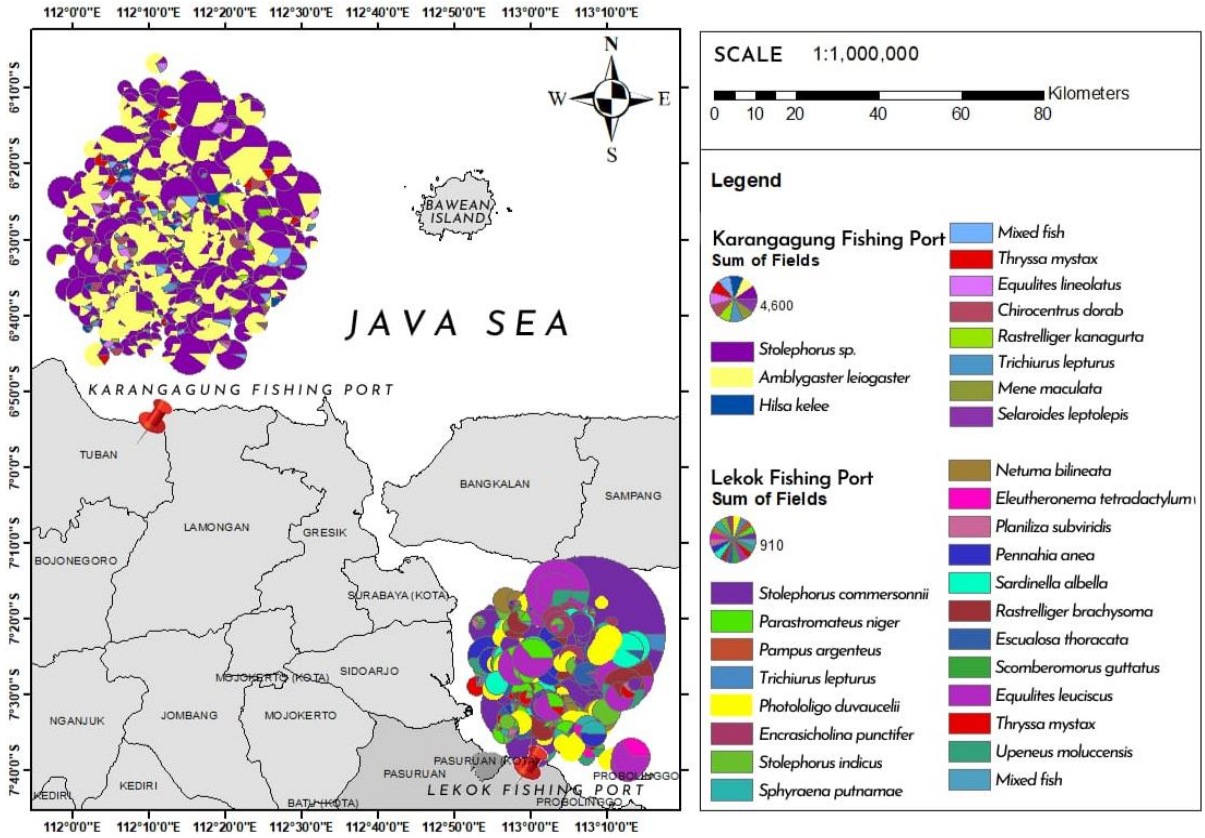

Figure 3. Catch distribution of Lekok and Karangagung fishing ports, East Java, Indonesia

In the study period, February - April 2022, there were 19 groups of species landed in two fishing sites (Figure 3). While in February - April 2020, in the same areas of study, there were only nine species landed, such as *Trichiurus* sp., *Rastrelliger* sp., *Scomberomorus guttatus*, *Eleutheronema tetradactylum*, *Stolephorus* sp., *Sardinella albella*, *Selaroides leptolepsis*, *Parastomateus niger*, and *Photololigo duvaucelii*. Within two years of study, there was a difference in the number of species landed in this area, wherein 2020 has a lower species composition than 2022. There were some species that available in two periods of study, such as *S. leptolepsis*, *S. commersonnii*, *E. punctifer*, *Pampus argenteus*, *Sphyraena putnamae*, *Netuma bilineata*, *Planiliza subviridis*, *Pennahia anea*, *Escualosa thoracata*, *Equulites leuciscus*, *Thryssa mystax*, and *Upeneus moluccensis*. These differences might occur due to differences in fishing seasons and duration of data collection that affect species catchability.

The distribution of fishing locations of the two landing sites is patterned, and no overlapping was found. The fishing location of the catch landed in Karangagung fishing port is in the Java Sea, which is close to the landing site. Similarly, the fishing location of the catch landed in Lekok fishing port is in Madura Strait, which is close to the landing site. This study is critically important to determine spatial management strategies for those fisheries, especially for highly migratory species (Calich et al. 2018).

Species categorization

Based on the results of the study, it was found that the species caught as supporting species of anchovy fishery were as follows (Table 2) (Table 3):

Like other tropical fisheries, the Indonesian fishery is assumed to be a multi-gear and multispecies fishery (Harlyan et al. 2021; Harlyan et al. 2022a; Harlyan et al. 2022b; Harlyan et al. 2022c) where fishing gears could not only catch main target species. The seine net does not only catch anchovies, and anchovies are not only caught using seine net, so it is necessary to analyze further what species are caught in fishing gear. In this study, the seine net is assumed to catch anchovies. It is necessary to see if the fishing status of anchovy is improved and what happens to other species, supporting species that are included in the ecosystem component of anchovy fisheries. It is necessary to classify the supporting species of anchovy fisheries, as for the classification. Namely, primary status, which is divided into main primary and minor primary, secondary, which is divided into major secondary and minor secondary, and ETP species (Southall et al. 2016; Bush and Oosterveer 2015). The existence of ETP species might differ since the discarding practices vary intensely across spatial and temporal scales (Gray and Kennelly 2018).

Species categorization was carried out based on the MSC's decision tree to categorize the species landed, which categorized as 19 species identified from the Lekok fishing port (Table 1), obtained three target species, namely *S. commersonnii* (31%), *E. punctifer* (3.5%), *S. indicus* (3.4%). There are two ETP species found, namely *P. argenteus* (0.6%), which is assumed to be a vulnerable species, and *E. tetradactylum* (1.2%), indicated as an endangered species. According to the IUCN Redlist, these two species are overexploited, and the tortoise has decreased in stock by 50-80% in the last five years in the Persian Gulf waters, so the presence of these two fish needs attention.

Table 1. Species categorization in the Lekok fishing port, East Java, Indonesia

Species categorization	Common name	Scientific name	Percentage of landings
			Total catch = 4600 tons
Target	Tropical Anchovy	*Stolephorus commersonnii*	31.0%
	Indian Anchovy	*Stolephorus indicus*	3.4%
	Buccaneer Anchovy	*Encrasicholina punctifer*	3.5%
ETP	Fourfinget Threadfin	*Eleutheronema tetradactylum*	1.2%
	Silver Pomfret	*Pampus argenteus*	0.6%
Main Primary	Squid	*Photololigo duvaucelii*	17.0%
	White Sardinella	*Sardinella albella*	7.3%
Minor Primary	Short Mackerel	*Rastrelliger brachysoma*	4.9%
	Black Pomfret	*Parastromateus niger*	4.8%
	Goldband Goatfish	*Upeneus moluccensis*	4.0%
	Bronze Catfish	*Netuma bilineata*	1.7%
	Largehead Hairtail	*Trichiurus lepturus*	0.9%
	Indo-Pacific Mackerel	*Scomberomorus guttatus*	0.6%
Main Secondary	Whipfin Ponyfish	*Equulites leuciscus*	7.2%
Minor Secondary	Donkey Croaker	*Pennahia anea*	3.9%
	White Sardine	*Escualosa thoracata*	3.4%
	Moustached Thryssa	*Thryssa mystax*	2.2%
	Greenback Mullet	*Planiliza subviridis*	1.1%
	Sawtooth Barracuda	*Sphyraena putnamae*	0.8%
-	Mixed Fish	-	0.4%

Table 2. Species categorization in the Karangagung fishing port, East Java, Indonesia

Species categorization	Common name	Scientific name	Percentage of landings
			Total catch = 960 tons
Target	Anchovy	*Stolephorus sp.*	51.3%
Main Primary	Smoothbelly sardinella	*Amblygaster leiogaster*	34.3%
Minor Primary	Kelee shad	*Hilsa kelee*	2.2%
	Ornate ponyfish	*Equulites lineolatus*	1.4%
	Indian mackerel	*Rastrellinger kanagurta*	0.6%
	Largehead Hairtail	*Trichiurus lepturus*	0.5%
	Moonfish	*Mene maculate*	0.4%
	Yellowstripe scad	*Selaroides leptolepis*	0.2%
Minor Secondary	Moustached Thryssa	*Thryssa mystax*	2.3%
	Dorab wolf-herring	*Chirocentrus dorab*	2.8%
-	Mixed fish	-	3.9%

There are two primary species, *S. albella* (7.3%) and *P. duvaucelii* (1.7%). There were six minor primary species, namely *Rastrelliger brachysoma* (4.9%), *P. niger* (4.8%). *U. moluccensis* (4%), *N. bilineata* (1.7%), *Trichiurus lepturus* (0.9%), and *S. guttatus* (0.6%). It found a major secondary species, namely *E. leuciscus* (7.2%) and finally, there were five minor secondary species, including *P. anea* (3.9%), *E. thoracata* (3.4%), *T. mystax* (2.2%), *P. subviridis* (1.1%), and *S. putnamae* (0.8%).

The target fish contained *Stolephorus* spp., with a unit of assessment (UoA) percentage or a total catch of 51.3% (Table 2). The main primary species was *Amblygaster leiogaster*, with a percentage of 34.3%. There were six minor species caught. namely *Hilsa kelee* (2.2%), *Chirocentrus dorab* (2.8%), *Rastrelliger kanagurta* (0.6%), *T. lepturus* (0.5%), *Mene maculata* (0.4%), and *Selaroides leptolepis* (0.2%). Species that are classified as minor secondary include *T. mystax* at 2.3% and *Equuilites lineolatus* at 1.4%. The catch of 3.9% goes to mixed fish where being caught as by-catch in low quality will be used as animal feed or fish flour.

Estimating stock status of anchovy utilization (*Stolephorus* sp.)

There are different time series of catch-effort data gathered from two fishing ports. The data from Karangagung fishing port ranged from 2017 to 2021, while the data from Lekok fishing port ranged from 2013 to 2021 (Table 3). Those are typical modest fishing ports that struggle to acquire catch-effort data. As a result, those ports were unable to provide earlier data.

Since no molecular and morphometrics study defines whether the anchovies landed in the Karangagung and Lekok fishing ports are the same population unit that must be managed together, the estimation of the stock status of those landings was separately calculated. These might be used to determine how these landings are managed. Therefore, this study is the baseline study to initially support the fishery management of anchovy fishery by applying the conventional surplus production model, Schaefer 1954 and Fox 1970 models.

Based on the Schaefer 1954 and Fox 1970 models' calculation results, it is possible to estimate the exploitation rate of the anchovy stock landed at PPI Karangagung, Tuban Regency, as shown in Table 4.

Table 3. Catch-effort data of Karangagung and Lekok fishing ports, East Java, Indonesia

No	Karangagung fishing port				Lekok fishing port		
	Year	Catch (tons)	Effort (trip)	CpUE (tons/trips)	Catch (tons)	Effort (trip)	CpUE (tons/trip)
1	2013	NA	NA	NA	132842	11129	11.94
2	2014	NA	NA	NA	125832	8154	15.43
3	2015	NA	NA	NA	122327	7891	15.50
4	2016	NA	NA	NA	104442	3545	29.46
5	2017	1708	3487	0.49	118822	4185	28.39
6	2018	1644	4509	0.36	130141	8316	15.65
7	2019	1503	4414	0.34	63282	2678	23.63
8	2020	1233	6220	0.20	42720	1652	25.86
9	2021	1474	7413	0.20	15393	625	24.63

Note: NA: not available

Table 4. The stock assessment of anchovy fishery

Calculated parameters	*Schaefer*			*Fox*		
	Lekok fishing port		Karangagung fishing port	Lekok fishing port		Karangagung fishing port
	Buccaneer anchovy	Commerson's anchovy	Commerson's anchovy	Buccaneer anchovy	Commerson's anchovy	Commerson's anchovy
a	24.21	29.57811	0.6998	3.0776	3.4462	0.05057
b	-0.0028	-0.00157	-0.00007	-0.0003	-0.000082	-0.00024
YMSY (kg/year)	52.609	139.170.95	4.778.34	25.946	140.434	4.143
FMSY (trip/year)	4.346	9.410	1.671.84	3.249	12.164	1.603.04
YJTB (kg/year)	47.347.98	125.253.85	1.504.66	23.350.97	126.390.41	2.079
FJTB (trip/year)	2.972	6.435	3.130	1.977	7.400	1.442.7
R^2	0.38	0.75	0.88	0.84	0.81	0.91
Exploitation rate	37%	76%	97%	75%	75%	105%
Stock Status	Moderate	Moderate	Moderate	Moderate	Moderate	Over exploited

Based on the above production surplus model, the selection of the best analytical model is based on 2 principles. The first principle is based on the R^2 value because the closer the R^2 value is to 1. The more valid the processed data (close to the actual situation), the closer the relationship between catch and fishing effort. The second principle is based on the precautionary principle. This principle is applied by looking at which MSY and TAC values are smaller than the best model (Rankin and Lemos 2015; Liao et al. 2021). Based on the first principle, the best model to analyze the stock status of Buccaneer Anchovy and Commerson's Anchovy from Lekok and Karangagung fishing ports is the Fox model because the R^2 values of the anchovies are at 0.84, 0.81, and 0.91. Based on the second principle, the best model for Commerson's Anchovy from Lekok fishing port is the Schaefer Model because the MSY and TAC values are lower than the Fox method.

In comparison, the best model for Buccaneer Anchovy from Lekok and Karangagung fishing ports is the Fox Model because the MSY and TAC values are lower than the Schaefer Model. The exploitation rate of anchovy landed in the Lekok fishing port is at a moderate level. This means that fishing efforts can be increased while still paying attention to stock status so that the fish stock remains sustainable. The exploitation rate of anchovy landed at Karangagung fishing port is over-exploited. This means it is necessary to reduce fishing efforts so that the fish stock remains sustainable (Harlyan et al. 2022a; 2022b).

Madura Strait waters experienced higher fishing pressure. From 2011-2016, the fishing pressure in the FMA 712 area increased as the number of vessels decreased (Yusrizal et al. 2018). The exploitation rate of anchovies caught in the northern waters of Tuban in 2017-2021, which landed at Karangagung fishing port, decreased occasionally in the last two years. The decrease in the percentage value of the exploitation rate from the waters of the Madura Strait indicates a good thing because anchovy fishery resources are no longer fully exploited. This can be caused by controlling fishing policies that have been going well or are in a declining phase from peak fishing due to depleting stocks (Hilborn et al. 2020). However, more attention is needed if there is an increase in exploitation rate from previous years (Harlyan et al. 2019; 2022b) and if there is an absence of a significant companion of anchovy fishery since the presence of anchovy might also affect the anchovy-dependent predators in the ecosystem (MacCall et al. 2016).

As the baseline study, the estimation results derived from the Schaefer model might lead to more advanced estimations to compare the fitness of several models simultaneously to conduct stock assessment. To cover uncertainty, a suite of extensions to deal with non-equilibrium conditions might be needed (Prager 1994; 2016). As an alternative, the combination of the production model and stock-recruitment model would be the best to deal with severely depleted stock sizes (Froese et al. 2017; 2021).

This study suggested that in terms of sustainability, the fishing effort of anchovy fisheries in the Karangagung fishing port should be lowered more compared to that in the Karangagung fishing port. Related to the supporting species, the fisheries in two landing sites have an impact on other species due to the overlapping species' habitats. Therefore, it is necessary to consider the status stock of supporting species while conducting anchovy fisheries in northern Java.

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