E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(4): 350-354

www.fisheriesjournal.com
Received: 08-05-2017
Accepted: 10-06-2017

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Population of Hammerhead Sharks (*Sphyrna lewini* Griffith and Smith, 1834) caught in aceh barat and aceh jaya water

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Abstract
Hammerhead shark (*Sphyrna lewini* Griffith & Smith, 1834) is catch target for Indonesian fisherman. Based on conservation status of hammerhead sharks in Indonesia, it is included in Appendix II CITES, thus hammerhead shark has gained a tremendous attention in the field of capture fisheries. This study was aimed to examine some populations of hammerhead sharks caught in the waters of Aceh Barat and Aceh Jaya from January to July 2014. Samples were obtained from fisherman catches in the waters of Aceh Barat and Aceh Jaya landed at PPI Ujong Baroh Meulaboh. Descriptive analysis and assessment using ELEFAN 1 in FiSAT II were performed. The results showed that 311 hammerhead sharks caught were dominated by male (111 sharks) at length ranging from 70.5 to 91.5 cm and female (57 sharks) at length ranging from 70.5 to 91.5 cm. The female sharks were included in immature young shark group, which potentially led to recruitment overfishing. Asymptote length of hammerhead shark may reach 262.50 cm. The rate of growth and mortality of female shark is higher than that of male shark. The population of hammerhead sharks has experienced excessive catching, thus their proper management and utilization were needed to make them sustainable and available in maximum length.

Keywords: Hammerhead shark *Sphyrna lewini*, shark population, Aceh Barat and Aceh Jaya waters, PPI Ujong Baroh

1. Introduction
Hammerhead shark (*Sphyrna lewini* Griffith and Smith, 1834) belongs to the *Sphyrnidae* family which is a common caught species in Indonesian waters (White *et al.*) [28]; hammerhead sharks are often caught in Indian Ocean in south of Java and Nusa Tenggara (Chodrijah; Fahmi and Dharmadi; Sentosa *et al.*) [2, 9, 1]. Population decline for hammerhead shark has been occurred, as a result of high catch rate and intensive trade especially for its fins as export commodity (Ferrttier *et al.*; Hayes *et al.*) [10, 14].
The hammerhead shark was originally a by-catch in fisheries but became catch target in artisanal fisheries in some areas (Fahmi and Dharmadi; IOTC; Drew *et al.* Sentosa *et al.*) [8, 16, 5, 1]. Population status of hammerhead shark is still not widely known, but it is suspected that hammer shark shows declined population around the world especially in Indian Ocean, and is considered as "endangered" (IOTC 2014). Galluccci *et al.* [12]; Musick *et al.* [20] reported that hammerhead sharks are vulnerable to fishing in term of life cycles such as their slow growth and maturity of genitals and low fecundity.
Red List International Union for the Conservation of Nature and Natural Resources (IUCN Red List) report that hammerhead shark is endangered (Sentosa *et al.* [1]). According to the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora, the shark is included in Appendix II (Dulvy *et al.* Fahmi and Dharmadi; White *et al.* Sentosa *et al.*) [6, 8, 28, 1]. In Indonesia, hammerhead sharks have been listed in prohibited species for export and in accordance with Ministerial Regulation Number 59/2014 [24] and Number 34/2015 [25]. Sharks with various sizes ranging from small to large are almost every day landed in fish landing base of Ujong Baroh Meulaboh. Information related to biological aspects (size, catch amount, age, size of first caught, growth, genital maturity) of the sharks landed in PPI Ujong Baroh Meulaboh is still poorly available. This current work was aimed to investigate the population of hammerhead sharks caught in the waters of Aceh Barat and Aceh Jaya.

2. Materials and Methods

This research was conducted at Fish Landing Station (PPI) of Ujong Baroh Meulaboh from January to July 2014. The samples were collected from fishermen that caught in Aceh Barat and Aceh Jaya waters. Data including composition of monthly catching, number of catching, shark sex, and distribution of shark length were collected. To determine the population of hammerhead sharks, several parameters such as asymptotic length (L∞), growth coefficient (K), natural mortality (M), catch rate (F), and the rate of exploitation (E) were investigated according to long data from January to July using FAO ICLARM Fish Stock Assessment Tools (FiSAT II) software.

The growth parameters were analyzed using von Bertalanffy growth model (Effendie [7]; Sparre and Venema [27]; Sentosa *et al* [1].) L∞ and K values were estimated using ELEFAN 1 consisting of subprograms present in FiSAT II (Gayanilo *et al.*[13]). The shark age (t_o) was estimated using empirical equation (Pauly [23]; Sentosa *et al.* [1]), while natural mortality coefficient (M) was estimated using the empirical equation (Pauly [22]).

$$Lt = L\infty (1 - e^{-K(t-t0)}) \quad 1$$

where:

Lt : Lifespan;
L∞ : Asymptotic length;
K : Growth coefficient;
T : The time required to achieve the length certain;
t_0 : Theoretical age at the same length of 0.

Total mortality was estimated using length-converted catch curve in FiSAT II (Gayanilo *et al.* [13]; Sentosa *et al.* [1]). Rate of catch mortality (F) was obtained from difference in total mortality (Z) and natural mortality rate (M), while exploitation rate (E) was obtained from catch mortality divided by total mortality (F/Z) (Pauly [23]).

3. Results

A total of 331 hammerhead sharks were landed at PPI Ujong Baroh from January to July 2014. The 206 dominant male sharks were arrested in April at 84 (40.78%). The number of female sharks as many as 105 head of the dominant caught in April as many as 38 (36.2%) of total caught. The lowest catch of male hammerhead sharks was in May (5 individuals or equivalent to 2,43% of total catch), while the lowest catch of female hammerhead sharks was in February (5 individuals or equivalent to 2,43% of total catch). A ratio of hammerhead sharks caught in Aceh Barat and Aceh Jaya waters was 2:1 (male: female) as exhibited in Figure 1.

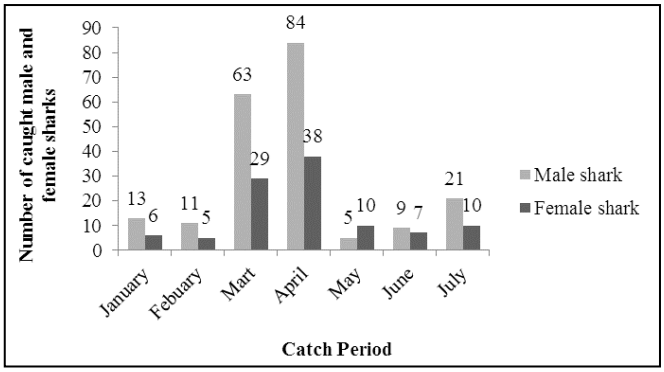

Fig 1: Number of hammerhead sharks caught in waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh.

The total length for male hammerhead sharks (111 sharks) ranged from 70.5 to 111.5 cm, while female hammerhead sharks (57 sharks) ranged from 70.5 to 91.5 cm. According to morphological aspect, male and female sharks showed similar size but more male sharks were caught (Figure 2).

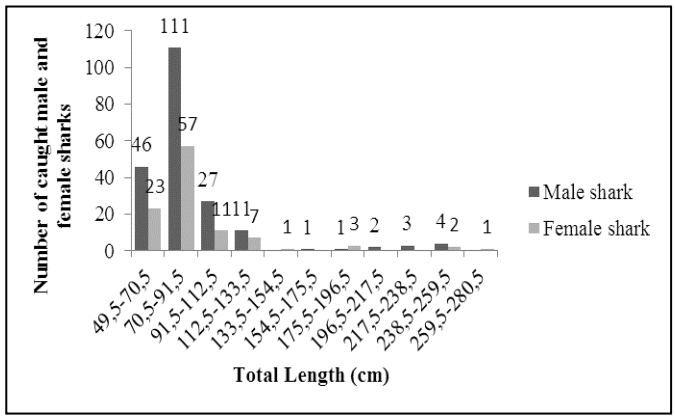

Fig 2: Distribution of male and female hammerhead sharks caught in waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh.

Table 1 exhibits shark growth determined using von Bertalanffy, which demonstrates increase in shark length as increase in age. In general, both sharks showed similar growth rate, although the coefficient value (K) was dissimilar.

Table 1: Growth of hammerhead sharks caught in waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh.

Sex	L∞	K	t_0
	cm	year-1	Year
Male	262,50	0,20	-0,28
Female	262,50	0,25	-0,34

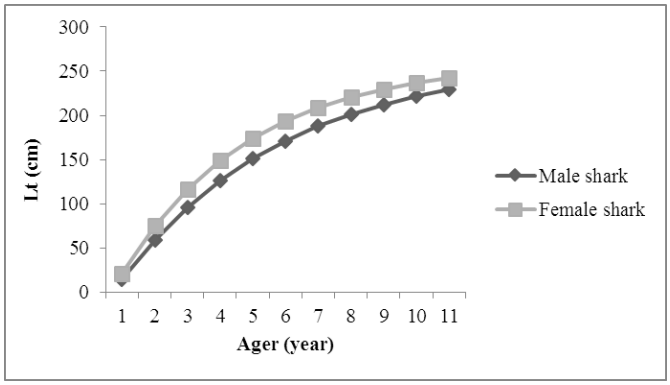

Fig 3: Growth of hammerhead sharks caught in waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh.

Based on the measurement, average temperature of sea surface in Meulaboh and Aceh Jaya waters was 29.7 °C. The mortality rate of male and female hammerhead sharks is presented in Table 2.

Table 2: Mortality of hammerhead sharks caught in waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh.

Sex	Z	M	F	E
	Year-1	Year-1	Year-1	Year-1
Male	0,04	0,35	0,31	7,75
Female	0,15	0,41	0,26	1,70

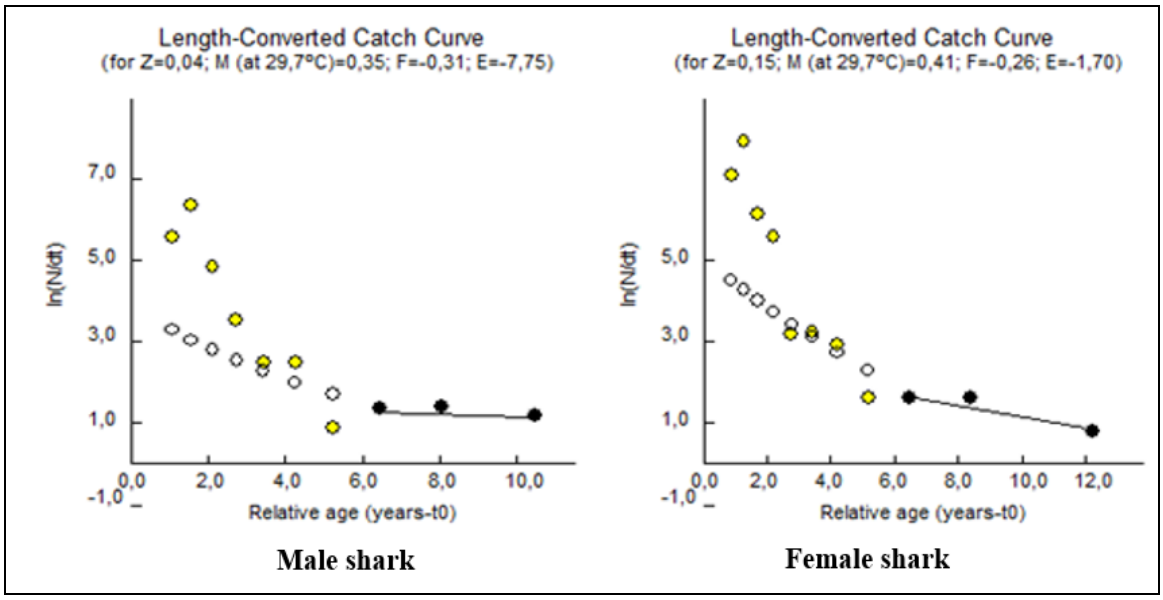

Fig 4: Mortality estimation curve of hammerhead sharks caught in waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh.

Discussion

The composition of hammerhead sharks caught by fishermen in the waters of Aceh Barat and Aceh Jaya landed in PPI Ujong Baroh was dominated by male sharks. This composition may be dissimilar as a result of different fishing areas (Harry *et al.*[15]). The sex ratio of hammerhead sharks caught in Indian Ocean in south of Nusa Tenggara was dominated by female sharks, while in Java and southern Kalimantan sea was dominated by male sharks (Muslih *et al.* [20]). The sex ratio is closely related to the number of fish produced in the next generation and as a population size control (Effendie [7]).

Hammerhead shark *(Sphyrna lewini)* is a common catch species in PPI Ujong Baroh. The length of male sharks was 50.8-250.4 cm, while the length of female sharks was 50.4-260.4 cm. Chodrijah and Setyadji [3] reported that length of hammerhead sharks ranged from 51-300 cm in 2010 and 43-320 cm in 2013. The size of hammerhead sharks in this current study is relatively smaller.

In general, length of hammerhead shark caught in the south of Indian Ocean of Nusa Tenggara ranged from 39 to 316.8 cm (White *et al.* [24]) and from 50 to 310 cm (Fahmi and Dharmadi [8]). This dissimilarity may result from differences in fishing equipment used by fishermen. Hammerhead sharks were mostly caught using gill net with a fishing ground of ± 20 mill from the beach.

Most caught sharks landed in PPI Ujong Baroh were immature and pre-reproductive sharks (93.4%) and female sharks (92.1%) at size of <165 cm. Length of hammerhead sharks that are at mature and reproductive stage was 165-175 cm for male and 220-230 cm for female (Fahmi and Dharmadi [8]; White *et al.* [28]). Manik [19] stated that adult hammerhead sharks could be 450 cm in length and often present in offshore areas.

The hammerhead shark population in Aceh Barat and Aceh Jaya waters varied due to environmental factors such as feed availability and oceanographical conditions (currents and turbulence). Fishermen selected some areas in which the sharks are abundant (Fahmi and Dharmadi [8]). The area included waters of Aceh Barat and Aceh Jaya WPP 572.

Sparre and Venema [24] stated that length frequency data could be used to estimate fish population. The hammerhead shark population is strongly influenced by several parameters such as growth, mortality and exploitation rate as previously reported in the study of the dynamics of fish population (Effendie [7]).

Our results indicated that L∞ value for male and female hammerhead sharks was comparable, but growth coefficient and age of both sharks were dissimilar. The growth of male hammerhead shark was slower than that of female hammer sharks. Fahmi and Dharmadi [8]; White *et al.* [27] reported that hammerhead shark *(S. Lewini)* was able to grow up to 370-420 cm. Froese and Binohlan[11] stated that L∞ was smaller (313,15 cm for male shark and 323,09 cm for female shark) in comparison with the empirical formula. In this formula, only maximum length parameter taken on the sample was used.

Based on the estimation result, the length of male and female hammerhead sharks would reach asymptotic length at age of 15 years. The maximum age is the theoretical age; hammerhead sharks in their habitat were incapable of growing up to the theoretical age since their growth was affected by environmental factors especially temperature and food availability (Sparre & Venema [27]). Klimley [17]) found that growth rate and maximum length of sharks were greatly diverse due to different geographic locations, especially in locations with different latitudes where sharks tend to grow faster in tropical waters than subtropics.

The estimation of shark life span should use direct method such as analysis of the number of annuli in the centrum vertebral (Drew *et al.* [5]; Klimley [17]; Rahardjo [26]). Average temperature in the waters of Aceh Barat and Aceh Jaya was 29.7 °C, indicating that the death of male sharks is faster than that of female sharks. White *et al.* [28] stated that lifespan of female shark was longer than that of male sharks. Natural mortality of sharks was strongly influenced by environmental conditions since they were included in cartilaginous fish that was highly dependent on water temperatures (Pauly [22]; Sentosa *et al.* [1]).

Table 3: Growth parameters of *Sphyrna lewini* in several landing locations

Number	Sex	L∞ (cm)	K (year^{-1})	Location	Source
1	Male	262,50	0,20	Aceh Barat and Aceh Jaya (India Ocean)	Current work
	Female	262,50	0,25		
2	Male	399	0,29	Southern Nusa Tenggara	Sentosa *et al.* [1]
	Female	399	0,24		
3	Male	259,8	0,15	Southern Java, Bali and Lombok	Drew *et al.* [5]
	Female	289,6	0,16		
4	Mixture	330,5	0,077	Eastern Australia	Harry *et al.* [15]

Total mortality (Z) of male hammerhead sharks was 0.04 year^{-1} that was relatively lower than that of female hammerhead sharks (0.15 year $^{-1}$). Mortality (Z) for male and female hammerhead sharks tends to be smaller than their natural mortality. These sharks are vulnerable to fishing activities since their habitat is close to estuary in offshore (Compagno [4]). The biological characteristics of hammerhead sharks are similar to those of other Elasmobranchii fish, where slow growth of genital maturity and low fecundity lead to declined population due to excessive fishing activities (Galluccci *et al.* [12]; Last & Stevens [18]; Musick *et al.*[20]).
White *et al.* [28] reported that length of *Sphyrna lewini* in Indonesia was 316,8 cm for mature female and 239,9 cm for mature male with litter size in uteri ranging from 14 to 41 (mean of 25) and gestation period of 9-10 months. Our study indicated that hammerhead sharks landed in PPI Ujong Baroh were at immature age, and this continuous fishing activities led to population decline (overfishing). Regulation for hammerhead shark fishing area in Indonesia is required as previously implemented in New South Wales, Australia, where *S. lewini* has been declared as "endangered" in coastal waters by (Drew *et al.* [5]).

3. Conclusion

Hammerhead sharks captured in Aceh Barat and Aceh Jaya waters and landed in fish harbour (PPI) Ujong Baroh were dominated by the sharks at total length of 70.9-91.5 cm. The asymptotic length of hammerhead sharks could reach 262.50 cm. The results indicated that the growth rate and mortality of female hammerhead sharks were higher than those of male hammerhead sharks. The most caught hammerhead sharks were at immature age and immature gonads, and their excessive fishing led to reduction of their population.

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