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Using Productivity and Susceptibility Analysis to Evaluate of Small Pelagic Fish Vulnerability in Sunda Strait, Indonesia

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Abstract: Small pelagic fish has important economic value that cause vulnerablility to fishing activities. Fishing activity will affect the existence of the fish stocks and catches biomass. The purpose of this study was to assess the level of vulnerability of small pelagic fish resources in the Sunda Strait. The analysis of productivity and susceptibility of the catch will be expected to provide information of the stocks so that these resources can be guaranteed sustainability. PSA assessment results the Indian mackerel (*Rastrelliger kanagurta*), short mackerel (*Rastrelliger branchysoma*), Island mackerel (*Rastrelliger faughni*), Indian Scad (*Decapterus russelli*) and fringscale sardinella (*Sardinella fimbriata*) are included in low categories ($\leq$1.6). The productivity value of the fishes showed different values while for the genus *Rastrelliger* fishes show the same results of susceptibility values. Based on these results, Indian Scad have the highest vulnerability index that is 1.58 while fringescale sardinella has the lowest vulnerability index by 1.37. After all, small pelagic fishes have vulnerability index by 1.28.

INTRODUCTION

Small scale fisheries in Sunda Strait dominantly landed in auction port Labuan that consist of small pelagic fish. Indian mackerel (*Rastrelliger kanagurta*), short mackerel (*R. branchysoma*), island mackerel (*R. faughni*), Indian Scad (*Decapterus russelli*) and fringscale sardinella (*Sardinella fimbriata*) include as small pelagic fishes which have important economic value. This led to the increasing capture of small pelagic fish resources in Sunda Strait. Fishing activities might affect the availability of fish stocks and obtained catches biomass. Small pelagic fish are generally caught with purse seine or purse seine. Research on the composition of purse seine catches ever undertaken by Wijopriono and Genisa. Use and operation of different fishing gear can affect the stability of the fishery resources in nature. Currently, the number of fish caught by various types of fishing gear has decreased. From the number of catches, some types of small pelagic fish not only decrease but also captured in smaller size. Results of research by Siregar showed that Indian mackerel has undergone biological overfishing while firngscale sardinella has experienced growth overfishing. If fishing activities keep going, in a certain point the number of catches tend to be less compared to the increase of fishing effort. The cause of the declining number and size of small pelagic fish caught due to the overfishing on a fish stock. Research by Fragolia (2015) showed that short mackerel and Indian Scad have been overfished.

Fish stocks status based on the parameters of productivity and susceptibility is called vulnerability. Productivity and susceptibility analysis of catches can provide stock information which is most vulnerable to fishing (Triharyuni *et al*., 2013). Results of research by Lestari (2013) regarding the vulnerability of the fish stocks in the Sunda Strait showed Indian mackerel and fringscale sardinella are low vulnerable. Knowledge of the level of vulnerability of small pelagic fish need to be examined in order to evaluate the sustainability of the stock in nature.

Indian mackerel (*Rastrelliger kanagurta*), short mackerel (*R. branchysoma*), island mackerel (*R. faughni*), Indian Scad (*Decapterus russelli*) and fringscale sardinella (*Sardinella fimbriata*) included as fishing target species. The rate of exploitation of small pelagic fish in Sunda Strait is constantly increasing. Fishing gear used are very diverse and not selective thus potentially lead to an increase in uncontrolled fishing effort. If the efforts of small pelagic fishing continues to increase, then the fish biomass is getting low. This will cause the productivity of the natural fish stocks decline due to biological pressure. In such conditions, fish resources can be declared vulnerable.

Vulnerability is a study to evaluate the sustainability of the fish stocks in nature through the parameters of productivity and susceptibility. Productivity is the capacity of fish resources to recover while fish resources susceptibility is a tendency to get caught. Stock fish with high levels of productivity and low susceptibility are stocks that have good survival ability. This study aims to assess the vulnerability level of small pelagic fish resources by looking at the value of productivity and susceptibility of small pelagic fish in the waters of the Sunda Strait.

MATERIALS AND METHODS

The fish sample collect from fishermen that caught in the around Sunda Strait (Fig. 1). These research was conducted from April to August 2015 with a month sampling interval. The analysis of samples carried out in the Laboratory of Fisheries Biology, Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Bogor Agricultural University.

The data collection was obtained from the collection of samples by the method of stratified random sampling and interviews. Collection of fish include fish that are small, medium and large with five times the sampling frequency. Interviews were conducted with fishermen who catch small pelagic fish. Indian mackerel (*Rastrelliger kanagurta*), short mackerel (*R. branchysoma*), island mackerel (*R. faughni*) Indian Scad (*Decapterus russelli*) and fringscale sardinella (*Sardinella fimbriata*) taken from the PPP Labuan brought in a cool box that has been given ice blocks. The number of fish samples taken from >200 individuals. Then the fish is weighed using a digital scale with a precision of 0.5 g and measured the total length using a ruler that has the smallest scale of 1 mm.

Female gonads with level of maturity 4 preserved with formalin for fecundity observation. Each part (anterior, middle and posterior) of gonad taken then

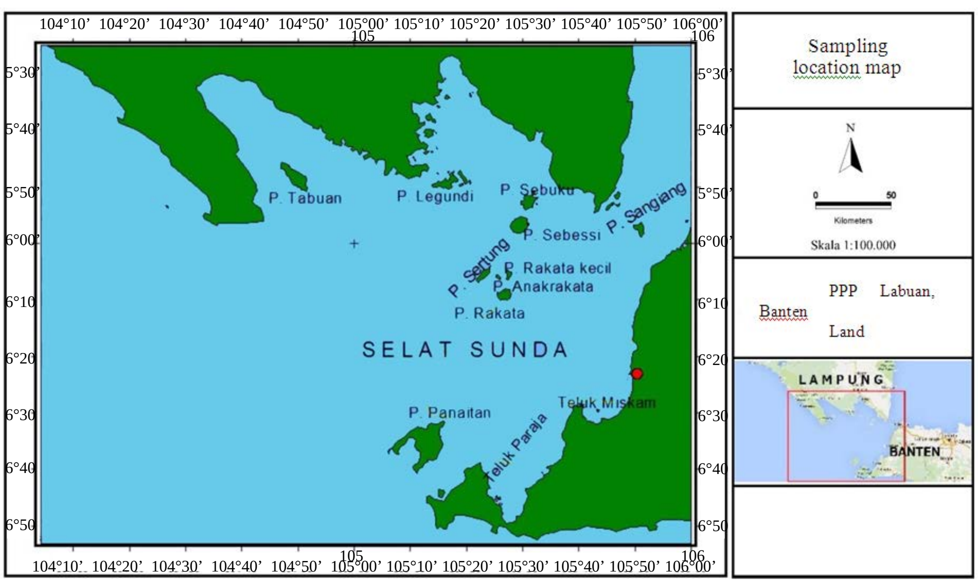

Fig. 1: Research area and data collecting

Table 1: Productivityatribut data

Data	Parameters	Analysis	Data types
Length	Maxium length	Length frequency analysis	Primary data
	Maximum age	Taylor equation	
	Length at first maturity	Udupa equation	
	Natural mortality (M)	Pauly's empiric equation	
	Fishing mortality (F)		
Weight	Growth coefficient (K)	Bertalanffy	
Catch	Intrinsic growth rate (r)	Growth Analysis	Secondary data
Gonad	Fecundity	Gravimetric and volumetric	Primary data
Maturity level	Recruitment pattern	Normsep and Gausian distribution	

Table 2: Susceptibilityatri but data collections

Data	Parameters	Analysis	Data types
Fish length	F/M	Pauly's empiric equation	Primary data
Biomass	SSB (Spawning Stock Biomass)	Ricker	
Distribution	Geographic concentration	Distribution	Secondary data
	Area overlap		
	Vertical overlap		
	Management Strategy		
Habitat	Fishing gear impact to environment	Distributionand habitat	Questionnaire
Schooling	Habitual response	Distribution patterm	
Morphology	Survival after capture	Morphology	
	Fishing gear impact to fish morphology		
Fish price	Economic value	Production value	
Migration	Seasonal migration	Distribution patterm	

weighed using a digital scale with the smallest scale 0.0001. Then gonad sample was diluted with 10 mL of distilled water. The fecundity is suspected by taking 1 mL sample diluted gonad. Data obtained in the form of data total fish length (mm), weight of fish (gram), gonad weight (grams), the price of fish and production data on catches. Overall these data include the parameters of productivity and susceptibility (Table 1 and 2) were used to assess the level of vulnerability of fish stocks.

There are many parameter for productivity and susceptibility calculate are growth parameter, mortality, length at first mature, fecundity, spawning stock biomass and etc. The estimation of the growth coefficient (K) and L∞ are using FISAT program (FAO-ICLARM Stock Assessment) II version 1.2.2 through ELEFAN I (Electronic Length-Frequency Analysis) methods. The t_0 value is estimated by Pauly equation (1983 in Sparre and Venema 1999). L∞ is the asymptotic length fish (mm), K is the coefficient growth rate (mm/unit time) and t_0 is the age of the fish when the fish length is equal to zero.

Total mortality rate (Z) is estimated using linearized curve based on length composition data. And the rate of natural Mortality (M) estimated using an empirical formula of Pauly (1980 in Sparre and Venema, 1999):

$$\ln M = -0,0152-0,279 \ln L_{\infty}+0,6543 \ln K+0,463 \ln T$$

Where:

M = The natural mortality

L∞ = The asymptotic length of the von Bertalanffy growth equation (mm)

K = The coefficient growth in the von Bertalanffy growth equation

t_0 = The age of the fish during the length of 0

T = The average surface temperature of 30°C

Pauly (1980 in Sparre and Venema, 1999) suggests the calculation for the type of fish that have schooling habit multiplied by the value of 0.8, so, the estimated value will be 20% lower:

$$M = 0,8e^{(-0.0152-0.279\ln\ln L_{\infty}+0.6543\ln K+0.463\ln T)}$$

Length at first maturity evaluate use length data to estimate the average size of the first maturity gonad is a method of Spearman-Karber (Udupa, 1986). Fecundity of fish want to know to make sure that number of eggs that mature before being released at the time of spawning. Others Biological parameters consist of intrinsic growth rate (r), capture power coefficient (q) and the carrying capacity (K). Multispecies biological parameters estimated using Schaefer models and obtained from the time series production data (catch), effort (trip) and the production per unit effort (CPUE). And then according to Patrick, etc., the following formula can be used to calculate the spawning stock biomass:

$$SSB = \frac{Bt}{Bo}$$

Vulnerability index calculate after scoring of attribute that referred to Euclidean distance from the origin of the X-Y axis in the scatter plot and the datum point:

$$v = \sqrt{(p-3)^2 + (s-1)^2}$$

where v is the vulnerability index which is derived from the value of p or productivity and s or susceptibility. Values of p and s is obtained by calculating the weighted mean of score and weight multiplication. Vulnerability index has three categories which are low vulnerable ($v \leq 1.6$), moderate vulnerable ($1.6<v<1.8$) and high vulnerable ($v \geq 1.8$). Patrick, etc., stated that if the value of $v>1.8$ then the fishes have high vulnerability risk to fishing.

RESULT AND DISCUSSION

Five species of small pelagic fish which used as examples in this study were Indian mackerel (*Rastrelliger kanagurta*), short mackerel (*R branchysoma*), Island mackerel (*R. faughni*), Indian Scad (*Decapterus russelli*) and fringscale sardinella (*Sardinella fimbriata*) (Fig. 2). The fishes are originally from different families and types that have different physiological characteristics. Indian mackerel has an elongated-flat body shape and height with black spots near the pectoral fins. Short mackerel has a shape similar to Indian mackerel but there are no black spots. Island mackerel has the most different characteristics than the others mackerel spesies, namely the height of a longer body. Each fish genus Rastrelliger have various local names in PPP Labuan Banten. Local names for Indian mackerel is Banyar, short mackerel is Kedongkor and island mackerel is Kembung.

Nontji stated that Indian Scad is one of the important components of the pelagic fisheries in Indonesia. Characteristics that can be found in Indian Scad is there a small fin (finlet) behind the dorsal fin and anal fin. The general characteristics of the fish song is a greenish-blue color on the back or upper body, silvery white on the bottom and form elongated body. The growth parameters estimated using fisat (FAO-ICLARM stock assessment) program with ELEFAN I method. The results of the growth parameters are presented in Table 3. The highest asymptotic length is found in short mackerel and Indian Scad. The highest growth coefficient of fish found in Indian Scad. Research on Indian Scad also carried by Destha with asymptotic length of 197.4 mm and growth coefficient value of 0.34.

The mortality rate can be divided into natural, fishing and total mortality. Total mortality rate (Z) is the result of a regression of linearized length data while the rate of natural Mortality (M) is calculated using the Pauly formula. The difference between the two is the rate of mortality caused by Fishing activities (F). The results of the analysis of the mortality rate and the rate of exploitation are presented in Table 4.

Table 3: Growth parameter estimation

Species	L∞ (mm)	K (year)	t0 (year)
Indian mackerel	258.3	0.55	-0.9951
Short mackerel	263.6	0.41	-1.3425
Island mackerel	237.3	0.50	-1.1246
Indian Scad	263.6	1.30	-0.4052
Fringscale sardinella	195.3	0.88	-0.6598

Table 4: Mortality and exploitation rate estimation

Mortality	Indian mackerel	Short mackerel	Island mackerel	Indian scad	Fringscale sardinella
M	0.55	0.46	0.54	0.98	0.83
F	2.57	1.23	1.64	5.36	3.46
Z	3.12	1.70	2.19	6.34	4.29
E	0.82	0.73	0.75	0.84	0.81

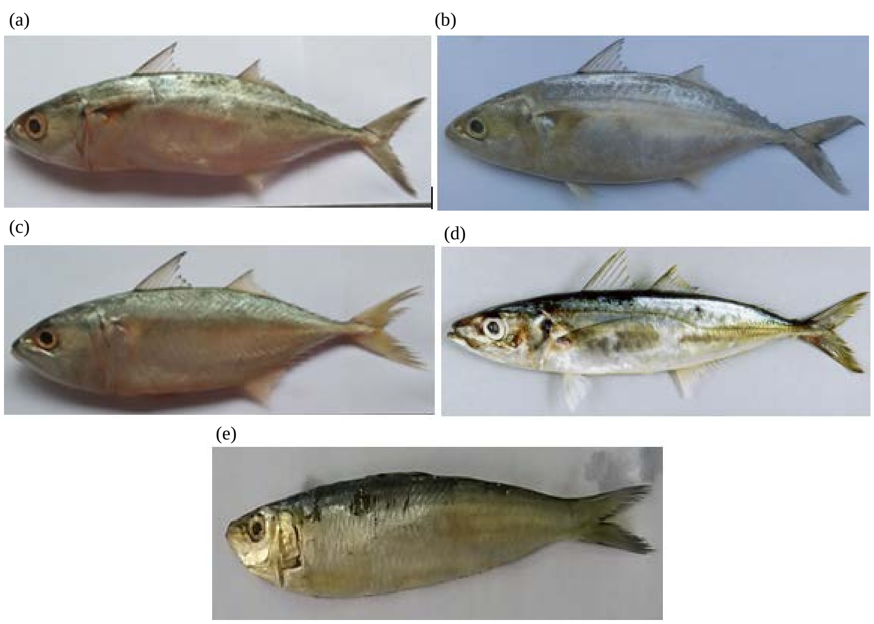

Fig. 2(a-e): The 5 main species are (a) Indian mackerel, (b) short mackerel, (c) island mackerel, (d) Indian Scad and (e) fringscale sardinella (50 mm)

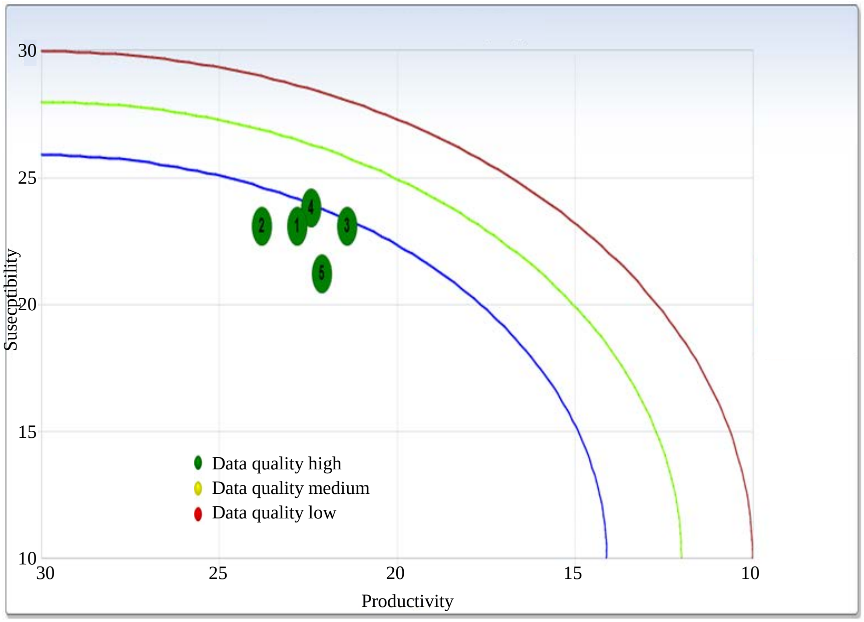

Fig. 3: Productivity and susceptibility of 5 small pelagic fishes

Table 5: Productivity parameters each species

Attribute	Units	Species: Indian mackerel	Short mackerel	Island mackerel	Indian Scad	Fringscale sardinella
Intrinsic growth rate (r)	ton/year	2.91	2.91	2.91	2.17	2.32
Maximum age	Years	4.46	5.97	4.88	1.90	2.75
Maxium length	mm	250	255	227	251	187
Growth coefficient (K)	Years	0.55	0.41	0.50	1.30	0.88
Natural Mortality (M)		0.55	0.46	0.54	0.98	0.83
Fishing mortality (F)		3.18	1.23	1.65	5.36	3.46
Fecundity	grain	96 531	283 572	50 858	19 6032	58 940
Recruitment pattern	%	26.87	19.96	21.90	17.09	20.58
t0		-0.10	-1.34	-1.12	-0.41	-0.66
Length at first maturity	mm	218.4	203.3	202.5	217.4	180.7

Based on Table 4 is known that the mortality rate of Fishing (F) will always be greater than the rate of natural Mortality (M). The highest value of the rate of exploitation found in the Indian mackerel whether the lowest found in short mackerel.

Productivity and susceptibility parameters: Stobutzki *et al*. (2001) defines productivity as the capacity of the species to recover once populations depleted. Productivity attributes are presented in Table 5.

Table 5 shows that the intrinsic growth of genus Rastrelliger fishes are higher than other fish. Short mackerel live in the longest period of time with the lowest growth coefficient. The maximum size of short mackerel is bigger than other fish, so, the short mackerel require a longer time to reach asymptotic length. Indian mackerel have the greatest recruitment patterns among the other fish. Recruitment pattern is a potential success in recruiting fish. Indian mackerel too long when first ripe gonads (Lm) that is greatest among other fish. Susceptibility is one parameter that indicates the tendency of fish to be caught by fishermen. Susceptibility attribute values are presented in Table 6.

Vulnerability index: The results analysis of productivity and susceptibility parameters that has been obtained were scored by considering weights, attribute values and the quality of the data and then generate a graph that links between productivity and susceptibility. Red line illustrates the vulnerability of fish stocks higher while a green line indicates medium level of vulnerability. As for the line of blue color indicates the level of vulnerability of fish stocks are low. Numbering circles in the figure indicate the type of fish studied Indian mackerel, short mackerel, island mackerel, Indian Scad and fringscale sardinella. The circle color shows the quality of the data and the numberswhich's analyzed. Productivity and susceptibility graph is presented in Fig. 3.

Based on Fig. 3, five fish are categorized as low vulnerable with different vulnerabilities index. The value

Table 6: Susceptibility parameters each species

Attribute	Fish types Genus Rastrelliger			Indian Scad (*Decapterus russelli*)	Fringscale sardinella (*Sardinella fimbriata*)
Management strategy	There isn't fishing limit and monitoring is not done well				
Geographic concentration	34.63% available in the fishing ground			57.28% available in the fishing ground	46.23% available in the fishing ground
Area overlap	Distribution 74.12% from total stock			Distribution 75.99% from total stock	Distribution 60.59% from total stock
Vertical overlap	52.94 % fishing in the same depth				
F/M	4.71	2.67	3.04	5.45	4.18
SSB (Spawning Stock Biomass)	2.85%		11.02%	31.67%	
Seasonal migration	Seasonal migration impacts to yield reduction				
Schooling aggregation	Schooling aggregation increases yield				
Morfology affecting	Fishing gear selectivity is medium				
Survival after capture	Survival after capture is high				
Desirability/value of the fishery	High Rp. 15 000-25 000 kg^{-1}			Medium Rp. 28 000-35 000 kg^{-1}	Low Rp. 5 000-10 000 kg^{-1}
Fishery impact to essential fish habitat				Environment friendly	

Table 7: Vulnerability 5 small pelagic fishes record from sunda strait

Species	Productivity	Susceptibility	Vulnerability index
Indian mackerel	2.28	2.31	1.49
Short mackerel	2.38	2.31	1.45
Island mackerel	2.14	2.31	1.57
Indian Scad	2.24	2.38	1.58
Fringscale sardinella	2.25	2.12	1.37
5 species	2.38	2.12	1.28

of productivity, susceptibility and vulnerability index are presented in Table 7. The level of vulnerability shown by Indian Scad is higher than the other four fishes. Susceptibility value of fringscale sardinella is lower than other fish, so it has the lowest vulnerability index.

The results showed that the growth parameters of fringscale sardinella (*Decapterus russelli*) is the largest while short mackerel (*Rastrelliger branchysoma*) had the smallest growth coefficient. If the coefficient of growth be smaller, it would need longer time for long reach asymptotic species, so, the age of the fish live longer. The results of the maximum age analysis of five species of fish above shows that the highest maximum age is in short mackerel. The maximum age also indicates the level of recovery of fish species. This is in line with the growth coefficient of short mackerel which had the lowest values so that the population grows slowest.

The value of intrinsic growth rate can provide information about the growth rate of a population that is growing in ideal conditions without limit. The calculations show that fish by the genus Rastrelliger has a growth rate higher than others. This is agreeable with the research of Yanti which shows that the intrinsic growth Indian mackerel is higher than fringscale sardinella and Indian Scad's.

Fish which has a longer life span and a larger maximum size will reach the level of maturity at an older age or a larger size in Usman (1996). Indian mackerel had first maturity size (Lm) that is greatest among others. Meanwhile, short mackerel who has the longest maximum size indicates lower size of the first maturity gonads. However, neither the Indian nor the short mackerel have first maturity gonad size smaller compared with the research results of Fragolia (2015). This indicates that the fishing pressure causes the reproduction occurs when the size of the fish are still small.

One aspect of reproduction, the fecundity is the number of eggs present in the ovary of fish (Nikolsky 1963). Fecundity of short mackerel was the highest among the other fish. Rickman *et al*. (2000) suggest that the species has a high fecundity will generate higher recruitment levels. Even so, the success of the fertilized egg to hatch and become new juvenile are still affected by the survival rate of the fish. The results of the recruitment pattern of Indian mackerel, short mackerel, island mackerel, Indian Scad and fringscale sardinella are derived from the largest recruitment percentage in certain months of the year. Indian mackerel which has the highest yield in April showed the peak recruitment, according to research by Abdussamad *et al*. (2010) which states that the peak spawning and recruitment Indian mackerel is from January to April.

Mortality or the death of fish in a population occurs due to natural factors and fishing factors. Natural factors include the condition of the aquatic environment, competition of space and feed, disease and predation. The results of natural mortality analysis in island mackerel showed the highest value. In contrast, short mackerel has the lowest value of natural Mortality (M). According to Patrick, etc., natural mortality negatively correlated to the maximum age of the fish. Short mackerel which has the longest maximum age will has the lowest value of natural mortality and vice versa for Indian Scad. Meanwhile, the fishing factors commonly associated with the use of fishing gear. According to Heriawan (2008), based on the technical aspects purse seine valued as priorities in the small pelagic fish catch.

Based on interviews with fishermen, purse seine does not negatively impact fish habitat because it is operated in the water column. Lestari (2013) also assessed the purse seine fishing gear is an environmental friendly fishing gear, so, it does not affect the morphology of the fish caught. Even so, fishing mortality showed fairly high value. According to Patrick, etc., the relative rate of fishing mortality to natural mortality or the value of F/M more than 1 means high susceptibility of fish stocks. If F/M of five species are >1, it tends to easily get caught. The exploitation rate of five species have exceeded the optimum exploitation rate (0.5), so that, the small pelagic fish stocks indicated as overfishing. The overfishing might be happened because there is no strict fisheries policy of fishing activities landed in PPP Labuan Banten, also the monitoring has not gone well. Research by Marselin (2015) mentioned that the number of ship and fishing activities are led to high area and vertical overlap. In addition, schooling small pelagic fish making it easier for fishermen to catch.

Dalzell and Lewis stated that the small pelagic fish of various groups usually live in the same habitat which is the surface waters with <200 m depth. Fish landed in PPP Labuan captured from several fishing ground including coastal waters of Krakatoa, Sebesi, Sangiang and Panaitan islands. Fish caught in one location may be landed elsewhere, causing fish stocks mixed (Sen *et al*., 2011).

Spawning Stock Biomass (SSB) is a parameter that can describe the decline of fish catch biomass since the first year of catching until current state (Patrick *et al*., 2010). SSB values for Indian mackerel, short mackerel, island mackerel and Indian Scad are categorized as low while for fringscale sardinella has the spawning biomass that's classified as moderate. Results of research by Siregar which states that overfishing Indian mackerel indicates decreasing spawning biomass due to high fishing effort.

Productivity parameter of short mackerel is higher than other fish (Table 7). This is due to the high value of fecundity, recruitment patterns and the intrinsic growth rate of the fish genus Rastrelliger. High productivity parameters showed a good ability to survive in the wild. Meanwhile, Indian Scad showed low productivity due to natural mortality and high catchability.

The susceptibility of genus *Rastrelliger* shows the same value because the scorings which is based on production data and interviews are not different. Indian mackerel (*Rastrelliger kanagurta*), short mackerel (*R. branchysoma*), island mackerel (*R faughni*) have higher economic value, so, the fish genus Rastrelliger more threatened by fishing activities.

Vulnerability analyzed from productivity and susceptibility parameters showed that the index of vulnerability is highest in Indian Scad the lowest is in fringscale sardinella. Vulnerability index which are obtained for each species of fish belonging to the category of low vulnerable. This is similar to the results of research by Lestari (2013) which indicates that the vulnerability index for Indian mackerel and fringscale sardinella included in the category of less vulnerable.

Value range of productivity and susceptibility for five species indicates that small pelagic fish resources is generally low vulnerable. It is caused by many factors, both internal and external. Internal factors such as low ability of fish to regenerate itself and survive the environmental conditions. Research Suruwaky and Endang (2013) states that the decrease in resources *R. kanagurta* allegedly due to the degradation of ecosystems that is supposed to support fish life. External factors derived from fishing pressure due to the high market demand, space or food competition and predation.

Cheung *et al*. (2007) assessed the status of fish resources based on fish life history and ecological characteristics, known as the species vulnerability index. Fish genus *Rastrelliger*, especially *Rastrelliger kanagurta* and *R branchysoma* have the same intrinsic vulnerability index as well as the fish genus Sardinella of 45. Meanwhile, the fish in genus *Decapterus* have lower intrinsic vulnerability index of 26. The five species classified as low vulnerable because it has a species vulnerability index that are <60.

Vulnerability index is generally compared with the rate of exploitation. Based on the research results Fardianti, the highest rate of exploitation indicates that fish stocks more vulnerable. In this research known that the Indian Scad has the highest vulnerability index with high exploitation rate too. This is due to the intrinsic growth rate and recruitment pattern which demonstrates the low ability to recover of Indian Scad, while the mortality is very high. Therefore, it is necessary to manage fish resources, so that, utilization of small pelagic fish remain sustainable.

Vulnerability is a risk assessment that can be used as a basis for fisheries management practice that know as data poor management. High productivity of fish resources must be maintained by keeping the habitats that support the fish life. It is needed to control the mobility of ships and fishing gear used to ensure that fishing activities do not threaten the existence of the stocks and fish habitat. In addition, verification of the fishing location by fishermen also can be done to reduce the area and vertical overlap. It is a form of fishing pressure control that is feared to cause a high level of fish vulnerability.

CONCLUSION

Small pelagic fish resources (Indian mackerel, short mackerel, Island mackerel, Indian Scad and fringscale sardinella) in the Sunda Strait included in the category of less vulnerable. The highest vulnerability index value is on Indian Scad while the lowest vulnerability index in fringscale sardinella. The vulnerability of small pelagic fish in Sunda Strait shown that the highly sustainability stock and fishing intensity are controlled. But tendency of stock production, important to endorse a precautionary approach in each fishing practice.

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REFERENCES

Abdussamad, E.M., N.G.K. Pillai, M. Kasim, O.M. Mohamed and K. Jeyabalan, 2010. Fishery, biology and population characteristics of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier) exploited along the Tuticorin coast. Indian J Fish., 57: 17-21.

Cheung, W.L., 2007. Vulnerability of marine fishes to fishing from global overview to the Northen South China sea. Master Thesis, The University of British Columbia, Columbia, USA.

Fragolia I., 2015. [Study of rastrelliger branchysoma female bloated fish stock (Bleeker 1851) in Sunda Strait waters]. Institut Pertanian Bogor, Bogor, Indonesia. (In Indonesian)

Heriawan, Y., 2008. [Small pelagic fishing unit allocation in pandeglang waters, banten: Towards controlled fishing]. Master Thesis, Institut Pertanian Bogor, Bogor, Indonesia. (In Indonesian)

Lestari, C.P., 2013. [Vulnerability of fish resources based on productivity and susceptibility data in the sunda strait]. Institut Pertanian Bogor, Bogor, Indonesia. (In Indonesian)

Marselin, D.W.I., 2015. [Vulnerability of large pelagic fish from gill net fishing tools landed at the cilacap ocean fisheries port, Central Java]. Institut Pertanian Bogor, Bogor, Indonesia. (In Indonesian)

Nikolsky, G.V., 1963. The Ecology of Fishes. Academic Press, New York, USA., .

Patrick, W.S., P. Spencer, O. Ormseth, J. Cope and J. Field *et al*., 2010. Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. Fishery Bull., 108: 305-322.

Rickman, S.J., N.K. Dulvy, S. Jennings and J.D. Reynolds, 2000. Recruitment variations related to fecundity in marine fishes. Fish Aquatic, 57: 116-124.

Sen, S., S. Jahageerdar, A.K. Jaiswar, S.K. Chakraborty, A.M. Sajina and G.R. Dash, 2011. Stock Structure analysis of *Decapterus russelli* (Ruppell, 1830) from east and west coast of India using truss network analysis. Fish. Res., 112: 38-43.

Stobutzki, I., M. Miller and D. Brewer, 2001. Sustainability of fishery bycatch: A process for assessing highly diverse and numerous by catch. Environ. Conserv., 28: 167-181.

Suruwaky, A.M. and G. Endang, 2013. [Identification of the level of exploitation of male mackerel (*Rastrelliger kanagurta*) resources judging from long-weight relationships (In Indonesian)]. Aquatic, 4: 131-140.

Triharyuni, S., S.T. Hartati and R.F. Anggawangsana, 2013. [Productivity and Vulnerability of Kurisi Fish (*Nemipterus* spp.) Cantrang catches in the Java Sea (In Indonesian)]. Indonesian Fish. Res., 19: 213-220.

Udupa, K.S., 1986. Statistical method of estimating the size at first maturity of fishes. Fishbyte, 4: 8-10.

Usman, R., 1996. [Some aspects of reproductive biology and eating habits of pompano (carangidae) in the Makassar Strait and Ambon bay (In Indonesian)]. Indonesian Fish. Res., 2: 12-17.