SOME BIOLOGICAL ASPECTS OF SCALLOPED HAMMERHEAD SHARKS (*Sphyrna lewini* Griffith & Smith, 1834) CAUGHT FROM COASTAL FISHERIES IN THE EASTERN INDIAN OCEAN

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Received; September 23-2013 Received in revised from December 02-2015; Accepted December 04-2015
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ABSTRACT

Indonesia has the largest chondrichthyan fishery in the world, with a reported of 105,000 and 118,000 tonnes landed in 2002 and 2003 respectively. Scalloped hammerhead shark was either targeted or by-catch from this fishery, mostly for its fins. Despite of the growing concern around the world, the availability of biological data of this species, especially in the Eastern Indian Ocean is still lacking. The objectives of this paper are to present some biological information (size composition and sex ratio) of the scalloped hammerhead, from coastal fisheries in Eastern Indian Ocean. The data used for the analysis comprised of two components, i.e. survey data in 2010 (February, March, June, August, October and December) and data from daily monitoring shark landing in 2013 (January to December). Substantially lower mean size, more immature sharks and more frequent of female caught over years showed that scalloped hammerhead shark in the Eastern Indian Ocean are facing intensive fishing pressure which could lead to overfishing. This could harm the sustainability of scalloped hammerhead shark resource in the long run. The relationship between clasper length and total length was positively correlated where every 5 cmTL increment on clasper length adding 51 cmTL on total length.

KEYWORDS: Scalloped hammerhead shark, sex ratio, clasper length, eastern Indian Ocean

INTRODUCTION

Scalloped hammerhead shark (*Sphyrna lewini*) is widely distributed and commonly found in warm temperate and tropical waters (Compagno, 1984). Its highly mobile and suspected as the most abundant among other hammerhead species (Maguire *et al*., 2006). Forming a large schooling around seamounts and oceanic islands makes sharks vulnerable to targeted fisheries (Baum *et al.*, 2007).

Scalloped hammerhead sharks are often targeted or taken as an incidental by-catch by some semi-industrial, artisanal (shark lines, hand lines) and recreational fisheries and industrial fisheries (pelagic longline tuna and gillnet) (IOTC, 2014). Shark fins are the main part of the shark to commercial as fisheries export product. Hammerhead shark species *Sphryna zygaena* and *S. lewini* were found to represent at least 4-5% of the fins auctioned in Hong Kong, the world's largest shark fin trading center (Clarke *et al.,* 2004a). It is estimated that between 1.3 and 2.7 million *S. zygaena* or *S. lewini* are represented in the shark fin trade each year or, in biomass, 49,000 to 90,000 tonnes (Clarke *et al.,* 2004b). As the case of most shark species, hammerhead shark catches are largely under-reported and unregulated, and there are significant discrepancies between catch and trade statistics (IOTC, 2014).

Indonesia has the largest chondrichthyan fisheries in the world. The fact that important number of shark landed in 2002 and 2003 with avalues reported of 105,000 and 118,000 tonnes, respectively (White *et al.,* 2006). Many studies reported that scalloped hammerhead population was declined around the world (IOTC, 2014), particularly in the Indian Ocean. The IUCN listed scalloped hammerhead as endangered species in sub population in Western Indian Ocean (Baum *et al.*, 2007). This is due to intense inshore fishing pressure and the present of foreign vessels targeting this species throughout Southeast Asia, where juveniles and neonates are very heavily exploited, with large numbers of immature sharks in catches in other areas also (SEAFDEC, 2006; Clarke *et al.*, 2006).

Despite of the growing concern around the world, the availability of biological data of this species is still lacking, especially in the Eastern Indian Ocean. Scalloped hammerhead has slow growth rates, lengthy gestation, long life and low productivity, which is vulnerable to overfishing (Castro *et al.,* 1999; Compagno, 1984; Last & Stevens, 1994). Therefore the need of basic biological data is imminent in related to understanding and assessing the shark fisheries in Eastern Indian Ocean, especially Indonesia. The objectives of the paper are to present some biological information (size

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composition and sex ratio) of the scalloped hammerhead, from coastal fisheries in Eastern Indian Ocean.

MATERIALS AND METHODS

Area and Sampling Methods

The specimen used for this study was scalloped hammerhead shark (*Sphyrna lewini*) (Figure 1). There were two types of data used for analysis, i.e. survey data back in 2010 (February, March, June, August, October and December) and data from daily monitoring shark landing in 2013 (January to December). The shark specimens collected were from Tanjung Luar Fish Landing Centre (PPI Tanjung Luar) (Figure 2). The data acquired during the survey and daily monitoring shark landing covers total body length (cmTL), sex and clasper length (cm). Total length was measured with fixed calipers to the nearest 1 cm, as for sex identification was conducted visibly due to clear sexual dimorphism between male and female. For further analysis, the discussion was separated by year of data collection (2010 and 2013, respectively).

Data Analysis

In this study hypothetically, sex ratio of male and female is equal to 1 at 95 % of confident interval (á=0.05), test on proportion of sex-ratio was done using chi-square test with the following equation (Sugiyono, 2004):

$$X^2 = \sum_{i-l}^{k} \frac{(f0 - fn)^2}{fn} \quad \text{.....(1)}$$

where in:

X^2 = Chi – Square
fo = frequency observed
fn = the expected frequency

Test table in the 95% significance level (n-1) with the following hypothesis:

H_0 : There is no real difference between the number of male and female fish.
H_1 : There are significant differences between the number of male and female fish.

If, X^2 count < X^2 tables, H_0, H_1 is rejected. If, X^2 test> X^2 tables, H_1 is accepted and H_0 is rejected (Effendie, 2002). All the statistical calculation was performed using open source statistical software R version 3.2.2.

Figure 1. Morphology of scalloped hammerhead shark (*Sphyrna lewini*).

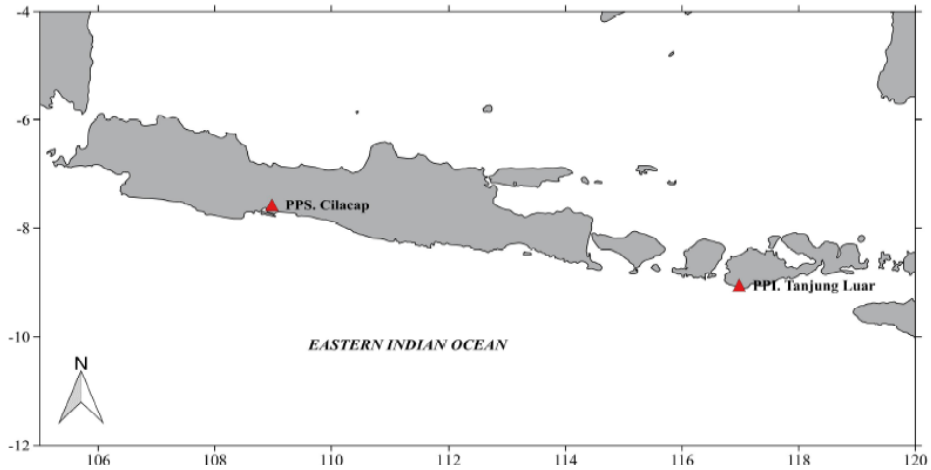

Figure 2. Map of research study.

RESULTS AND DISCUSSION

Results

Length Frequency Distribution

The length distribution of sharks from survey data in 2010 ranged from 51-300 cmTL (mean=178,45 cmTL). The length male ranged from 127-244 cmTL (mean=171.61 cmTl), whereas the female was between 51-300 cmTL (mean=182.63 cmTL). The length distribution from daily landing data in 2013 were varied from 43-320 cmTL (mean=154.64 cmTL). The male ranged from 47-296 cmTL (mean=121.34 cmTL) and female ranged from 43-320 cmTL (mean=168.53 cmTL) (Figure 3).

According to the 50% of length at first maturity information derived from IOTC (2014) most of the female sharks caught in 2010 were registered as immature (65.27%), while in 2013 the percentage decrease to 55.53%. The exploitation of male sharks put pressure on the fisheries. In 2010 most of the shark caught listed as mature male (95.45%) and the proportion fall down in 2013 where most of the shark caught (64.42%) were immature.

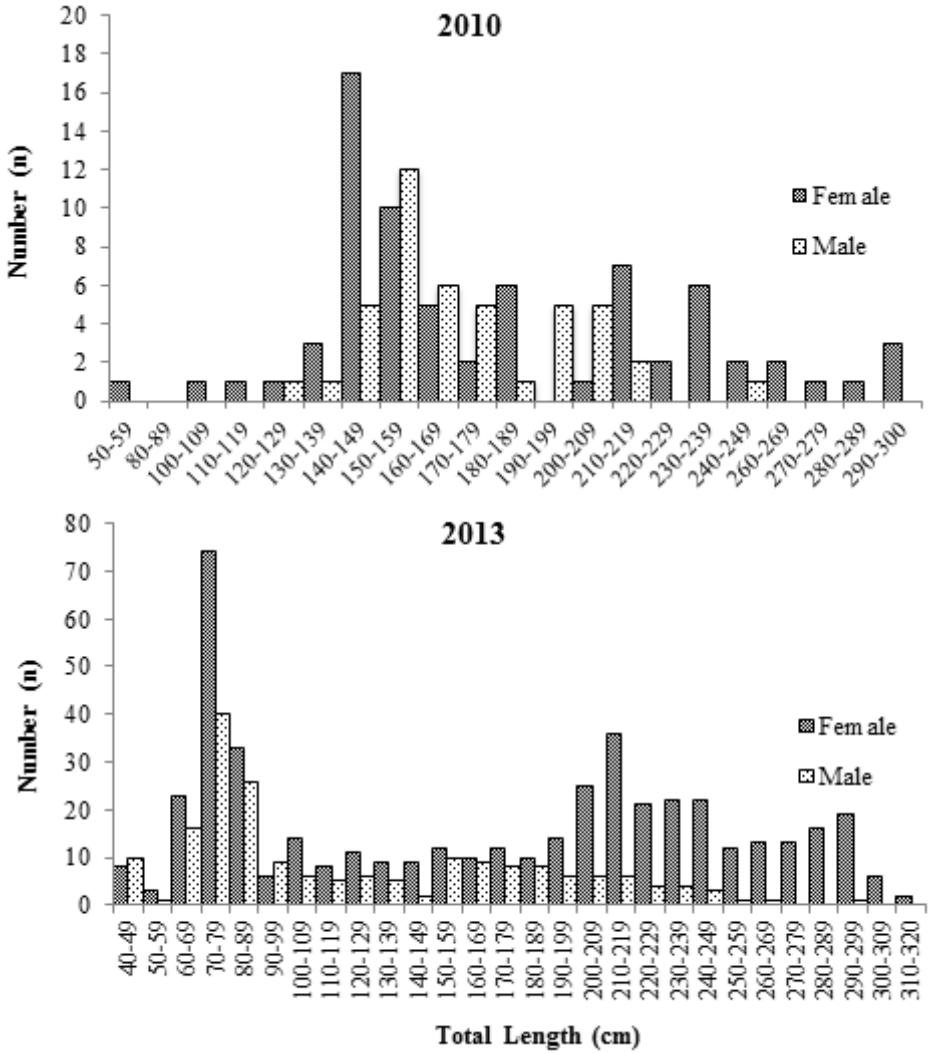

Figure 3. Length distribution of both female and male scalloped hammerhead sharks caught from coastal fisheries in Eastern Indian Ocean.

Four mature female sharks were recorded during the field observation. The shark possessed some embryos taken at both left and right pocket counted around 16-38 (average of 27 embryos) for each individual. The length of the embryos varied from 32-53 cmTL, its average weight was around 200 gram (Table 1; Figure 4).

Table 1. The amount and size range of embryos caught from coastal fisheries in Eastern Indian Ocean

No	Species	Number (n)	Male (n)	Female (n)	Length (cmTL)
1	*Sphyrna lewini*	16	8	8	38 - 43
2	*Sphyrna lewini*	31	18	13	50 - 53
3	*Sphyrna lewini*	24	*	*	32 – 36
4	*Sphyrna lewini*	38	*	*	34 - 38

Remarks : * : no data

Figure 4. The embryos of scalloped hammerhead sharks caught from coastal fisheries in Eastern Indian Ocean.

Sex Ratio

A total of 129 specimens data of scalloped hammerhead sharks were managed to be collected during 2010, which 44 individuals were identified as male, 537 were female and the others were unidentified). While in 2013, 193 specimens listed as male, 463 listed as female and 67 listed as unidentified (Table 2). The sex ratio between female and male shark in 2010 was 1.64:1, which ratio of female significantly different than male (X^2=111.14; $X^2_{0.05)}$=3.84). And in 2013 the sex ratio was 2.40:1, which also showed that the ratio of female was significantly different than male (X^2=6.76; $X^2_{(0.05)}$=3.84).

Table 2. Summary table of sex ratio and chi-square test between male and female scalloped hammerhead sharks caught from coastal fisheries in Eastern Indian Ocean

Year	Male	Female	Unidentified	X^2	$X^2_{(0.05)}$	p-value
2010	44	72	13	6.76	3.84	0.00933**
2013	193	463	67	111.13	3.84	2.2e-16**

Relationship between Clasper Length and Total Length

The relationship between clasper length and total length is positive with a linear regression equation of CL = 0.0971*TL-2.8435 (R^2=0.6889). It showed that the length of the claspers increase proportionally with the length of the body (Figure 5).

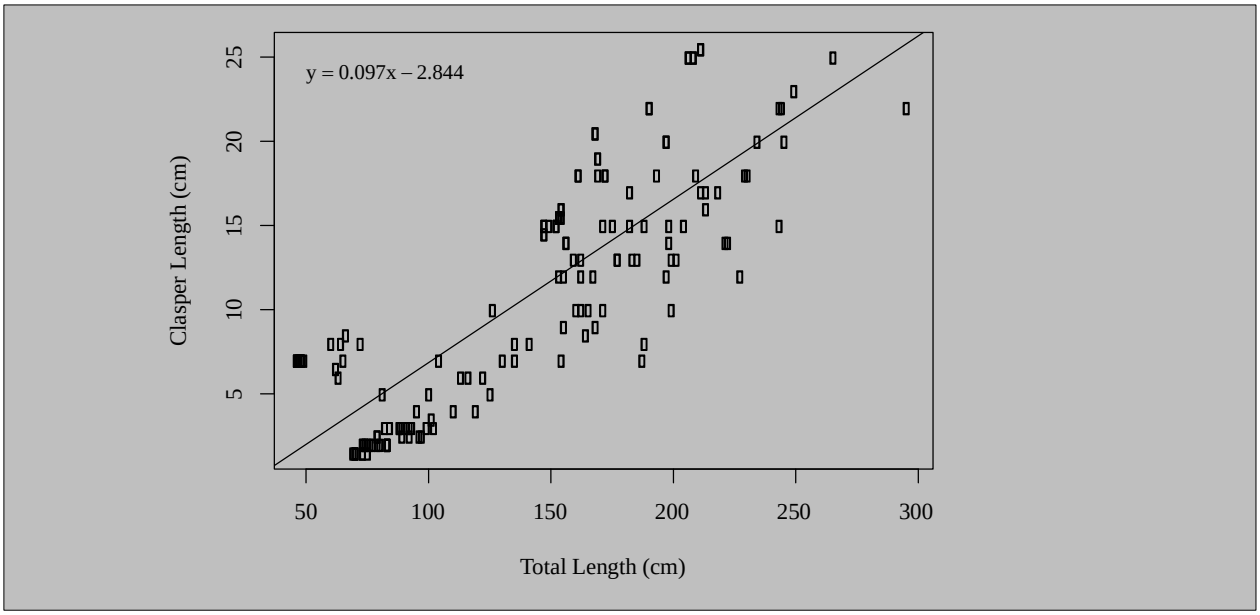

Figure 5. The relationship between total length and clasper length of scalloped hammerhead sharks caught from coastal fisheries in Eastern Indian Ocean.

Discussion

Length distribution of scalloped hammerhead in this study was 43-230 cmTL, which has wider range of length size compared to White *et al*. (2006) in relatively same sampling location and in the southwestern equatorial of Atlantic Ocean (Hazin *et al*., 2001) in the southwestern equatorial of Atlantic Ocean which was 165-230 cmTL and 121-321 cmTL, respectively, with remarks that more juveniles were caught in this study. The mean size of both male and female sharks in 2013 decrease significantly compared to 2010. This could indicate the fishing pressure for this species was high and intensive.

Most of the scalloped hammerhead sharks landed was immature (except for male sharks in 2010). The more immature shark caught the more vulnerable it populations in the future. Moreover scalloped hammerhead shark are known to have aggregating habit thus large schooling is vulnerable to fisheries (Baum *et al*., 2007). It also characterized with slow growth, lengthy gestation, long life, low productivity and has poorest ability to recover from increased mortality (Castro *et al.,* 1999; Compagno, 1984; Last & Stevens, 1994, Smith, 1998). If more immatures were caught in the future the recruitment would be decreasing, and the rebound will take several years. According to Pitcher & Hart (1982), such condition will lead to unbalanced population and will trig growth overfishing. A condition where exploitation causes a lot juvenile caught before reaching their optimum growth.

The proportion of female shark was significantly different against male both in 2010 and 2013, this result was higher compared to Hazin *et al.* (2001) in northeastern Brazil and Henderson *et al*. (2009) in Oman waters, but similar with Fahmi & Sumadhiharga (2007) in western Indonesia. The imbalance sex ratio between female and male was allegedly because adult female may occur at shallower water to give birth (Simpfendorfer, 1992). Juveniles and immature sharks are also known occupy shallow and coastal waters (Fahmi & Sumadhiharga). This condition might explain why more immature female was caught more frequent than male.

According to White *et al*. (2008) the number of juvenile born by this shark is about 14-41 pups with an average of 25 pups in the past 9-10 months, and the shark is viviparous with a yolk placenta (yolk-sac placenta). Despite having more pups compared to other species of sharks, the frequent exploitation could lead to declining of this species in the wild.

The relationship between clasper length and total length was lineary positive where every 5 cmTL increment on clasper length adding 51 cmTL on total length. The relationship between those two variables were allegedly depended on clasper condition. The more calcium contained on the clasper, the shorter it will be. Relationship between the clasper length with total body length is usually used to determine the size at which the fish Elasmobranchii reach maturity (Stevens & McLoughlin, 1991). There are two parts of clasper on female shark but only one, which actually

incorporated with cloaca during copulation. But some calcareous clasper that would make the length shrunk biased the data. In the future analysis the calcareous clasper should be separated with non-calcareous, in order to find more cohesive relationship between them.

Based on this study, scalloped hammerhead shark is becoming a subject to overfishing especially in the eastern part of Indonesian waters where sharks fishing are more intensive in this particular area (White *et al.*, 2006; Fahmi & Sumadhiharga, 2007; Kembaren *et al.*, 2013). Substantially lower mean size and more immature sharks caught over years showed it. Many efforts have been done in order to reduce the catch and bring the population back in the wild. In the Indian Ocean, IOTC has come out with some resolution on this matter, namely Resolution 13/03, 13/06, 11/04 and 05/05. Those regulations concern on the obligation from the members to record, monitor, and report any activities related to sharks fisheries either as a target catch, by-catch or discard (retained or released). Based on the results of the 16th CoP to CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) in March 2013, a group of kind hammerhead shark (*Sphyrna spp*) has been agreed to be included in Appendix 2 of CITES. Thus international trade in commodities hammerhead shark is limited and must follow the regulations of CITES. In accordance with the world concern, Indonesian Government through Ministry of Marine Affairs and Fisheries issued the Ministerial Regulation No. 59/PERMEN-KP/2014. This regulation strictly prohibits any activities related to transporting parts or whole of sharks, namely ocean whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead shark (*Sphyrna lewini*), great hammerhead shark (*Sphyrna mokarran*) and smooth hammerhead shark (*Sphyrna zygaena*) to overseas. In order to monitoring the progress of such regulation, continuous efforts of data collection both landing data and scientific observer data are necessary.

CONCLUSION

Substantially lower mean size, more immature sharks and more frequent of female caught over years showed that scalloped hammerhead shark in the Eastern Indian Ocean are facing intensive fishing pressure which could lead to overfishing. This could harm the sustainability of scalloped hammerhead shark resource in the long run. The relationship between clasper length and total length was positively correlated where every 5 cmTL increment on clasper length adding 51 cmTL on total length.

ACKNOWLEDGEMENTS

This paper was a contribution of research activities on shark resources in the Indian Ocean South of Java Fisheries Management Area (FMA) 573 in 2010 and 2013, under the Research Institute for Marine Fisheries, Muara Baru, Jakarta. High appreciation is expressed to Dr. William White from ACIAR-CSIRO, Australia.

REFERENCES

Baum, J., S. Clarke, A. Domingo, M. Ducrocq, A.F. Lamónaca, N. Gaibor, R. Graham, S. Jorgensen, J.E. Kotas, E. Medina, J. Martinez-Ortiz, J. Monzini Taccone di J. Sitizano, M.R. Morales, S.S. Navarro, J.C. Pérez-Jiménez, C. Ruiz, W. Smith, S.V. Valenti & C.M. Vooren. 2007. Sphyrna lewini. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>. Downloaded on 01 June 2015.

Castro, J.I., C.M. Woodley & R.L. Brudeck. 1999. *A Preliminary Evaluation of the Status of Shark Species.* FAO Fisheries Technical Paper No. 380. Rome: FAO.

Clarke, S.C. 2004a. Shark Products Trade in Hong Kong and Mainland China and Implementation of the CITES Shark Listings. TRAFFIC East Asia, Hong Kong.

Clarke, S.C. 2004b. Understanding pressures on fishery resources through trade statistics: a pilot study of four products in the Chinese dried seafood market. *Fish and Fisheries*. 5: 53–74.

Clarke, S.C., M.K. McAllister, E.J. Milner-Gulland, G.P. Kirkwood, C.G.J. Michielsens, D.J. Agnew, E.K. Pikitch, H. Nakano & M.S. Shivji. 2006. Global estimates of shark catches using trade records from commercial markets. *Ecology Letters.* 9: 1115-1126 doi: 10.1111/j.1461-0248.2006.00968.x.

Compagno, L.J.V. 1984. *Sharks of the World. An Annotated and Illustrated Catalogue of Shark Species Known to Date. Part 2: Carcharhiniformes*. FAO Fisheries Synopsis No 125, Vol. 4, Part 2. Rome: FAO.

Effendie, M.I. 2002. (In Indonesian). *Fisheries Biology*. Yayasan Pustaka Nusantara. Yogyakarta. 163 pp.

Fahmi & K. Sumadhiharga. 2007. Size, sex and length at maturity of four common sharks caught from Western Indonesia. *Mar. Res. Indonesia*. 32 (1): 7-19

Hazin, F., A. Fischer & M. Broadhurst. 2001. Aspect of reproductive biology of the scalloped hammerhead shark, *Sphyrna lewini*, off northeastern Brazil. *Environmental Biology of Fishes*. 61: 151-159.

Henderson, A.C., J.L. McIlwain, H.S. Al-Oufi, S. Al-Sheile & N. Al-Abri. 2009. Size distributions and sex ratios of sharks caught by Oman's artisanal fishery. African Journal of Marine Science. 31 (2): 233-239.

Kembaren, D.D., U. Chodrijah & A. Suman. 2013. Size distribution and sex ratio of scalloped hammerhead sharks (*Sphyrna lewini*) in Indian Ocean at southern part of Java and Nusa Tenggara, Indonesia. *Paper presented in IOTC 9th Working Party on Ecosystem and By-catch, 12-14 October 2009, Mombasa, Kenya*. 9 pp.

IOTC (Indian Ocean Tuna Commission). 2014. Status of the Indian Ocean scalloped hammerhead shark. *IOTC-2013-SC16-ES19*. 6 pp.

Last, P.R. & J.D. Stevens. 1994. *Sharks and Rays of Australia*. CSIRO. Pp. 513

Maguire, J.J., Sissenwine, M., Csirke, J., Grainger, R. & S. Garcia. *The state of world highly migratory, straddling and other high seas fishery resources and associated species*. FAO Fisheries Technical Paper. No. 495. Rome: FAO. 84 pp.

Pitcher, T.J & P.J.B. Hart. 1982. *Fisheries ecology*. Croom Helm, London.

SEAFDEC (Southeast Fisheries Development Center). 2006. Report on the study of shark production, utilization and management in the ASEAN region 2003-2004. Southeast Fisheries Development Center, Bangkok, Thailand. 299 pp.

Simpfendorfer, C. 1992. Biology of tiger sharks (*Galeocerdo cuvier*) caught by the Queensland shark meshing program off Townsville, Australia. *Aust. J. Mar. Freshwater Res*. 43: 33-43.

Smith, S.E., W.Au. David & C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. *Marine and Freshwater Research* 49 (7): 663–678.

Stevens, J.D. & K.J. McLoughlin. 1991. Distribution, size and sex composition, reproductive biology and diet of sharks from northern Australia. *Australian Journal of Marine and Freshwater Research*, 42 (2): 151-199 DOI: 10.1071/MF9910151.

Sugiyono. 2004. *Nonparametric statistic for Research*. Penerbit CV. Alfabeta, Bandung: vi + 306.

White, W. T., P.R. Last, J.D. Stevens, G.K. Yearsley, Fahmi & Dharmadi. 2006. Economically important sharks and rays of Indonesia. National Library of Australia Cataloging-in-Publication entry. Australia. 329 pp.

White, W.T., C. Barton & I.C. Potier. 2008. Catch composition and reproductive biology of *Sphyrna lewini* (Griffith & Smith) (Carcharhiniformes, Sphyrnidae) in Indonesian waters. *Journal of Fish Biology***.** Vol 72, Issue 7, P1675 – 1689. http://onlibrary.wiley.com/downloaded in 19 June 2013.