The role of mangrove in support of coastal fisheries in Indramayu Regency, West Java, Indonesia

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Abstract. Coastal waters at Indramayu Regency is a fishing ground for small scale fisheries of fishing gears: beach seine net, set gillnets and stake traps. Approximately 70% of the catch with the fishing gears are fish associated with mangrove. The existence of mangrove around 1,770 supply provisioning services in support of coastal fishing activities by the increase in the catch, effort and economic rents in static equilibrium of OA, MSY and MEY.
Key Words: mangrove, coastal fisheries, bio-economic, fish-habitat interaction.

Introduction. Habitat conservation will be meaningful if it is able to provide ecosystem services that supply benefit for humans. Ecosystem services are the benefits obtained from an ecosystem for humans (MEA 2005; Liu et al 2010). One of the many coastal ecosystems that provide services for the benefit for human is the mangrove. The mangrove ecosystem can support the complexity of food chain, trophic level organism and niche for life, so mangrove ecosystems has high productivities and carrying capacity for marine life (Islam & Haque 2004). Mangrove can supply foods (Sasekumar et al 1992; Islam & Haque 2004; Nagelkerken et al 2008; Saenger et al 2013), nursery area (Ron & Padilla 1999; Barbier 2003; Manson et al 2005; Allen et al 2012), shelter for the biota of the threat of predators (Nagelkerken et al 2008), as a habitat for fish (Sasekumar et al 1992; Barbier 2003; Saenger et al 2013), both for the entire life cycle as well as most of its life cycle (Nagelkerken et al 2008). As a nursery area, mangrove has an important role in supporting commercial fisheries (Barbier 2000; Allen et al 2012). Mangroves as a habitat of fish is linked to fisheries, for example aligned with shrimp populations (Martosubroto & Naamin 1977; Lee 2004; Islam & Haque 2004; Harahab 2009) and as an important habitat for demersal fish (Barbier & Strand 1997; Barbier 2000). Artisanal fisheries with a contribution of 85-95% is strongly influenced by the presence of mangrove (Islam & Haque 2004). In Fiji, over 60% of the species were found to spend some time in the mangroves (Lal 1984). Approximately 70% of the catch in Nigeria coastal fisheries are directly and indirectly dependent on the mangrove (Udoh 2016). Thus mangroves can provide provisioning services to humans in the form of commercial fish.

Fishing is a system consisting of three interacting components, namely aquatic biota, aquatic habitat and humans as users of those resources (Lackey 2005), therefore it is important to care to mangroves as a habitat for fish. Fish are a resource that is hunted, so that the activity somewhere will affect the presence of fish in an area other (Adger & Cecilia 2000), the effects of an activity on mangrove will affect fishing activities offshore (Barbier 2003) and the destruction of mangroves will have an impact on the decline of the marine fisheries (Islam & Haque 2004). Therefore, understanding the interaction between the mangroves to fisheries is essential to determine the mangrove management policies and fisheries management.

Indramayu Regency, West Province Java, Indonesia that is in a position 107^{o}52'-108^{o}36' East longitude and 6^{o}15'- 6^{o}40' South latitude has a coastal area covering 68.703 km^{2} or 35% of total area Indramayu Regency (Department of Fishery and Marine, Indramayu Regency 2014). In coastal areas there are mangrove vegetation conditions are degraded (Hamdan 2007; Gumilar 2010). Based on data from Perhutani (2000) in Gumilar (2010), in 1999, area mangrove forests in the coastal areas of Indramayu district recorded around 12,153 hectares, but in early 2008 had been reduced to be 7,807.65 hectares (Gumilar 2010), or about 36 percent. One of the activities that utilized the fish resources around the beach is a traditional fishery. Department of Fisheries and Marine Resources, West Java province (2015) states that in 2014 the number of fishermen in Indramayu regency as many as 40,545 persons, 6,115 RTP (fisheries households) and the number of fishing vessels as many as 6,115 units. From the number of fishing vessels and the RTP there are 3,109 units of the fishing fleet (approximately 50.84%) and 1,659 RTP (around 27.13%). The boats were operated by fisherman weighing under 5 GT and they are a small-scale fishermen with fishing operations in the area around the beach. With the mangroves on one side and their fishing activities around the beach on the other side, it is necessary to do an assessment.

The aim of this study is to compare the performance of the fishing activity (effort, harvest and rent) on the condition of the waters with the presence or influence of mangrove and without their influence. The performance of the coastal or nearshore fisheries will present in equilibrium of open access (OA), maximum sustainable yield (MSY) and of maximum economic yield (MEY). Results of this study are expected to provide early information on the fish resources management policy and management of mangroves policy as a habitat for fish.

Material and Method. The study was conducted from October to December 2015. The research location is in Indramayu, West Java Province, Indonesia (Figure 1). The research data is time series data of catch and fishing effort (unit) between 2000 and 2014 were obtained from the Office of the Department of Fisheries and Marine West Java province, while the time series data of mangrove coverage between 2000 to 2014 obtained from satellite imagery LANDSAT 7 + ETM and LANDSAT 8 OLI.

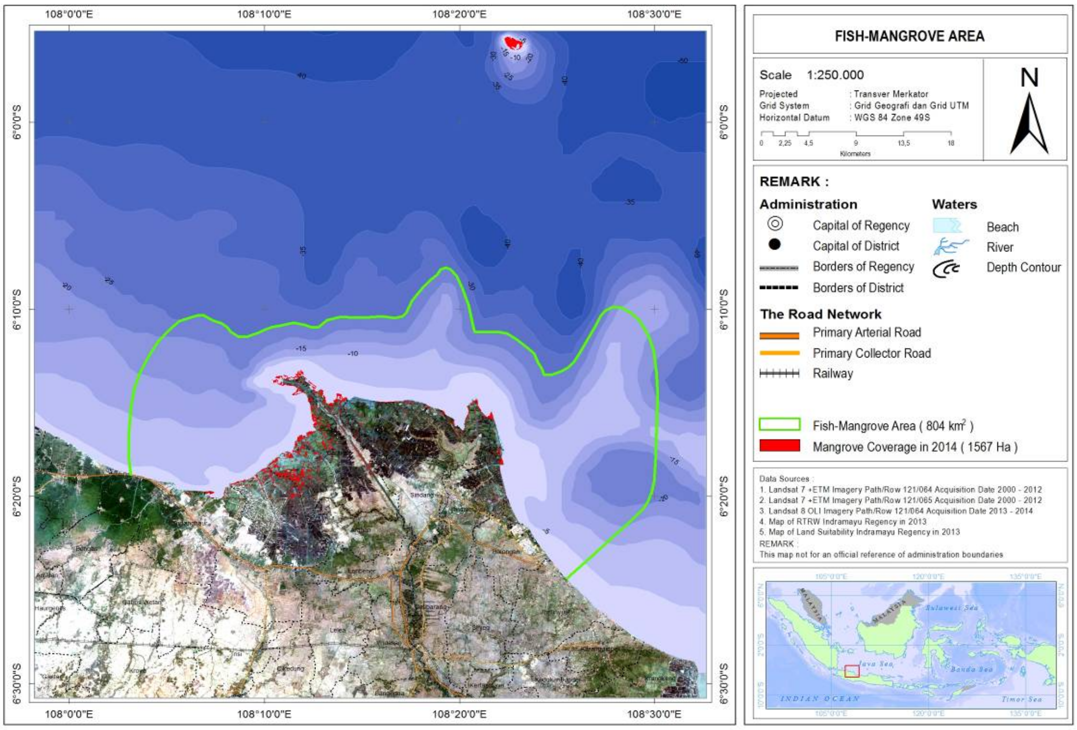


Figure 1. Fishing ground of nearshore fisheries in Indramayu regency.

To achieve the objectives of the study will be an analysis of the model of essential fish habitat (Barbier & Strand 1997; Barbier 2000; Foley et al 2012) and Gordon-Schaefer model (Schaefer 1954; Fauzi 2010). Both models use the logistic growth functions of fish and Schaefer's production function as a basis for analysis. Model Gordon-Schaefer suggested a link between the catch and fishing effort, whereas in the fish-habitat models suggested a link between the catch with the fishing effort and presence of mangrove-habitat. Fish-habitat interaction model assume their mangrove influence the carrying capacity of the environment (Barbier 2000; Foley et al 2012). Finally, with the increase in the carrying capacity of the environment will increase the catch.

The function of logistic growth of fish populations in the Schaefer model is:

$$F(X) = rx(1 - X/K) \quad (1)$$

where r is the intrinsic growth rate, X is the fish stock and K is the carrying capacity of the environment. Assuming the relationship between environmental capacity and mangrove is $K(M) = \mu M$, for $\mu > 0$ (Barbier 2000), the function of logistic growth model on fish-habitat model can be written:

$$F(X,M) = rx(1 - X/\mu M) \quad (2)$$

where M is the area of mangrove. On the condition of the natural balance will occur when the growth rate equal to zero ($\partial \quad \partial = 0$) and the fish stocks will be equal to the carrying capacity of the environment. The maximum growth rate will occur in the condition of K/2 and the fish stock in these condition is a maximum sustainable yield (MSY). In fisheries activities, human intervention (fishermen) is expressed in the production function:

$$h(X,E) = qXE \quad (3)$$

where h is the catch, q is the coefficient of catchability and E is the fishing effort (unit). With their fishing activities in the utilization of resources, the growth of fish stock of Schaefer model can be written as:

$$\partial X/\partial t = F(X) - h(X,E) \quad (4)$$

while the growth of fish stock of fish-habitat interactions model or essential fish-habitat model can be written as:

$$\partial X/\partial t = F(X,M) - h(X,E) \quad (5)$$

In the management of fish resources requires that the state long-term balance (equilibrium) of fish stock is constant, which means also the growth rate of fish is equal to the rate of fishing, so that the production function for the Gordon-Schaefer model (GS model) and a model of essential fish habitat (FH model) each of which can be written as:

$$h_{GS} = qKE - \frac{q^2K}{r}E^2 = aE - bE^2 \quad (6)$$

$$h_{FH} = qK(M)E - \frac{q^2}{r}E^2 = q\mu EM - \frac{q^2}{r}E^2 = \alpha EM - \beta E^2 \quad (7)$$

By using Ordinary Least Square method (OLS) then parameters a, b, α and β be obtained. The fisheries performance of both models will be shown in the equlibrium of open access (OA), MSY and maximum economic yield (MEY). Equations (6) and (7) refer to the relationship between effort and yield and than it can be described in terms of the effort-yield curve. In the perspective of Schaefer's management is the best solution when sustainable production is on highest level at effort-yield curve, and it is known as the MSY level. The MSY achieved in marginal effort is equal to zero, $dh/dE = 0$, so sustainable fishing effort (Emsy) for Schaefer model and model of essential fish habitat can be written:

$$E_{GS_{msy}} = \frac{a}{2b} \quad (8)$$

$$E_{FH_{msy}} = \frac{\alpha}{2\beta}M \quad (9)$$

Besides by using MSY approaches, fisheries management the other is based on the approach of Gordon-Schaefer that refer to the concept of maximum economic yield, MEY and it is achieved on condition marginal revenue equals marginal cost, so optimal fishing effort (Emey)for both models that can be written

$$E_{GSmey} = \frac{a}{2b} - \frac{c}{2bp} \quad (10)$$

$$E_{FHmey} = \frac{\alpha M}{2\beta} - \frac{c}{2\beta p} \quad (11)$$

The condition of open access fishery is achieved when economic rent equal to zero, so fishing effort in the open access condition (EOA) for both models can be written:

$$E_{GSoa} = \frac{a}{b} - \frac{c}{bp} \quad (12)$$

$$E_{FHmey} = \frac{\alpha M}{\beta} - \frac{c}{\beta p} \quad (13)$$

where p is the price of fish (Rp.million ton^{-1}), c is the fishing cost (Rp $unit^{-1}year^{-1}$) and M is mangrove areas (hectares). The fishing effort that obtained from equation (8) to the equation (13) then substituted into the equation (6) and equation (7) to obtain the value of the yields (h) on the condition of OA, MSY and MEY.

Results and Discussion. The small-scale fishermen at Indramayu Regency operate the fishing gears: beach seine nets, set gillnets and stake traps. The fishing ground of the fishing gears is in the coastal waters with an area of about 800 km^2 (Figure 1). Most of the catch are fishes in group of families Leiognathidae, Sciaenidae, Mugilidae, Synodontidae, Bothidae, Ariidae, Plotosidae, Nemipteridae, Clupeidae, Polynemidae, Sphyraenidae, Lutjanidae, Engraulidae, Hemiramphidae, Atherinidae, Trichiuridae, Channidae and Latidae. Around 70% of the families are fishes associated with mangrove (Appendix 1).

Table 1 and Figure 2 show the description of fisheries and mangrove. Figure 2 shows that the fishing gears tend to increase and while the production shows increase from 2000 to 2008 and then decrease from 2008 to 2014. It also shows that the mangrove and the catch per unit effort (CPUE) tend to decrease.

Table 1

The data of fisheries and mangrove

Year	*N*	*Production mean (tonnes $years^{-1}$)*	*Effort mean (unit)*	*Mangrove coverage (hectares)*	*Price (million Rp $tonnes^{-1}$)*	*Cost (million Rp $unit^{-1}year^{-1}$)*
2000-2014	15	20,778	1,424	1,770	6,75	24.55

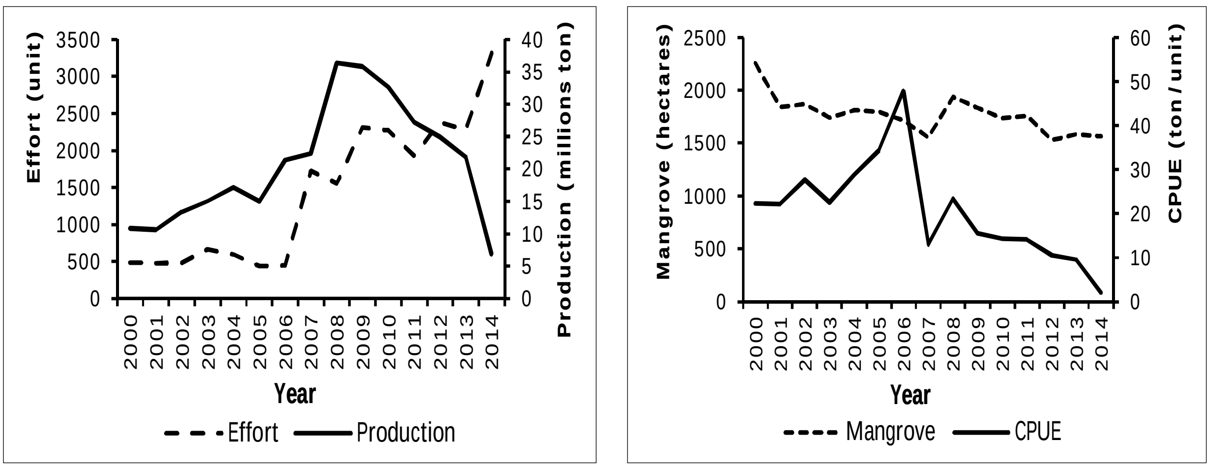


Figure 2. The yields and effort (left) and mangrove and CPUE curve (right).

By using time series data to catches, the number of fishing gears and mangrove coverage, then regression analysis can be done to solve the equation (6) and equation (7). The results of regression analysis are presented in Table 2. The parameters of both models area statistically significant at the level of siginificant 0.01 (t-test) and there is no autocorrelation shown by Durbin-Watson value (d_{DW}). By using a regression equation (Table 2), the performance of the fishery to both two models in equilibrium OA, MSY and MEY can be estimated and the result of estimation shown by Table 3, Figures 3 and 4.

Table 2

Equation of Gordon-Schaefer bio-economic model and fish-habitat bioeconomic model of nearshore fishery

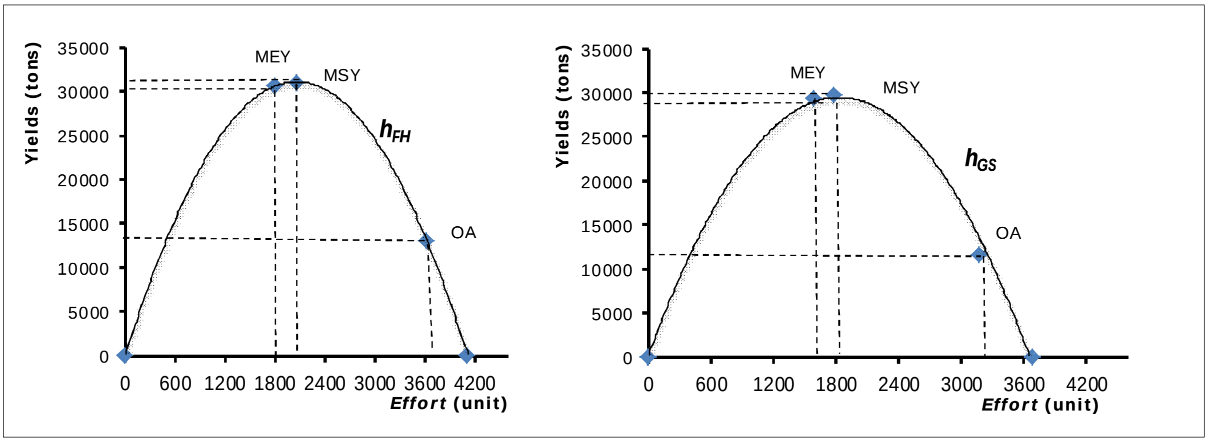
Bio-economic model	*Equation*
Gordon-Schaefer (GS)	h_{GS} = 33.4833 E – 0.0094 E^2
	t-statistic *5.2903 **** *(4.8666)****
	N=15; R^2=70.96; F =14.66; d_{DW}=1.81
	*** *significant at α=0.01*
Habitat-Fish Interaction (FH)	h_{FH} = 0.01706 EM – 0.00735 E^2
	t-statistic *7.3261 **** *(6.4861)****
	N=15; R^2=82.32; F=27.93; d_{DW}=1.73
	*** *signifikan at α=0.01*

Table 3

Estimated performance of the fishery on the management conditions of open access, MSY and MEY

Fishery management	*Fishery performance*	*Bio-economic model*	
		Gordon-Schaefer	*Fish-Habitat interaction*
Open access	Effort (unit)	3,174	3,615
	Catch (tonnes yr^{-1})	11,538	13,143
	Economics rent (Rp^a yr^{-1})	0	0
MSY	Effort (unit)	1,780	2,055
	Catch (tonnes yr^{-1})	29,805	31,022
	Economics rent (Rp^a yr^{-1})	157,570	159,043
MEY	Effort (unit)	1,587	1,808
	Catch (tonnes yr^{-1})	29,454	30,572
	Economics rent (Rp^a yr^{-1})	159,943	162,081

[a] Rp = Rupiah; in 2016: 1 US Dollar = Rp 13,500.



(A) (B)

Figure 3. The comparative of effort-yield curve between Fish-Habitat model (A) and Gordon-Schaefer model (B).

Fisheries management based on the concept of MSY of the GS model, the amount of effort that can be operated to catch fish in order that the stocks remain sustainable are around 1,780 units, sustainable yields are 29.805 tonnes year^{-1} and the economic rent amount of Rp 157.570 million year^{-1}. While based on the concept of MSY of the habitat-fish model state that the amount of effort are 2,055 units that it will provide sustainable catches around 31,022 tonnes year^{-1} and the economic rent around Rp 159,043 million year^{-1}. Fisheries management based on the concept of MEY of the GS model, the amount of effort that can be operated to catch fish in order that the stocks remain sustainable are around 1,587 units, sustainable yields are 29.454 tonnes year^{-1} and the economic rent amount of Rp 159.943 million year^{-1}. While based on the concept of MEY of the habitat-fish model state that the amount of effort are 1,808 units that it will provide sustainable catches around 30,572 tonnes year^{-1} and the economic rent around Rp 162,081 million year^{-1}. By compared with the average actual catches around 20,778 tonnes, the nearshore fishery has not shown biological and economical overfishing. However, when it is referred to the actual condition of the catch in 2008, 2009 and 2010, the nearshore fisheries have shown the phenomenon of overfishing. In addition, when it is viewed from the actual CPUE, there is a declining trend in CPUE around 1.58 tonnes year^{-1}.

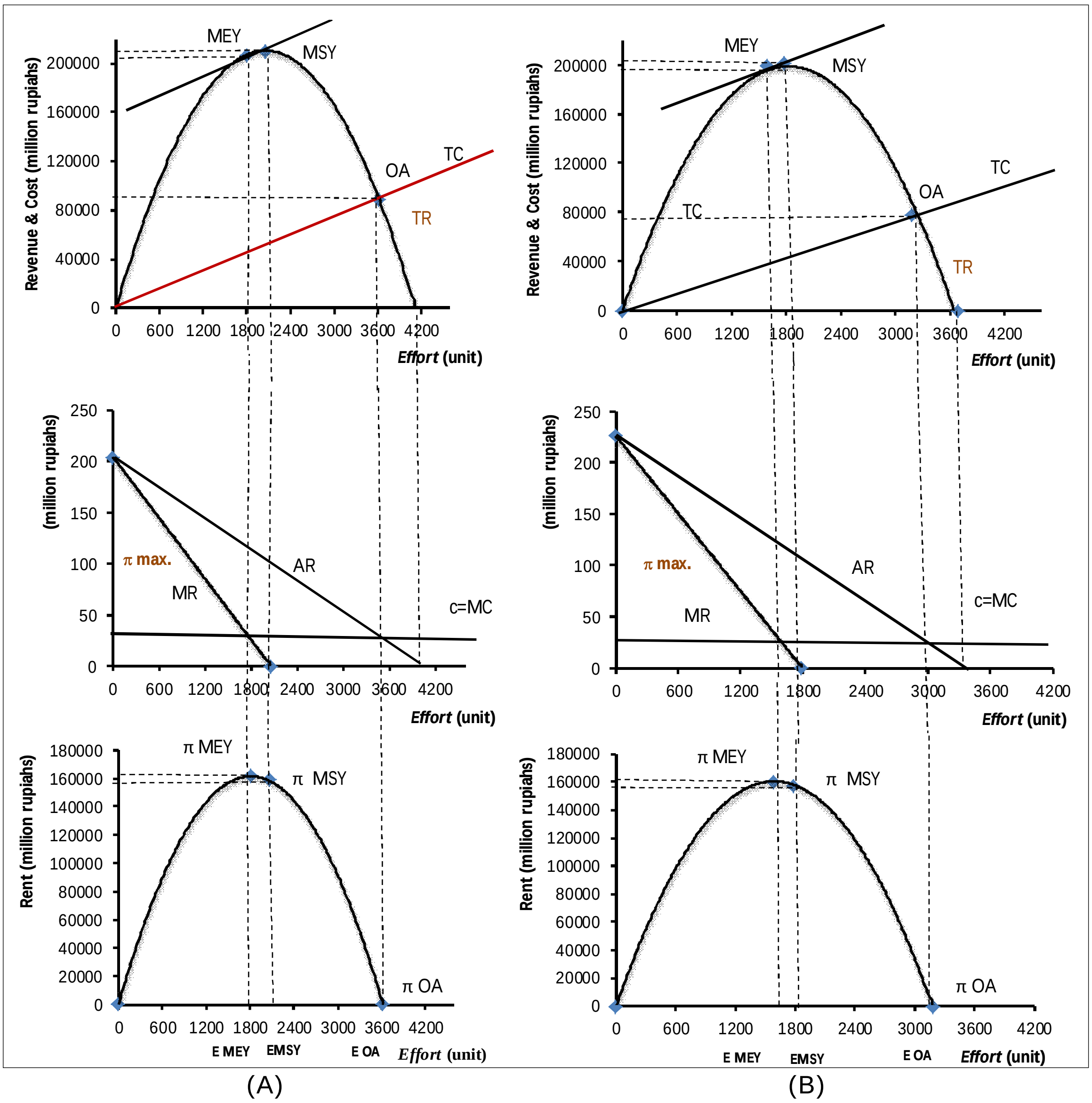


Figure 4. The comparative of static equalibrium between Fish-Habitat model (A) and Gordon-Schaefer model (B).

Figure 3 shows the curve of catch and fishing effort both the GS model and the FH model. By the existence of mangrove (model FH), the catch and effort in equilibrium OA, MSY and MEY are greater compared with the catch and fishing effort on the condition without mangrove (GS models). The difference between the catches of FH model and GS model in equilbrium of OA, MSY and MEY are respectively 13.90%, 4.08% and 3.8%, while the difference in effort between the two models respectively are 13.90%, 15.44% and 13.90%.

Figure 4 shows the comparison of bio-economic model on the condition of static equilibrium between the FH model (A) and the GS model (B). By the existence of mangrove (FH model), total revenue and economic rents in equilibrium of OA, MSY and MEY is greater than the total revenue and economic rent on the condition of fisheries without mangrove (GS models). The difference between the total revenue of FH model and GS model in equilbrium of OA, MSY and MEY respectively are 13.25%, 6.86% and 6.24%, while difference in the economic rents between the two models respectively are 0%, 1.95% and 3.09%.

Conclusions. The existence of mangroves can provide provisioning services to coastal fisheries by increasing in the catch, fishing effort and economic rents in fisheries management on the static equlibrium condition of open access (OA), maximum sustainable yield (MSY) and maximum economic yield (MEY). So, the conservation of mangroves as a fish habitat can be done to support fisheries around the coast. Thus, to prevent overfishing of fish resources and the continuation of coastal fisheries need two strategies: 1). maintain mangrove area at least 1,770 ha; 2). the optimal number of effort that can be operated up to 1,808 units and the maximum number of allowable catch are 30,572 tonnes year^{-1}.

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Appendix 1

The commercial biota associated with mangrove

Family	*References*
Mugilidae	Lal (1984); Kawaroe et al (2001); Ramli et al (2011); Kottelat et al (1993); Barbier (2000)
Leiognathidae	Lal (1984); Asikin et al (1993); Kottelat et al (1993); Kawaroe et al (2001); Wahyudewantoro (2009)
Cynoglossidae	Asikin et al (1993)
Clupeidae	Asikin et al (1993); Barbier (2000)
Lutjanidae	Lal (1984); Kottelat et al (1993); Wahyudewantoro (2009)
Sciaenidae	Kottelat et al (1993)
Hemiramphidae	Kottelat et al (1993)
Plotosidae, Ariidae, Haemulidae, Channidae, Latidae, Bothidae, Mullidae	Lal (1984); Kottelat et al (1993); Allen (1997); Wahyudewantoro (2009); Barbier (2000)
Penaeidae	Martosubroto & Naamin (1977); Barbier (2000); Harahab (2009)
Portunidae	Lal (1984); Le Vay (2001)