Habitat quality and reef fish resources potential in Karimunjawa National Park, Indonesia

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Abstract. This study was conducted to analyze habitat quality related to the potential of reef fish resources in Karimunjawa National Park (KNP) as one of the marine protected area (MPA) in Indonesia. This study was conducted in Karimunjawa National Park (KNP), Jepara Regency, Central Java Province, Indonesia. Data were collected by survey and observation methods, including water quality, coral cover and recruitment, fish catches, fishing trip, type of fishing gear, and number of fish species. The data was analyzed descriptively by presenting table of water quality, the yearly catches and trips. The reef fish catches was also viewed from different zones by observing the catches trend per year per zone. The results of this study indicated that the marine waters in KNP area have met the Environment 51/2004 standards. The proportion of the coral cover in KNP (59.34%) indicates that the coral reef is in good condition. Total reef fish catches in the Karimunjawa waters increased in 2010, and declined until 2012, and increased again until 2014. The largest fishing effort used hand line, followed by speargun, and traps. The fishing catches outside the KNP in the past two years (2013 and 2014) were larger than the catches inside the MPA. The decline in the traditional fishing zone was related to fishing activities within the core and protected zone. The decline was also associated with the decrease in the composition of fish families that were the main target of fishers.
Key Words: biodiversity, marine protected area, zone, coral reef, coral cover.

Introduction. Marine protected area (MPA) has an important role in the sustainability of the ecosystem and fish resources in Indonesia. Based on Article 1 of the Government Regulation No. 60/2007, marine protected areas (MPA) are defined as marine areas that are protected and managed using a zoning system to create a sustainable fishery resource and environmental management. According to Law No. 27/2007, protected areas on coastal areas and small islands are areas with specific characteristics which are protected to create a sustainable coastal and small island management. The main purpose of declaring an MPA is to protect, preserve, and utilize natural resources sustainably, and to strengthen fish production, strengthen food and nutrition provision, and increase the income of fishers (Nainggolan et al 2013; White 2014; Bennet & Dearden 2014). The benefits of the presence of an MPA for local fishers is to improve the fisheries productivity and fish biodiversity, protect habitats, and regulate the exploitation of coastal and marine resources (Ulloa et al 2013). MPA is an important tool for achieving global coral reef conservation (Allen et al 2011). Until mid-2012, Indonesia had 15.78 million hectares of marine, coastal, and small island protected areas (Ruchimat et al 2012). One form of MPA is a national park, in addition to nature reserves and wildlife preserves. Karimunjawa National Park (KNP) is an MPA that protects the coral reef ecosystem and fish resources. The protection is expected to create a fish resources, reserve for the waters surrounding KNP. Therefore, the quality of KNP waters must be good to support the health of coral reefs. A well-preserved coral reef affects to the reef fish resources (Rembet et al 2011), and also affects to recreational SCUBA divers (Wilegus et al 2010) who enjoy marine ecotourism.

Karimunjawa waters are divided into several zones. The area allocated for fishing activities in KNP is the traditional fisheries zone, which covers an area of 92.18% of the

national park (Yuliana et al 2016a). In the traditional fisheries zone, fishers can catch various kinds of fish, including reef fish (fish that live in the coral reef habitat). Reef fish are the dominant catches because KNP has a highly diverse coral reef. Meanwhile, recreational activities carried out in the utilization of the marine tourism zone, that developed for nature tourism activities (marine and other nature tourism), recreation, environmental services, education, research and development that support utilization, and support activities for mariculture (KNPA 2017; Yuliana 2019). Both activities are the main activities in KNP. Concerns are rising about decreasing the habitat quality and the sustainability of reef fish resources due to the activities.

This study aimed to analyze the habitat quality and the reef fish resource potential in KNP as an MPA. Habitat quality is measured in water quality and percentage of coral cover, while the potential of reef fish resources is measured in the number of catches, number of trips, reef fish species, and composition of reef fish families. The results of the analysis could provide a description of the condition of the reef fish resources as a reserve for fishers' catches.

Material and Method

Study area. The research was conducted in Karimunjawa National Park (KNP) area, which is located in Jepara District, the Province of Central Java (Figure 1).

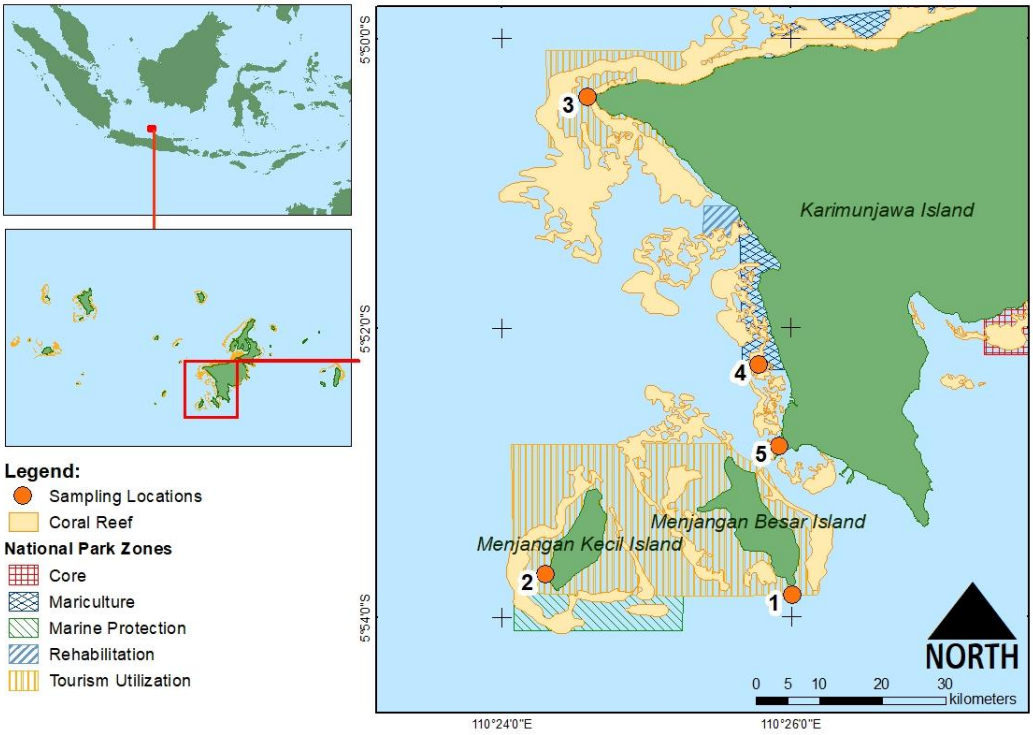

Figure 1. The study site at Karimunjawa National Park.

Object of study. The reef fishes were caught by the traditional fishers and were landed in Karimunjawa Village. Reef fishes data were collected from 5 fish collectors who had the largest number of fish collected in Karimunjawa Village. The study also included the determination of pH, total dissolved oxygen (TDS), temperature, biologycal oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), and salinity as indicators of water quality, coral cover and coral recruitment including the observed object.

Data collection. Data was collected by survey and observation methods. Water samples were taken from five locations (Figure 1) that represent several zones in a KNP area

(Yuliana et al 2019): (1) 100 meters south from the Menjangan Besar Island (Ujung Gantungan); (2) 50 meters to west from Menjangan Kecil Island; (3) 100 meters to the west of Tanjung Gelam; (4) Legon Buaya (west of Karimunjawa Island); and (5) H. Afif harbor. Water sampling was carried out at 09.00-15.00 (local time) on the surface layer. Samples were taken in a composite manner by taking water samples three times, each repetition was represented by 500 mL from each location and then mixed into one composite sample and placed in a bottle, then the samples were stored in a cool box, and tested in a water quality laboratory. A composite sample is a mixture of samples from several observations in order to represent the research location (Guntur et al 2017).

Data collection of coral cover was conducted using the point intercept transect (PIT) method by recording 100 substrate points on a 50 m transect. The data was collected at shallow/reef crest and reef slope depths, at each depth repeated four times (Hill & Wilkinson 2004; Yulianto et al 2012). In this study the recording of coral species was carried out on hard corals.

Data collection of hard coral recruitment was using a 50 x 50 cm quadrate transect (QT) method that was placed side by side with PIT at each 10 m interval. QT replication ranges from 20 to 24 replications. The number of coral recruitment with size <4 cm was counted in each transect. Observations were made at shallow and deep depths (Hill & Wilkinson 2004; Yulianto et al 2012).

The data about fish resources was obtained from the Karimunjawa National Park Authority (KNPA), Coastal Fisheries Port of Karimunjawa, and Wildlife Conservation Society – Indonesia Program (WCS – Indonesia Program). The data included fish catches, fishing trips, fishing gears, coral reefs cover, and coral recruitment. The fish samples were taken from 5 collectors in Karimunjawa Village, chosen by purposive sampling. Collectors selected by their large number of fish collected, the continuous availability of fish, and the diversity of fish collected.

Data analysis. The primary data were analyzed in the laboratory based on the indicators of water quality. The result of the laboratory analysis was then compared to marine water quality standards. The reef fish resource potential was analyzed descriptively by presenting the catches and trips per year, from two different areas: inside and outside of the KNP area. The reef fish catch were also analyzed from a number of different zones, by observing the catch trend per year per zone. Linear regression was used for analyzing fish catch trends per zone.

The analysis of coral reefs cover was carried out by measuring the total length of the coral reef expansion divided by the length of the transect line. The measurement was expressed through following equation (KNPA 2013).

$$n_i = \frac{l_i}{L}$$

Where:

n_i = % of coral reefs cover
l_i = total length of the coral reef expansion
L = the length of the transect line

Criteria for evaluating the condition of coral reefs refers to Gomez & Yap (1988) and Aldyza et al (2015), i.e. coral cover 0-25% (damaged); 26-50% (medium); 51-75% (good); and 76-100% (excellent).

Analysis of coral recruitment calculations used the following formula (Hill & Wilkinson 2004):

$$\text{Coral recruitment} = \frac{1}{n} \times \frac{\Sigma \text{ colony of each transect}}{m^2} \times 4$$

Where: coral recruitment = number of colonies (no. m^{-2}); n = number of repetitions.

Results

Water quality. Water quality is one of the crucial factors for the sustainability of KNP, particularly because coral reefs need a certain level of water quality to be a healthy habitat for reef fish and other groups of biota. The assessment of water quality in this regard is aimed at finding out whether the condition of waters in KNP has met the Water Quality Standards for Marine Biota set forth in the regulation (Decree of the Ministry of State for the Environment of Indonesia No. 51/2004). This action is necessary since KNP has recently become one of the tourist destinations that attract a large number of people. The main concern in this matter is the possible increase of pollution in KNP's waters due to the increasing number of visitors in the area. The results of the measurement (Table 1) show the general condition of water quality in question.

Table 1

Water quality analysis of KNP's waters and the water quality standards for marine biota

Parameters	*Values*	*Standards*[*)]
pH	8.67	7-8.5
TDS (ppm)	2.70	-
Temperature (°C)	29.33	28-30
BOD (mg L^{-1})	< 0.79	20
COD (mg L^{-1})	70.95	-
TSS (mg L^{-1})	< 8.00	20
Salinity (‰)	33.00	33-34

*) The Decree of the Ministry of State for the Environment No. 51/2004.

The quality of marine waters in KNP area has met the standards imposed by the Decree of the Ministry of State for the Environment No. 51/2004 concerning the water quality standards for marine biota (Table 1). Salinity in the area is 33.0‰, which is within the standardized range of salinity, 33–34‰. The concentration of hydrogen ion (pH) has also met the standard, because the standard has a tolerance of 0.2 for each limit (Makmur et al 2012). High and low pH is influenced by fluctuations in O_2 and CO_2 content (Rukminasari et al 2014). The other parameters show values that are smaller than their respective standards.

Total dissolved solid (TDS) is not mentioned in sea water quality standard for marine biota (Decree of the Ministry of State for the Environment of Indonesia No. 51/2004). TDS is the number of solid particles dissolved, whether in the form of organic or inorganic compounds smaller than 1 nanometer (Tanto et al 2018). The TDS value of 2.70 ppm in Karimunjawa is categorized normal due to dynamic waters of Karimunjawa. Environmental Protection Agency (EPA) USA advised that the ideal value of TDS of waters reaches 50 ppm (Tanto et al 2018).

Coral cover and recruitment. The percentage value of coral reef cover represents the proportion of living coral to the total coral cover. The higher the value is, the better is the condition of the waters and the activities in the subjected area. It has been reported that the percentage of coral reef cover in KNP area showed an 2.92% increase, from 72.00% in 2010 to 74.55% in 2013 (KNPA 2014). In 2015, it amounted to 44.13% (Table 2) (Yuliana et al 2016b). Based on these values, the average coral cover in KNP is calculated at 59.34%.

The condition of coral reefs in the present research is evaluated using four categories suggested by Gomez & Yap (1998). Based on these categories, the proportion of the coral cover in KNP (53.94%) indicates that the coral reef is in good condition.

According to the results of research Yuliana et al (2017), the best condition of coral cover was in Taka Malang area (in 2013) and Pulau Batu (in 2015), while the worst was in Nirvana area. There are indications of high fisheries and marine tourism activities causing low percentage of coral cover in Nirvana. Therefore, it requires management of a

marine protected area that can integrate multiple interests in the KNP so as not to adversely affect each other.

Table 2

Percentage of hard coral at three locations of KNP in 2015 (Yuliana et al 2017)

Observation station	*Zone*	*Hard coral (%)*
Nirwana	Traditional fisheries	35.45
Pulau Batu	Traditional fisheries	58.35
Geleang	Marine protection	38.60
Average		44.13

Fish catches. Fishing activities in the Karimunjawa waters are conducted by small-scale fishers using traditional fishing gear that has been used for generations. The fish which are the main fishing target are pelagic fish and reef fish. The pelagic fish that are most commonly caught are mackerel tuna (*Euthynnus affinis*) and narrow-barred Spanish mackerel (*Scomberomorus commerson*), while the reef fish most commonly caught was redbelly yellowtail fusilier (*Caesio cuning*) (PPP Karimunjawa 2014).

Total catch in Karimunjawa waters for the period 2010-2014 (Table 3) indicated that the largest total fish catch in Karimunjawa waters was achieved in 2010, then declined until 2012, and increased again until 2014. One of the reasons for the large catch in 2010 was the operation of muro-ami nets which have the ability to catch high fish qunatity. However, since 1st February 2012, the use of the muro-ami has been prohibited by the Ministry of Fisheries and Marine Affairs of the Republic of Indonesia Regulation No. 02/Men/2011, so the catch tended to decline. The increase in the catch from 2013 to 2014 signified that the fish resources had started to recover from depletion.

Table 3

Total fish catches (kg) in Karimunjawa waters

Year	*Fishing gear*					
	Gill nets	*Hand line*	*Muro-ami*	*Spearguns*	*Traps*	*Total*
2010	813.70	24,073.90	15,418.83	27,016.80	1,283.80	68,607.03
2011	468.30	14,670.00	2,646.90	14,698.00	833.20	33,316.40
2012	71.30	9,816.10	0.00	10,955.35	352.53	21,195.28
2013	722.90	13,270.36	0.00	6,649.40	3,340.54	23,983.20
2014	1,812.25	15,328.96	0.00	10,965.30	4,198.11	32,304.62

Data source: WCS 2014.

The largest effort was done by hand line fishers, followed by speargun and trap users (Table 3). These three kinds of fishing gear were most commonly used by fishers. Gill nets are rarely used in the Karimunjawa waters because in these waters there are a lot of coral reefs, so gill nets are unable to reach deeper waters. Muro-ami nets have no longer been used by fishers since 2012, providing an opportunity for fish resources to recover, because muro-ami nets have the largest catching capacity compared to other fishing gear.

Table 4

Total effort (trips) by fishers in Karimunjawa waters (WCS 2014)

Year	*Fishing gear*					
	Gill nets	*Hand line*	*Muro-ami*	*Spearguns*	*Traps*	*Total*
2010	9	1,126	46	445	48	1,674
2011	8	794	7	225	28	1,062
2012	1	562	0	152	13	728
2013	11	631	0	115	117	874
2014	10	589	0	207	165	971

Total fishing effort for the period of 2010-2014 (Table 4) had a similar pattern with the fishing catch (Table 2), there was a decline until 2012, followed by an increase until 2014. In Table 2 is presented that there was a fairly large increasing trend in trap usage. The fish that were sold live were usually caught using traps. In the most recent years, there has been an increased demand for live fish as the number of tourists to KNP increased, so there has been an increase in the fishing effort using traps.

Part of the Karimunjawa waters was declared as the Marine Protected Area of Karimunjawa on 9 April 1986 through the Decree of the Ministry of Forestry No. 123/Kpts-II/1986 which covered an area of 111,625 ha. And then there was a change in function to KNP through the Decree of the Ministry of Forestry and Plantations Number 78/Kpts-II/1999 on 22 February 1999. In 2001, the entire aquatic area in KNP was declared as a Marine Protected Area through the Decision of the Minister of Forestry Number 74/Kpts-II/2001 (KNPA 2014; Campbell et al 2013). The surrounding area was non-conservation waters. The Karimunjawa Islands consists of 27 islands, 22 islands inside the national park area and five outside (KNPA 2014). The following is the comparison of the condition of the catches inside the KNP (Table 5) and outside the KNP (Table 6).

Table 5

Total fish catches (kg) inside KNP area (WCS 2014)

Year	*Fishing gear*					
	Gill nets	*Hand line*	*Muro-ami*	*Spearguns*	*Traps*	*Total*
2010	813.70	9,851.90	13,136.83	17,125.10	948.30	41,875.83
2011	405.10	9,467.30	2,346.90	8,476.00	412.50	21,107.80
2012	71.30	8,451.50	0.00	6,531.15	40.80	15,094.75
2013	722.90	7,059.91	0.00	2,736.02	958.15	11,476.98
2014	1,420.25	6,203.84	0.00	4,351.95	944.91	12,920.95

Table 6

Total fish catches (kg) outside KNP area (WCS 2014)

Year	*Fishing gear*					
	Gill nets	*Hand line*	*Muro-ami*	*Spearguns*	*Traps*	*Total*
2010	0.00	14,222.00	2,282.00	9,891.70	467.70	26,863.40
2011	63.20	5,202.70	300.00	6,222.00	444.20	12,232.10
2012	0.00	1,364.60	0.00	4,424.20	311.73	6,100.53
2013	0.00	6,073.53	0.00	3,913.38	2,495.17	12,482.08
2014	384.80	9,125.11	0.00	6,613.35	3,253.20	19,376.47

The fish catches in the Karimunjawa waters started to increase in 2013 and 2014 (Table 4 and 5). The total catches in these two years were higher outside of the protected area than inside. This signified that the fish resources inside the protected area were displaying signs of depletion. The catches outside the protected area instead gave hope to the local fishers. However, to reach the waters outside the protected area they needed a fishing fleet with rather high exploring abilities. If the fishers used a fleet of <5 GT, they could only reach the waters within the protected area because most of the fishers live in Karimunjawa Village (inside the protected area).

Reef fish resources. Reef fish are fish that spend their entire lives in the coral reef ecosystem (Nybakken 1998). Reef fish is the main catch in KNP's waters. There are 33 fishing grounds for reef fish in KNP area. The most frequented fishing zones are Genting, East of Cendekian, Batu Item, West of Cemara Besar, West of Cemara Kecil, dan Geleang (Figure 2). Genting is not part of KNP, but there have been an increasing number of fishermen preferring Genting over KNP's waters as their main fishing ground. This preference can be considered an indication that fish resources in KNP's waters have

started to decrease, and consequently, many fishers choose to go further away from their homes to find fishing grounds with higher fish availability.

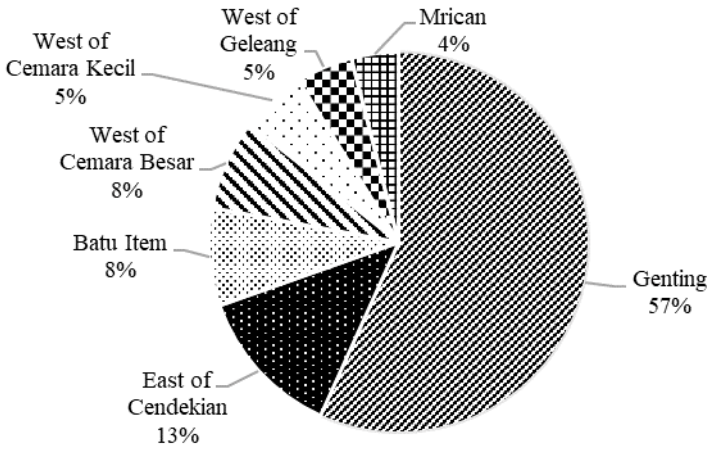

Figure 2. Distribution of fishing grounds for reef fish in KNP's waters.

The reef fish catches in KNP area had declined constantly from 2010 to 2013, then there was a slight increase in 2014. Even though the muro-ami had been banned since 1 February 2012, the reef fish resources needed time to recover to a better condition. Muro-ami was not included in the analysis of this article because it is not considered environmentally-friendly and it has been prohibited by the government. The fishing gear with the highest yield was spearguns, even though there was a decrease until 2013 and increased again in 2014 (Table 7).

Table 7

The reef fish catches (kg) inside KNP area (WCS 2014)

Year	*Fishing gear*					
	Gill nets	*Hand line*	*Muro-ami*	*Spearguns*	*Traps*	*Total*
2010	28.00	3,506.90	11,872.83	17,000.90	947.30	33,355.93
2011	23.00	2,691.20	2,338.60	8,229.70	412.50	13,695.00
2012	0.00	1,794.40	0.00	6,220.38	40.80	8,055.58
2013	10.50	1,884.43	0.00	2,723.92	936.05	5,554.90
2014	1.10	792.64	0.00	4,293.05	785.41	5,872.20

Reef fish catches per zone. KNP area is divided into nine zones that have different functions and allocations and are described in the Decision of the Director General of Forest Protection and Nature Conservation No. SK 28/IV/Set /2012 (KNPA 2014). The nine zones are: core, jungle, marine protection, land utilization, marine tourism utilization, mariculture, religious, cultural, and historical, rehabilitation, and traditional fisheries zone. The fishing activities are mainly carried out in the traditional fisheries zone. However, fishing in the core and sanctuary zone still occur, even though catching fish in these two zones is prohibited. Intensive supervision is still needed to monitor the prohibition of fishing in the core zone and the protection zone.

The reef fish catches in the traditional fishery zone drastically decreased between 2010 and 2013, then there was an increase in 2014 (Figure 3). One of the factors that caused the catches' decrease that's muro-ami fishing gear is still permitted in 2010-2013, and this fishing gear has the ability to catch fish in very high quantity. Fishing activities were mostly carried out in traditional fishing zones, so that fish catches are decreasing because the fish population decreased. But, from 2012 fishers did not used muro-ami along with the prohibition based on Regulations from Ministry of Marine and Fisheries Affairs No. Per.02/Men/2011 about fishing lines and tool placement fishing and fishing

aids in fisheries management area, which began to take effect on 1 February 2012. It was expected that after 2012 fish resources will begin to recover. Another factor was the decline in the composition of the fish families that were the main target for fishers, i.e. Caesionidae, Scaridae, and Labridae. The fish family Pomacentridae (ornamental fish) dominates the composition the reef fish families (70-80%) because this type of fish is prohibited for capture in the KNP area, their abundance is well maintained. This is also the case with the Chaetodontidae family fish (indicator fish for coral reef fecundity) which are not all consumption fish. Based on the data from WCS (2014), the types of fish from the Chaetodontidae family most caught in the KNP area was *Chelmon rostratus*.

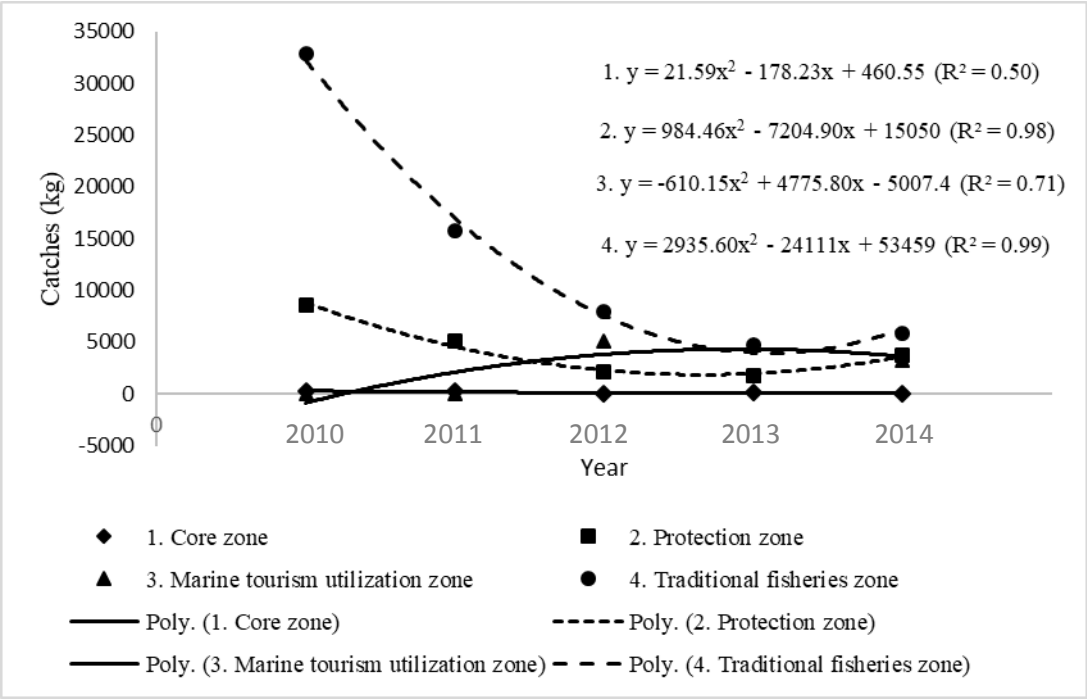

Figure 3. The reef fish catch per zone.

Figure 3 also indicates that fishing activities were still occurring in the core zone and the protection zone, even the fish catches in the protection zone indicate a decline. This is a very important finding for the KNPA that some fishers still do not obey the zone rules. The core zone and the protection zone are no-take zones for fishers, because they are only for research and education activities, so that prohibited for fishing activities. The decline catches between 2010 and 2013 in the protection zone indicates that fish resources in the zone began to decrease due to fishing activities, therefore more intensive socialization is needed regarding the prohibition of fishing in the core zone and the protection zone.

Reef fishes in the KNP area are very diverse. The number of fish species on the coral reef identified as many as 412 species, originating from 44 families and 146 genera (Muttaqin et al 2013). In general, reef fish species in KNP area are dominated by target fishes. Only a few species are used for ornamental fish (prohibited from being caught). Ornamental fish is dominated by the family Pomacentridae, and target fish is dominated by the family Caesionidae, Lutjanidae, Siganidae, Serranidae, and others. Coral fish communities have a close relationship with coral reefs as their habitat (Rembet et al 2011; Mardasin et al 2011). Diversity of reef fish species in the KNP area is certainly produced by good quality coral reefs.

The reef fish in the KNP area are caught using environmentally friendly fishing gear (hand line, spearguns, and traps). The fishing gear often used in the core zone were hand line and spearguns, while in the protection zone, fishers used hand line, spearguns, and traps (Table 8). The data in Table 8 shows that spearguns are the most widely used by the Karimunjawa fishermen. The use of spearguns was usually accompanied by the

use of a compressor as a respiratory aid. Speargun fishing did not only occur in traditional fishing zones, but also occurred in other zones (tourism, protection, and core zones). There is the polemic regarding the use of a compressor in fishing. Law No. 45 of 2009 about Fishing Article 9 prohibits the use of assistive devices compressor, but the detailed provisions are not written in the Ministerial Regulation which regulates tools and pathways fish catching (Yuliana et al 2016b). So, fishers were still using compressors and spearguns for fishing.

Hand line was the second fishing gear used in Karimunjawa. This fishing gear is very environmentally friendly, but rather difficult to use to catch reef fish, because fishing line will often be blocked by coral. Hand line is more suitable for catching pelagic fish. The trap was also often used to catch reef fish, especially to catch live fish, such as grouper. Based on the data in Table 8 the trap has never been used in the core zone, but is still used in the protection zone.

Education and training for fishers and the community is still needed, especially regarding certain activities that may be carried out in certain zones and which may not. Bennett & Dearden (2014) explained that the success of an MPA is strongly affected by the involvement of the local people and the management of the MPA. The fisher's perception and knowledge of the zoning system is important for the success of a conservation area (Kincaid et al 2014).

Table 8

Reef fish catches per fishing gear (kg) in each zone (WCS 2014)

Fishing gear	*Year*	*Core zone*	*Protection zone*	*Tourism zone*	*Traditional fisheries zone*
Hand line	2010	79.60	2,092.80	-	7,679.50
	2011	88.70	2,118.50	-	7,260.10
	2012	0	1,133.10	3,246.60	4,071.80
	2013	192.66	902.57	3,273.08	2,754.75
	2014	69.00	1,992.25	1,149.39	2,993.21
Speargun	2010	217.40	3,469.40	-	13,438.30
	2011	155.60	1,803.50	-	6,516.90
	2012	0	948.22	1,771.31	3,811.62
	2013	6.70	480.81	1,201.32	1,047.19
	2014	6.94	946.30	1,684.12	1,714.59
Trap	2010	0	108.20	-	707.90
	2011	0	41.30	-	347.70
	2012	0	0	0	40.80
	2013	0	326.07	192.12	327.85
	2014	0	525.71	258.15	161.05

Discussion. KNP's waters are a good environment for marine life, apart from the fact that it has not been spoilt by human activities on land. They can provide a healthy environment for coral reefs as well as the fishes which make the reefs their main habitat. Coral reefs are vulnerable to sewage pollution which includes solid waste (in solvent or suspension) because it can prevent sunlight penetration from reaching the reefs and therefore prevent them from getting one of the most important elements they need to survive. Coral reefs are one of the most economically valuable and biologically diverse ecosystems in the world, but which are also continually threatened by various stressors including sewage pollution (Wear & Thurber 2015; Abaya et al 2018). Monitoring of water quality for sewage pollution is essential, because the population in KNP continues to grow and the construction of facilities also increases. Water quality in KNP's waters will affect not only coral reefs' survival, but also that of other marine biota inhabiting the area. Fish is one of the sources of livelihood for the community living in Karimunjawa, and good water quality is vital for fish survival.

Water quality is important for the coral reef health. One of the factors that contributes to the increasing proportion of coral cover in KNP from 2010 to 2013 is the

declining use of potassium cyanide and the banning of muro-ami fishing technique since 2012 (Campbell et al 2013). As for its decreasing proportion in 2015, it is presumed that the contributing factor in the occurrence is the increasing number of tourists coming to KNP (Yuliana 2019) as a result of the increasing popularity of marine ecotourism among them (Satria 2009). In that case, KNP visitors need to be warned or advised of the importance of preserving the environment, particularly the coral reefs, in any tourism activity they do in the national park. Coral recruitment is the capability of coral reefs to regenerate and reproduce. During the period of 2009–2013, coral recruitment was increasing in the marine protection zone and marine tourism utilization zone. There was a decrease in the recruitment in the core zone, but it was insignificant (Muttaqin et al 2013).

Most reef fish hold direct recruitment in coral reefs. Planktonic levels of reef fish are always on the coral substrate. Some fish families are not directly associated with coral reefs, the movements are mostly associated with special structure and biotic state coral reefs (Allen & Werner 2002). Therefore, the health of coral reef habitats is very influential on the sustainability of reef fish resources. Maintaining the habitat quality of coral reef is necessary and requires strongly commitment from the authority (KNPA) and communities to achieve sustainable fisheries. Sustainable fisheries management includes three aspects (Charles 2001), namely: 1) Bioecological aspects, related to maintaining sustainability stock or biomass (ecological sustainability, maintaining the sustainability of stocks or biomass so that it does not exceed the carrying capacity of its environment, as well as increasing the capacity and quality of ecosystems); 2) Socio-economic aspects, related to the sustainability of the welfare of fisheries players at the individual/community level for maintain and achieve higher prosperity; 3) Governance aspects, related to maintenance sound financial and administrative aspects. Thus, fisheries management that integrates the three aspects is very necessary in the KNP. Fishing in the core and protection zones raises concerns that it could cause damage to the coral reef which should be protected as a nursery ground, feeding ground, and spawning ground (Kenchington & Day 2011). Core and protection zones are no-take zones which play a role in exporting eggs and larvae from spawning and exporting fish biomass (spillover) to the outlying areas (Leleu et al 2012). Most of the fishers (65.95%) believed that the zone boundary markers were not clearly visible, so that it make difficult for them to differentiate the core and protection zones from the other zones. Surveillance is not running well, due to a large percentage of fishers, 52.13% and 65.96%, did not report other fishers who caught fish in the core and protection zones to the KNPA. The level of the fishers' compliance in not fishing in the core and protection zones in average was 78.56% (Yuliana et al 2016a).

The fishing that occurs in the core zone is related to the fishers awareness for not catching fish in the core and protection zone. This awareness needs to be built for the optimum management of the protected area. Collaboration between the government and the people is required in order to build this awareness (Campbell et al 2013). Based on field observations, one of the causes for fishing activities in the core and protection zones is the unclear zone boundaries in the field. Unclear boundary signs make it difficult for fishermen to know that they have entered the core zone or the protection zone (Yuliana et al 2016a). The application of the zoning system is one of the foundations of the creation of a MPA. Building the local people's capacity pertaining to zoning is urgently needed (Garces et al 2013) so that the purpose of creating MPA could be achieved. Going forward, it is hoped that there is a firmer policy from the KNPA to secure the core zone and the protection zone from fishing and other activities besides education and training. Thus, the sustainability of reef fish resources in Karimunjawa can be maintained properly.

Conclusions. The highest total amount of fish caught in the Karimunjawa waters was achieved in 2010, which then declined until 2012, and increased again until 2014. The largest fishing effort was conducted using fishing rods, followed by spearguns and traps. The fish catches outside the KNP area in 2013 and 2014 were larger than the catches inside the protected area.

The reef fish catches in KNP continued to decline from 2010 to 2013, then slightly increased in 2014. The fishing gear which produced the highest yield was spearguns, with the largest fishing effort.

The decrease of catch in the traditional fishery zone was an effect of fishing activities in the core zone and sanctuary zones, reducing the spillover to other zones. The decline was also associated with the decrease in the fish family proportion which was the main target for fishers.

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