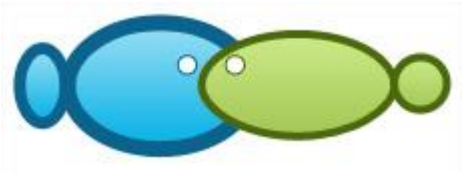

Determination of potential fishing zones of areolate grouper (*Epinephelus areolatus*) based on analysis of productivity, gonad maturity and fish length in Karimunjawa National Park, Indonesia

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Abstract. Areolate grouper (*Epinephelus areolatus*) is one of the superior commodities of capture fisheries in Karimunjawa waters. Traditional fishermen have not considered the composition of fish length in determining the potential fishing zones. The main orientation of fishermen is to increase catches as much as possible (profit-oriented) without considering the carrying capacity of the environment. This study aimed to determine the potential fishing zones of *E. areolatus* in Karimunjawa waters through analysis of the catch productivity, gonad maturity and fish length composition. Data related to the fishing spot, fishing operation time, fish length, gonad maturity, catches, and fishing effort was collected through the experimental fishing method. Samples of fish were dissected to retrieve the gonads, then the weight, color, shape, size, and softness of the gonads were observed. Gonad maturity level analysis was used as a reference to determine the fish length in the biologically feasible category (legal size). The productivity level was determined through the analysis of catch per unit effort (CPUE). Appropriate criteria for an indicator of productivity and fish length composition then were used as a basis for determining the category of fishing ground (potential, moderate, or less potential fishing zone). The highest productivity was found at nine fishing spots, namely around the southwest of Nyamuk, east of Genting, north of Laut Jawa, Genting Seruni, Krakal, Menjangan, Parang Kembar, southeast of Karimunjawa, and Gundul. The catches of *E. areolatus* in Karimunjawa waters were dominated by illegal size categories (65%) and only 35% of the catches corresponded to legal-size categories. The legal size category was found only in two fishing spots, namely around Genting Seruni and Sintok waters. The spatial distribution for less potential fishing zone category was more than (18 spots) potential fishing zone category (2 spots).

Key Words: capture fisheries, CPUE, fishing spot, legal size, potential.

Introduction. Karimunjawa National Park consists of several zones, namely: the core zone, protection, tourism, rehabilitation, mariculture, and traditional fisheries zone. The traditional fisheries zone is allocated for fishing activities because the zone has quite a good potential of reef fish, including *Epinephelus areolatus,* which is a superior commodity in Karimunjawa (Simbolon et al 2016), with an important role in the traditional fishermen income increasing.

Traditional fishermen in Karimunjawa generally use fishing gear with handline, trap, and spear for catching the reef fish (Simbolon et al 2016). They assume fish resources found throughout this region can be exploited without regard to the carrying capacity of the available resources. The main target of fishermen is to increase the catches as much as possible without considering the biological characteristics of fish species (Maksum 2005). This condition shows that the utilization of fish resources (including *E. areolatus*) in the traditional fishing zone of Karimunjawa has not been carried out optimally and it threatens the sustainability of fish resources and also the continuity of the capture fisheries business in the future.

Biological aspects of fish such as length and gonad maturity are very important in fisheries resource management (Gulland 1983). This relates to the determination of the legal size of catch or biologically feasible category, used as a basis for the resources management (Suwarni 2009). Furthermore, Yusuf (2013) stated that the length at first maturity is one of the main references in determining the category of biologically feasible and legal size. Catches dominated by the legal size category will not impact on reducing the amount of spawner stock. On the other hand, the catches dominated by juvenile or illegal size categories will drastically reduce spawner stocks and also the rate of recruitment. Related to this problem, Simbolon (2017) has suggested that information about the fish length and gonad maturity level should be considered in determining potential fishing spots, besides catch productivity. This condition shows that in the determination of potential fishing zones there is not only considered the fish abundance (catch productivity) but also the dominance of legal size, therefore the fish length variable should have a higher priority than the catch productivity in the determination of a potential fishing zone.

Based on the description above, the gonad maturity level relationship to the length of the *E. areolatus* needs to be urgently examined for the biologically feasible category determination, before the Karimunjawa waters becoming intensively exploited. Determination of the length size of *E. areolatus* that can be caught (legal size) needs to be evaluated as a protection of the capacity of fish reproduction, preventing the degradation of traditional fishing zones in the Karimunjawa waters. Minsaris (2013) also consider that the implementation of management strategies by determining the allowable minimum length to be caught will make fish stock resistant to the high pressure of fishing activities. The catches that dominated by illegal size are likely to cause degradation of fish resources, especially when the amount of catches is abundant, while the dominance of legal size will not negatively impact fish resources.

Restriction on the fish length that allowed to be caught is intended to maximize the opportunity for fish to spawn before being caught. Therefore, it is important to analyze the gonad maturity level to determine the legal size category for *E. areolatus*. This is in line with the opinion of Effendie (1997) that the fish length can be used as an estimator of the gonad maturity level and fish reproduction status. However, information about the length size composition relationship to the gonad maturity level of *E. areolatus* is still limited in Karimunjawa waters.

This study aims to determine the potential fishing zones of *E. areolatus* in the Karimunjawa waters based on catch productivity and fish length composition analysis. The results of this study are intended to serve as a recommendation to the fishermen and to the policy makers in in determining potential fishing zones and the minimum length allowed for *E. areolatus* fishing.

Material and Method

Time and location. The study was conducted in Karimunjawa waters, Jepara Regency, Central Java Province (Figure 1) with two stages of data collection. The first stage was conducted on November 2015 at the coastal fishing port of Karimunjawa, by collecting data on fishing spots, directly sourced from the fishermen and catch rate comprising fish length and gonad maturity of *E. areolatus,* from a large catch rate. The second stage was conducted in February 2016 to process data similar to the first stage, which was sourced from the Wildlife Conservation Society (WCS 2015) for the period January 2010-October 2015.

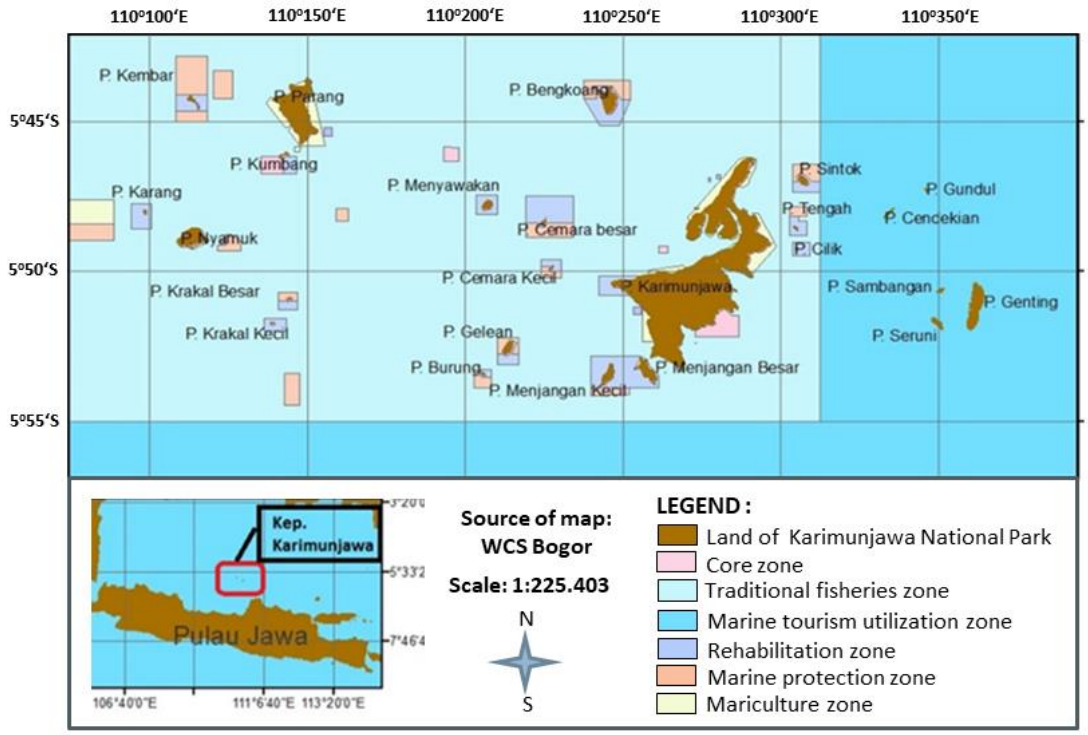

Figure 1. Research location of Karimunjawa waters, Jepara Central Java.

Data collection. Primary data were obtained through direct observation of fishing activities. The number of boats that land their catches at the coastal fishing port of Karimunjawa was only 1-2 boats every day, so data on the position of fishing spots, and the kind of fishing gear used can be obtained directly. The catch rate was only about 15 *E. areolatus* per day during the study so that all the individuals could be measured in length.

In order to increase the data amount and accuracy, the current study processed the results of the observations conducted by WCS during 2010-2015 (WCS 2015), with their approval. Secondary data on the monthly production and fishing effort in the Karimunjawa waters was collected from the relevant agencies, as well as from previous studies, through a literature review.

The length and size data were analyzed descriptively by grouping fish lengths based on class intervals. This is intended to determine the length distribution, average size and length of the dominant caught. The determination of class interval refers to the formula of Walpole (2005).

Data analysis. Fish samples for gonad observation were determined by purposive sampling to represent the entire length. The fish samples were dissected to obtain the gonads. Gonad maturity level from many fish samples was then analysed by observing gonad shape, gonad size, gonad color, and gonad softness (Tester & Takata 1953), as presented in Table 1. Fish that had the gonads were classified into five gonad maturity levels, whereas fish that have not yet the gonad were classified as juveniles (Tester & Takata 1953).

Fishes that have already reached the gonad's maturity were classified as the biologically feasible category or legal size, while fishes that have not yet mature gonads were classified as a biologically not feasible category. Discrimination between legal and illegal size categories, in relation to the biological appropriateness, refers to the criteria used by Simbolon & Girsang (2009) and also by Wujdi et al (2013), as follows: a category is (1) biologically feasible (legal size) if the fish is longer than the length at first maturity (LM), or (2) biologically non-feasible (illegal size), if the fish is shorter or equal to the length at first maturity.

Table 1

Gonad maturity classification according to Tester & Takata (1953)

Gonad maturity level	*Classification*	*Criteria*
1	Not mature	Gonads are very small like a thread and transparent; their cross section is flat with grey color in males and round with a reddish color in females
2	First mature	Gonads fill a quarter of the body cavity; in male fish they are gray or white and flat, while in female fish they are reddish or yellow and round. Eggs are not visible
3	Half mature	Gonads fill half the body cavity; they are white in male fish and yellow in female fish. The shape of the egg can be seen through the ovary wall
4	Mature	Gonads fill three quarters of the body cavity; white male gonads are filled with white liquid, female gonads are yellow, almost translucent or clear. Eggs begin to appear, Sometimes with subtle pressure on the stomach there will be protruding on the release hole
5	Adult/very mature	Almost the same as the second stage and difficult to distinguish. Male gonads are white, sometimes with brown spots, female gonads are red, soft and eggs are not visible.

The assessment of fishing spots based on the measurement of fish length was done by comparing the populations of fish in the legal size (LS) category with those in the illegal size (IS) category. If the catches were dominated by the legal size category, the fishing spots were classified as a potential fishing zone. Conversely, if the catches were dominated by the illegal size category, the fishing spots were classified as a less potential fishing zone. However, if the catch composition between legal size and illegal size was the same, the fishing spots were classified as moderate fishing zone (Table 2).

Table 2

Assessment of fishing spots through the fish length indicator

Fishing spots	*Criteria*	*Description*
1	LS/IS>1	Potential fishing spot
2	LS/IS=1	Moderate fishing spot
3	LS/IS<1	Less potential fishing spot

Data on the number of *E. areolatus* catch^{-1} and fishing effort were used in calculating the catch per unit effort (CPUE). Before calculating the CPUE, standardization of fishing effort should be done, because the various fishing gears (handline, trap, and spear) have different catching ability. The stages of analysis in this standardization refer to the formula used by Purwaningtyas et al (2006). The result of the calculation of the standardized CPUE was then used as a reference in determining the catch productivity in an observed fishing ground. According to Simbolon & Girsang (2009), if the CPUE in the observed fishing spots are greater than the average CPUE, the fishing spot is categorized as a potential fishing zone. Conversely, if the CPUE in the observed fishing spot is less than or equal to the average CPUE, the fishing spot is classified as less potential fishing zone or moderate potential fishing zone (Table 3).

Table 3

Assessment of fishing spots through CPUE indicator (Simbolon & Girsang 2009)

Fishing spots	*Criteria*	*Description*
1	$CPUE_{-std} > CPUE_{-ave}$	Potential fishing spot
2	$CPUE_{-std} = CPUE_{-ave}$	Moderate fishing spot
3	$CPUE_{-std} < CPUE_{-ave}$	Less potential fishing spot

$CPUE_{-std}$ - average of standardized CPUE at the observed fishing spot; $CPUE_{-ave}$ - average cumulative CPUE.

The fish length indicator was combined with the catch productivity to determine the suitability level and the category of fishing spots as presented in Table 4. Fishing spots were considered as potential fishing zones if the catches were dominated by legal size with a high catch productivity (high CPUE). This means that the fishing spots were financially profitable and the catches did not cause degradation of fish resources. Fishing spots categorized as moderate fishing zone if the catches were dominated by legal size, but with a low CPUE. Fishing spots were considered as less potential fishing zones if the catches were dominated by illegal size, independently of the catch productivity.

Table 4

Assessment of fishing spots by combining indicators of fish length and catch productivity

Fishing spot	*Criteria*		*Fishing spot category*
	Fish length	*Productivity*	
1	LS dominant	High CPUE	Potential fishing zone
2	LS dominant	Low CPUE	Medium fishing zone
3	IS dominant	High CPUE	Less potential fishing zone
4	IS dominant	Low CPUE	Less potential fishing zone

Fishing spots that have been grouped into categories of potential fishing zone, moderate and less potential fishing zone then presented in the form of thematic maps. Thematic maps of the fishing zone were created using ArcGIS software. The presentation of the thematic map was intended to the users, especially traditional fishermen, in order to facilitate the determination of the spatial distribution of fishing zones. Thus the results of this study were expected to be useful for fishermen in their fishing operations planning.

Results and Discussion

Catch productivity of E. areolatus. The variety fish catch at a traditional fishing zone of Karimunjawa waters was dominated by reef fish, namely *E. areolatus*, *Caesio teres* and *Lutjanus campechanus*. Fishing gear type used to exploit these fishes was a handline, trap, and spear. The most catch of reef fish was yellowtail compared to the other two species. However, *C. teres* and *L. campechanus* were not caught continuously during the study, like *E. areolatus*. Therefore, observation of the size and level of gonad maturity was focused on white-tailed grouper. The number of fishing efforts in Karimunjawa is only 5 trips so that the catch rate was only small.

Based on the observations from January 2010 to October 2015, the spatial distribution of fishing spots at Karimunjawa was quite wide (Figure 2). The highest production was found in the southern part of Karimunjawa, while the lowest production was found in the north of Karimunjawa. The difference in the catch rate was not only influenced by the abundance of fish in the waters but also by the magnitude of the fishing effort, expressed in number of trips. In the south of Karimunjawa there were recorded as many as 83 trips, which produced the highest catch rate (117.6 kg $trip^{-1}$). On the other hand, in the northern part of Karimunjawa there were recorded only 5 trips, with a catch rate of only 3.23 kg $trip^{-1}$. The result of this study was in line with the statement of Sriati (2011), that the most influential factors on the catch productivity were: (1) the fishing effort expressed in number of trips, efficiency of the fishing unit and duration of the fishing operations, and (2) the abundance of fish in the waters.

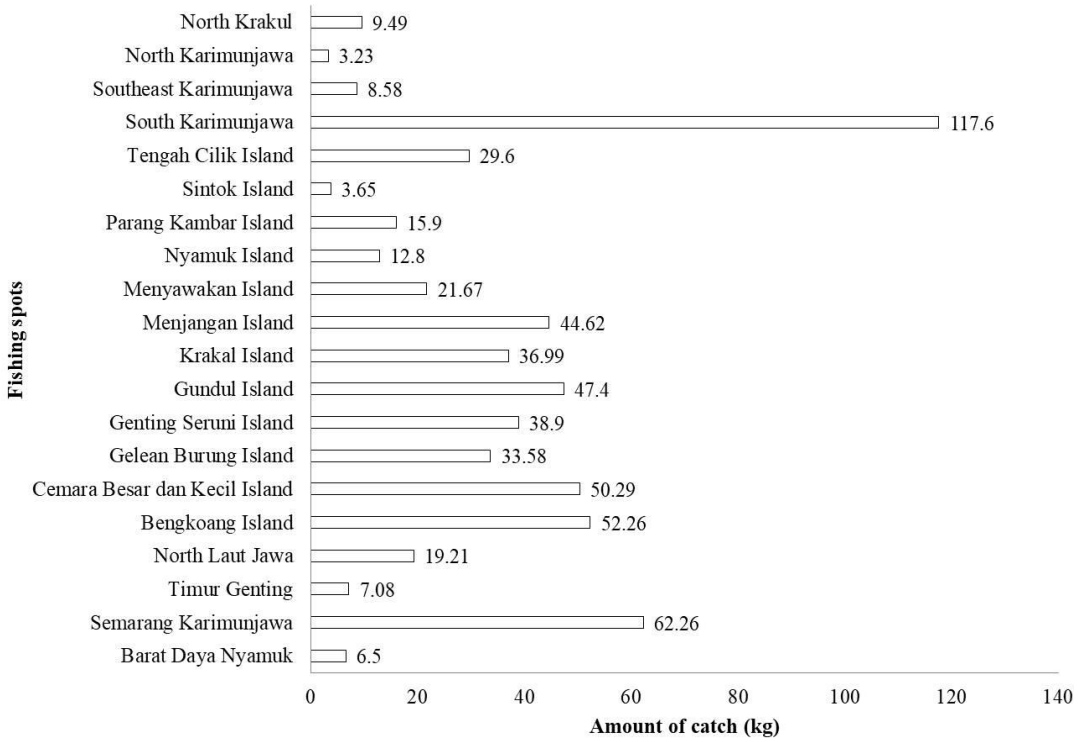

Figure 2. Catch number of *Epinephelus areolatus* landed at the coastal fishing port of Karimunjawa, from January 2010 to October 2015.

The catch productivity level was one of the references used to determine the fishing spots categories that were evaluated in Karimunjawa waters. The CPUE obtained at each fishing spot was compared to the CPUE average. The catch productivity average obtained from 20 fishing spots in Karimunjawa waters from January 2010 to October 2015 was 2.11 kg trip^{-1}. This productivity was smaller than resulted from the direct observation (verification) at 4 fishing spots during the period 17-28 November 2015 (3.92 kg trip^{-1}). Verification was carried out around Pulau Menjangan, southeast of Karimunjawa, Pulau Genting Seruni, and Pulau Cemara.

Spatial distribution of the catch productivity for *E. areolatus* derived observations from January 2010 to October 2015 is presented in Figure 4. The catch productivity of *E. areolatus* fluctuated between 0.65 kg trip^{-1} to 4.83 kg trip^{-1} with an average of 2.1 kg trip^{-1}. The highest productivity was found around Pulau Gundul waters (3.95 kg trip^{-1}), while the lowest productivity was found in the north of Karimunjawa (0.65 kg trip^{-1}). With a reference to the average productivity, fishing spots that were included in the category of potential fishing zones were found at the southwest of Nyamuk, east of Genting, north of Laut Jawa, Pulau Genting Seruni, Pulau Krakal, Pulau Menjangan, Pulau Parang Kembar, southeast of Karimunjawa and Pulau Gundul. The potential fishing zone category was found in 9 areas, and this shows that the spatial distribution for potential zones is narrower than the less potential fishing zone category, namely 11 areas (Figure 3).

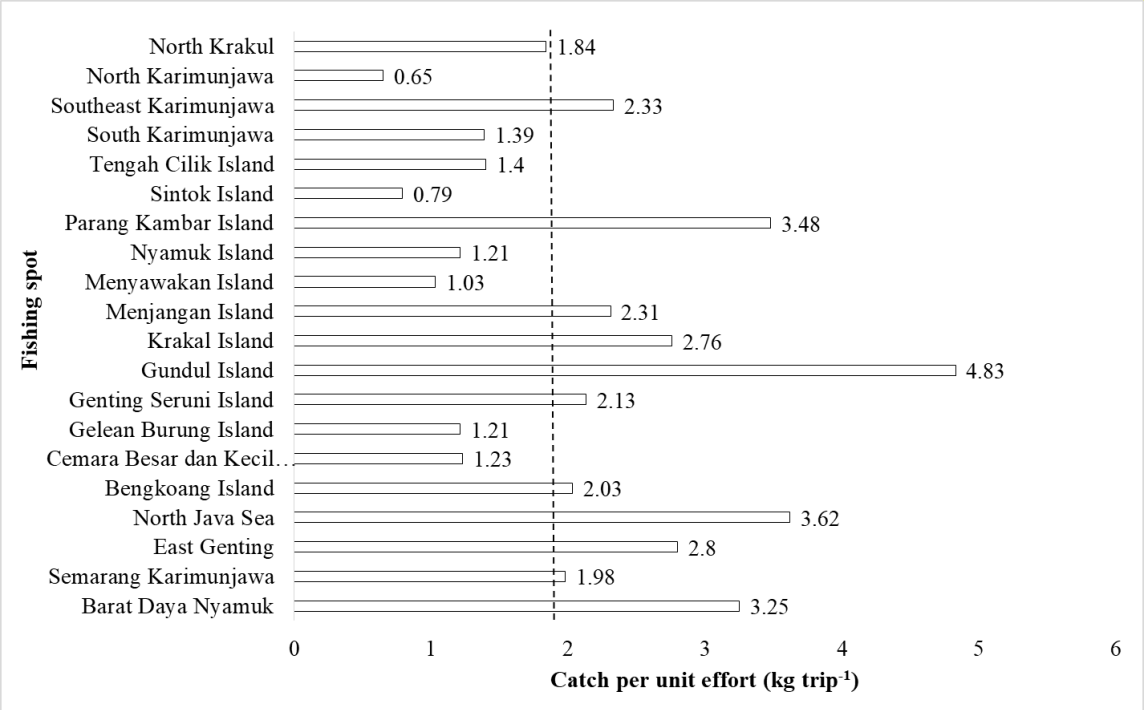

Figure 3. Spatial distribution of the catch productivity (CPUE) for *Epinephelus areolatus* around Karimunjawa waters, from January 2010 to October 2015.

The temporal distribution of *E. areolatus* productivity at Karimunjawa waters tended to fluctuate (Figure 4). This temporal distribution can be assumed as the fishing season, and its peaks occur three times a year, namely in January, April, and September. The presence of the fishing season in January was marked by higher catch productivity (3.25 kg trip^{-1}) compared to 3 months before January (October-December) and 2 months after January (February-March). In April, the fishing season reappeared with catch productivity of 3.20 kg trip^{-1}, but catch productivity tended to be low again for 4 months (May-August). Furthermore, productivity increased sharply back in September up to 3.95 kg trip^{-1} but decreased again during the October to November period. The above conditions indicate that the duration of the fishing season only occurs in a narrow time (one month), but the season occurs three times (January, April, and September) in a year. Darwisito (2002) reported that the peak of the fishing season for *E. areolatus* occurred from November to February. However, Sudjiharno (2004) found that the fishing season of *E. areolatus* around Lampung and Papua waters occurred in the period June to September. Differences in the water characteristics (such as temperature, fertility, salinity, and current of waters) will affect the presence and abundance of fish and subsequently will affect the pattern of the fishing season. Besides, Andriyeni & Zulkhasyni (2015) stated that fishing season indicates the success of fishermen in fishing operations which also depends on the weather conditions and on the catching ability of the fishing gear.

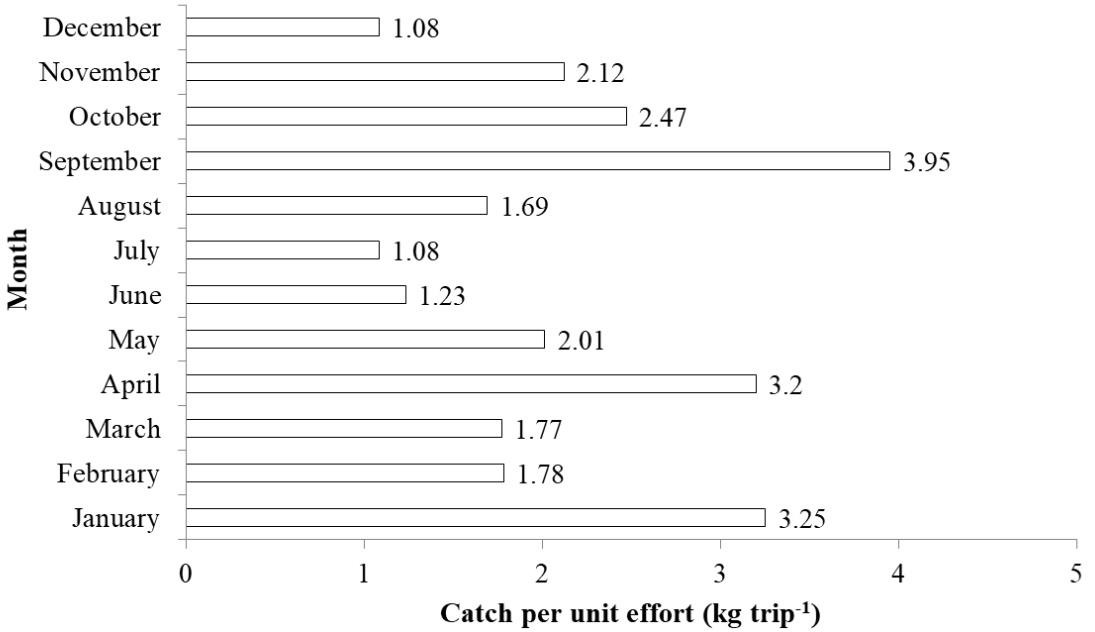

Figure 4. Temporal distribution of the catch productivity (CPUE) for *Epinephelus areolatus* around Karimunjawa waters, on January 2010 to October 2015.

The gonad maturity level of E. areolatus. The gonad maturity level of *E. areolatus* samples was determined based on a result of morphological analysis (Figure 5). The length of *E. areolatus* that already have gonads varies from 18 cm to 51 cm. Gonad maturity level 1 (GML-1) was found in many fish samples with a range of fork length 18-26 cm, GML-2 in the range of 27-32 cm, GML-3 in the range of 33-38 cm, and GML-4 in the range of 39-51 cm, whereas fish samples that had GML-5 were not found in this study. According to Effendie (1997), fish can be considered mature when the gonad has reached GML-3. Based on Effendie's statement, the length at first maturity for *E. areolatus* from Karimunjawa waters was 33 cm.

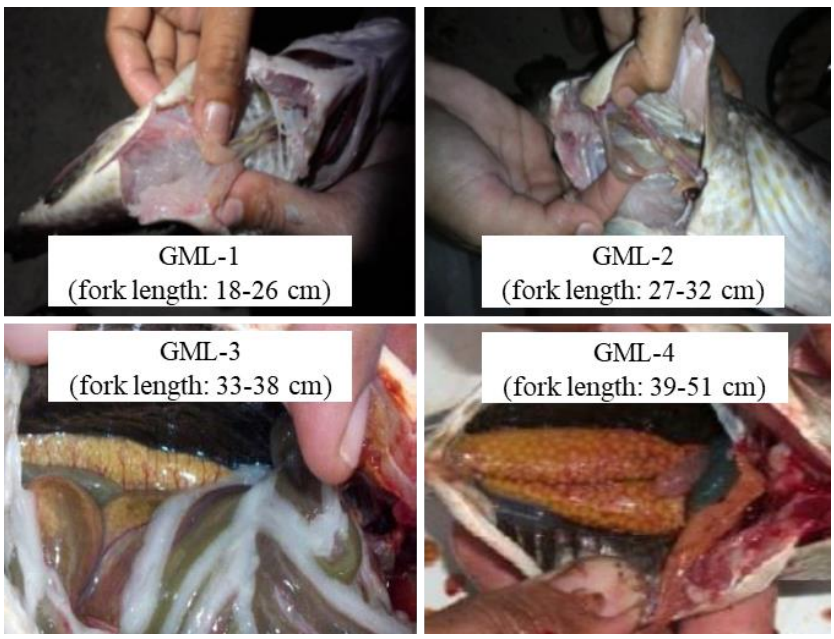

Figure 5. Gonad morphology display based on the level of gonad maturity in Karimunjawa waters (original).

The result of this study shows the length at first maturity for *E. areolatus* at Karimunjawa waters was 33 cm (GML-3), however, based on the information obtained from various references, the same parameter measured 20 cm (Fishbase 2016), 23 cm (Sitepu 2014) and 25 cm (TNC 2015), as presented in Table 5. The length at first maturity variability has been influenced by differences in water characteristics at different locations (Nasution 2005). The main parameters that affect the level of gonad maturity can be grouped into internal and external factors. Internal factors included the difference of species, age, size, and physiological characteristics fish, while external factors included environmental conditions such as variability of temperature, salinity, and current, as well as the presence of food sources (Effendie 1997). Furthermore, Effendie (2002) states that the same species of fish at different geo-locations (dispersed on more than five degrees) will usually have different sizes and ages when achieving a certain gonad maturity level. Differences of geographic locations affect the fertility level, the nutrient content, the variability of temperature and the salinity, current and food availability patterns, with an impact on the growth of fish and implicitly on the gonad maturity level.

Table 5

Comparison of research results related to the length at first maturity of *Epinephelus areolatus* in various locations

Location research	*Length at first maturity (cm)*	*Time of study*	*Source*
-	20	-	Fishbase.org (2016)
Desa Galesong, Takalar Makasar	23	May 2013	Sitepu (2014)
-	25	2014	TNC (2015)
Karimunjawa waters	33	November 2015	Penulis (2016)

Fish length. Fish length measurements from January 2010 to October 2015 were carried out on 1073 samples. The result showed that fish length varies range from 3 cm to 51 cm. The catches'length with reference to the gonad maturity level was found at the verification time (November 2015), namely: <18 cm (juvenile), 18-26 cm (GML-1), 27-32 cm (GML-2), 33-38 cm (GML-3), and 39-51 cm (GML-4). The composition of the catches, based on the length intervals from January 2010 to October 2015, is presented in Figure 6. The highest number was found to range from 27-32 cm (422 fishes), while the least amount was found at size <18 cm (9 fishes).

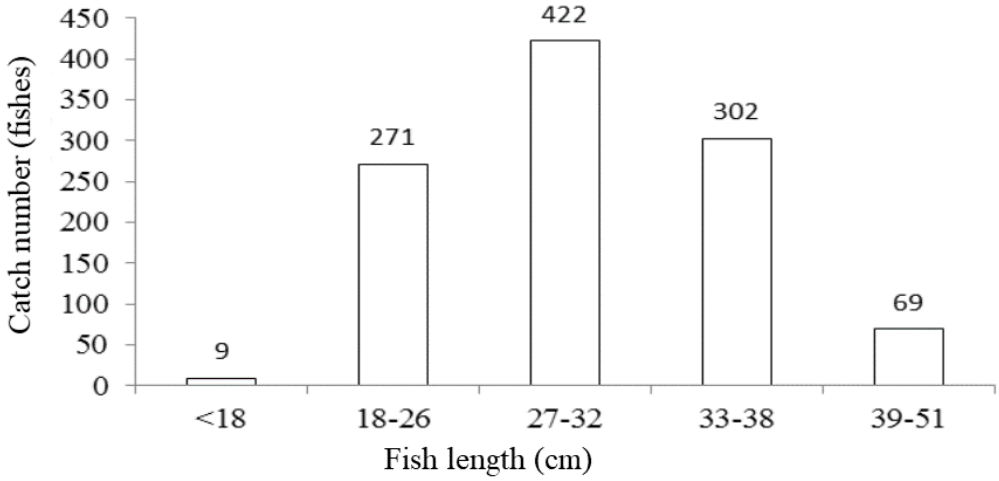

Figure 6. Length composition of *Epinephelus areolatus* based on the spatial distribution at Karimunjawa waters during January 2010 to October 2015.

The average length ranged from 29 cm to 33 cm. The longest size (51 cm) was caught around Cemara waters, but big fish was also caught from several other fishing spots such

as from Semarang Karimunjawa, Genting Seruni, Menyawakan, south, and north of Karimunjawa. The smallest fish (3 cm) was caught from Gundul waters, but all fishing spots also contribute to small size catches but with different composition of numbers (Figure 7).

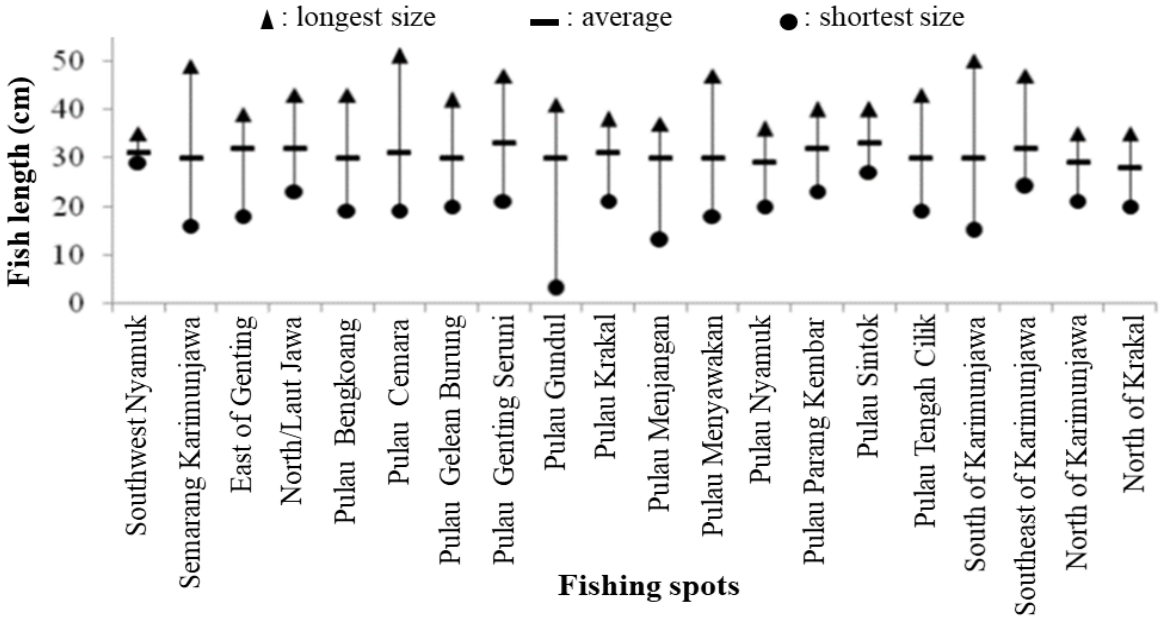

Figure 7. Length composition of *Epinephelus areolatus* based on fishing spots at Karimunjawa waters during January 2010 to October 2015.

Based on the length at first of maturity (33 cm), *E. areolatus* from Karimunjawa waters were dominated by the biologically infeasible category. The number of infeasible categories was 65% from the total sample (1,073 fishes), and the feasible category was only 35% (Figure 8). The infeasible spatial distribution was more than the feasible spatial distribution (Table 6). The *E. areolatus* feasible category was found only on Pulau Genting Seruni and Pulau Sintok waters, while 16 other fishing spots were not a feasible category. These conditions indicate that fishing activities and production pursuing will trigger the degradation of *E. areolatus* resources around a traditional fishing zone of Karimunjawa waters.

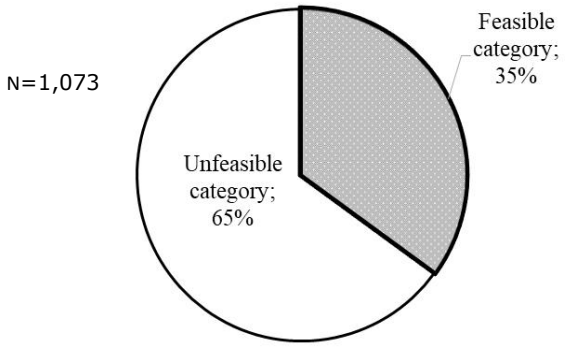

Figure 8. The amount composition of *Epinephelus areolatus* for feasible and unfeasible categories.

Table 6
The average length of *Epinephelus areolatus* catches spatially at Karimunjawa waters on January 2010 to October 2015

No	*Fishing spot*	*Average length (cm)*	*Catch category*
1	Pulau Genting Seruni	33	Feasible
2	Pulau Sintok	33	Feasible
3	Eastern of Genting	32	Unfeasible
4	North of Laut Jawa	32	Unfeasible
5	Pulau Bengkoang	30	Unfeasible
6	Pulau Cemara	31	Unfeasible
7	Pulau Gelean Burung	30	Unfeasible
8	Pulau Gundul	30	Unfeasible
9	Pulau Krakal	31	Unfeasible
10	Pulau Menjangan	30	Unfeasible
11	Pulau Menyawakan	32	Unfeasible
12	Pulau Nyamuk	29	Unfeasible
13	Pulau Parang Kembar	32	Unfeasible
14	Pulau Tengah Cilik	30	Unfeasible
15	South of Karimunjawa	30	Unfeasible
16	Southeast of Karimunjawa	32	Unfeasible
17	North of Karimunjawa	29	Unfeasible
18	North of Krakal	28	Unfeasible

Another factor that affects the degradation of the traditional fishing zone of Karimunjawa is the presence of fishing gear that is not selective and not environmentally friendly. For example, fishing gear of Muro Ami (local name) is still operated in these waters despite its banning by the government, because the fishing gear often causes social conflicts between fishermen (Wiyono & Kartawijaya 2012). Based on the in-depth interviews with fishermen, Muro Ami, blast fishing (fish bomb), and cyanide fishing were also still frequently operated around a coral reef ecosystem. Subandi (2004) states use blast fishing (bomb) causes degradation of fish resources and of the environment in the sea, especially the coral reef ecosystem. This degradation will cause fish to migrate to other areas and, consequently, a decrease in the abundance of fish and in the number of catches.

Information about length at first maturity is very important as a consideration in determining a sustainable fisheries management. Length at first maturity can be used as a reference to estimate adult fish so that the length of adult fish is determined as a legal size in capture fisheries. This is in line with the study of Mustaruddin (2006), stating that one of the first steps to realizing sustainable fisheries is to determine the size of fish that were allowed to be caught. The sustainable fisheries will have implications for the achievement of the basic objectives of fisheries management, namely sustainable production and sustainable fish stocks for a long time, and to improve the welfare of fishermen and fisheries industries (Widodo & Suadi 2006).

Mapping of potential fishing zones. Based on productivity indicator, the potential fishing zone category was found in 9 areas, namely at the southwest of Nyamuk, east of Genting, north of Laut Jawa, Pulau Genting Seruni, Pulau Krakal, Pulau Menjangan, Pulau Parang Kembar, southeast of Karimunjawa, and Pulau Gundul. However, the potential fishing zone based on fish length indicator was found only at Pulau Genting Seruni and Pulau Sintok waters (Table 6). Both indicators, productivity and fish length, were combined from assessment fishing spots (Table 7).

Table 7
Assessment of fishing grounds at Karimunjawa Waters on January 2010 to October 2015

No	*Fishing spots*	*Indicator of productivity*			*Indicator of fish length*			*Fishing spot category*
		$CPUE_{-i}$	*$CPUE_{-A}$*	*Desc.*	*L*	*Lm*	*Desc.*	
1	Southwest of Nyamuk	3.25	2.11	High	31	33	IS	Less potential
2	SemarangKarimunjawa	1.98	2.11	Low	30	33	IS	Less potential
3	East of Genting	2.80	2.11	High	32	33	IS	Less potential
4	North of Laut Jawa	3.62	2.11	High	32	33	IS	Less potential
5	Bengkoang	2.03	2.11	Low	30	33	IS	Less potential
6	Cemara	1.23	2.11	Low	31	33	IS	Less potential
7	Gelean Burung	1.21	2.11	Low	30	33	IS	Less potential
8	Genting Seruni	2.13	2.11	High	33	33	LS	Potential
9	Gundul	4.83	2.11	High	30	33	IS	Less potential
10	Krakal	2.76	2.11	High	31	33	IS	Less potential
11	Menjangan	2.31	2.11	High	30	33	IS	Less potential
12	Menyawakan	1.03	2.11	Low	32	33	IS	Less potential
13	Nyamuk	1.21	2.11	Low	29	33	IS	Less potential
14	Parang Kembar	3.48	2.11	High	32	33	IS	Less potential
15	Sintok	0.79	2.11	Low	33	33	LS	Moderate
16	Tengah Cilik	1.40	2.11	Low	30	33	IS	Less potential
17	South of Karimunjawa	1.39	2.11	Low	30	33	IS	Less potential
18	Southeast of Karimunjawa	2.33	2.11	High	32	33	IS	Less potential
19	North of Karimunjawa	0.65	2.11	Low	29	33	IS	Less potential
20	North of Krakal	1.84	2.11	Low	28	33	IS	Less potential

$CPUE_{-i}$-average CPUE each fishing spots; $CPUE_{-A}$-average CPUE values on 2010-2015; L-fish length average at each fishing spots; Lm-length at first maturity (cm); LS-dominant illegal size; IS-dominant illegal size.

Based on catch productivity and length size (Table 7), fishing spots categorized as potential fishing zone were found only in Genting Seruni waters, and a moderate fishing zone was found only in Sintok waters. The remaining 18 fishing spots were categorized as less potential fishing zones. This shows that the fishing spots were dominated by the less potential fishing zone category more than by the potential fishing zone category. The spatial distribution of the fishing zone of *E. areolatus* is presented in Figure 9.

Pulau Genting Seruni waters were the only fishing spot having a high level of compatibility with the catch productivity and fish length indicators. Catch productivity was relatively high, with a CPUE value of 2.13 kg $trip^{-1}$. The catches were also dominated by legal-size fish (biologically feasible category). This condition justifies why Genting Seruni was categorized as a potential fishing zone. The suitability level of Genting Seruni was closely related to the condition of coral reefs. Coral reefs in this area were quite wide and in good condition. Hastuty et al (2014) suggest that coral reefs, as habitats for many reef fish species, have a positive correlation with the abundance of reef fishes.

The internal factors that can affect the condition of fishing grounds are the oceanographic characteristics. Reddy (1993) states that the oceanographic parameters affecting fish reproduction are the water temperature and current. Temperature changes can affect fish behavior during spawning and the gonad maturation process. The extreme temperature at the spawning area during the spawning season can force fish to migrate to other areas, and consequently, the spawning area moves periodically. Fish also tend to react directly to changes in the current, because fish will swim along the current direction. Changes in spawning areas that occur as a result of temperature and current anomalies will influence the change of spatial distribution of fishing ground.

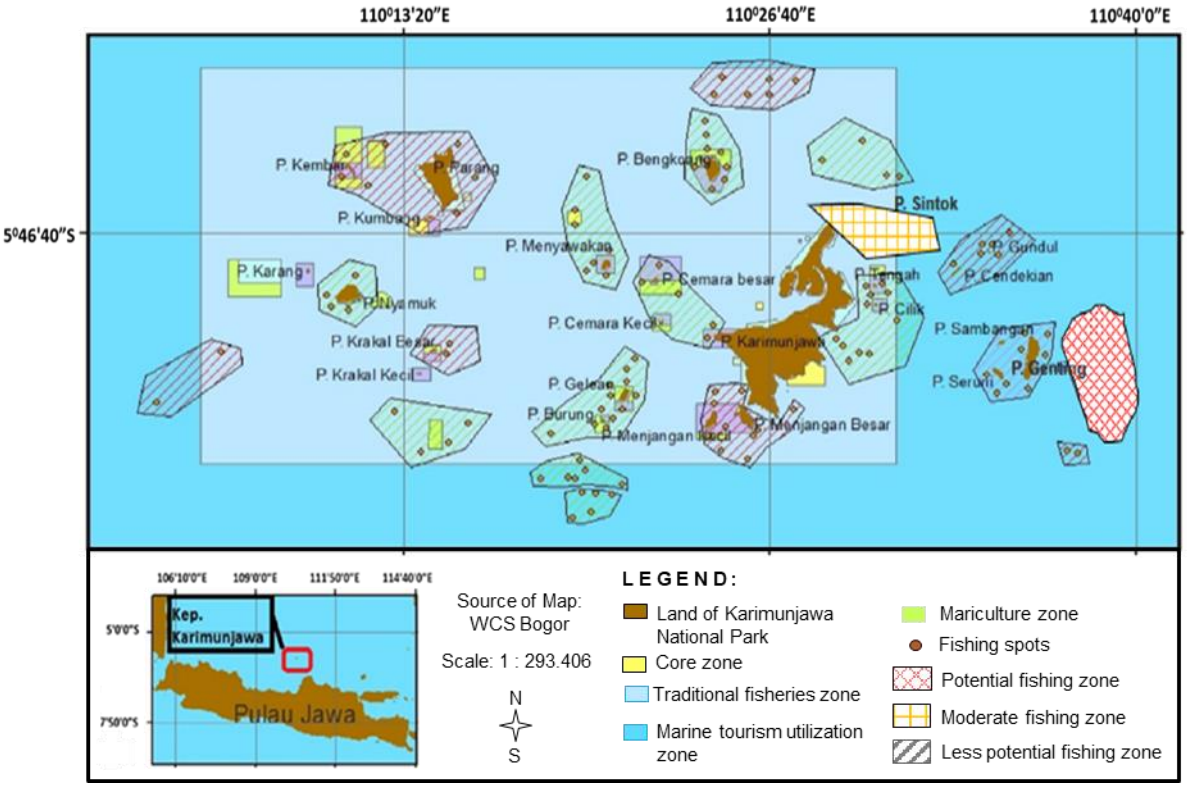

Figure 9. Zoning of fishing spots for *Epinephelus areolatus* at the traditional fishing zone of Karimunjawa waters.

High catch productivity was found at 9 fishing spots. However, a high productivity does not automatically indicate the potential fishing zones. The chance of degradation will be higher if the large catches were dominated by the illegal size category. Therefore, the main thing and the most prioritized in the determination of potential fishing zone was a fish length in the legal size category. The paradigm in determining the potential fishing zone has been adopted in the research of Prasetya (2010) in the waters of Lasongko Bay-Buton-Sulawesi Tenggara. Although the rate of exploitation of *E. areolatus* at Lasongko Bay has been optimal, the fishing effort must still be controlled because the catches were dominated by small size (illegal size).

Information on fish length for legal size (biologically feasible category) was very important in the preparation of sustainable fisheries policy. The information was also needed in determining a minimum mesh size so that it can improve the selectivity of fishing gear to a certain size. Management of capture fisheries through controlling minimum size that can be caught has been done in various countries, as following: the minimum size of 50 cm for tiger grouper (*Epinephelus fuscoguttatus*) at Queensland, Australia (Pears 2005), the minimum size of 38 cm for spotted coral grouper (*Plectropomus leopardus*) at Great Barrier Reef (John et al 2001), the minimum size of 42-50 cm for greasy grouper (*Epinephelus bleekeri*) at Arabian Gulf (Tharwat 2005), the minimum size of 55.9 cm for black grouper (*Epinephelus striatus*) at Dry Tortugas waters, Florida (Ault et al 2006).

Conclusions. Distribution gonad maturity level (GML) into fish length *E. areolatus* was GML-1 with a range of fork length of 18-26 cm, GML-2 in the range of fork length of 27-32 cm, GML-3 in the range of fork length of 33-38 cm, and GML-4 in the range of fork length of 39-51 cm. The catches were dominated by GML-2 (422 fishes), then followed by GML-3 (302 fishes), GML-1 (271 fishes), GML-4 (69 fishes), and juvenile (9 fishes). Based on a length at first maturity of 33 cm (*E. areolatus*), the catches were dominated by the biologically infeasible category (illegal size) in proportion of 65%, and only 35% were included in the biologically feasible category (legal size). Based on the analysis of the fish length of *E. areolatus*, fishing spots categorized as potential fishing zone were

found only Genting Seruni and Sintok waters. However, the productivity with a high potential category in the traditional fishing zone of Karimunjawa waters was found around the southwest of Nyamuk, east of Genting, north of Laut Jawa, Genting Seruni, Krakal, Menjangan, Parang Kembar, southeast of Karimunjawa, and Gundul. Based on the fish length and catch productivity indicators, the spatial distribution of potential fishing zone in the traditional fishing zone was only in Genting Seruni waters, and the moderate potential fishing zone category was found around Sintok waters. The fishing intensity around the east of Genting, Bengkoang, Cemara, Gelean Burung, Gundul, Krakal, Menjangan, Menyawakan, Nyamuk, Parang Kembar, Tengah Cilik, southern, southeast and north Karimunjawa should be reduced because these areas belong to less potential fishing zone category.

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