Fishery characteristics of Indo-Pacific king mackerel (*Scomberomorus guttatus*) in Riau Islands waters (IFMA 711), Indonesia

[1,2]Tegoeh Noegroho, [2]Mennofatria Boer, [2]Luky Adrianto, [2]Sulistiono

[1] Research Institute for Marine Fisheries, Ministry of Marine Affairs and Fisheries, Cibinong, Bogor, West Jawa, Indonesia; [2] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Darmaga-Bogor, Indonesia. Corresponding author: T. Noegroho, teguhnug80@gmail.com

Abstract. Indo-Pacific king mackerel has been long caught in Riau Islands. The mackerel is one of the targets of gillnet. The fishery characteristics of the mackerel in Riau Islands were not well described, thus a study needs to be carried out. The present study was carried out in 2015-2017. Data was collected by researchers with the help of 2 enumerators who collected data from the fishermen and middlemen. The method used is direct observation at the study site and in-depth interviews with fishermen and middlemen. It aimed to analyse fishery characteristics such as fishing aspect, catch composition, catch per unit effort (CPUE), fishing season, fishing ground, habitat condition, and catch marketing pattern. The results show that Indo-Pacific king mackerels are dominantly caught by gillnets on < 10 GT vessels and 2.5-4 inches meshsize. Catch composition of < 10 GT vessel is dominated by wolf-herring (*Chirocentrus* sp.) with 23%, then Indo-Pacific king mackerel (*Scomberomorus guttatus*) with 18%, while > 20 GT vessel by longtail tuna (*Thunnus tonggol*) with 29%, kawakawa (*Euthynnus affinis*) with 22.7%, and narrow-barred Spanish mackerel (*Scomberomorus commerson*) with 16.3%. CPUE of < 10 GT vessel in 2015-2017 were 17, 24, and 21 kg trip^{-1} day^{-1}, respectively. Fishing seasons are in March to May and October to December. Fishing grounds for < 10 GT vessel gillnet are around Moro waters and other islands. Oceanographic conditions of mackerel's habitat are temperature 29-30°C, salinity at 32-33 PSU, and pH 8.75-8.85. Export destination countries of Indo-Pacific king mackerel are Malaysia and Singapore.
Key Words: composition, CPUE, fishing ground, fishing season, Indo-Pacific king mackerel.

Introduction. Locally known as *tohok* and scientifically as *Scomberomorus guttatus*, Indo-Pacific king mackerel is one of the mackerel species in Riau Islands waters. In general, the species is distributed in almost all coastal waters and islands across Indonesia. Indo-Pacific king mackerel is a neritic tuna species believed to be less migratory than *Scomberomorus commerson* that may be encountered in turbid waters with reduced salinity (Collette & Nauen 1983). In Riau Islands waters, the species is dominantly caught by gillnet with < 10 GT vessels and in 1-3 fishing days. The fishing belongs to small-scale fisheries category.

Capture fisheries in Indonesia is dominated by small-scale fishing. Hermawan (2006) reports that around 15% of fisheries businesses in Indonesia are large-scale fisheries, while small-scale fisheries are 85%. Small-scale fishery is characterised as a dynamic and growing sector that uses fishing, processing and distribution technologies to exploit fisheries resources in the sea and other waters. The fishing is carried out as a full-time or part-time activity, or even seasonal activity, the targets of which are often fish supply and fishery products for local and export markets or integrated in bigger global markets (Bene 2006). In addition, according to FAO (1999) small-scale fishery is a traditional fishery involving fishermen household, using relatively small capital and energy, relatively small boat (if applicable), relatively short fishing time, near the shore, and the catch is for local consumption or export. The main and most used fishing gear is gillnet (Seilert 2002). Fishermen with maximum 10 GT vessels belong to small fishermen category (Ministerial Regulations-MMAF/IR/No.18/2016).

Noegroho et al (2018b) reported the size structure of Indo-Pacific king mackerel caught by gillnet, i.e. 10-75 cm FL with mode 49-51 cm FL and 37-39 cm FL (FL = fork length). The mackerel's spawning season is in January-August, being April-May the peak of the spawning season. The exploitation rate of the mackerel in Moro waters of Riau Islands is high, leaning to overfishing (Noegroho et al 2018a). High exploitation rate should be lowered to reach the optimum rate to keep Indo-Pacific king mackerel resources more sustainable.

Riau Islands waters are in Indonesia Fisheries Management Area (IFMA) 711, i.e. Karimata Strait and Natuna Sea. Both areas are important in global fishery productions and have high diversity (Talaue-McManus 2000). Fishermen's catches in Riau Islands are usually sold to middlemen (*tangkahan*) around their settlement. In the islands, there are only a few government's fish landing ports such as fish auction site (FAS) and fish landing centre (FLC), making *tangkahan* a centre for landing and selling the catch. From *tangkahan,* the fish is sold to local and export markets. Fish for export are fresh, preserved in ice only.

Fishery characteristic of Indo-Pacific king mackerel is not well described. Therefore, the present study aimed to determine and analyse the fishery characteristic of the species in Riau Islands waters, comprising fishing aspect, catch composition, CPUE, fishing season, fishing ground, habitat condition, and catch marketing pattern. The study is expected to provide scientific data and information serving as a basis for policy on management of Indo-Pacific king mackerel in Riau Islands waters and in Indonesia's waters generally.

Material and Method. The study was carried out in 2015-2017 in Moro waters of Riau Islands that is located in North Natuna Sea (FMA 711) (Figure 1). Data was collected by researcher with the help of 2 enumerators who collected catch data from the fishermen and middlemen. The data consisted of catch, fishing ground, fish size, and fishing operation data, and were collected from small-scale (< 10 GT) gillnet operating in Moro and the surrounding waters. Fishing operation data consisted of vessel name, type and specification of fishing gear, number of trip, species and number of catch, etc.

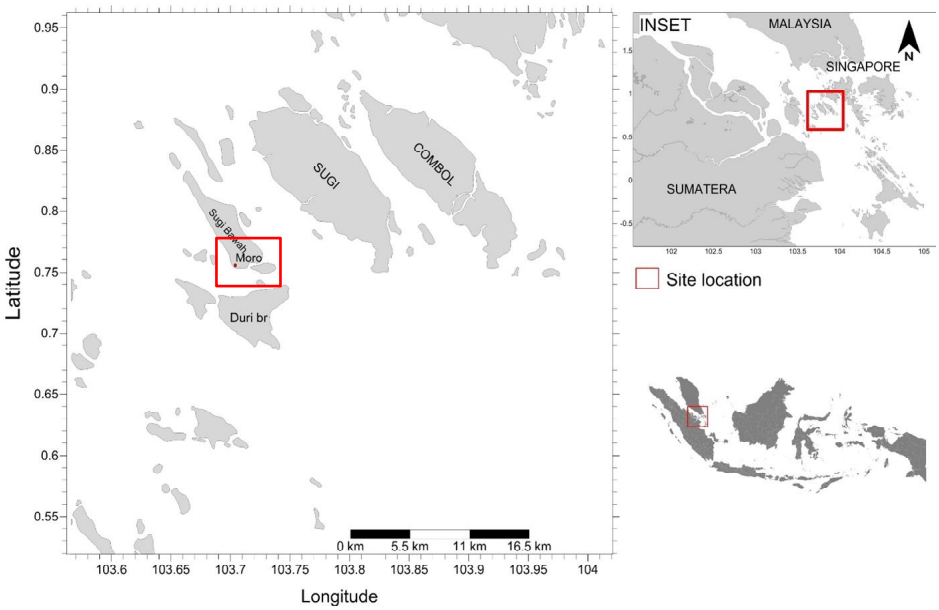

Figure 1. Study area in Moro waters of Riau Islands.

Data collection. Data on vessel's fishing aspect was obtained through in-depth interview with gillnet fishermen and middlemen as well as on-board observation on gillnet vessels. The observation was carried out to obtain fishing ground coordinate. Fishing ground data was also obtained through interview with fishermen by showing maps with coordinates (gridding) to them and asking where the locations of the fishing grounds are. Data on catch composition was obtained through observation on landing site (*tangkahan*) and

direct on-board observation on the vessel. The composition was presented in percentage by fish weight in kg. In addition, data on fishing ground habitat condition employed secondary data from Research Institute for Marine Fisheries (RIMF 2017), consisting in temperature, salinity, turbidity, dissolved oxygen, and pH. On the other hand, data on catch marketing pattern was obtained through interview with fishermen, middlemen, and export vessel's crew.

Data analysis. Catch per unit effort (CPUE) was calculated based on gillnet catch data to understand the abundance trend and level of utilisation status of fishery resources exploited in a water. CPUE is total catch Y_i divided by total fishing effort f_i (Sparre & Venema 1999). Below is the formula to calculate CPUE.

$$CPUE = \frac{Y_i}{f_i}$$

where: CPUE = catch per unit effort (kg trip^{-1} day^{-1});
Y_i = total catch (kg);
f_i = total fishing effort (trip).

Fishing season. To understand fishing season pattern, average percentage method based on time series analysis (Spiegel 1961) was employed. The calculation process is as follows.

1. Calculate CPUE using the following formula:

$$\bar{U} = \frac{1}{m}\sum_{i-1}^{m} U$$

where: $\bar{U}$ = monthly average CPUE in a year (ton trip^{-1});
U_i = CPUE per month (ton trip^{-1});
m = 12 (total month in a year).

2. Calculate U_p, i.e. ratio between U_i and $\overline{U}$, shown in percent:

$$Up = \frac{U_i}{U} x\, 100$$

where: U_p = average CPUE ratio (%)

3. Then calculate season index:

$$IM_i = \frac{1}{t}\sum_{i-1}^{t} Up$$

where: IM_i = season index n-I;
t = total year of the data.

Fishing season is when the season index is higher than 1 (above 100%) or above average, and not a fishing season when the season index is lower than 1 (below 100%). IM = 1 (100%) is equal to monthly average price, meaning that the condition is normal or balanced. Fishing season pattern is calculated using moving average method to determine the suitable period to fish.

Results and Discussion. Sample vessels are made of wood with gillnet fishing gear. The vessel dimension is 10 x 1.75 x 2.5 m (length x width x depth). Sample vessels are 5 GT in size with 16 PK engine power. In Table 1 we can see the specification of gillnet vessels in Moro waters and the surroundings.

Table 1

Specification of gillnet vessels in Moro waters and the surroundings

Criteria	*Sample vessel 1*	*Sample vessel 2*	*Sample vessel 3*
Site	Jang Luar Island	Moro Island	Jang Dalam Island
Vessel size (LxWxD)	10 x 1.75 x 2.5 m	12 x 1.7 x 2.5 m	15.0 x 2 x 2.5 m
Vessel weight	5 GT	5 GT	7 GT
Fishing days	1-2 days	1-2 days	1-3 days
Crew	1 person	1 person	1-2 persons
Fishing ground	Moro waters	Moro waters	Moro waters

The specifications of small-scale gillnet in Moro waters are shown in Figure 2.

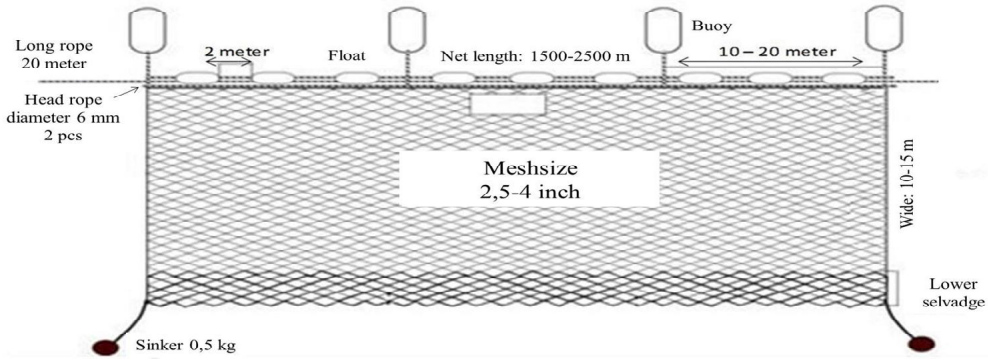

Figure 2. Specification of small-scale gillnet in Moro waters and the surrounding.

The specification of net used is as follow: net is made of nylon, each head rope and ground rope are around 1,627 m long. The average net length is 1,500-2,500 m long and 10-15 m wide. The mesh is 2.5 inch (2.5-4 inch). Both stones, placed at the most end of the bottom of the net, and lead rope, also at the bottom of the net, function as sinkers. The net has big and small floats. Both the ends of the head rope function as bolch lines, and one of the ends is tied onto wood stick with marking light.

Catch composition. The gillnet catch composition by < 10 GT vessel is dominated by wolf-herring (22.9%), followed by Indo-Pacific king mackerel (18.3%). Numerous species are caught in smaller percentage, as shown in Table 2.

Table 2

Gillnet catch composition by < 10 GT vessel

Catch composition species		*Weight (kg)*	*Percentage*
English name	*Scientific name*		
Indo-Pacific king mackerel	*Scomberomorus guttatus*	12	18.3
Spanish mackerel	*Scomberomorus commerson*	2	3.1
Queen fish	*Scomberoides commersonianus*	7	10.7
Wolf-herring	*Chirocentrus* sp.	15	22.9
Threadfin	*Polynemus* sp.	6	9.2
Giant catfish	*Arius thalassinus*	3	4.6
Black pomfret	*Formio niger*	4	6.1
Torpedo scad	*Megalaspis cordyla*	5	7.6
Bronze croaker	*Otolithoides biauritus*	5	7.6
Silver pomfret	*Pampus argentus*	1	1.5
Requiem sharks	*Carcharhinus* sp.	1.2	1.8
Jack trevallies	*Carangidae* sp.	1.2	1.8
Hairtails	*Trichiurus lepturus*	0.2	0.3
Greater lizardfish	*Saurida* sp.	0.2	0.3
Trevallies	*Selaroides* sp.	0.2	0.3
Croacker	*Pseudociena* sp.	0.3	0.5
Terapon	*Therapon* sp.	0.3	0.5
Fringescale	*Sardinella* sp.	0.3	0.5
Indian halibut	Psettodidae	0.3	0.5
Ilisha	*Ilisha* sp.	0.4	0.6
Indian mackerel	*Rastrelliger kanagurta*	0.4	0.6
Swimming crab	*Portunus* sp.	0.5	0.8
Total		65.5	100

As comparison, gillnet catch composition by > 20 GT vessel (Karimata Strait fishing ground) is dominated by longtail tuna (29%), kawakawa (22.7%), and narrow-barred

Spanish mackerel (16.3%). In smaller percentage, there are barracuda, wolf-herring, cobia, Indo-Pacific king mackerel, giant catfish, torpedo scad, and shark. See Table 3 for gillnet catch composition by > 20 GT vessel. This result is almost the same as the study conducted by Wudji & Suwarso (2014), researching the composition of the catch on 20-240 GT vessels. The composition of the catch shows the dominance of the kawakawa and longtail tuna which alternates with each other.

Table 3

Gillnet catch composition by > 20 GT vessel

Catch composition species		*Weight (kg)*	*Percentage*
English name	*Scientific name*		
Common dolphin fish	*Istiophorus platypterus*	12	0.4
Stingray	*Dasyatis* sp.	20	0.6
Wolf-herring	*Chirocentrus* sp.	25	0.8
Torpedo scad	*Megalaspis cordyla*	30	0.9
Jack trevallies	*Carangidae* sp.	50	1.6
Sharks	*Carcharhinus* sp.	79	2.5
Great barracuda	*Sphyraena barracuda*	120	3.7
Indo-Pacific sailfish	*Istiophorus platypterus*	125	3.9
Barracuda	*Sphyraena* sp.	130	4.0
Giant catfish	*Arius thalassinus*	190	5.9
Queen fish	*Scomberoides commersonianus*	229	7.1
Narrow-barred Spanish mackerel	*Scomberomorus commerson*	523	16.3
Kawakawa	*Euthynnus affinis*	730	22.7
Longtail tuna	*Thunnus tonggol*	930	29.0
Cobia	*Rachycentron* sp.	18	0.6
Total		3211	100

See Figure 3 for CPUE of gillnet vessels. In 2015 the average CPUE was 17 kg trip^{-1} and increased to 24 kg trip^{-1} in 2016. The highest CPUE trend was during February-April and October-November. CPUE in 2017 showed fluctuating trend where the highest was in March and the CPUE in other months were almost the same (21 kg trip^{-1} in average). Fishing effort in 2016 (310 days year^{-1}) was surprisingly lower than that in 2015 (637 days year^{-1}). In average, fishing efforts per month were 53 trips in 2016 and 28 trips in 2015.

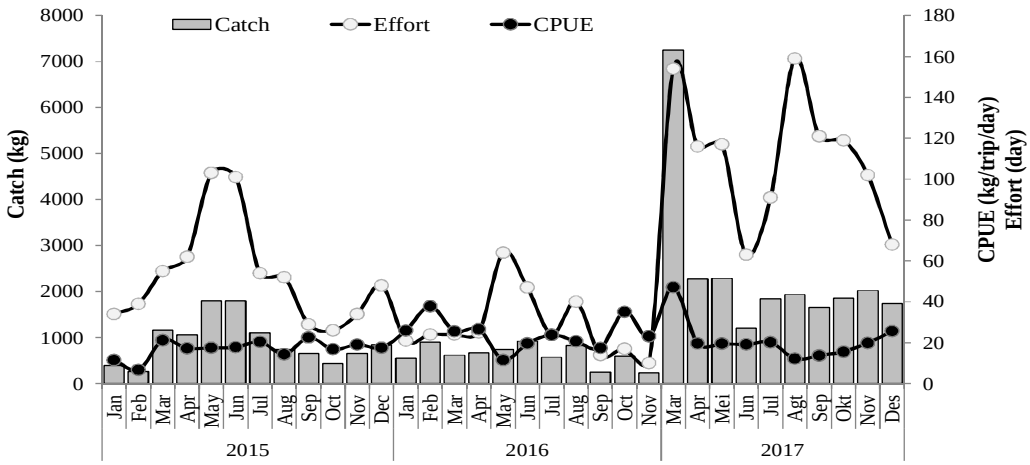

Figure 3. CPUE of small-scale gillnet in Moro waters and the surrounding (2015-2017).

CPUEs or the abundances of Indo-Pacific king mackerel in 2015-2017 were 4.7, 6.6, and 5.1 kg trip^{-1} day^{-1}, respectively. The percentages of the mackerel CPUE of the total gillnet catch in 2015-2017 were respectively 28%, 27%, and 25%, meaning that in 2015 the abundance (4.7 kg trip^{-1} day^{-1}) was 28% total abundance of gillnet catch (17 kg trip^{-1} day^{-1}). See Table 4 for the CPUE data in 2015-2017.

Table 4

Percentage of Indo-Pacific king mackerel CPUE of gillnet CPUE

Year	CPUE (kg trip^{-1} day^{-1})		
	Indo-Pacific king mackerel	*Gillnet*	*Percentage*
2015	4.7	17	28
2016	6.6	24	27
2017	5.1	21	25

Fishing season. Fishing seasons for Indo-Pacific king mackerel are March-May and October-December, being March the peak of the season (Figure 4) and June-September low season period.

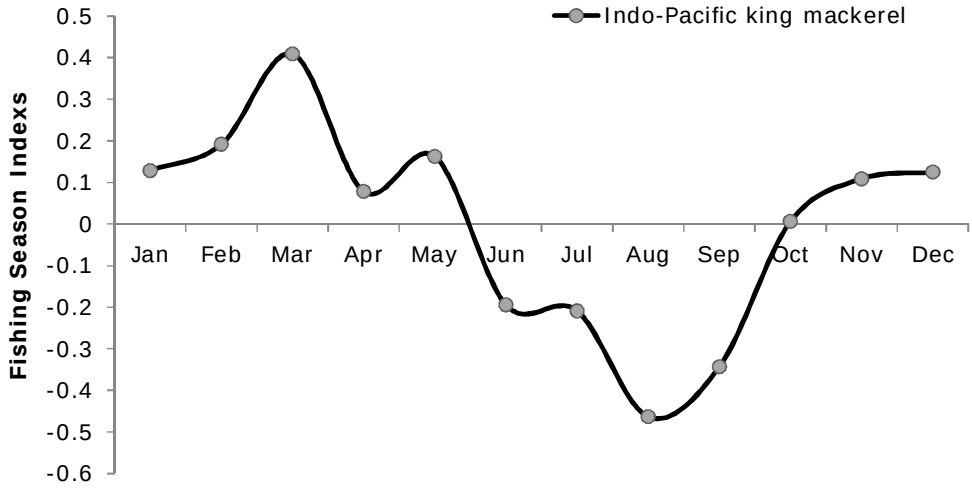

Figure 4. Fishing season for Indo-Pacific king mackerel in Moro waters of Riau Islands.

Fishing ground. Fishing grounds for < 10 GT gillnet vessel are waters around Moro, Iyang, Pao, Sugi, Sugi Bawah Islands, as well as other islands in Riau Islands (Figure 5); while for > 20 GT gillnet vessels are around Karimata Strait and Natuna Sea. There are only a few < 10 GT gillnet vessels in Moro waters, while > 20 GT gillnet vessels were previously vessels with seine net as their fishing gear before switching to gillnet.

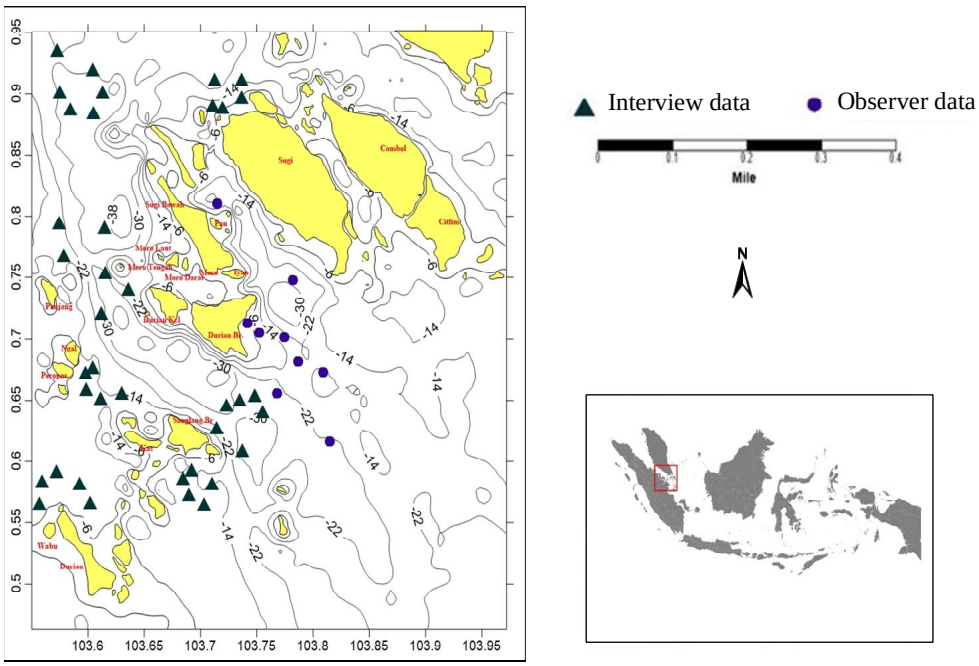

Figure 5. Map of fishing ground for < 10 GT gillnet vessels in Moro waters and the surrounding.

The fishing gear was switched following the Regulation of the Minister of Marine Affairs and Fisheries No. 2/2015 (Ministerial Regulations-MMAF/IR/No.2/2015) on prohibition of using trawl and seine net in Indonesia's FMAs. Gillnet vessels are in waters around the islands, not far from fishermen's settlement.

Fishing ground habitat conditions. Gillnet fishing ground habitat condition, or habitat condition of Indo-Pacific king mackerel, was understood based on marine survey data by RIMF (2017), consisting in oceanographic parameters such as temperature, salinity, turbidity, dissolved oxygen, and pH as shown in Table 5.

Table 5

Oceanographic parameters of Indo-Pacific king mackerel fishing ground

Parameter	*Value*
Temperature	29-30°C
Salinity	32-33 PSU
Turbidity	0.4-0.8 NTU
Dissolved oxygen	5.75-6 mg L^{-1}
pH	8.75-8.85

Catch marketing pattern. Small-scale gillnet fishermen sell their catch directly to big middlemen (*tangkahan*) or to local market. Fishermen usually establish partnership with *tangkahan*, i.e. *tangkahan* provides supplies (diesel fuel and ice) for fishermen, and fishermen sell their catches to *tangkahan.* Fish collected at *tangkahan* are mostly exported to Singapore and Malaysia using fish cargo ship. Fish distribution routes from South China Sea and North Natuna have several categories: via Batam - fish are from Anambas, Natuna, and other islands around Batam; via Tanjung Balai Karimun - fish are from fishermen in Tanjung Balai Karimun and the surrounding islands; via Tanjung Pinang - fish are from Bintan, Kijang, and the surrounding small islands; via Moro - fish are from Belitung, Bangka, Moro, and other islands around Moro.

The fish distribution pattern is depicted in Figure 6. Based on the interview, export destination countries are Malaysia and Singapore. One of the destinations in Singapore is Jurong, while in Malaysia is Batupahat.

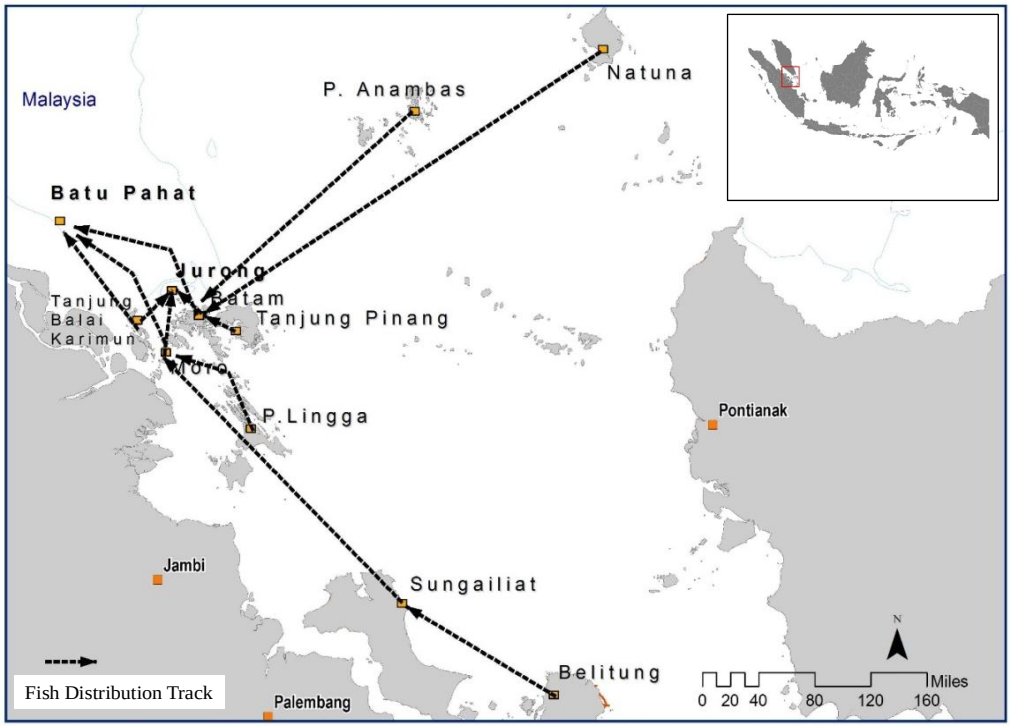

Figure 6. Fish distribution routes from South China Sea and North Natuna to export destination countries (Singapore and Malaysia).

Discussion. Indo-Pacific king mackerel in Moro and the surrounding waters are mostly caught by gillnet. As also reported by IOTC (2016), in Indian Ocean the mackerels are caught by gillnet. In Indonesia's part of the ocean, 65% mackerels are caught by gillnet as opposed to other fishing gears (IOTC 2016). Based on vessel size, fishing gear size, fishing days, and number of resources involved, the fishing is small-scale fishery (FAO 1999). Gillnet mesh size is crucial in determining the size of fish caught. Hosseini et al (2017) stated that gillnet with 3.5 inches (90 mm) mesh is the most suitable to catch Indo-Pacific king mackerel because, in addition to obtain the catch, the gillnet allows small fish to pass through the mesh. In Moro waters and the surroundings, fishermen use mesh in various sizes, i.e. 2.5-4 inches.

The composition of gillnet catch consists of various fish species, indicating Moro waters have fairly high biodiversity. However, the fish are caught in small percentage, presumably due to trawl operations prior to prohibition. The trawl operation slightly decreased fish abundance in Moro waters, although the species diversity is still high. Catch composition shows two dominant species, namely wolf-herring and Indo-Pacific king mackerel. During site observation, the two species were seen taking turns dominating each catch, where sometimes wolf-herrings are caught a lot and some other times Indo-Pacific king mackerels.

The catch composition has to be continuously monitored to understand the composition of fish species for each fishing trip. With gillnet operation in certain period of time, will the catch composition change? Or will other fishery activity affect the composition? When there are one or more fish species with declining abundance, or even disappear from the catch composition, it indicates fishing pressure from dominant and intensive gillnet operations. From the catch composition, it is clear which fish species are from the same habitat and interact with each other.

CPUE of < 10 GT gillnet vessels in 2015-2017 fluctuated, i.e. respectively 17, 24, and 21 kg trip^{-1} day^{-1}. The declining CPUE in 2017 was normal due to increasing efforts, i.e. from 637 trips in 2016 to 1,110 trips in 2017. CPUE in 2016 started to increase, presumably because trawl vessels stopped their operations in Moro waters and the surroundings since 2015 (Ministerial Regulations-MMAF/IR/No.2/2015). CPUE of Indo-Pacific king mackerel (Table 4) also experienced declining trend in 2017, in line with the overall declining gillnet CPUE. More trips in 2017 did not equal more catch. The abundance of the mackerel CPUE of the gillnet CPUE was 25-28%. Such fluctuating CPUE indicates the fishery resources still can grow and can be utilised.

CPUE of gillnet operated by > 20 GT vessels is different with those by < 10 GT vessels due to their different fishing grounds, i.e. Karimata Strait and Natuna Sea for big gillnet vessels, and neritic waters or around the coast for small gillnet vessels. The fishing grounds certainly have different characteristics, habitat traits and species, and thus different catch composition. The results are in line with Wujdi & Suwarso (2014) who stated that the catch composition of gillnet operating in South China Sea is dominated by kawakawa (*Euthynnus affinis*) (46.86%), longtail tuna (*Thunnus tonggol*) (36.98%), narrow-barred Spanish mackerel (*Scomberomorus commerson*) (15.32%), and Indo-Pacific king mackerel (*Scomberomorus guttatus*) (0.84%). Changes in catch composition can be influenced by fishing areas, fishing gear, fish abundance, and water environmental conditions.

There are two fishing seasons, i.e. during March-June which was the first transitional season to east monsoon, and during October-December which was the second transitional season to west monsoon. Similar condition was also reported by Noegroho (2013) that in Kwandang Bay waters of Sulawesi Sea, fishing seasons for narrow-barred Spanish mackerel are during April-June and October-November. In addition, Kasim & Triharyuni (2014) also stated that there are two fishing seasons for narrow-barred Spanish mackerel in Java Sea, i.e. April to June and October to November each year.

Information on fishing season highly benefits small fishermen, i.e. information on the first season period that starts at the beginning of the year and ends ahead of the east monsoon that is characterised by strong winds, and the second season that starts before

and until the year ends ahead of the west monsoon that is characterised by high rainfall and strong winds. During strong winds and high rainfall, the fishermen do not fish.

Fishing grounds for < 10 GT vessel gillnet are neritic water, coastal area, and slightly turbid waters with low salinity. Fishermen depart to the sea 2-5 nautical miles from their settlements. The fishing ground is 10-40 m deep. According to Fischer & Whitehead (1974), fishing grounds for Indo-Pacific king mackerel are in coastal waters 15-80 m deep. The mackerel's fishing grounds are not too far from the coasts, indicating that they are not highly migratory fish (Williams & Lawson 2001; Collette & Nauen 1983).

Oceanographic conditions of Indo-Pacific king mackerel fishing ground indicate that the waters are healthy and sound for fish growth. The conditions meet seawater quality standards for fish, i.e. physical parameters (temperature 28-32°C and turbidity < 5 NTU) and chemical parameters (pH 7-8.5, dissolved oxygen > 5 mg L^{-1}, and salinity 33-34 ppt (LIPI 2016). Moro waters of Riau Islands are a part of water mass from South China Sea and Natuna waters, meaning that the waters are slightly affected by the Pacific water transport (Fang et al 2010). Riau Islands waters are shallow and slightly turbid, partially due to river's run-offs. However, such condition is suitable for Indo-Pacific king mackerel's habitat, i.e. slightly turbid waters with low salinity (Collette & Nauen 1983).

The marketing of Indo-Pacific king mackerel and other fish exported through *tangkahan* with fish cargo ship, are collected from several fish landing sites (Figure 6). *Tangkahan* is individually owned fish landing site, local and export fish trading site, and integrated with workshop, cold storage, and processing site. Shipping process to Singapore requires 4-5 hours of sea trip, while to Malaysia 6-8 hours. Export time will be short if there are adequate airport and aircrafts to export through air. Fishermen's exported catch should be through *tangkahan* because it is the only one having access and facility to export fish. The Government should take it into account to help fishermen to market and process their catch to improve export and local fish markets.

Conclusions. Indo-Pacific king mackerels in Moro waters of Riau Islands are caught by gillnets mostly on < 10 GT vessels. Catch composition of < 10 GT gillnet vessel is dominated by wolf-herring and Indo-Pacific king mackerel, while > 20 GT vessel by longtail tuna, kawakawa and narrow-barred Spanish mackerel. CPUE in 2015-2017 shows fluctuating trends, indicating that Indo-Pacific king mackerel still can be utilised, of course with precautionary and environmentally friendly principles. There are 2 fishing seasons for the mackerel, i.e. March-May and October-December, being March the peak of the season. Fishing grounds for < 10 GT vessels are around the coastal waters, island waters, and nearby the fishermen's settlements, while > 20 GT vessels in Karimata Strait and Natuna waters. Oceanographic conditions of the mackerel habitat are temperature 29-30°C, salinity 32-33 PSU, and pH 8.75-8.85. Export destination countries of the mackerel are Malaysia and Singapore via Batam, Tanjung Balai Karimun, Tanjung Pinang, and Moro.

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Authors:
Tegoeh Noegroho, Research Institute for Marine Fisheries, Ministry of Marine Affairs and Fisheries, Komplek Raiser Ikan Hias Cibinong, Jl. Raya Bogor KM 47, Bogor, Indonesia, Bogor; Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Lingkar Kampus 1, Darmaga Campus, Bogor City 16680, Indonesia, e-mail: teguhnug80@gmail.com
Mennofatria Boer, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Lingkar Kampus 1, Darmaga Campus, Bogor City 16680, Indonesia, e-mail: mboer@ymail.com
Luky Adrianto, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Lingkar Kampus 1, Darmaga Campus, Bogor City 16680, Indonesia, e-mail: lukyadrianto@gmail.com
Sulistiono, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Lingkar Kampus 1, Darmaga Campus, Bogor City 16680, Indonesia, e-mail: onosulistiono@gmail.com

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