

Shark and ray monitoring on the marine critical habitat in Aceh Province

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Abstract. Aceh is the leading province in Indonesia, where the marine protection area for juvenile sharks and rays was first established, precisely in Aceh Jaya waters. Rigaih is the fishing port located closest to Aceh Jaya waters, where the angler fish closely with the marine protected area and even intersect with the juvenile's habitat. This study aimed to examine shark and ray catches in Aceh Jaya before and after establishing the marine protection area. We conducted landing monitoring from 2017 to 2019 (before establishing a conservation area) and monitored in 2020 when the conservation area was established. We recorded that 73% of sharks and ray caught on set gill net. The composition of sharks and rays landed at PPI Rigaih consisted of *Sphyrna lewini* (75%, n=1783), *Chiloscyllium punctatum* (8%), *Neotrygon caeruleopunctata* (7%, n =175), and other species (10%). This study aimed to provide scientific recommendations to support shark conservation action in Aceh Jaya Waters. We found that Aceh Jaya waters are an important area for the life stages of several threatened species, including Scalloped Hammerhead Sharks (*S.lewini*) and Bottlenose Wedgefish (*R.australiae*) that are listed in Critically Endangered and listed in Appendix II CITES. Management to support the conservation action needs to be strengthened not only limited to Marine Protected Areas but also fisheries management to reduce the incidental catch of threatened sharks and ray species. Further studies need to be conducted to delineate the habitat range of threatened shark and ray species and identify fishing behaviours that pose a risk for incidental catches of sharks and rays.

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1 Introduction

Sharks and rays are listed into cartilaginous fishes from the Chondrichthyes class, *Elasmobranchii* subclass. This subclass consists of two large groups, namely groups, shark and ray. Shark and ray (*Elasmobranchii*) fisheries are one of the most essential fisheries commodities in the world. However, this group of fishes has unique biological characteristics such as long longevity, late maturity, and number of pups. Naturally, these groups have high susceptibility due to it given biological factors and are also threatened by habitat loss and fishing pressure [1].

The total catch of Elasmobranch fish in the world is increasing from year to year 1950 - 2010, and 2003 was the highest catch of sharks and rays in the world reached 800,000 tons/year [1]. On other side, research showed that in the last 50 years, the population of pelagic sharks declined reached to 70%, and more than 30% of total species already listed into IUCN redlist threatened species [2, 3].

Shark and ray fisheries in Indonesia existed for a long time, recordlike even before 1940's [4, 5]. The fisheries growth until Indonesia was recorded as the leading country for shark fisheries. Shark fisheries itself started in the 1980's due to the increase of shark fin demands in the international market [5]. The average elasmobranch production annually is not less than 100,000 tons [6, 7]. On a local scale, Aceh Province significantly contributed to the shark fisheries in Indonesia. Within two decades, there has been a decreasing trend in shark and fisheries production rays in Aceh Province. This is shown by [8], in years 1989 - 2000, the *average* production of sharks and rays reached ~3200 tons/year then in From 2001 to 2010, shark and ray fisheries production was only around ~2900 tons/year. There was a 10% decline in production over a decade. This situation indirectly reveals that the waters of Aceh serve as a primary fishing ground and a habitat for sharks and rays.

Sharks and rays that are caught and landed need conservation action with the robust science baseline to support conservation and fisheries management to ensure the sustainability of the populations, considering at least 74 shark species in Aceh waters threatened by extinction referred to IUCN Red-List of Threatened Species [2]. For example, scalloped hammerheads that regularly landed that listed as Critically Endangered species or a step behind extinct in the wild [2]. Aceh Jaya waters were the first marine protected area that protected juvenile scalloped hammerheads in Indonesia. Nevertheless, the water is not only the habitat of juvenile scalloped hammerheads but also other elasmobranch species.

This research provided information about time series data of sharks and rays that were caught and landed at Rigaih landing site. Time series data would be important to show the baseline information to support the impact of marine protected area establishment, considering Rigaih waters had been established as a Marine Protected Area in 2020 [9]. The aim of this research was to provide information about species composition and catch abundance based on fishing power index standardisation.

2 Material and Methods

2.1 Time and Place

We conducted landing monitoring at the Rigaih fishing port 15 days in a month. During the data collection, we also followed and adjusted to the local activity and rules, including respecting Friday as a working day. We collected data from 2017 to 2019 by recording sharks and rays, which landed through census monitoring from 6 am till mid-day, adjusted with fishers' landing time.

2.2 Data and Monitoring Methods

This study used primary and secondary data. Primary data consisted of catch information and fishing behaviour that the enumerator recorded. We recorded sharks and rays that landed on the fishing port, measured the length, and identified species and sexes. We also recorded information about fishing gear, the fishing vessels, and fishing grounds. This information was taken from the boat crew, boat owners, and captains; we interviewed several fishers at the same time to verify the information. To complete the time series information, we also collected statistics data from the government as secondary data.

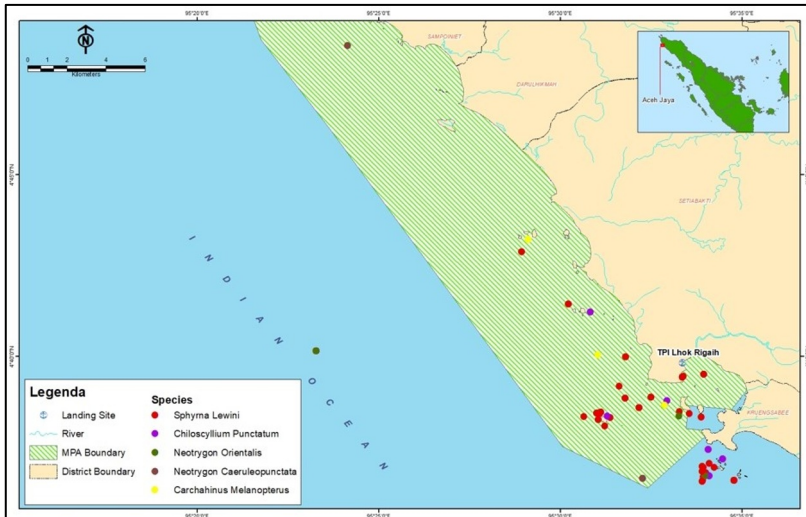


Fig. 1. Critical habitat mapping: sharks and rays catch site at PPI Rigaih - Aceh Jaya.

2.3 Data Analysis

2.3.1 CPUE Standard with Method Fishing Power Index (FPI)

Catch per Unit Effort (CPUE) is known as an approach to assess fish population by the catch abundance considering its uncertainty. CPUE is known as one of population estimation which proposed a relationship between harvest effort and the probability of capture [10]. Population trend often assumedly changes along the trend changes of CPUE [11]. CPUE is calculated with the use formula:

$$CPUE = \frac{Catch}{Effort}$$

Where:

CPUE = Catch per fishing effort (fish/trip)

Catch (C) = Total catch (head)

Effort (E) = Total fishing effort (trips)

2.3.2 Identify The Type of Shark and Ray

We considered analysis until the species level to make the study more applicable for management; however,

sharks and rays identification until species level need to be done precisely. Identification is conducted by a protocol which developed by [7], whereas the enumerators need to take pictures of sharks and rays. The images that have been taken are identified using the shark and ray identification book:

1. Sharks of The World [12]
2. Rays of The World [13]
3. Sharks and Rays which have Important Economic Value in Indonesia [14]
4. Descriptions of New Sharks and Rays from Borneo [15]

2.3.3 Composition of Shark and Ray Species

The species composition of sharks and rays caught was analyzed based on the number of individuals, fishing areas and size distribution. There are more than ~200 species of sharks and rays in Indonesia, which are spread across various regions, including Aceh. Considering the high diversity of sharks and rays, several priority species of sharks and rays will be selected. The sharks and rays that are included in the priority analysis are the sharks and rays that are predominantly caught and landed, the types that have been included in Appendix II of the Convention International Trade in Endangered Species (CITES), and species that have a high threat conservation status based on the red criteria list International Union for Conservation of Nature (IUCN). This type of composition analysis aims to determine catch patterns of sharks and rays, which is expected to help explain the type composition, resource conditions and habitat distribution based on size.

3 Result and Discussion

3.1 Site Overview

Rigaih Fishing Port is located on Western Coast of Sumatera Island in Aceh Province. The precise geographical positions are 4° 39,739 N and 95° 33,355 E. The fishing port was built in 2006, named Rigaih Fishing Port, under the district authority. Administratively, PPI Rigaih is located in Gampong Lhok Timon, Setia Bakti District, and is precisely located on the edge of Rigaih Bay.

The main fisheries characteristics are pelagic and demersal that sharks were not the main targeted fish in Aceh Jaya Regency. Conversely sharks and rays regularly landed as additional and valuable catches. We recorded 26 fleets from three landing locations with coastal and small pelagic fishing fleets with various fishing gear such as handlines, gill nets, bottom longlines, and left nets. Sharks and rays that landed were dominated by small size individuals, including juveniles and immatures.

The main fishing grounds were relatively close from the fishing base, which were in small and scattered islands; there are: Raya Island, Keuh Island, and Khek Island. Those islands and the waters surrounding it have distance approximately 30 kilometers parallel from the coastline.

3.2 Sharks and Rays Catch at PPI Rigaih - Aceh Jaya

Based on monitoring data since July 2017, the highest catches were recorded on August 2019. Averagely the number of catches relatively high in the middle of the year counted from July till September. Those months are the west wind season, which made the fishers shift their

fishing gear into entangle nets, which also caught more sharks and rays compared with other fishing gear. (Fig. 2).

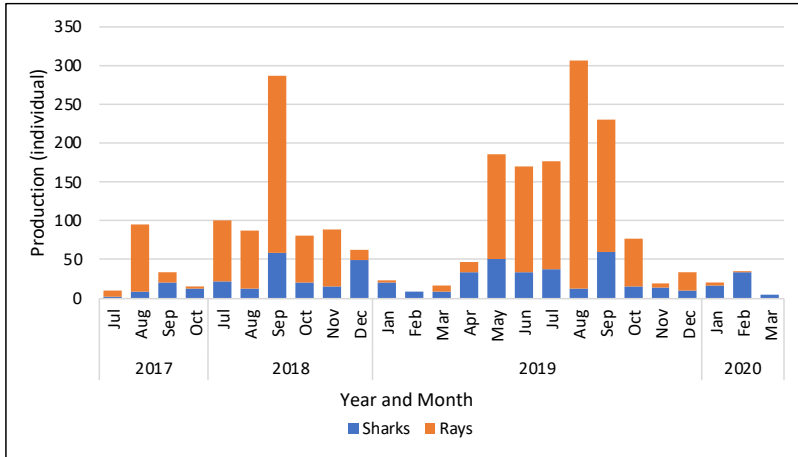


Fig. 2. Monthly production of sharks and rays at PPI Rigaih - Aceh Jaya.

The analysis results showed that the catch abundance based on the fishing power index showed some decreasing and increasing trends yet relatively stable from 2017 to 2019. The number of vessels and efforts that operated in Rigaih fluctuated, however, we used standardisation through fishing power index to reduce the bias due to these fluctuations. The highest CPUE was recorded in 2019, when every boat landed a shark every trip. (Fig. 3).

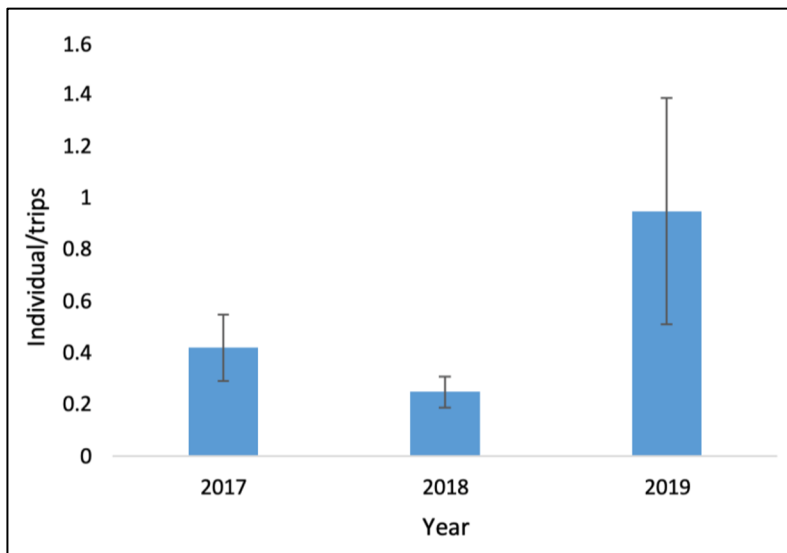


Fig. 3. Shark CPUE graph in PPI Rigaih - Aceh Jaya 2017-2019.

3.3 Composition of shark and ray catches

Sharks and rays that landed were dominantly caught by Gillnet. However, sharks and rays are also caught by other fishing gear such as drift gillnets, longlines, handlines, and trammel nets (Table 1). The species composition that landed consisted by *Sphyrna lewini* (75%),

Chiloscyllium punctatum (8%), and *Neotrygon caeruleopunctata* as much as (7%). Meanwhile, the species composition of sharks and rays caught during the landing survey included *Sphyrna lewini* (80 %), *Loxodon macrorhinus* (4%), *Carcharhinus sorrah* and *R. australiae* as much as 3% (Fig. 4).

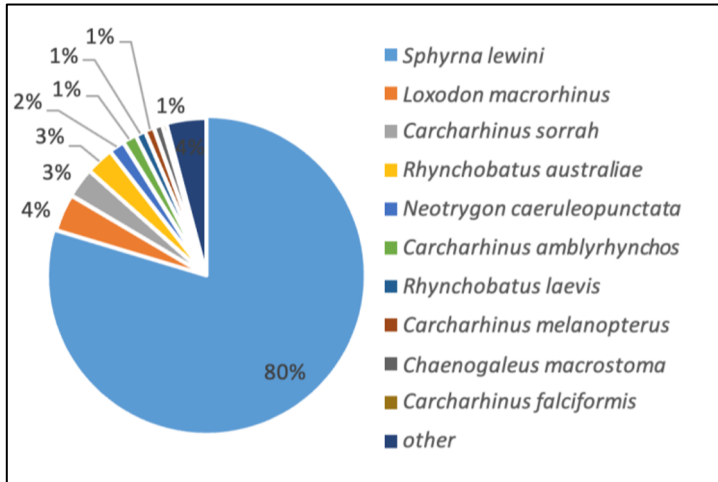


Fig. 4. Composition of shark and ray catches at PPI Rigaih - Aceh Jaya.

73% of the sharks and rays landed at the Rigaih Fishing Port, Aceh Jaya, were caught by gill net fishing gear. Other fishing gear used for catching sharks and rays at PPI Rigaih are drift gill nets, longlines, hand lines and trammel nets (Table 1).

Table 1. Catch composition based on fishing gear at PPI Rigaih.

Fishing Gears	Number of Individuals
Gill Net	1836
Drift Gill Net	137
Trammel Net	35
Tuna drift longline	107
Hand lines and troll lines	39

The Scalloped Hammerhead Shark that caught and landed were classified by catch from gill net fishing gear; in addition the catches were dominated by juveniles and immature individuals. The average total length recorded was 66 cm, and the catches recorded between 66 cm and 240 cm. We also recorded embryos that were possibly accidentally delivered from pregnant females with size 29 cm (Table 2). The hammerhead catches were caught in the coastal area within 12 miles of the coast.

Table 2. Length of sharks and rays caught at PPI Rigaih - Aceh Jaya.

Species	Number of Sharks and Rays	Average total length	Total length Maximum	Minimum Total Length
<i>Sphyrna Lewini</i>	1783	66	240	29
<i>Neotrygon caeruleopunctata</i>	175	36.8	81	7
<i>Loxodon macrorhinus</i>	65	63.7	120	43
<i>Rhynchobatus australiae</i>	54	92.8	236	47
<i>Carcharhinus sorry</i>	52	80.6	123	53
<i>Chiloscyllium punctatum</i>	31	55.8	82	40
<i>Carcharhinus amblyrhynchos</i>	24	76.8	120	40
<i>Gymnura poecilura</i>	18	35	45	30
<i>Rhynchobatus laevis</i>	18	105.3	221	64
<i>Carcharhinus melanopterus</i>	17	110.9	156	66
<i>Chaenogaleus macrostoma</i>	15	84	120	46

Based on three years of landing monitoring at Rigaih fishing port, we recorded 1783 individuals of Scalloped Hammerhead (*S. lewini*) that are dominated by juveniles and immature individuals. Then followed by the *Neotrygon caeruleopunctata*, which counted 175 individuals. There are several rays of this type that were caught in juvenile condition, namely 7 cm in size. Other species that were recorded were *Rhynchobatus australiae*, *Rhynchobatus laevis*, *Chaenogaleus macrostoma*, and *Carcharhinus falciformis*. The composition of shark and ray catches based on IUCN red list status is 47%. The composition of the IUCN red list includes the composition Vulnerable 31%, Endangered 6%, and Critically Endangered 10% (Fig. 5).

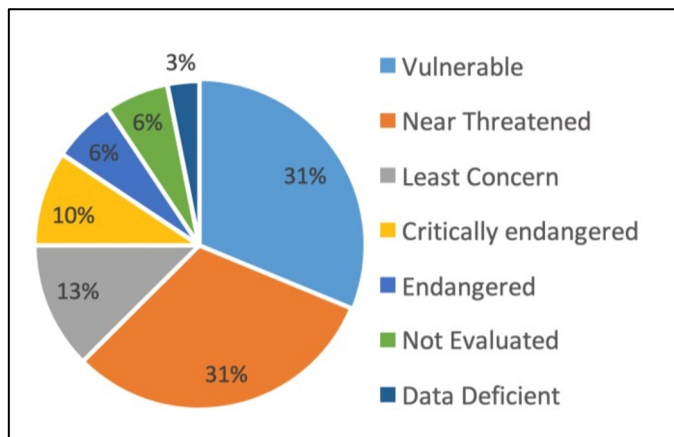


Fig. 5. The IUCN Redlist Threatened Species composition of sharks and rays that landed at Rigaih Fishing Port, Aceh Jaya.

We recorded 14% of shark and ray catches had been listed into CITES Appendix II. The species composition of CITES appendix II list showed that 95% dominated by Scalloped Hammerhead (*Sphyrna lewini*), followed by Bottlenose Wedgefish (*Rhynchobatus australiae*) 3% and other mix species 1% including Silky Shark (*Carcharhinus falciformis*)

and Pelagic Thresher Shark (*Alopias pelagicus*). All species recorded dominated by immature rather than mature individuals.

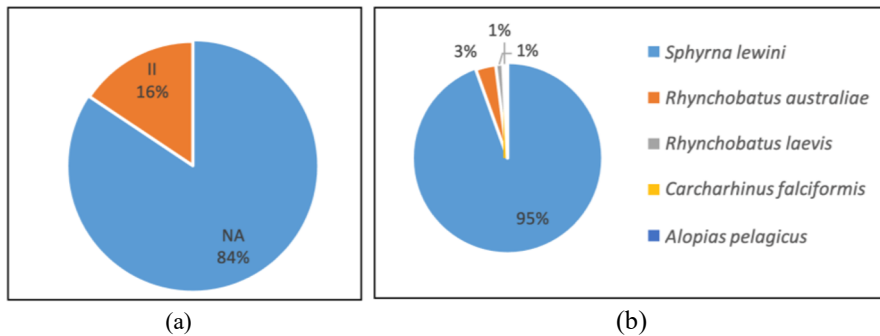


Fig.6. (a) Catch results sharks and rays based on the status of Appendix II (b) types sharks and rays Appendix II category which was landed at PPI Rigaih - Aceh.

A Sharks and rays catches that landed in Rigaih Fishing Port were dominated by threatened species referred to IUCN Redlist Threatened Species and CITES Appendix II list. The sharks and rays that landed relatively had similar range sizes, there were small species of sharks and rays or juveniles. These conditions commonly found due to sharks and rays tend to aggregate on the same size with the mix species [16].

The catches dominated by Scalloped Hammerhead as Critically Endangered species that also listed into CITES Appendix II. Management and conservation action is needed to ensure its healthy population in the ocean. Some of the species listed in Appendix II CITES, including Scalloped Hammerhead, had been regulated by catch quota and minimum size limit. However, the catches in the Rigaih fishing port were not complied with the size limit that was 200 cm [17].

Scalloped hammerhead known as migratory species however it has specialist behaviors and habitat preferences, the juveniles inhabit in inner bay and coastal environment [18], while adult distributed globally and migrated in schoolings between waters [19-22]. The Scalloped Hammerhead that landed in Rigaih fishing port varied from mature females, juveniles, and embryos. This condition showed that fishing grounds of Aceh Jaya fishers have overlay with area that important to Scalloped Hammerhead for carrying out their vital functions highly probability as reproduction and nursery area. Coastal waters close with Rigaih Fishing Port are shallow continental shelf located with the edge of Indian Ocean that known as suitable habitat for life-stages for Scalloped Hammerhead. This was supported by another research that individuals of Scalloped Hammerhead occupied shelf waters and the juveniles could be found in nearshore bay and estuarine habitats [23-26].

Another dominant threatened species that recorded was the juveniles of Bottlenose Wedgefish (*R. australiae*) that also listed as Critically Endangered by IUCN Redlist Threatened species and listed into Appendix II CITES. The mature individuals could be found encounter across broad habitats; however, juveniles stages tend to be a specialist feeder with preys consisted by small bony fishes and crustaceans [27, 28]. This condition relevant with fisheries that exist in Aceh Jaya, pertaining trammel net targeting crustacea that the main prey of juveniles Bottlenose Wedgefishes.

The leading fishing gears that incidentally caught sharks and rays were gillnet, drift gillnet, drift longline. Although those fishing gears had different operational methods, they were all operated in relatively the same fishing grounds. In fact, the fishing grounds located outside of Marine Protected Area. This showed that MPA that has been established had low impact to reduce the number of sharks and rays that caught and landed. We assumed that

based on vertical and horizontal movements of the sharks and rays, yet there is still a high risk of incidentally catching sharks and rays. To determine the swimming layer and overlay between fishing ground and habitat range, further research needs to be done.

The average catch abundance from 2017 to 2019 showed insignificant differences, meanwhile the number of catches increased almost three times higher in 2019 compared with 2017. These conditions demonstrate that fishing effort also influences the number of catches. However, further studies need to be conducted to determine the specific fishing behaviors that impact the catch numbers and identify the necessary fisheries management measures.

4 Conclusion

Aceh Jaya waters are important area for the life stages of several threatened species including Scalloped Hammerhead Sharks (*S. lewini*) and Bottlenose Wedgefish (*R. australiae*) that listed into Critically Endangered and listed in Appendix II CITES. Management to support the conservation action need to be strengthen not only limited on Marine Protected Area but also fisheries management to reduce the incidental catch of threatened shark and ray species. Further studies need to be conducted to delineate the habitat range of threatened shark and ray species and identify fishing behaviours that pose a risk for incidental catches of shark and ray.

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