Global J. Environ. Sci. Manage. 6(1): 119-132, Winter 2020

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

ORIGINAL RESEARCH PAPER

The susceptibility level and sustainability potential of groupers; *Plectropomus* sp. in a marine national park

M. Tadjuddah[1,*], Abdullah[1], S. Kamri[1], N.I. Wianti[2]

[1]Department of Fisheries Capture, Fisheries and Marine Sciences Faculty, University of Halu Oleo, Kendari, Southeast Sulawesi Province, Indonesia
[2]Department of Extension Agriculture, Agricultural Faculty, University of Halu Oleo, Kendari, Southeast Sulawesi Province, Indonesia

ARTICLE INFO

Article History:
Received 09 April 2019
Revised 25 August 2019
Accepted 20 September 2019

Keywords:
Grouper
Plectropomus Sp.
Productivity And Susceptibility Analysis (PSA)
Susceptibility Leve
Wakatobi National Park

ABSTRACT

Wakatobi National Park has a tropical marine ecosystem with typically dynamic aquatic resources, and it also has a potentially massive number of groupers such as red (*Plectropomus leopardus)* and black groupers *(Plectropomus areolatus)*. However, the sustainability of the grouper resources has not been managed effectively and environmentally friendly. This study aims to determine the susceptibility level of red and black groupers in the research area based on the productivity and susceptibility analysis. This study was conducted from May to November 2018, in which the data were collected from the grouper's fishermen using hand line with simple random methods as a fishing gear in Wanci and Tomia islands of Wakatobi. Based on the collected data, productivity attribute of red groupers is at 1.8, and the susceptibility level is at 2.08, while the black groupers have 1.7 for the productivity attributes and 2.0 for their susceptibility level. Based on the susceptibility index of both types of fish, it indicates that red groupers are at 1.61, and the black groupers' susceptibility level is at 1.64. This study implies that the susceptibility index of red and black groupers at Wakatobi National Park is moderate which means that the groupers as a matter of fact experience fishing pressure. Therefore, some sustainable efforts to effectively and environmentally friendly manage the fishing activity in the island need to be done in the future.

DOI: 10.22034/gjesm.2020.01.10

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
42	5	5

*Corresponding Author:
Email: *muslim22jan@uho.ac.id*
Phone: +6204013193391
Fax: +6204013193391

Note: Discussion period for this manuscript open until April 1, 2020 on GJESM website at the "Show Article.

INTRODUCTION

The water area of Wakatobi National Park located in Wakatobi of Southeast Sulawesi has a tropical marine ecosystem with dynamic resources as it has a massive number of grouper resources under the sea. The abundant potential resources of groupers in Wakatobi Island should be a great opportunity for people to boost the economy and increase their local revenue. However, the local people have not managed this resource very effective and environmentally friendly, such as the absence of sustainable ways to manage the resources, for example by limiting the fish size and number of catches. Groupers are found globally, predominantly in the tropics and subtropics with the enormous diversity in the Coral Triangle (CT). The absolute number of species classified as threatened is the highest in parts of the Caribbean, the southeastern United States, Brazil and Southeast Asia (particularly at CT) including in Indonesia (Bellwood and Wainwright 2002; Bellwood and Meyer 2009; Sadovy *et al*., 2012). Many types of groupers are caught by fishermen in Wakatobi, but the most frequent ones are red (*Plectropomus leopardus*) and black groupers (*Plectropomus areolatus*). The groupers are one of the high economic value commodities and are actively exported to other regions. The utilization of grouper resources has been done since long time ago. Besides, the high value of sales and market demand will encourage grouper fishermen to exploit this resource in an uncontrolled way so that it will threaten the existence of the fish. This study is undertaken by Sadovy *et al.,* (2012) that 12% of all grouper species worldwide already have the risk of extinction including in the territorial waters of Indonesia due to the capture pressure. In connection with the management efforts, FAO, (1995) suggests a practical approach that can be developed to evaluate the productivity and the level of excessive fishing risk using a productivity and susceptibility analysis (PSA) approach. The approach aims to evaluate the susceptibility level of fish species as a result of over-fishing activity based on the biological sensitivity, productivity and vulnerability to fishing activities on target species (Hobday *et al.,* 2007). Currently, many qualitative risk analyses are used by fishery scientists, but PSA is a useful method for determining the susceptibility as it allows the evaluation of both productivity and susceptibility of the fish stocks as a result of the fishing activities (Patrick *et al.,* 2009, 2010; Arrizabalaga, *et al.,* 2011). In Mexico, this method was first used to evaluate the effect of the artisanal shark fishery on shark populations at the entrance of the Gulf of California (Furlong Estrada *et al*., 2017). According to Zhou and Griffiths (2008), a risk-based approach such as PSA has now been extended and it focuses on which approach is implemented as an ecosystem-based approach to fisheries management. Meanwhile, according to Smith *et al*. (2007) and Hobday *et al.* (2011), PSA is a semi-quantitative in nature but it relies on a good scientific basis, while Cortes *et al.* (2010) refers PSA as a good approach applied to fisheries with inadequate data, such as limited data on the number of fish captured and time series' effort. The purpose of this study is to determine the susceptibility level of red and black groupers caught at Wakatobi National Park. The benefits of this research are expected to be the information on the susceptibility level of red and black groupers so that future policymakers can deal with the more sustainable management which also can enrich repertoire of science. With the enactment system regulation, the open-close-fishing system will ensure the sustainability of groupers fishing activities in the future. This study has been carried out at Wakatobi Marine National Park especially in Wanci and Tomia Island in Indonesia in 2018.

MATERIALS AND METHODS

Research Date and Location

This study was conducted from May to November 2018. The data were obtained from the grouper fishermen from Wanci and Tomia sland at Wakatobi National Park (Fig. 1).

Sample collection of fish

The groupers used as sample were taken using random sampling technique. The primary data of this research sample are 87 red groupers and 103 black groupers caught using the hand line fishing gear (Fig. 2).

Analysis method

The PSA software version 1.4.0.0 was used to analyze the data and generate the plots. The collection of primary data on productivity attributes includes maximum age, maximum length (cm), the coefficient of growth and natural mortality. Meanwhile, other data such as fecundity (gr), reproductive strategies, the pattern of recruitment,

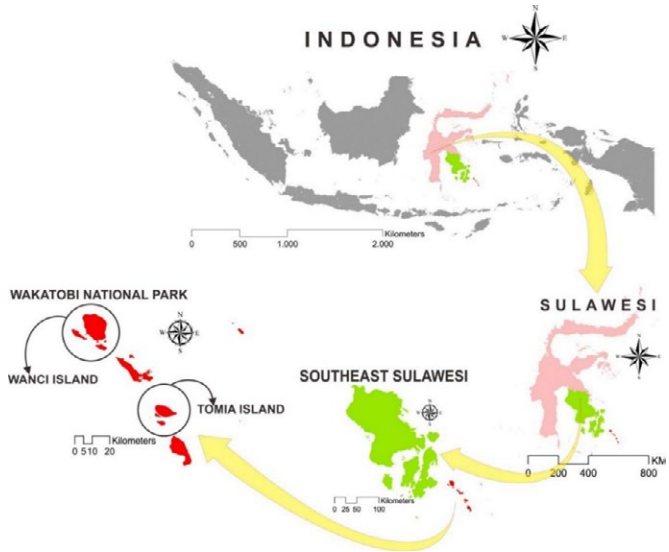

Fig. 1: Geographic location of the researcharea at Wakatobi National Park, Wanci and Tomia Island, in Indonesia

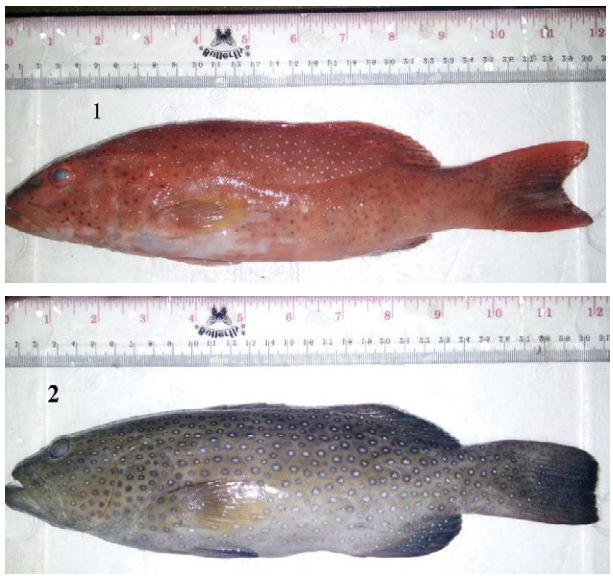

Fig. 2: Groupers caught at Wakatobi National Park (1) *Plectropomus leopardus,* (2) *Plectropomus areolatus*

the first measure mature lick, trophic level were taken from the Fishbase (FAO, 2011; Patanda *et al.,* 2017).The susceptibility attributes data came from interviews with fishermen. The interview was conducted by a descriptive survey using a list of questions. It aims to obtain information about the required parameters while other biological pieces of data from the samples were collected by conducting relevant literature studies. All attributes were scored on a three-point scale: 1–3 (corresponding to the low, medium and high categories respectively), according to their relative value to its perceived contribution to the overall productivity or susceptibility score. Patrick *et al*. (2009) criteria were used to determine the fish susceptibility level. While the data quality scoring system consists of two categories: score one shows

the data obtained directly in the field and the score 4 derived from a review of the relevant literature. Productivity and susceptibility assessments are graphically depicted in the form of scatter plot XY. The x-axis shows the productivity. Meanwhile, the y-axis shows the susceptibility. In Fig. 5, a graph that provides an overview of fish species susceptibility shows the position of the number on the x-axis which is reversed, starting at three and ending at 1. It means that a plot close to the origin (3.1) means stocks with high productivity and low susceptibility. This condition indicates the low susceptibility. Euclidean distance from the origin to the data point is used as a measure of overall stock susceptibility level (Patrick *et al*., 2009). This chart provides the description of the susceptibility level of each species of fish. The susceptibility index is obtained using Eq. 1.

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

Where:
v = overall score of susceptibility
p = productivity
s = susceptibility

Fish with a susceptibility index (v) of more than 1.8 indicates a high risk of susceptibility to fishing activities. The susceptibility index has three categories, which are less susceptible (v <1.6), moderate susceptible (1.6 ≤ v <1.8) and high susceptible (v ≥ 1.8). The average value of productivity and susceptibility level is used to determine the categories of data quality. The data quality is considered high if the value of V is obtained less than 2, a moderate value if V is equal to 2 and a low value if V is less than 3. Nevertheless, the productivity and susceptibility analysis does not analyze economic, social, and cultural parameters. The research only uses the ecological and biological parameters of groupers. Also, PSA does not include an analysis of environmental parameters. Therefore, the limitations of this research are that some parameters such as climate change, ocean warming, raising the water level are not included. Besides, the parameter of growth coefficient (k) and L∞ was obtained using equation Von Bertalanffy through Ms. Excel. The theoretical estimation of the fish life time at the time of its length being equal to zero is obtained through Eq. 2 (Pauly, 1984; Sparre *et al.,* 1999; Mudjirahayu, *et al*., 2017).

$$\log(-t0) = 3.3922 - 0.2752(\log L\infty) - 1.038(\log K) \quad (2)$$

Where,
L∞ = Asymptotic length of fish
K = Growth rate coefficient
t = Age of the fish
t_0 = Age of the fish when its length is equal to zero.

The value of K can be determined by determining the maximum age of groupers, and estimating the maximum age of the fish (t_{max}) can be done using Eq. 3 (Pauly, 1984; Mudjirahayu, *et al*., 2017).

$$t_{max} = \frac{3}{k} + t_0 \quad (3)$$

Natural mortality is estimated empirically using Eq. 4 (Pauly, 1984; Mudjirahayu, *et al*., (2017); Kiyaga, *et al*., (2014).).

Table 1: Productivity attributes and rankings

Productivity attribute	Ranking		
	High (3)	Moderate (2)	Low (1)
Maximum age	< 10 years	10 - 30 years	> 30 years
Maximum size	< 60 cm	60 - 150 cm	> 150 cm
von Bertalanffy growth coefficient (k)	> 0.25	0.15 - 0.25	< 0.15
Estimated natural mortality	> 0.40	0.20 - 0.40	< 0.20
Measured fecundity	> 10e4	10e2 - 10e3	< 10e2
Breeding strategy	0	Between 1 and 3	≥ 4
Recruitment pattern	Highly frequent recruitment success (> 75% of year classes are successful)	Moderately frequent recruitment success (between 10% and 75% of year classes are successful)	Infrequent recruitment success (<10% of year classes are successful)
Age at maturity	< 2 year	2 - 4 years	> 4 years
Mean trophic level	< 2.5	Between 2.5 and 3.5	> 3.5

$$M = (-0,0152 - 0,279 \ln L\infty + 0,6543 \ln k + 0,463 \ln T) \quad (4)$$

Where,
M = Natural mortality
L∞ = Asymptotic length on Von growth equation Bertalanffy (mm)
K = Coefficient of growth
t^0 = Age of the fish when the length is 0
T = Average temperature of the water surface (^{0}C)

After the mortality rate (Z) and thenatural mortality rate (M) are known, then the fishing mortality (F) rate can be determined by Eq. 5 (King, 1995; Mudjirahayu, *et al*., 2017; Kiyaga, *et al*., 2014).

$$F = Z - M \quad (5)$$

PSA analysis results will be drawn based on the eleven susceptibility and nine productivity attributes. The attributes and productivity assessment criteria for risk analysis are presented in Table 1.

Fish species with low productivity are potentially more susceptible to over-exploited because of the high risk. Limitation of productivity attribute ratings is determined based on discussions with experts who understand the character of groupers in the research area while the limit for referring the susceptibility level of vote's ratings from the Marine Stewardship Council (MSC, 2019; Ponte, 2012) is presented in Table 2.

RESULTS AND DISCUSSION

Productivity is the resource capability to recover from the damage caused by fishing pressure. Results of the productivity attribute assessment of red and black groupers caught in the waters area of Wakatobi

Table 2: Susceptibility attributes and rankings

Susceptibility attribute	Ranking		
	High (3)	Moderate (2)	Low (1)
Areal overlap	> 50% of stock occurs in the fishing area.	Between 25% and 50% of the stock occurs in the fishing area	< 25% of stock occurs in the fishing area.
Geographic concentration	Stock is distributed in < 25% of its total range	Stock is distributed in 25% to 50% of its total range	Stock is distributed in > 50% of its total range
Seasonal migrations	Seasonal migrations increase overlap with the fishery	Seasonal migrations do not substantially affect the overlap with the fishery	Seasonal migrations decrease overlap with the fishery
Schooling/ aggregation and other behavioral responses	Behavioral responses increase the catchability of the gear (i.e., hyperstability of CPUE with schooling behavior)	Behavioral responses do not substantially affect the catchability of the gear	Behavioral responses decrease the catchability of the gear
Morphology affecting capture	Species shows high selectivity to the fishing gear	Species shows moderate selectivity to the fishing gear	Species shows low selectivity to the fishing gear
Desirability/ value of the fishery	Stock is highly valued or desired by the fishery (>$2.25lb; >$10000k/year) landed, >66% retention)	Stock is moderately valued or desired by the fishery ($1-$2.25; $500k - $10000k/year) landed, 33-66% retention	Stock is not highly valued or desired by the fishery (less than $500k) landed, <33% retention
Management strategy	Targeted stocks do not have catch limits or accountability measures; non-target stocks are not closely monitored	Targeted stocks have catch limits and reactive accountability measures	Targeted stocks have catch limits and proactive accountability measures; non-target stocks are closely monitored.
Fishing rate relative to M	> 1	0.5- 1.0	< 0.5
Biomass of spawners (SSB) or other proxies	B is between 25% and 40% of B0 (or maximum observed from time series of biomass estimates	B is between 25% and 40% of B0 (or maximum observed from time series of biomass estimates	B is > 40% of B0 (or maximum observed from time series of biomass estimates)
Survival after capture and release	Probability of survival <33%	Probability of survival between 33% and 67%	Probability of survival >67%
Fishery impact to EFH or habitat in general for non targets	Adverse effects more than minimal or temporary and are not mitigated	Adverse effects more than minimal or temporary but are mitigated	Adverse effects absent, minimal or temporary

are shown in Table 3.

Table 3 indicates that the maximum age of red and black groupers reaches 5.30 years and 6.34 years with a maximum length of 78.8 cm for red groupers and 76.7 cm for black groupers. Growth coefficient (k) of the two types of fish shows t 0.71 for the red groupers and 0.54 for the black ones. In both types of fish, mortality attribute indicates a value not much different from that of 0.20 for red groupers and 0.22 for black type. Similar values can also be seen from the second trophic level fish species which are 4.4 for red groupers and 4.5 for black groupers. As can be seen from Fig. 3 regarding the results of scoring productivity attributes show that the majority of the attributes which are Maximum age (MA), Maximum length (ML), The coefficient of growth (CG), Natural mortality (M), Reproductive Strategies (RS), The pattern of recruitment (PR), The first measure mature gonads (MG), and Tropic level (TL) between red groupers and black groupers have the same score. Nevertheless, for Fecundity (F) attribute, black groupers who have score 3 are higher than red groupers which have a score of 2.

Susceptibility is a situation in which the resources

Table 3: Productivity attributes of Red and Black Groupers at Wakatobi National Park

Productivity attributes	Unit	*Plectropomus leopardus*			*Plectropomus areolatus*		
		Value	Score	Quality	Value	Score	Quality
Maximum age	Year	4.66 (*)	3	1	4,90 (*)	3	1
Maximum length	Cm	82.3 (*)	2	1	76 (*)	2	1
The coefficient of growth	Year	0.89 (*)	3	1	0.80 (*)	3	1
Natural mortality		0.19 (*)	1	1	0.18 (*)	1	1
Fecundity	Grain	457 900 (****)	3	4	8959 (****)	2	4
Reproductive strategies		protogyny -non-guarders, open water egg scatterers spawning aggregations Recorded (**)	2	4	protogyny -non-guarders, open water egg scatterers spawning aggregations Recorded (**)	2	4
The pattern of recruitment	%	Recruitment rare (<10%) (***)	1	4	Recruitment rare (<10%) (***)	1	4
The first measure mature gonads	Cm	21-60 (**)	1	4	21-60 (**)	1	4
Trophic level		4.4 (****)	1	4	4.5 (****)	1	4

*: Primary data. **: FAO, 2018 ***: Patanda *et al.*, 2017, ****: Fishbase, 2019

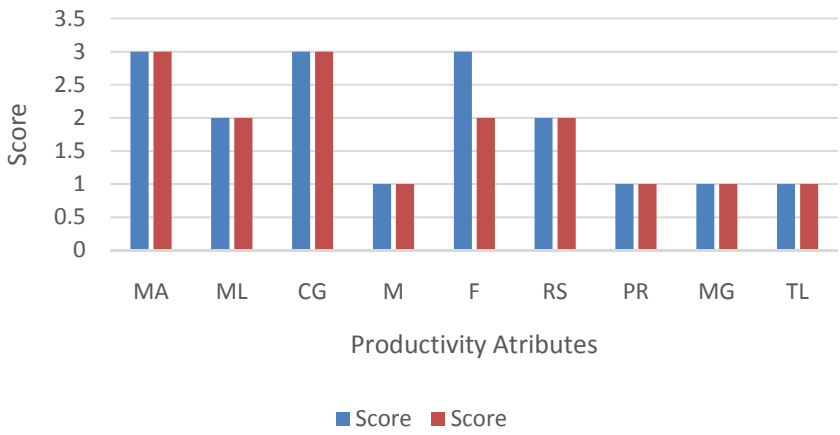

Fig. 3: Score of Plectropomus areolatus and Plectropomus leopardus based on Productivity Attributes. MA, Maximum age; ML, Maximum length; CG, the coefficient of growth; M, Natural mortality; F, Fecundity; RS, Reproductive strategies; PR, The pattern of recruitment; MG, The first measure mature gonads; TL, Trophic level

are easily caught by the fishermen leading the decline of the species number. The susceptibility attribute of red and black groupers was obtained through interview with stakeholder who marks the data quality (1) and reviews of related literature with the data quality (4). The results obtained on the attributes of the fish species are presented in Table 4.

A scoring result, in Fig. 4, shows that almost all the attributes of red groupers and black groupers for susceptibility attributes have the same score. This

Table 4: Susceptibility attributes of red and black groupers at Wakatobi National Park

Susceptibility attributes	*Plectropomus leopardus*			*Plectropomus areolatus*		
	result	Score	Quality	result	Score	Quality
Management strategies	Stock does not have catch limits but are closely monitored and monitored (*)	2	1	Stock does not have catch limits but are closely monitored and monitired (*)	2	1
Areas of overlap	Catching the red groupers > 50% of the resources (*)	3	1	Catching black groupers > 50% of the resources (*)	3	1
Geographic concentration	Groupers are distributed red> 50% of total range	1	4	Groupers are distributed red> 50% of total range	1	4
Vertical Overlapping	> 50% of the red groupers caught at the same depth (*)	3	1	> 50% of black groupers caught at the same depth (*)	3	1
Fishing mortality	1.1 (*)	3	1	0.56 (*)	2	1
Seasonal migration	Seasonal migration to lower overlap with other fish (*)	1	1	Seasonal migration to lower overlap with other fish (*)	1	1
Clump or custom response	are not clustered so it does not increase the catch (*)	2	1	are not clustered so it does not increase the catch (*)	2	1
Morphology affect catches	Morphology does not significantly affect fishing gear (*)	2	1	Morphology does not significantly affect fishing gear (*)	2	1
Survival after capture	The ability to live after being caught about 90% (*)	1	1	The ability to live after being caught about 90% (*)	1	1
Economic value	The price of fish Rp 350,000 / kg so its fishing activity is increase (*)	3	1	The price of fish Rp 70000-200000 / kg so its fishing activity is increase (*)	3	1
The impact of fishing gear on habitat	Fishing gear does not adversely affect the environment (*)	1	1	Fishing gear does not adversely affect the environment (*)	1	1

*: Primary data. **: FAO, 2018 ***: Patanda *et al.*, 2017, ****: Fishbase, 2019

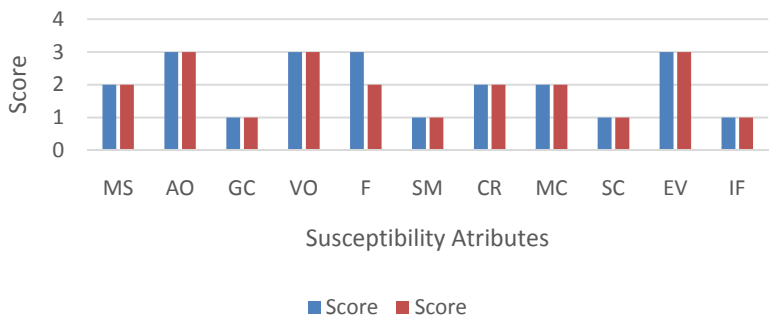

Fig. 4: Score of *Plectropomus areolatus* and *Plectropomus leopardus* based on Susceptibility Attributes. MS, Management strategies; AO, Areas of overlap; GC, Geographic concentration; VO, Vertical Overlapping; F, Fishing mortality; SM, Seasonal migration; CR, Clump or custom response; MC, Morphology affect catches; SC, Survival after capture; EV, Economic value; IF, The impact of fishing gear on habitat

trend occurs in ten attributes such as Management strategies (MS), Area of overlap (AO), Geographic concentration (GC), Vertical Overlapping (VO), Seasonal migration (SM), Clump or custom response (CR), Morphology affect catches (MC), Survival after capture (SC)), Economic value (EV) and The Impact of Fishing gear on habitat (IF). Interestingly, the Fishing Mortality (F) attribute has a different score between black groupers and red groupers. Red groupers have lower F scores than black groupers. Red groupers have a value of 2 while black groupers have a score of 3.

The PSA analysis result indicate that productivity and susceptibility attributes of each fish are shown in Fig. 5.

The analysis result in Fig. 5, which refers to the modification shown by PSA Software indicate that number 1 and 2 shows the types of fish where 1 is the red groupers and number 2 is the black ones. The green color is the quality of data which the yellow color of the plot of each fish shows enough reliable data quality. The analysis results on productivity and susceptibility attributes of red groupers are at 1.8 and 2.08, respectively for susceptibility level and productivity score, while the productivity of black groupers is 1.7 and its susceptibility is 2. (Fig. 5).

The susceptibility index of red and black groupers in this research was obtained from the formula of productivity and susceptibility attribute of each fish presented in Table 5.

In this study, productivity is the ability of a resource to sustain the population under threat due to a decrease in the stock because of fishing pressure. Productivity of a species or stock-based life story traits that determine whether a species could sustain or recover from fishery-related impacts. (Hobday *et al.,* 2007; Dudi *et al.,* 2019). While, Stobutzki *et al.* (2001) define "productivity" as the capacity of a species to recover once the population is depleted. According to Smith *et al.* (2007) and Hobday *et al.* (2011), productivity and susceptibility analysis is semi-quantitative in nature but it relies on a good scientific basis. Based on the analysis, the productivity attribute values obtained the maximum length (L∞) in which red groupers reached 82.3 cm with the growth coefficient (k) was 0.89 per year, while the results of another study conducted by Prasetia (2010) report that red groupers (*P. leopardus*) in Lasongko waters have long infinity (L∞) of 75.70 mm with the growth coefficient (K) 0.21 per year, while different research (Landu,2013) indicates that red groupers in

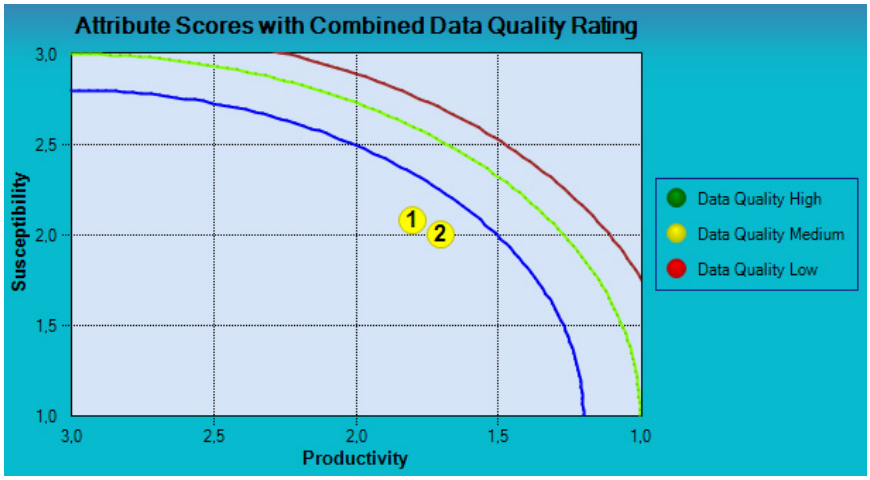

Fig. 5: The results of the susceptibility and productivity analysis of red and black groupers.

Table 5: Susceptibility index of red and black Groupers at Wakatobi National Park

susceptibility	Name of fish	
	Plectropomus leopardus	*Plectropomus areolatus*
Value	1.61	1.64
Category	Moderate susceptibility	Moderate susceptibility

Kolaka, South-East Sulawesi reached a maximum length of 92.40 cm with the growth coefficient (k) 0 , 75 per year. In the eastern Torres Strait island, the growth parameter of red tiger groupers (P. *leopardus*) is L∞ of 746 mm in length with a growth coefficient (K) of 0.07 (Williams, 2008; Pet *et al.,* 2006). While Ernaningsih *et al.* (2014) report that P. *leopardus* in Sarappo and LumuLumu Island was dominated by 22,5 cm groupers, while, in Langkai Island was 37,5 cm. Ebisawa, (2013) affirms that *Plectropomus leopardus* in the Okinawa Islands was estimated at L ∞ 61.2 cm FL, k 0.289, and t^0 0.41, respectively. The results of the five locations show differences in maximum length and the coefficient of growth with a red groupers in both research locations. This difference can be caused by internal factors, such as environmental factors and the difference in the respective locations. This is supported by Pauly (1984) and Henriques *et al.,* (2012) who state that the same fish species and live in different water locations will experience different growth because of factors within and outside factors that affect the growth of the fish. Generally, such factors as it is difficult to control some factors like heredity, gender, age, and disease, while the main external factors that affect fish growth are temperature and food. The coefficient of fish growth can describe its range of age, so in this recent study, red groupers are 4.66 years old. In line with, Pauly (1984) and Mudjirahayu *et al*. (2017) states that the value of the growth coefficient can be used to predict the maximum age of the fish. Based on the analysis in this study, the value of the growth coefficient of red groupers tend to be high because it has long lifespan. Age and growth of the fish population are dynamics parameters which have an important role in the assessment of fish stocks. Growth is the length or weight within a certain period. Knowledge of the aspects of the age and growth of fish stocks being exploited is investigated in order to be used as one of the basic considerations in managing the stocks due to the success and future of the fisheries sector relies on the addition of new individuals and composition of age classes of fish stocks as the fishery target throughout the year (Ricard *et al.,* 2012). Based on the mortality analysis, red groupers natural mortality takes up 0.19 and catching mortality is up to 1.1. This value indicates that red groupers' fishing mortality is greater than its natural mortality, whereas the results of another study conducted by Prasetya (2010), reports the red groupers' natural mortality in Lasongko is 0.49 and capture greater mortality is 0.52. In addition, Landu (2013) argues that the rate of natural mortality on red groupers in Kolaka is 0.60 while deaths from catching is bigger up to 1.30. Based on the mortality of red groupers from three different locations, they show similarities on the level of utilization where the mortality rate due to fishing activities is greater than its natural death. While the red groupers mortality in this study site shows a difference with the results in another location, it is due to the different utilization levels in the respective locations. This is supported by Gulland (1969) and Kiyaga *et al*. (2014) who states that the fishing mortality rate is due to the exploitation of a stock because of human activities such as fishing activities during a certain period, all the causes of death affect the population. While the annual death natural cause is an opportunity where the dead fish by natural processes is observed (Gulland 1969 and Kiyaga *et al*. (2014). The mortality rate is a measure of the fish deaths at certain time intervals. Natural mortality is mortality caused by predation, disease, stress, spawning, hunger and old age. Predation is a common external factor as a cause of natural mortality. The value of the natural mortality rate is associated with von Bertalanffy growth parameter values, namely K (growth coefficient) and L∞ (theoretical maximum length of a type of fish). Fast-growing fish has a high natural mortality rate (M). Natural mortality is associated with L∞ because the predators for larger fish and it is less for smaller fish because they easily prey to other fish species (Sparre *et al.,* 1999; Mudjirahayu, *et al*., 2017). Based on the longitudinal research results, black groupers obtained the maximum length of 76 cm with the value of the growth coefficient (k) of 0.80 per year, while Patanda *et al.* (2017) argues that the maximum length of black grouper in Wangi-Wangi island is 80 cm with the growth coefficient (k) is 0.4 per year. In line with Williams *et al.* (2008) state that the growth of black groupers (P. areolatus) in the eastern part of the Torres Strait, Australia has long infinity (L∞) up to 764 mm with the growth coefficient (K) is 0:09 each year. Yulianto *et al.* (2015) found P. *areolatus* at Karimunjawa National Park with 25 cm length. The results of the three different locations indicate that the difference in the maximum length and the growth coefficient of groupers in this research can be caused

by internal factors such as type of fish and environmental conditions in each location. Gulland (1969) and Kiyaga *et al*. (2014) also states that the growth is defined as the increase of the length and the weight in time. Internal factors are usually difficult to control because they are derived from from the genetics of a species, such as heredity, sex, age, and disease. The main external factors affecting the fish growth are food and water temperature. Additionally, Gulland (1969) and Kiyaga *et al*. (2014) points out that several indicators affecting the fish growth arenumber and size of the food available, temperature, dissolved oxygen, water quality, age and amount of oxygen and gonad maturity. Furthermore, it is said also that the old fish is growing faster than the younger ones. The maximum age of the black groupers indicates long enough age range, reaching 4.90 years. Black groupers generally have a long life. Cook *et al.* (2009) shows that based on radiocarbon measurements groupers live for at least 40 years. It can be inferred from the size of a long fish with fish growth coefficient tends to be high. This is supported by Sparre *et al.* (1999) and Mudjirahayu *et al*. (2017) who suggest that if the fish has the high growth rate coefficient (k) it has a higher growth rate and usually the fish requires a short time to reach a maximum length, whereas fish with low coefficient, takes a long time to reach the maximum length, then tend to live longer. Based on the results obtained, the natural mortality value for black grouper is 0.18, while the fishing mortality is 0.56. The difference value indicates that the black groupers have a mortality rate as a result of fishing activity greater than a natural death. The same case can also be seen on the red groupers at Teluk Cendrawasih National Park, Papua undertaken by Bawole (2017) who reports that the natural mortality of black groupers showed a low value is 0.75 while the capture mortality was 0.86. Based on the black groupers mortality rate in this study, it showsthe same utilization level for each location which indicates that deaths from fishing activity are more frequent than the natural death. This condition occurs due to the high level of utilization carried out by the fishermen. Mortality can be defined as the number of creatures dying during the interval of time. Mortality is divided into two groups: natural mortality (M) and fishing mortality (F). Natural mortality is mortality caused by factors other than the arrest as cannibalism, predation, stress at spawning time, hunger and old age. The same species usually have different capabilities depending on the density of predators and competitors affecting the process. High natural mortality is found in organisms which has high growth coefficient rate and vice versa. Low natural mortality is obtained in organisms who has a similar growth rate coefficient (Sparre *et al.,* 1999; Mudjirahayu, *et al*., 2017). The trophic level implies that the fish belongs to the consumer level in the food pyramid. The lower the fish trophic level, the greater productivity level is. Stocks with low productivity and high susceptibility are considered susceptible to over-fishing, while stocks with high productivity and low susceptibility are then the least vulnerable (Patrick *et al.,* 2009). The susceptibility of fish is a situation describing the certain fish which experience fishing pressure. When the fishermen are fishing excessively, it will lead to a high pressure so that it will threaten fish resources. Sterner (2007) spells out that fish stocks can be threatened by the over-fishing. Based on these results, the productivity and susceptibility attributes of red and black groupers indicate low productivity and high susceptibility (Fig. 5). The productivity level of red groupers is at 1.8 and the susceptibility at 2.08, while the black groupers have 1.7 for the productivity level and 2 for their susceptibility. Based on the susceptibility analysis on both fish types, each index indicates that red groupers are at 1.61 and the black groupers are at 1.64. Based on the susceptibility index, both groupers are categorized in moderate susceptibility level. This category refers to Patrick *et al.* (2009) who states that fish with a value equal to the susceptibility of 1.6 to 1.8 indicates that the fish has a medium risk susceptibility to fishing activities. Accordingly, this study illustrates that red and black groupers caught at Wakatobi National Park have been experiencing fishing pressure so as to enable its unsustainable utilization. The cause of high susceptibility is caused by various factors. For instance, the internal factor is the fish cannot be renewable, while the high fishing pressure is considered as external factor. Susceptibility to a power source can be minimized with the perpetration of a fishery management. Such management involves limiting the number of fishing activity, keeping an eye on the number of fishing efforts and systematically collecting data on catches

as well as providing complete information about fish biology. In addition, it is necessary to limit the number of catches especially for small fish. This supervision is important because the red and black groupers are the export commodities which are very demanding in the market. This paper has argued that this research aims to determine the productivity and susceptibility level of red and black groupers caught at Wakatobi National Park. This study has shown that red and black groupers found at Wakatobi National Park are indicated to have a high risk of susceptibility against fishing activities. It depicts that the fish has experienced fishing pressure so that it is necessary to have a sustainable effort to manage and maintain the fishing activities. In these cases. Robinson *et al.* (2014) recommend taking a holistic approach to assess the risks posed to reef fish aggregations by fishing, grounded in the principals of fisheries science and emerging social-ecological thinking. Furthermore, Hoffman *et al.* (2010) also argue that without conservation efforts, the rate of loss would have been significantly higher. It is thus critical to continue focusing on conservation management efforts for all animal groups even in the face of such dire estimates of extinction risk of a global scale. Meanwhile, Grafton *et al.* (2006) contend that much greater emphasis must be placed on fisher motivation when managing fisheries. Furthermore, Rhodes *et al.* (2013) declare that catch restrictions on adult groupers, during spawning times, at reproductive sites, combined with gear-based management, and enhanced enforcement, are recommended to maintain spawning stocks. The result of this research supports the idea of the effort for managing the sustainability of groupers; 1) apply the system to open-close fishing activity in spawning of the grouper; 2) apply the control of fish-size catches to give the opportunity of grouper to be adult and spawn for minimum once; 3) Take into account the legalization system with open-close-fishing policy; 4) Participation of local fishermen is a must in order to design and implement the open-close-fishing system.

CONCLUSION

Fishermen tend to catch many types of fish in Wakatobi, but the highest number of fish captured is red and black groupers. This is due to the high market demand so that the value of sales continues to increase; this is what drives the grouper's fishermen to continue to exploit these resources in an uncontrolled way leading to threaten the existence of this grouper type. This study aims to determine the susceptibility level of red and black groupers captured at Wakatobi National Park using PSA software version 1.4.0.0. PSA is considered as the most appropriate approach applied to the fishery issue with inadequate data, such as limited data for captured fish and time series' effort. PSA has now been extended, and it focuses on an ecosystem-based approach to fisheries management. Based on the results, it shows the productivity level of red grouper up to 1.8 and susceptibility level taking up to 2.08, while the black grouper is at 1.7 for the productivity level and at 2 for susceptibility. Based on the susceptibility index, it shows that the red grouper is at 1.61 and the black grouper is at 1.64 which means that both types are categorized in a moderate level of susceptibility. This can illustrate that the red and black grouper captured at Wakatobi National Park experienced fishing pressure because of the unsustainable use of fishing gear. Some managerial strategies to be taken into consideration are to limit the number of fishing activities, monitor the number of fishing efforts and systematically collect data on fish captured as well as provide complete information about fish biology such as the legal size of fish worth catching and supervise closely the grouper catching system considering the groupers are the export commodity which is in high demand by the market.

ACKNOWLEDGEMENTS

Authors would like to thank the Republic of Indonesia Ministry of Technology and Higher Education for financial support research with PDUPT-2019 scheme on managing the sustainability of groupers in the Wakatobi National Park with grant number [171/SP2H/LT/DRPM/ 2019]. Finally, thanks to all students who helped the researcher with data collection throughout the current study.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

%	Percentage
AO	Areas of overlap
CPUE	Catch per unit effort
CG	The coefficient of growth
CR	Clump or custom response
cm	Centimeter
^oC	degrees Celsius
EV	E Economic value
Eq.	Equation
Fig.	Figure
FL	Fork length
F	Fishing mortality
F	Fecundity
GC	Geographic concentration
gr	Grain
IF	The impact of fishing gear on habitat
K	Growth coefficient
$L\infty$	Asymptotic length of fish
log $(-t^0)$	Logarithm of Age of the fish at the time of the length is equal to zero
log K	Logarithm of growth coefficient
log $L\infty$	Logarithm of asymptotic length of fish
ln	Natural logarithm
ln $L\infty$	Natural logarithm of asymptotic length of fish
ln K	Natural logarithm of growth coefficient
ln T	Natural logarithm of temperature
MSC	Marine Stewardship Council
MA	Maximum age
M	Natural mortality
ML	Maximum length
MC	Morphology affect catches
MG	The first measure mature gonads
MS	Management strategies
mm	Millimeter
NEFSC	Northeast Fisheries Science Center
PSA	Productivity and susceptibility analysis
p	Productivity
PR	The pattern of recruitment
RS	Reproductive strategies
s	Susceptibility
SSB	Spawners of biomass
SM	Seasonal migration
SC	Survival after capture
T	*Average temperature of the surface of the water (^oC)*
TL	Trophic level
t	*Age of the fish*
tmax	*Maximum of age of the fish*
t^0	*Age of the fish at the time of the length is equal to zero*
v	*Overall score of susceptibility*
VO	Vertical Overlapping
Z	Total mortality rate

REFERENCES

Arrizabalaga, H.; De Bruyn, P.; Diaz, G. A.; Murua, H.; Chavance, P.; de Molina, A. D.; Kell, L.T., (2011). Productivity and susceptibility analysis for species caught in Atlantic tuna fisheries. Aquat. Living Resour., 24: 1–12 **(12 pages).**

Bawole, R., Rahayu, M., Rembet, U.N., Ananta, A.S., Runtuboi, F., Ridwan, S., (2017). Growth and mortality rate of the Napan-Yaur Coral Trout, Plectropomus leopardus (Pisces: Serranidae), Cenderawasih Bay National Park, Indonesia.biodiv Vol : 18 (2). **(6 pages).**

Bellwood, D.R.; Meyer, C.P., (2009). Endemism and evolution in the Coral Triangle: a call for clarity. J. Biogeogr., 36(10), **(12 pages).**

Bellwood, D.R.; Wainwright, P.C., (2002). The history and biogeography of fishes on coral reefs. Coral reef fishes: Dynamics and diversity in a complex ecosystem, 5: 32 **(27 pages).**

Cook, M.; Fitzhugh, G. R.; Franks, J.S., (2009). Validation of yellow edge grouper, Epinephelus flavolimbatus, age using nuclear bomb-produced radiocarbon. Environ. Biol. Fish 86: 461–472 **(12 pages).**

Cortes, E.; Arocha, F.; Beerkircher, L.; Carvalho, F.; Domingo, A.; Heupel, M.; Holtzhausen, H.; Santos, M. N.; Ribera, M.; Simpfendorfer, C., (2010). Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. Aquat. Living Resour., 23: 25–34 **(10 pages).**

Dudi, T.J.; Tadjuddah, M.; Arami, H., (2019). Productivity and susceptibility analysis of yellowfin tuna (Thunnus Albacares) landed at sodohoa fishing base, Kendari City, Indonesia. IOP Conference Series: Earth and Environmental Science Conference. Volume 253 **(8 pages)**.

Ebisawa, A., (2013). Life history traits of leopard coral grouper Plectropomus leopardus in the Okinawa Islands, southwestern Japan. Fish Sci., 79: 911–921 **(11 pages).**

Ernaningsih.; Budimawan.; Natsir Nessa.; Sudirman., (2014). Biology population and exploitation rate of coral trout (plectropomus leopardus) spermonde island south Sulawesi. Aust. J. Basic Appl. Sci., 8: 438-444 **(7 pages).**

Fishbase, (2019). FishBase mirror: Kiel, Germany mirror: Kiel, Germany.

FAO, (1995). Code of Conduct for Responsible Fisheries. FAO, Rome.

FAO, (2011). EAF planning and implementation tools. Productivity Susceptibility Assessments (PSA). EAF Tool fact sheets. Text by EAF Toolbox Team. Rome.

FAO, (2018). The State of World Fisheries and Aquaculture. Meeting the sustainable development goals. Rome. License: CC BY-NC-SA 3.0 IGO. (**227 pages**).

Furlong-Estrada, E.; Galván-Magaña, F.; Tovar-Ávila, J. (2017).

Use of the productivity and susceptibility analysis and a rapid management-risk assessment to evaluate the vulnerability of sharks caught off the west coast of Baja California Sur, Mexico. Fish Res., 194. 197–208. **(12 pages).**

Grafton, R.Q, ; Ragnar A.; Trond Bj.; David C., Harry F.C.; Colin W. C.; Robin C.; Diane P.D.; Rögnvaldur H.; Ray H.; James E. K.; Tom K.; Daniel E.L.; Gordon R. M.; Sean P.; Dale S.; Stein I. St.; Bruce R. T.; Quinn W., (2006). Incentive-based approaches to sustainable fisheries. Canad J. Fish Aquatic Sci., 6: 699-710 **(12 pages).**

Gulland, J.A., (1969). Manual of methods for fish stock assessment. Part 1. Fish population analysis **(325 pages).**

Henriques, P.; Sousa, R.; Pinto, A. R.; Delgado, J.; Faria, G.; Alves, A.; Khadem, M. (2012). Life history traits of the exploited limpet Patella candei (Mollusca: Patellogastropoda) of the north-eastern Atlantic. J. Marine Biol. Assoc. UK. 92(6): 1379–1387 **(9 pages).**

Hobday, A.J.; Smith, A.D.M.; Stobutzki, I.C.; Bulman, C.; Daley, R.; Dambacher, J.M.; Griffiths, S.P., (2011). Ecological risk assessment for the effects of fishing. Fish Sci., 108: 372-384 **(13 pages).**

Hobday, A.J.; Smith.; A.D.M.; Webb, H.; Daley, R.; Wayte, S.; Bulman, C.; Dowdney, J.; Williams, A.S.M.; Dambacher, J.; Fuller, M.; Walker, T., (2007). Ecological risk assessment for the effects of fishing: Methodology report r04/1072 for the Australian Fisheries Management Authority, Canberra **(174 pages).**

Hoffmann, M.; Hilton, T.C.; Angulo, A.; Böhm, M., Brooks, T.; M., Butchart; S.H.; Darwall, W.R., (2010). The impact of conservation on the status of the world's vertebrates. Science, 330: 1503-1509 **(7 pages).**

Kiyaga, V.B., Perker, M.; Manasirli, M., (2014). Reproduction, growth, mortality and exploitation rate of penaeus semisulcatus de haan, 1844 (decapoda, penaeidae) from iskenderun bay (northeastern mediterranean*).* Crustaceana, 87(4): 385–400 **(16 pages).**

Landu A., (2013). Growth, the rate of exploitation and reproduction of grouper groupers (Plectropomus leopardus) in the waters of Kolaka Regency, Southeast Sulawesi. [Thesis]. Bogor Agriculture Institute, Bogor. [Indonesia].

MSC, (2019). Risk-based framework'. Marine Stewardship Council. London.

Mudjirahayu, Bawole, R.; Rembet, U.N.W.J.; Ananta, A.S.; Runtuboi, F.; Sala, R., (2017). Growth, mortality and exploitation rate of Plectropomus maculatus and P. oligocanthus (Groupers, Serranidae) on Cenderawasih Bay National Park, Indonesia. Egypt. J. Aquatic Res., 43(3): 213–218 **(6 pages).**

Patanda, M.; Wisudo, S.H.; Monintja, D.R.; Wiryawan, B., (2017). Sustainability for reef fish resource based on productivity and susceptibility in Wangi-Wangi Island, Southeast Sulawesi, Indonesia. AACL Bioflux, 10: 861-874 **(14 pages).**

Patrick, W.S.; Spencer, P.; Ormseth, O.; Cope, J.; Field, J.; Kobayashi, D.; Gedamke, T.; Cortes, E.; Bigelow, K.; Overholtz, W.; Link, J.; Lawson, P., (2009). Use of productivity and susceptibility indices to determine stock vulnerability, with example applications to six U.S. fisheries. Dep. Commer., NOAA tech. memo. nmfs-f/Spo-101: **(90 pages).**

Patrick, W.S., Spencer, P., Link, J., Cope, J., Field, J., Kobayashi, D., Lawson, P., Gedamke, T., Cortés, E., Ormseth, O., Bigelow, K., Overholtz, W., (2010). Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. Fish. Bull., 108: 305–322 **(17 pages).**

Pauly, D., (1984). Fish Population dynamics in tropical waters: a manual for use programmable calculators. ICLARM studies and reviews 8, Manila, World Fish **(325 pages).**

Pet, J.S.; Mous, P.J.; Rhodes, K.; Green, A., (2006). Introduction to monitoring of spawning aggregations of three grouper species from the Indo-Pacific. A manual for field practitioners. Version 2.0, Indonesia, (**98 pages)**.

Ponte, S., (2012). The Marine Stewardship Council (MSC) and the making of a market for 'sustainable fish. J. Agrarian Change. 12(2-3), **(15 pages).**

Prasetya, R., (2010). Potential and exploitation rate of grouper in gulf of Lasongko, Buton, Southeast Sulawesi. [Thesis]. Bogor Agricultural Institute. [Indonesia].

Rhodes, K.L.; Taylor, B.M.; Wichilmel, C.B.; Joseph, E.; Hamilton, R.J.; Almany, G.R., (2013). Reproductive biology of squaretail coral grouper Plectropomus areolatus using age-based techniques. J. Fish Biol., 82: 1333-1350 (**17 pages**).

Ricard, D.; Coilin, M.; Olaf, P.J.; Julia, K.B., (2012). Examining the knowledge base and status of commercially exploited marine species with the ram legacy stock assessment. Fish and fisheries, 13: 380-398 **(19 pages).**

Robinson, J.; Cinner, J. E.; Graham, N. A. (2014). The influence of fisher knowledge on the susceptibility of reef fish aggregations to fishing. PloS one, 9(3), **(14 pages).**

Sadovy, Y.; de Mitcheson, Y.; Craig, M. T.; Bertoncini, A. A.; Carpenter, K. E.; Cheung, W.W.L.; Choat, J. H., Cornish; A. S.; Fennessy.S. T.; Ferreira, B. P.; Heemstra, P. C.; Liu, M.; Myers, R. F.; Pollard, D. A.; Rhodes, K.L.; Rocha, L. A.; Russell, B.C.; Samoilys, M.A.; Sanciangco, J., (2012). Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. Fish Fisheries 14: 119–136 **(17 pages).**

Smith, A.D.M.; Fulton, E.J.; Hobday, A.J.; Smith, D.C.; Shoulder, P., (2007) Scientific tools to support the practical implementation of ecosystem m-based fisheries management. ICES J. Mar. Sci., 64: 633–639 **(7 pages).**

Sparre, P.E. Ursin; Venema, S.C., (1999). Introduction to tropical fish stock assessment. FAO. Rome part 1 **(227 pages).**

Sterner T., (2007). Unobserved diversity, depletion and irreversibility the importance of subpopulations for management of cod stocks. Ecolecon., 61: 566–574 **(9 pages).**

Stobutzki, I.; Miller, M..; Brewer, D., (2001). Sustainability of fishery by catch: a process for assessing highly diverse and numerous by catch. Environ. Conserv., 28: 167-181 **(14 pages).**

Williams, A.J.; Currey, L.M.; Begg, G.A.; Murchie, C.D.; Ballagh, A.C., (2008). Population biology of coral trout species in eastern Torres Strait: Implications for fishery management. Continental Shelf Res., 28: 2129–2142 **(13 pages).**

Yulianto, I.; Hammer C; Wiryawan, B.; Harry, H.W., (2015). Fishing-induced groupers stock dynamics in Karimunjawa National Park, Indonesia. Fish Sci., 81: 417–432 **(15 pages).**

Zhou, S.; Griffiths, S.P., (2008). Sustainability assessments for fishing effects (safe): a new quantitative ecological risk assessment method and its application to elasmobranch by catch in an Australian Trawl fishery. Fish Res., 91: 56-68 **(13 pages).**

AUTHOR (S) BIOSKETCHES

Tadjuddah, M., Ph.D., Associate Professor, Department of Fisheries Capture, Fisheries and Marine Sciences Faculty, University of Halu Oleo, Kendari, southeast Sulawesi Province, Indonesia. Email: *muslim22jan@uho.ac.id*

Abdullah, M.Sc., Assistant Professor, Department of Fisheries Capture, Fisheries and Marine Sciences Faculty, University of Halu Oleo, Kendari, southeast Sulawesi Province, Indonesia. Email: *abdullah@uho.ac.id*

Kamri, S., M.Sc., Assistant Professor, Department of Fisheries Capture, Fisheries and Marine Sciences Faculty, University of Halu Oleo, Kendari, southeast Sulawesi Province, Indonesia. Email: *syamsulkamri@uho.ac.id*

Wianti, N.I., M.Sc., Assistant Professor, Department of Extension Agriculture, Agricultural Faculty, University of Halu Oleo, Kendari, Southeast Sulawesi Province, Indonesia. Email: *wianti.ni@uho.ac.id*

COPYRIGHTS

© 2020 The author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers.

HOW TO CITE THIS ARTICLE

Tadjuddah, M.; Abdullah; Kamri, S.; Wianti, N.I., (2020). The susceptibility level and sustainability potential of groupers; Plectropomus sp. in a marine national park. Global J. Environ. Sci. Manage., 6(1): 119-132.

DOI: 10.22034/gjesm.2020.01.10

url: https://www.gjesm.net/article_36527.html