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Research Article

A Multi-Criteria Approach and Sustainability Index as a Consideration on Torpedo scad Fisheries Management in Sunda Strait

Yonvitner[1], Mennofatria Boer[2], Vera Ardelia[3]

[1]Fisheries Management Division, Aquatic Resources Management, Faculty of Fisheries, and Marine Science. And Centre for Disaster Studies (CERDAS) IPB University. Indonesia

[2]Fisheries Management Division, Aquatic Resources Management, Faculty of Fisheries, and Marine Science Indonesia

[3]Islamic University Ogan Kemiring Ulu District, South Sumatera. Indonesia

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*) Corresponding author:
E-mail:

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Abstract

Torpedo scad species known are both economic and ecologic important pelagic fish that fishing catch tends to increase last a few decades. For sustainability, in the long term, needed a management strategy that complies with measurable fish population indicators. This effort is a part of the precautionary approach in fiseries management in related exploitation. This research was conducted in Labuan fishing port performed for more than 8 months and then analyzed with population parameters. Composite analysis by multi-criteria approaches found that the average score of Torpedo scad is 1.48 and then grouped as moderate sustainability. Schooling fish, including torpedo scad has been moderate until high sustainability levels. Overall population status in this area refer to moderate potential risk and needs a precautionary approach on management.

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1. Introduction

Torpedo scad species is a carnivorous pelagic fishthat affects the balance of aquatic ecosystems (Johnson and Tamatamah, 2013). Small fish tend to school together (Brehmer *et al*., 2007) among small yellowfin tuna species (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), Mackarel thunuss (*Auxis thazard*) and Thunuss (*Euthynuss* sp). According to Ahmed *et al*. (2014), Torpedo scad (*Megalaspis cordylla*) is part of a multispecies school consisting of 100 to more than 5000 individuals.

One of the biggest problems in the world of fisheries is the global fisheries crisis, which began in the early 1990s. When the global demand for fish increased to 90,9 million metric ton 2018 from 79,2 million metric ton (FAO, 2018) with the growth of the world's population 1,05% per year (World Bank, 2018), the intensity of global fishing also increases significantly (Adrianto, 2005). The impact is that fishers tend to exploit fish in quite large numbers, including fish with productivity of 11.24 tons per year in 2016 (KKP, 2018). Catching without reason and evidence of the sustainability of fish stocks in the sea can affect the growth of fish populations.

Kusumawardani (2014) analyzed the production of Torpedo scad fish, and the standardized fishing effort in the waters of the Sunda Strait in 2011-2014 experienced fluctuations every year from 566, 524, 444, and 623 ton per year. The highest production of Torpedo scad fish that occurred in 2014 amount to 623 tons with the highest effort to catch Torpedo scad fish occurred in 2014 amount to 1.096 trips. Therefore, it is necessary to manage fisheries resources. According to FAO (2003), the fisheries resource management approach uses two main concepts, namely, ecosystem-based management (*ecosystem-based management*) and the precautionary approach (*the precautionary approach*).

The precautionary approach needs to be done in the context of sustainable development in the field of fisheries to ensure that future exploitation where fisheries will still benefit future generations (Martosubroto, 2010). Indicators of caution include natural history and population dynamics. This approach was dominantly used in global management as the data for fisheries management is limited (Khatami *et al*., 2019). The availability of stocks is largely determined by biological indicators, population dynamics, and environmental indicators. Studies on biological indicators and population dynamics are needed to regulate population utilization of these resources. The purpose of this research is to analyze the status of Torpedo scad fish resources and their potential for sustainability in Sunda Strait waters. This result is expected to be useful in the context of the management of the fisheries sector in the Sunda strait.

2. Material and Method

2.1 Location and time

This research was conducted at the coastal fishing port (PPP) Labuan, Banten, and Bogor Agricultural University 2015. The data collect is production, effort, and other biology data that for five months, from April to August 2015. The fish sample obtained was analyzed at the Fisheries Biology Laboratory, Department of Aquatic Resources Management. Figure 1 shows the location of the research and fish landing port at PPP Labuan, Banten.

2.2 Data Collection

This study used a field survey method to get a picture that can represent the biological conditions and stock of torpedo scad fish in the Sunda Strait waters. Data collected include small, medium, and large fish. Fish samples taken each month are around 200 fish, with a total number of samples during the observation of 1,596 fish. Secondary data were obtained from the annual report from PPP Labuan from 2008 to 2014 and fisherman interviews. The biology data that was collected, such as total length using a ruler with the smallest unit value of 1 mm (accuracy of 0.5 mm). Weighting the fish is carried out using a scale with the smallest unit value of 1 gram with an accuracy of 0.5 mm.

2.3 Data Analysis

TKG (Gonad Maturity Stage) determination is done in the field or a laboratory-based on morphological observations and gonad size. TKG is determined morphologically using a modified method from Cassie in Effendie and Sjafei (1976) based on the shape, color, size, and weight of the gonad. Fecundity is the number of eggs produced just before spawning using a combined analysis method with the following equation (Effendie, 2002). Egg diameter is calculated to determine the fish spawning patterns by converting micron units to millimeters and looking at the distribution pattern of egg diameter distribution.

An analysis of the relationship of the length of the weight is carried out to determine the pattern of fish growth according to the exponential equation. According to Effendie (1997), the formula for determining the relation between weight and length is where W is the weight of the fish (grams), L is the length of the fish (cm), the value of α and β is the weight growth coefficient. The β value is used to estimate the growth pattern obtained from the calculation of length and weight, whether it has an isometric or allometric pattern.

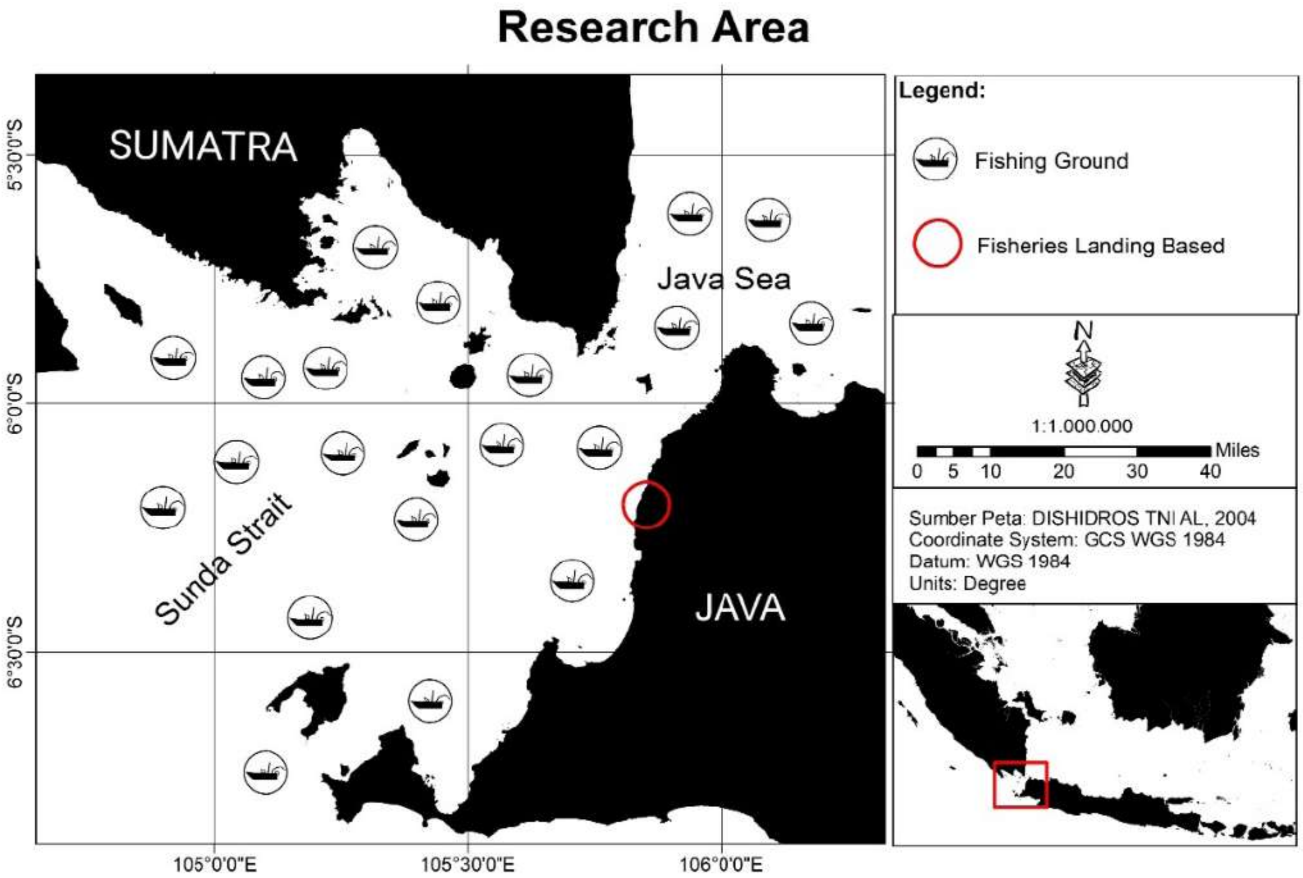

Figure 1. Research area and fishing ground in Sunda Strait

Furthermore, the condition factor was calculated using a metric system based on the length relationship of the sample fish weight. The sex ratio is analyzed to determine the comparison between the sexes of fish as a consideration in reproduction, rejuvenation, and conservation. Then the gonad maturity index (IKG) is needed to determine the ratio of gonad development in the body of fish species. The relation of length-weight and gonad maturity needs to estimate the first time the gonads mature is done using the Spearman-Karber method (Udupa, 1986).

M is the log of length of the fish at the first gonad maturity. Symbol xk is the log of the middle class of the last length of the fish that has gonad matured. And then symbol x is the log of the length increase in the middle value. Symbol pi is the proportion of the mature gonad fish in the i-th class with the number of fish in the interval the length of the i-th, ni is the number of fish in the i-th class, qi is 1 - pi, Lm is the length of the fish when the gonad is first mature at the size of antilog m.

The size of the first catch (Lc) was calculated by the covered condensed method. The results of these calculations form a sigmoid shape of the curve. Then the length of frequency distribution was analyzed to determine the age group of fish. Estimation of age groups was analyzed by analysis of fish frequency using the ELEFAN I method in the FISAT II (FAO-ICLARM Stock Assessment Tool) software. Age groups then become the basis for estimating growth according to Von Bertalanffy with the following formula (King, 1995) Lt is the size of the fish at the age of t unit time (mm), K is the maximum length of asymptotic length (mm), K is the growth coefficient (month-1), and t0 is the age of the fish hypothesis at zero-length (month).

The total mortality rate (Z) is the sum of the capture mortality rate (F) and the natural mortality rate (M). The value of the natural mortality rate is related to the value of Von Bertalanffy K growth parameters and infinity length (L∞). The exploitation rate (E) is part of an age group that will be caught as long as the fish is alive.

Besides, the rate of exploitation can also be interpreted as the number of fish caught compared to the total number of fish that die due to all factors, both natural and fishing factors (Pauly, 1984).

The Surplus Production Model analyzes the catch and effort in estimating the potential of the Torpedo scad fish. Schaefer and Fox developed the surplus production model to asses the stock status of the fish population.

Table 1. Variable in multi-criteria approach

No	Variable	Remark
1	Composition	The composition of fish based on the life cycle can be quite adequate if the structure of larvae> pre-adult> adult based on the number.
2	Ratio Sex	The sex ratio for the total population at a good level with proportion is 1:1.
3	Length and Weight	Length and weight relationships are proportional if the b coefficient is (b = 3).
4	Condition Factor	Condition factor relatively high and stable at a value more than 1 (>1)
5	TKG	The proportion of gonad maturity balance among (stage 1, 2, 3 and 4) as below (25:25:25:25).
6	IKG	Gonadal masses which are relatively heavy become high and low allegations of reproduction on the precautionary approach.
7	Fecundity	Fecundity which tends to be lower than average potential fecundity is not sustainable . 0.5- sb < F < 0.5 + sb
8	Eggs Diametre	The smaller the diameter of the egg, the low potential of stock sustainability and then so needes precautionary approach
9	Size Structure	Capture group mode that is bigger than Lm size is classified as good status. If the largest population (mode) is smaller than Lm, then the stock status decreases.
10	Lm dan Lc	Low-risk prudence is Lm <Lc, so there is still a chance to reproduce
11	K	The growth rate is relatively good if the growth coefficient (K) value more than 0.3.
12	MLm Ratio MLc	Ratio of more than 1.
13	Mortality rate	If is F > M, potentially high risk and low sustainability.
14	Ep	If is Ep > 0.5, potentially un-sustain and high risk to stock.
15	Fopt	If is Factual > Foptimum, Needed precautionary action
16	Actual Production MSY/JTB	If actual production is higher than MSY/JTB, stock potentially to sustainable

Note: TKG (Gonad maturity stage), IKG (Gonad index), Lm (Length at first mature), Lc (Length at first catch), K (coefficient growth rate), ML_c (mean of Lc), ML_m (mean of L_m), Ep (Exploitation rate), F_{opt} (Fishing optimum), MSY (Maximum sustainable yield), JTB/TAC (total allowable catch).

Table 2. Flag model by precautionary approach indicator

Score composite	Flag Model	Remark	Criteria
1		Bad	= Low *sustainability*
2		Moderate	= Medium sustainability
3		Good	= High Sustainability

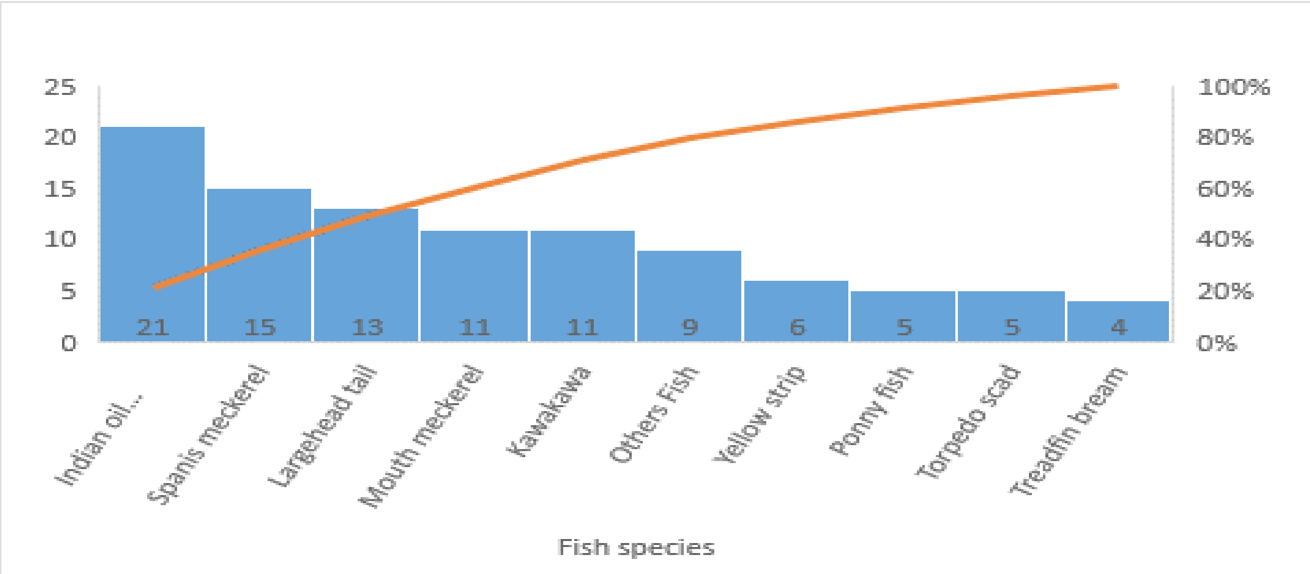

Figure 2. Fish catch composition in Labuan

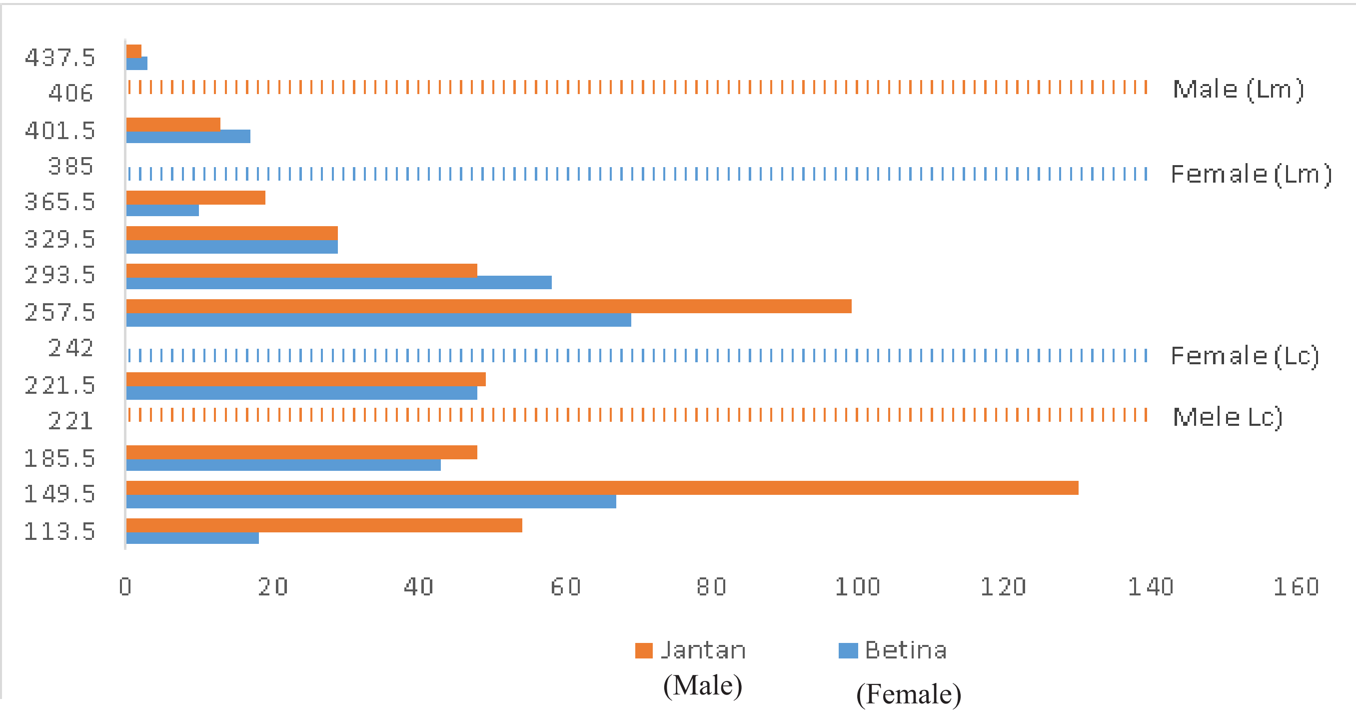

Figure 3. Length distribution frequency of Torpedo scad (*M. cordyla*)

This model can be applied within well-known catch per unit of capture effort (CPUE) or by species and capture effort within several years.

2.4 Precautionary Approach

The precautionary approach or prudential approach in the context of fisheries management applies a broad prudential approach for the management of fisheries resources. A precautionary approach to fisheries management for Torpedo scad fish was described in Table 1. Multi-criteria assessment of each indicator is a composite approach based on arithmetic averages analysis. This result is then known as a sustainability index that formulates as follows (Ardelia, 2016): Where SI is a sustainability index, is the total of indicator value and n is the total parameter assessed. In the explanation of the sustainability index result, we use a flag model from data analysis in each parameter. The display model and formula from the sustainability potential index are then displayed in the form of a flag model with criteria as can be seen in Table 2 below.

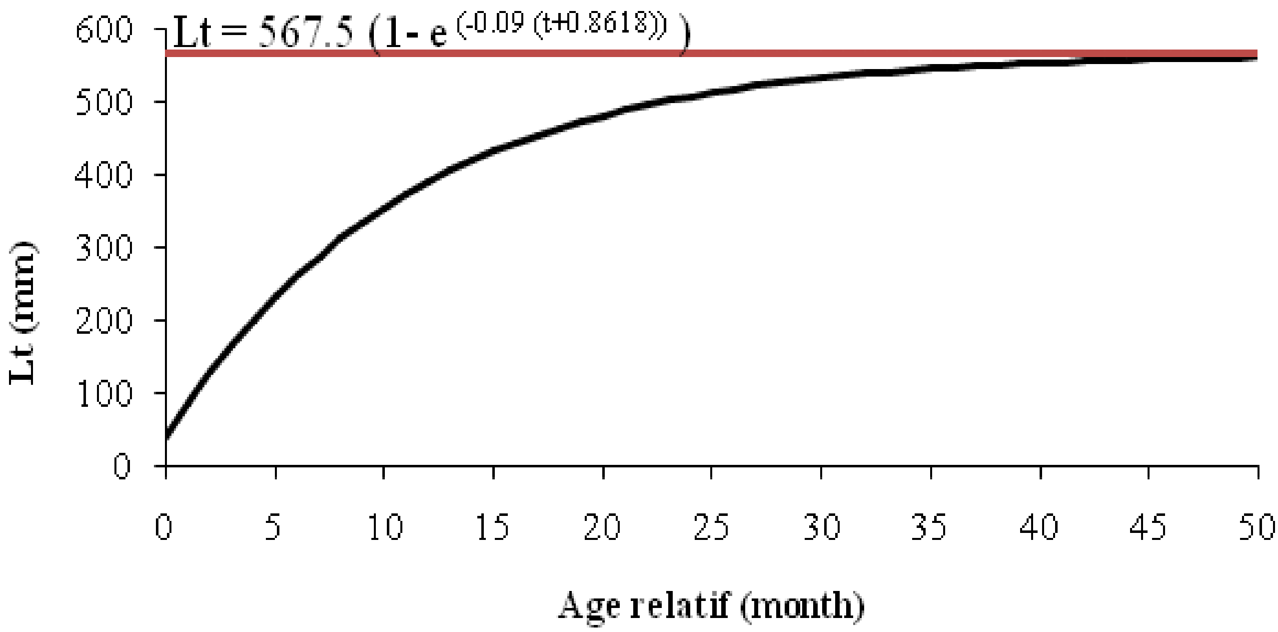

Figure 4. Growth rate of Torpedo scad (*M. cordyla*)

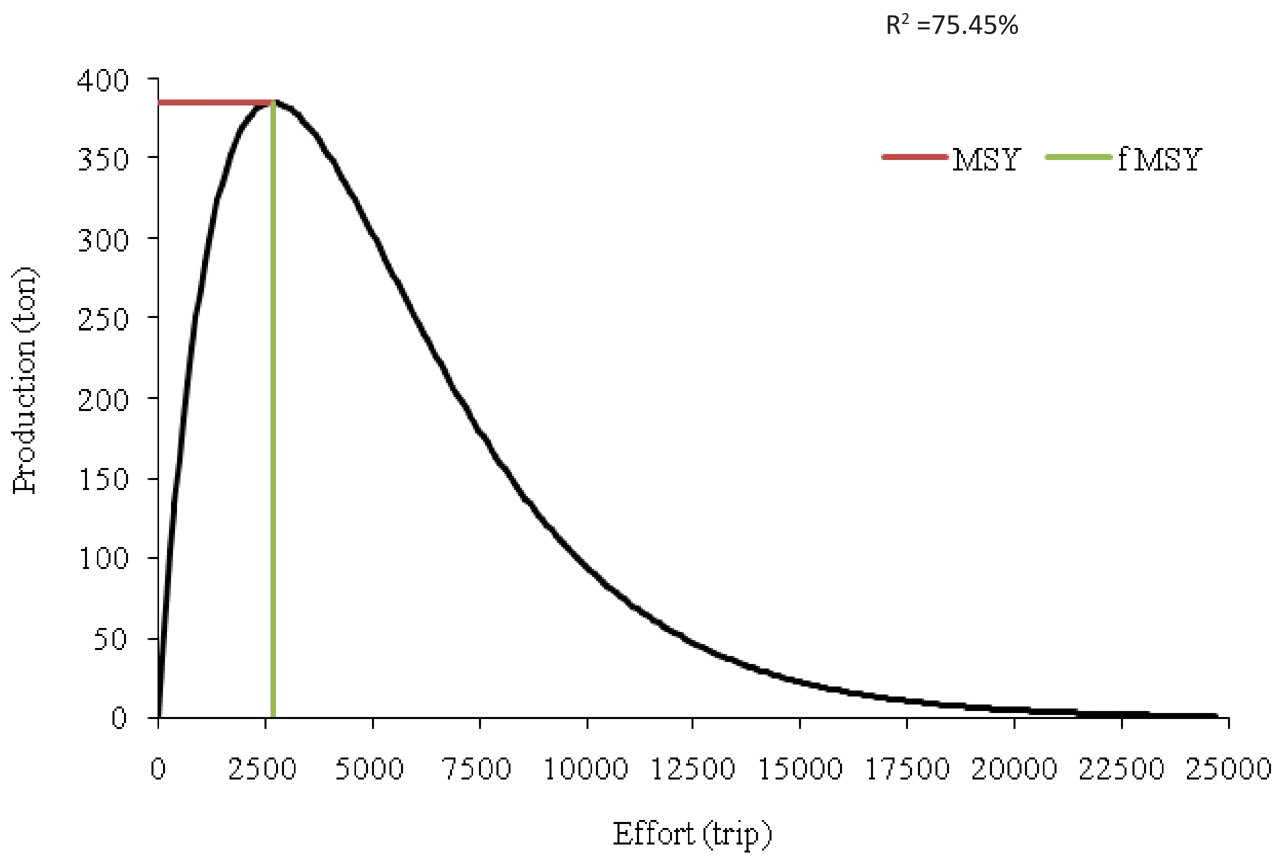

Figure 5. Production surplus model of Torpedo scad by fox model

3. Results and Discussion

3.1 Fish Biology

The composition of fish caught at PPP Labuan Banten various species is Indian oil sardine (21%), Spanish mackerel (15%), large head-tail (13%), mouth mackerel (11%), Kawakawa (11%), other fish (9%), yellowstrip (6%), ponny fih(5%), Torpedo scad (5%), and Treadfin bream (4%). The torpedo scad (*M. cordyla*) is one of the fish caught by fishermen is about 5% of the total catch shown below (Figure 6). The composition of torpedo scad in Sunda Strait higher than Pemalang water (2,2%) that use purse seine gear (Nurdin, 2017) and usually found as part of schooling pelagic fish (Yonvitner *et al*, 2018).

The sex ratio between male and female Torpedo scad fish is 1.35: 1, which shows that the ratio is unbalanced ($t_{hit} > t_{tab} = 7.57 > 3.84$). The long weight relationship model for female fish $W = 2 \times 10^{-5} L^{2.9183}$ with a determination coefficient of 96.56%, and male fish $W = 1 \times 10^{-5} L^{2.9955}$ with a determination coefficient of 97.85%, and the equation model for total fish is $W = 1 \times 10^{-5} L^{2.966}$ with a coefficient of determination of 97.39%. The results of the b value for a long relationship as an indicator of growth patterns of female fish are allometric negative, while male fish are isometric.

The condition factor for male fish is 1.1463; female fish is 1.1860. The highest level of gonad maturity (TKG IV) occurs in May and June, so it can be expected that fish will experience the spawning season in May and June. The IKG value of female fish ranges from 0.8343-2.1444, while the IKG value of male fish ranges between 0.3619-1.7939. The highest IKG values in both female and male fish were found in July.

Fecundity values range from 1,401-103,825 eggs with an average of 14,293 eggs in at length of 195-446 mm. Tengkek fish have a range of diameter eggs that also vary, ranging from 0.0250-1.4250 mm. The egg diameter with the highest frequency is in the class interval from 0.2224-0.3210 mm, while the lowest frequency is in the class interval between 0.2224-0.321 mm. In general, fish are classified as a group of fish with a total spawner pattern where spawning once in a spawning process. The size of the first gonad ripening and first catch ranged between 383-387 mm. The first size of mature male gonad fish lies between 404-407 mm in length, and the total fish has mature gonad size ranging from 369-373 mm in length. The first length caught for female, male, and total fish were 241.62 mm, 221.31 mm, and 231.31 mm respectively.

3.2 Lenght-Frequency Distribution and Cohort

The highest frequency of female fish is in the long class interval of 206-210 and 141-145 mm. The highest frequency of male fish and total fish is relatively the same, namely in the class interval of 146-150 mm. Das *et al* (2014) record in Paninsula coast, torpedo scad length ranging from 173-375 mm, smaller than Sunda strait record. The Length distribution of the Torpedo scad is present in the following figure 3.

Growth of Torpedo scad fish occurs three times a year, which is from April to June each year. The growth rate of female is $Lt = 465.15\ (1- e^{(-0.12\ (t+0.6753))})$, male is $Lt = 598.4\ (1- e^{(-0.08\ (t+0.9597))})$, and for the total is $Lt = 567.5\ (1- e^{(-0.09\ (t+0.8618))})$. Growth models, according to the total fish logistic curve, is shown in the following figure 4.

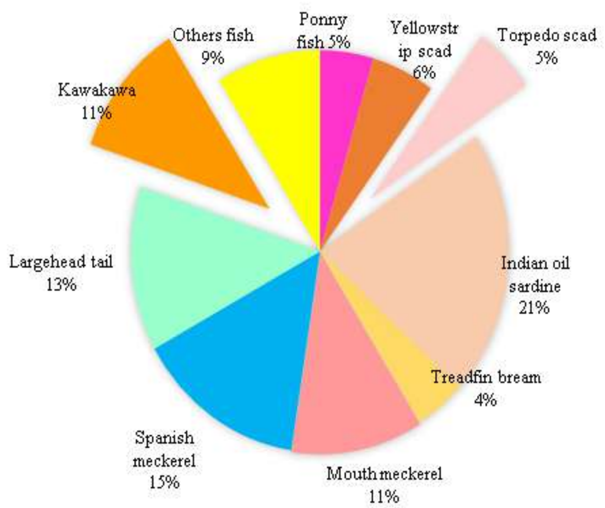

Figure 6. Fish catch composition in Labuan

The exploitation of torpedo scad in western Indian Ocean relatively high than other area, because also as consumption by community (Kempter *et al*, 2017). The rate of male exploitation is higher than the rate of female fish exploitation (E_{Male} 0.9560> E_{female} 0.9238). and $E_{total} = 0.9872$. That means that fishing activities caused 92.38% of female deaths of total mortality. The results of the analysis of the production surplus model from the highest yield and capture effort data in 2014 amounted to 623 tons with an effort of 1,096 trips. The potential value of fish resources using the Fox model, optimum effort value (fMSY), and Maximum Sustainable Yield (MSY) was obtained (2,693 trips and 385.50 tons). The curve model of the surplus production of Torpedo scad fish is as follows.

3.3 Multi Criteria

Multi-criteria analysis is an attempt to integrate several variables as a precautionary consideration. The value of each parameter was classified according to the level of value limitation which is characterized by the color of the flag and was given a score value. The results of determining the multi-criteria value are as follows:

Table 3. Multi-criteria approach, flag, and the score of data of each variable

No	Indicator	Value and Score		
		Value	Flag	Score
1	Fish Composition	Age structure complete (larva, pre-adult, adult stage)		3
2	Sex Ratio	1.35 : 1		2
3	Length and Weight	Isometric		3
4	Condition Factor	Female : 0.5717 - 2.7556 Male : 0.2500 – 2.4811		3
5	TKG	TKG IV May : 15.79%, June 5.54%		2
6	IKG	Female : 0.8343 – 2.1444, Male : 0.3619 – 1.7939		2
7	Fecundity	1 401 -103 825		3
8	Eggs Diameter	0.0250-1.4250		3
9	Size Structure	Modus Less than > Lm		1
10	Lm and Lc	Lm > Lc		1
11	Growth rate	0.09		1
12	Mortality rate	M<F		1
13	M ratio ML_c	$\frac{ML_m}{ML_c} > 1$		2
14	Ep	Ep >0.5		3
15	F_{opt}	F_{akcual}<Fopt		3
16	Actual production = MSY/JTB	Prod.$_{Aktual}$ > MSY/JTB		3

Note : : Good (score 3) : Medium (score 2) : Bad (score 1)

The results of the composite analysis of all variables are techniques for determining the potential for stock sustainability. The analysis results obtained, the total potential value of the sustainability of *Torpedo scad* fish is 1.48. These results explain that Torpedo scad fish have a moderate to a high level of sustainability.

Overall, sex ratio is in an unbalanced condition caused by female and male fish not being in the same spawning area so that the chance of being caught differs (Febianto, 2007). Differences in the results of the value of b for the length-weight relationship of the Torpedo scad fish, according to Lawson (2013), can be due to season, habitat, gonad maturity, sex, stomach fullness, and fish health. Meanwhile, the condition of male fish, which tends to be higher than female fish, means that during reproduction, most of the metabolism results in gonad development.

Generally, gonad weight of female fish is 10-25%, and male fish 5-10% of body weight. The higher the condition factor value indicates suitability between the fish and its environment. Gonad maturity stage (TKG) was used to estimate the time of fish spawning. The results of the analysis showed that the breeding season of the Torpedo scad was suspected to occur in May and June.

Furthermore, in July and August, there were no fish with mature gonads, so it is estimated that the fish are facing spawning phase. Jadhav and Mohite (2013) stated that along the coast of Ratnagiri, the maturity of the Torpedo scad fish gonad indicates that the spawning season is in May - January with the peak of spawning during May - October.

Male fish have a lower average of gonad maturity index (IKG). The highest IKG values in both female and male Torpedo scad were found in July. The main factors affecting the gonad maturity index of a fish are temperature and food. In general, the gonad maturity index varies greatly according to body length and gonad maturity level, but there is a tendency for a positive relationship between the gonad maturity index and its maturity level (Sari, 1999).

Torpedo scad fish fecundity is classified as moderate to high, which is thought to be related to adaptation and recruitment strategies. Fish fecundity will change if environmental conditions change. If environmental conditions are unfavorable, generally, females will delay egg removal or release eggs in smaller amounts than usual (Sjafei *et al*., 1993). Tengkek fish fecundity along the Ratnagiri coast is found in the range from 92 268 to 549 900, with an average of 247 671 eggs (Jadhav and Mohite, 2013) and relatively similar to Sunda Strait waters.

First female fish with mature gonads appears at a smaller size compared to male fish. During research, female fish were dominantly found to have matured gonads compared to male fish. The fish size at which gonad matures varies between and within species (Udupa, 1986). Symptoms of decreased Lm are a response to the high intensity of capture. Exploitation will generally catch fish that are larger and older (King, 1995). The average size of the first catch is smaller than the size of fish with first gonad maturity (Lc <Lm).

Furthermore, spawning fish spawning patterns occur throughout the year with a total spawner type, which is thought to occur in May-June to be a separate consideration in management. This means that the fish caught are fish with immature gonads or have not been recruited (new individuals). If this happens continuously, then biologically, the fish stocks in the Sunda Strait waters will not be sustainable.

The results of the analysis of the size groups showed that the fish tended to shift in a rightward curve from May to August. The existence of an age group on the left side in August indicates the recruitment process. Recruitment is an event where new individuals enter an environment (Sparre and Venema, 1999). The catch mortality rate (F) is higher than the natural mortality rate (M), which indicates that many died due to fishing activities. The rate of exploitation of Torpedo scad fish in this study has exceeded 0.5, so it is suspected that the resources of Torpedo scad fish have experienced overexploitation.

Analysis of the potential of Torpedo scad fish resources using the Fox model obtained optimum effort value (f_{msy}) and Maximum Sustainable Yield (MSY) of 2 693 trips and 385.50 tons. Therefore, it can be suspected that the Torpedo scad in the Sunda Strait Waters has experienced overfishing. The CPUE value of tilapia has fluctuated over the last few years due to a large number of fishing efforts. Recommended management recommendations are optimal fishing effort control and do not exceed f_{msy}. According to Nurhayati (2001), the high and low levels of catches are influenced by the number and efficiency of fishing units, the length of fishing operations, and environmental conditions.

According to FAO (2005), precautionary is the principle of prudence in giving consideration to fisheries management decisions that result from a lack of or limited knowledge. Caution in limiting the size of the catch with a mature proportion of the gonads is not caught so that there can still be space for the fish to reproduce. The age group of fish and Torpedo scad is smaller than Lm, so it can be said that the fish has decreased. Growth coefficient (K) for low-level fish or less than 0.5. Therefore, caution is needed in setting targets for arrest.

Precautionary of the ratio of MLm and MLc values of tilapia is more than 1. This means that natural mortality does not occur simultaneously with the capture process. The mortality rate for catching Torpedo scad fish is greater than the natural mortality rate. The condition of exploitation of Torpedo scad fish has exceeded the value of optimal exploitation, so it needs caution in overfishing that leads to overexploitation; in fact the Torpedo scad fish is still considered quite good.

Using the precautionary approach, the total catch allowed (JTB) is generally 80% of MSY (Barani, 2004 ; Mous *et al*., 2005). Based on this, JTB of Torpedo scad fish amounted to 515 tons per year. The declining CPUE trend is an indication that the level of exploitation of tilapia fish resources is increasing. If left unchecked will lead to a condition called overfishing and even collapse.

The sustainability of the population serves to protect stocks and avoid overfishing with the status of exploitation that most influences (Sibagariang, 2014). According to Badrudin *et al.* (2010), one index of stock abundance and is one indicator for the status of the utilization of fish resources and an indicator of the sustainability of marine fisheries development is CPUE. In addition, in order to maintain the sustainability of fish populations, it is also necessary to have a size regulation that can be caught. For this reason, fish which have a size larger than the size of the first mature gonad are retained, so that fish can spawn at least once in their lives which will prevent stock degradation (Musbir *et al*., 2008). Thus, the size of fish allowed to be caught are fish that are at a size exceeding the size of the first time the fish have matured its gonads that are 369-373 mm. Limitation of the size of fish caught is done as a protection against the reproductive capacity of fish (Holland, 2003). This restriction is intended so that fish can reach the minimum size to reproduce or maintain the sex ratio of fish (Sluka *et al*., 2001).

The precautionary approach with the multi-criteria model obtained an average score of 1.48 for fish with the category of moderate to high sustainability potential. Thus, overall the fish of the Torpedo scad is a group of fish that live in groups that have moderate to high sustainability potential. For this reason, the utilization of Torpedo scad fish can be regulated under current conditions so that it remains sustainable.

4. Conclusion

The biological status of tengkek fish is still in good condition and potentially sustainable. Meanwhile, in population dynamics, status can be seen from changes in the length size of the torpedo scad. The condition of the exploitation of Torpedo scad is high and must be controlled so as not to cause over-exploitation. Biological indicators and status of sustainability index still show a moderate level of sustainability. For this reason, the principle of the precautionary approach (caution) needs to be considered so that fish are not over-fished and over-exploited.

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Author's Contribution

All authors discussed the results and contributed to from the start to the final manuscript; Yon: Prepare a concept note about fish sustainability index and technic analysis, supervise research team, and written report and paper. Profesor Mennofatria Boer has supervised this research, data analysis, and paper writing. Vera: As a research team, conducting data, sample, analysis, and write a report and Gentha as Laboratory assistant for sampling equipment.

Conflict of Interest

The authors declare that have no conflict of interest and all team members agree to publish.

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