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SIZE, SEX AND LENGTH AT MATURITY OF FOUR COMMON SHARKS CAUGHT FROM WESTERN INDONESIA

Fahmi and Kurnaen Sumadhiharga
Research Center for Oceanography — Indonesian Institute of Sciences
Jl. Pasir Putih I, Jakarta Utara 14430, Indonesia
e-mail: fahmi_lipi@ yahoo.com

ABSTRACT

A study on four common shark species in Indonesia, the spinner shark *Carcharhinus brevipinna* (Muller and Henle, 1839), silky shark *Carcharhinus falciformis* (Bibron, 1839), spot-tail shark *Carcharhinus sorrah* (Valenciennes, 1839) and scalloped hammerhead *Sphyrna lewini* (Griffith and Smith, 1834) was conducted at several shark landing sites in western Indonesia from March 2002 to December 2004. Data were collected from the surveyed areas including the length of frequency, sex composition and length at maturity. In general, they were caught at size smaller than their maturity size. The proportion of immature *C. brevipinna, C. falciformis, C. sorrah* and *S. lewini* to their total number recorded at the surveyed area during the study were about 87%, 50%, 80% and 65%, respectively. According to the length at maturity, females generally attained their maturity in larger size than males. Some factors contributing the catches in immature size and conservation status of those four species were also discussed.

Keywords: Shark, Size composition, Western Indonesia

INTRODUCTION

Shark fishes are one of the most important fishery commodities in Indonesia. They are caught either as a target of fishing in artisanal fisheries or as by catch in the pelagic tuna fisheries. Even though they only contribute about 2% of the total production of marine fisheries in Indonesia in 2001, the total catch of shark in Indonesia is 65,860 t (DKP, 2003). This record makes Indonesia being recognized as a country that has the highest annual total production of sharks in the world (Stevens *et al.,* 2000; Bonfil, 2002; TRAFFIC, 2002), which is of concern due to global alarm toward the status of shark resources. Due to their biology, sharks and rays are more vulnerable to over-exploitation than other fishes (Camhi *et al.,* 1998; Stevens *et al.,* 2000). Therefore, elasmobranch fishes are considered as fully exploited in Indonesian waters with indications of depletion in some areas (Bonfil, 2002; White *et al.,* 2006).

In order to encourage regional concerns on shark conservation and management, information about sharks should be accumulated in each country. Unfortunately, studies on shark diversity and their biology in Indonesia are very few. Attention on shark in Indonesia starts in 2001 through a cooperative study between Indonesia and Australia on elasmobranch fishes. Several preliminary surveys have been conducted since then and some information about shark at several locations in Indonesia has been recorded.

Four shark species are indicated as common species in Indonesian waters, namely spinner shark, *Carcharhinus brevipinna* (Muller and Henle, 1839), silky shark, *C. falciformis* (Bibron, 1839), spot-tail shark, C. *sorrah* (Valenciennes, 1839) and scalloped hammerhead, *Sphyrna lewini* (Griffith and Smith, 1834). They have been recorded during studies in a number offish landings in western Indonesia, including Sumatra, Jawa, Bali and Nusa Tenggara. Several studies on shark diversity in other areas also indicate that these species are quite common in the world (Amorim *et al.,* 1998;Krogh, 1994; Pepperell, 1992). They are normally caught by gill nets and long lines from coastal areas to the open seas as by catch or even as target of fishing in Indonesia.

Habitat of each shark species varies, depending on their characterizations. C.

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brevipinna is known as a common coastal-pelagic shark; it lives in shallow waters at a depth less than 30 m, but ranging down to at least 75 m depth (Compagno, 1984). *C. falciformis* inhabits oceanic waters near and beyond the continental slopes, but also inhabit in coastal waters. *C. sorrah* is common coastal, shallow water tropical shark of the continental and insular shelves, primarily around coral reefs at depth up to 73 m. Whilst *S. lewini* is a coastal pelagic, semi oceanic, warm temperate and tropical species occurring over continental and insular shelves and in deep water adjacent to them, often approaching close inshore and entering enclosed bays and estuaries. It ranges from the intertidal and surface down to at least 275 m depth (Compagno, 1984; 1999).

This paper presents data on species and size compositions of *C. brevipinna, C. falciformis, C. sorrah* and *S. lewini* in western Indonesia, and also provides some biological information, such as sex ratio, length at maturity and litter size. Conservation status of these species is also discussed.

MATERIALS AND METHODS

A total of 14 survey trips were undertaken from March 2002 to December 2004 at nine landing sites and fish markets in western Indonesia. These locations were grouped into five zones based on their fishing areas including the Malacca Strait (Belawan and Tanjung Balai), West Sumatra - (Bengkulu, Padang, Sibolga), South Sumatra (Lampung), South Java (Pelabuhan Ratu and Cilacap), and South Bali-Lombok (Kedonganan and Tanjung Luar) (Fig. 1). Survey trips in Java, Bali and Lombok were funded by ACIAR project, while survey trips in Sumatra, one trip in Bali and Lombok were funded by LIPI. All sites in Sumatra were surveyed only once and other sites were more than one trip (Table 1).

Data was collected by recording the number of shark species landed including size composition based on their total length (to the nearest millimeter using tape meter-scale), the outer clasper length (to the nearest 0.1 mm using dial caliper), sex and maturity stages. Species identification was carried out using the keys and descriptions in Compagno (1999).

Size distributions of each species were tested using two-samples Kolmogorov-Smirnov Test (Motta *et al.,* 2005), and sex ratio between males and females of each species was analyzed using Chi-square test to determine the significant difference from the expected ratio 1:1 (Gay, 1996). Maturity stages of males were classified based on the condition of the claspers. The mature males were indicated by their calcified and enlarged claspers, while females were indicated as mature by the presence of embryos, large developing ova

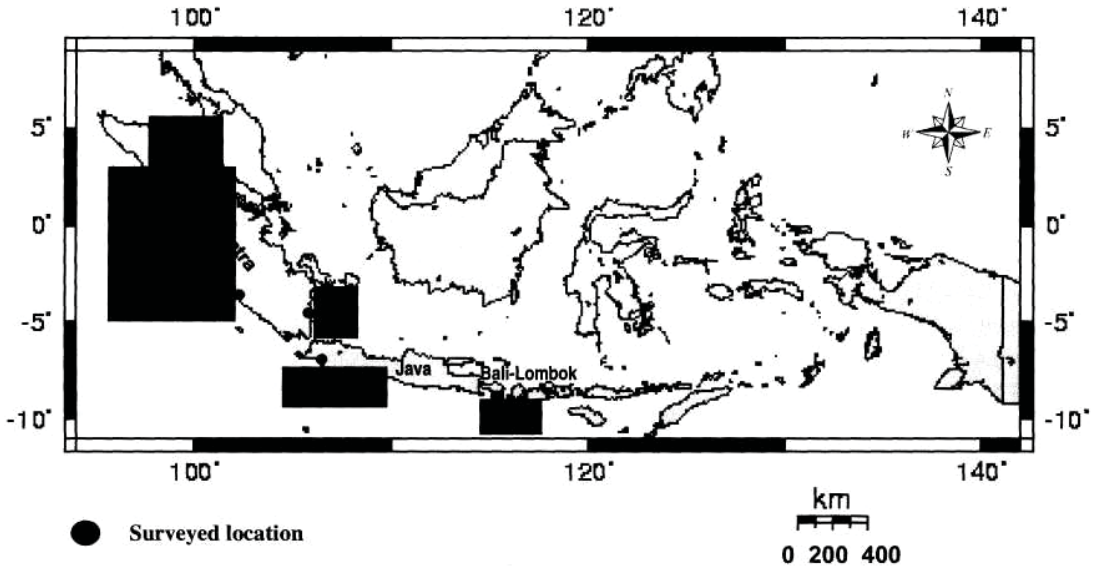


Figure 1. Nine surveyed shark landings in western Indonesia representing of five fishing areas: a) the Malacca Strait; b) West Sumatra; c) South Sumatra; d) South Java; and e) South Bali-Lombok

Table 1. Number of day trips each landing site that was sampled on each of the 13 trips in western Indonesia.

Region	Landing site	2002				2003				2004					
		Mar	Jun	Aug	Oct	Feb	Jun	Jul	Sep	Apr	Jun	Jul	Sep	Oct	Dec
Java	Pelabuhan Ratu	2	-	1	-	2	-	-	-	-	2	-	-	-	-
	Cilacap	2	2	1	-	-	-	-	-	2	-	1	3	2	2
Bali	Kedonganan	4	8	4	5	4	-	-	-	3	4	4	3	4	3
Lombok	Tanjung Luar	2	3	2	1	-	-	-	-	2	2	2	4	4	4
Sumatra	Belawan	-	-	-	-	-	3	-	-	-	-	-	-	-	-
	Tanjung Balai	-	-	-	-	-	4	-	-	-	-	-	-	-	-
	Sibolga	-	-	-	-	-	3			-	-	-	-	-	-
	Padang	-	-	-	-	-	2	-	-	-	-	-	-	-	-
	Bengkulu	-	-	-	-	-	-	3	-	-	-	-	-	-	-
	Lampung	-	-	-	-	-	-	-	4	-	-		-	-	-

and the enlarged uteri (Hazin *et al.,* 2000; Wetherbee *et al.,* 1997; White *et al.,* 2002).

RESULTS

During the present studies, there were more than 80 shark species have been recorded, representing 16 families. The most common shark family encountered was Carcharhinidae (27 species), making up 33.75% of the total species of sharks in Indonesia. *C. brevipinna, C. falciformis, C. sorrah* and *Sphyrna lewini* (Sphyrnidae) are the most common sharks occurring in Indonesian waters. They were found in significant number at most of the observed fish landing sites and fish markets. A Total of 360 C. *brevipinna,* 672 *C. falciformis,* 293 *C. sorrah* and 265 *S. lewini* were recorded from nine locations (fish markets or landing sites) in Sumatra, Java, Bali and Lombok, represented of five zones in western Indonesia. The size ranges of these species in each location are showed in Table 2 and general information on each species are showed in Table 3.

Size composition

During the study, 190 females and 170 males of *C. brevipinna* were examined. The size of females ranged from 710 to 2490 mm total length (TL) and males from 670 mm to 2490 mm TL. Females were about equal in size with males (t=0.25; P>0.05) and the Kolmogorov-Smirnov test was failed to detect the difference of size distributions between them (P>0.05). More than 50% of males and females were recorded at size less than 800 mm TL (Fig. 2a).

Another carcharhinid, *C. falciformis* was consisted of 342 females and 330 males during the study. The size of females ranged from 650 to 2800 mm TL and males from 695 to 2450 mm TL. The Kolmogorov-Smirnov test was failed to detect the difference of size distributions between them (P>0.05). About 50% of females were recorded at size less than 1429 mm TL while the 50% of males were between 553 and 1401 mm TL (Fig. 2b).

A total of 179 females and 114 males of C. *sorrah* were recorded. Females size ranged from

Table 2. Size ranges (in mm TL) of the most common species in the surveyed locations (n/a = not available).

Location	*Carcharhinus brevipinna*		*C. falciformis*		*C. sorrah*		*Sphyna lewini*	
	Female	Male	Female	Male	Female	Male	Female	Male
Pelabuhan Ratu	760 - 784	780 - 790	855 -1450	900-2060	720 - 800	720	510 - 760	n/a
Cilacap	780 - 800	670 - 815	720 -1540	768-1470	792	n/a	390 - 560	560
Kedonganan	750 - 850	770 - 840	760 - 946	n/a	n/a	n/a	740 - 815	745 - 900
Tanjung Luar	900 - 2990	840 - 2220	650 - 2800	695-2450	1240- 1430	840 - 1140	1075 -3060	2355
Lampung	660 - 770	690 - 1000	n/a	n/a	650- 765	700 - 740	580 - 685	510 - 750
Bengkulu	800	1365	n/a	n/a	n/a	n/a	475 - 850	490 - 600
Belawan	n/a	n/a	n/a	n/a	500 - 640	580 - 600	n/a	n/a
Tanjung Balai	n/a	n/a	n/a	n/a	580 - 640	520 - 620	n/a	n/a
Sibolga	780 - 1040	n/a	650 - 795	n/a	1320	1090 -1140	475 -2880	435 -2260

Table 3. Size at maturity, minimum and maximum size (in mm TL) and overall sex ratio of four shark species in western Indonesia.

	Carcharhinus brevipinna	*C. falciformis*	*C. sorrah*	*Sphyna lewini*
Known maturity size (Compagno 1984; 1999)				
Female	1700 – 2000	2130 - 2300	≤ 1060	2120
Male	1590 – 2030	1870 – 2170	1100 - 1180	1400 – 1650
Observed maturity size				
Female	from 1700	from 2170	from 1328	from 2130
Male	1660 – 1865	1830 - 2150	1030 - 1180	1620 – 1769
Known size at birth (mm) (Compagno 1984; 1999)	600 – 800	570 - 870	500 - 600	420 - 550
Min. juvenile size (mm)				
Female	700	650	500	440
Male	670	690	520	430
Known max. size (Compagno 1984; 1999)	2780	3300	1600	3700 – 4200
Observed max. size				
Female	2990	2800	1572	3168
Male	2499	2450	1235	2355
Overal sex ratio (males to females)	1 : 1.05	1 : 1.03	1 : 1.57	1 : 1.71

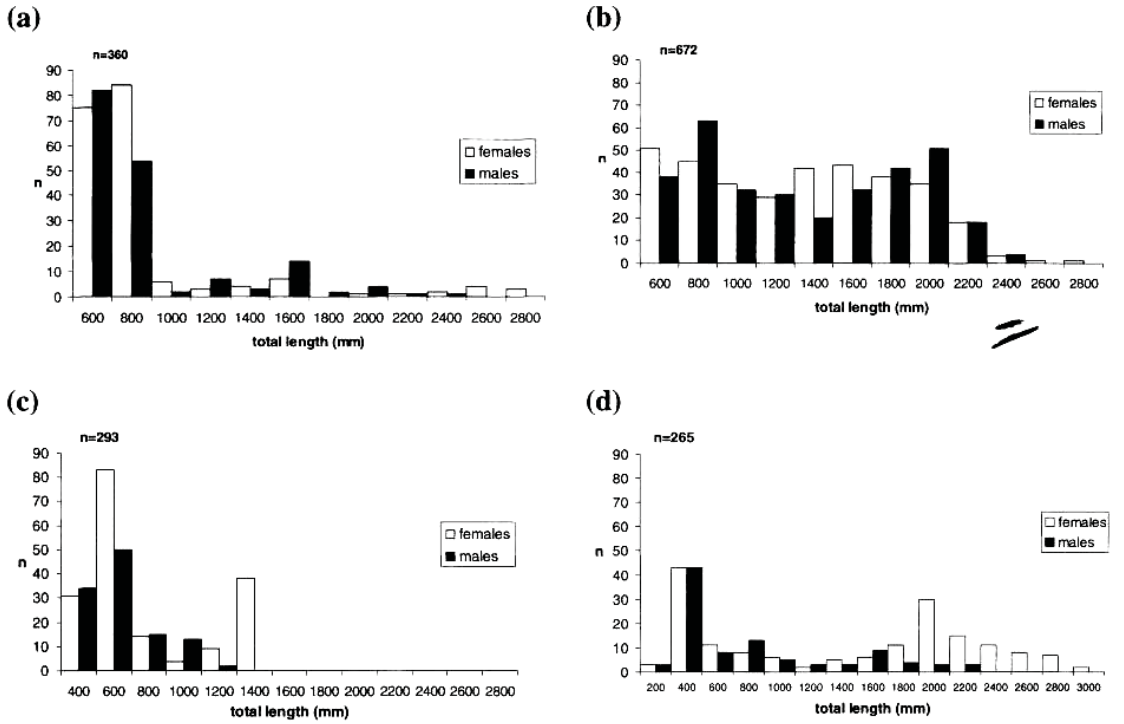


Figure 2. Total length frequency of the most common shark species in surveyed locations: (a) *Carcharhinus brevipinna*, (b) *Carcharhinus falciformis*, (c) *Carcharhinus sorrah*, (d) *Sphyrna lewini*

500 to 1430 mm TL and males from 520 to 1235 mm TL. The Kolmogorov-Smirnov test detected significant differences in the length frequency distributions between females and males ($P<0.05$). About 50% of females were recorded at size between 500 and 720 mm TL while males were between 520 and 612 mm TL (Figure 2c). The size class that was best represented for both female and male *C. sorrah* in western Indonesia was in the 600 – 799 mm TL size class.

Sphyrna lewini was the most common sphyrnid in western Indonesia during the study,

consisting of 164 females and 96 males. The size of females ranged from 440 to 3168 mm TL and males from 430 mm to 2355 mm TL. The Kolmogorov-Smirnov test detected significant differences in the length frequency distributions between females and males ($P<0.05$). About 50% of females were recorded at size between 440 and 1815 mm TL while 50% males were recorded at size less than 700 mm TL (Fig. 2d). The 400 - 599 size class represented the most abundance size class of *S. lewini* in western Indonesia.

At least 87% of total catch of *C. brevipinna* in all surveyed areas during this period in Indonesian waters was in immature size (< 1400 mm TL) and 55.48 % of them were juveniles (less than 800 mm TL and having an umbilical scar). Both small and large individuals of this species were recorded in large numbers in the South Bali-Lombok region during the study. The Kedonganan fish landing site in Bali contributed 67.61 % of total immature sharks recorded in the region (215 individuals). Conversely, most of larger sharks were recorded at the Tanjung Luar landing site in Lombok. At this area, 51.39 % of the spinner sharks were considered as mature (more than 1600 mm TL).

Almost 50 % of total catch of *C. falciformis* in all surveyed areas during the study in Indonesian waters was in immature size (< 1400 mm TL), but less than 5% of them were juveniles (less than 700 mm TL and having an umbilical scar). Female juveniles contributed 1.94% and male juveniles were only 0.30% of the total number of silky sharks recording in western Indonesia during this study. The most abundant sharks were recorded from the South Bali-Lombok region (69.30%), especially from the Tanjung Luar landing site.

The smallest C. *sorrah* (520 mm TL) was recorded from Tanjung Balai landing site in the Malacca Strait region and the largest (1572 mm TL) was from Tanjung Luar landing site in the South Bali-Lombok region. During the study, this species was commonly caught at size between 520 and 1030 mm TL. About 80% of total number of C. *sorrah* recording during the study was immature (< 1100 mm TL). A large number of those species recorded from Tanjung Balai landing site contributed most.

On the other hand, a male juvenile of this scalopped hammerhead from Cilacap, South Java (432 mm TL) was considered as the smallest species recorded and the largest 5. *lewini* was a female (3168 mm TL) that was also recorded from Cilacap in October 2004. Juveniles (at size between 440 and 620 mm TL) represented for 34.33 % of the total hammerheads that have been recorded in western Indonesia during the study. Immature size contributed about 65% of total species recorded during the study.

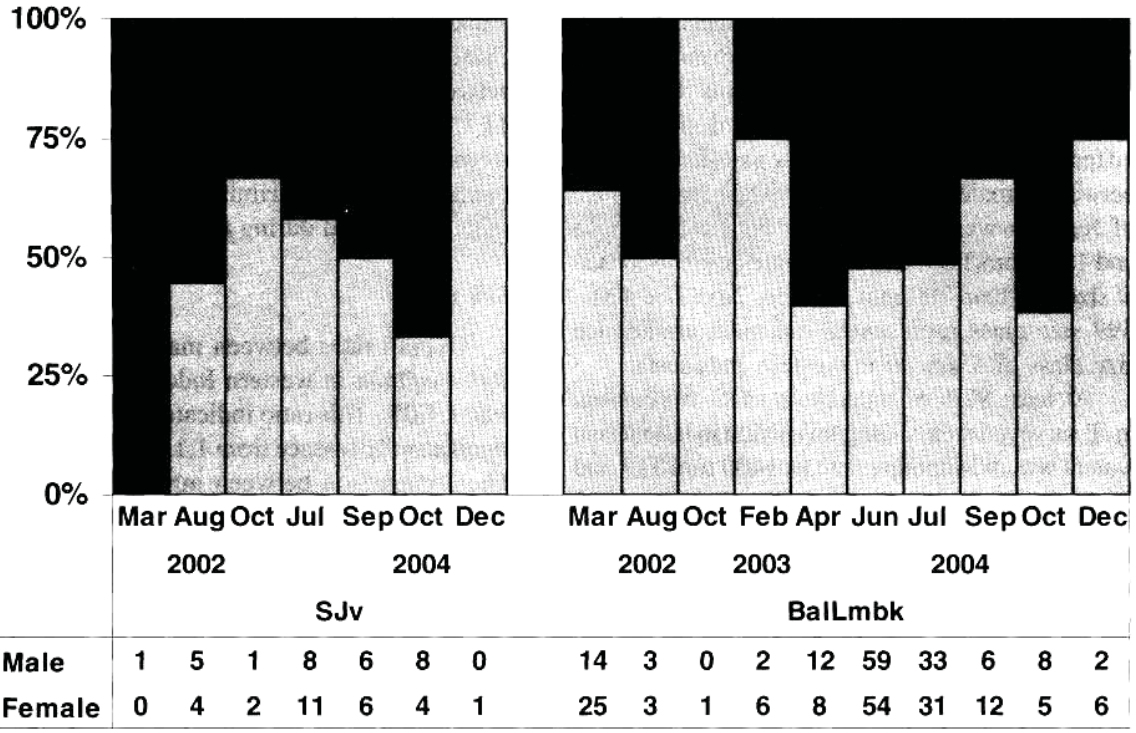
Sex ratio

Overall ratio between males and females of *C. brevipinna* in western Indonesia during study was 1:1.05. This ratio indicated that there was no significant difference from 1:1 (χ^2=0.22; P>0.05). The comparison between males and females in each region were also equal (χ^2 = 0.01 - 1.5; P>0.05) as shown in the South Java and South Bali-Lombok regions at several occassions (Fig. 3).

The overall sex ratio of *C. falciformis* was 1:1.04. This ratio was not significantly different from ratio 1:1 (χ^2= 0.42, P>0.05). Generally, the proportions of males and females were equal in each region (χ^2= 0.07 - 1, P>0.05). The sex ratio of this species in South Java and South Bali-Lombok regions was also equal except for June 2002 in South Java (χ^2=4.; P<0.05) and for August 2002 in South Bali-Lombok region (χ^2= 4.84.; P<0.05). Females were dominated in the abundance of C. *falciformis* in both occassions (Fig. 4).

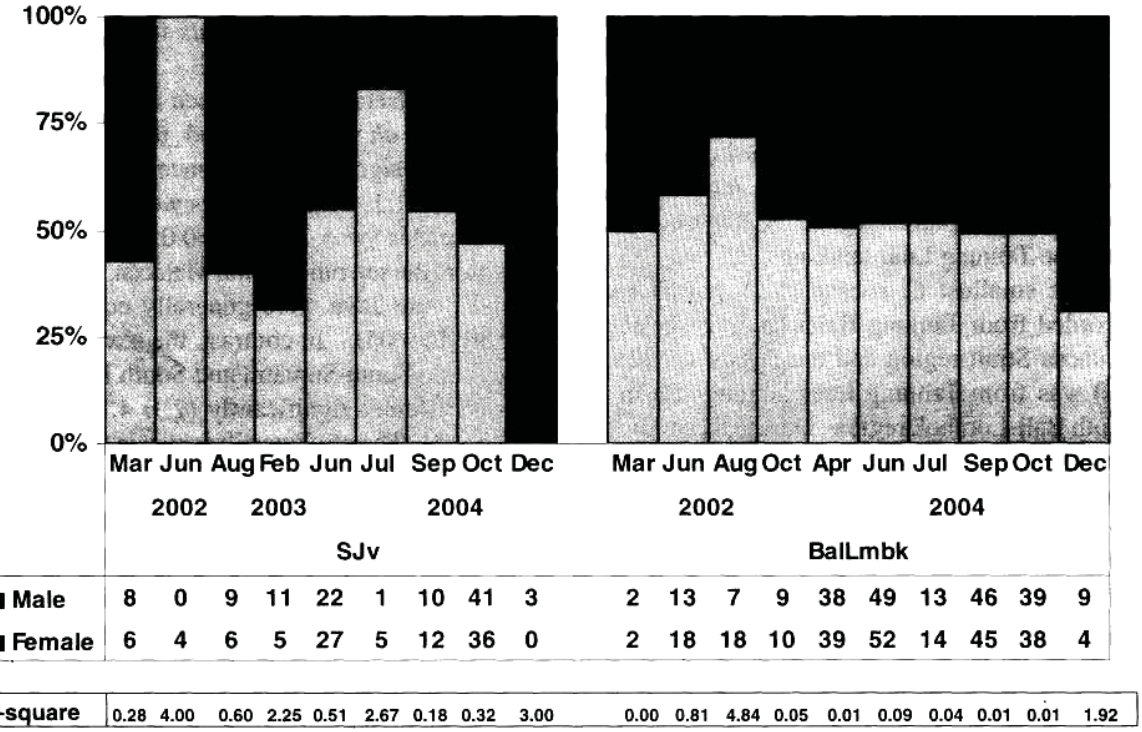
The overall ratio between males and females of *C. sorrah* was 1:1.57 and the Chi Square test showed a significant difference from the expected sex ratio 1:1, which females were more abundant than males (χ^2 = 14.20, P<0.05). Based on the region, the sex ratios in the Malacca, West Sumatra and South Java were generally equal (χ^2 = 1 - 2.30; P>0.05). In contrast, the sex ratio in other regions (South Sumatra and South Bali-Lombok) was different significantly (χ^2= 4.17 and 13.12; P<0.05). The obvious difference in the proportion between males and females in the South Bali-Lombok was showed on the comparison of both sexes in April 2004 with the ratio 1:14 (Fig. 5).

The overall males and females ratio of the scalloped hammerhead sharks, *S. lewini,* was 1:1.71 and it showed a significant difference from the expected ratio 1:1 (χ^2= 17.78, *P*< 0.05). Based on the region, the sex ratio in the South and West Sumatra and South Java was generally equal (χ^2 = 0.13 - 1.67; P>0.05). In contrast, the overall



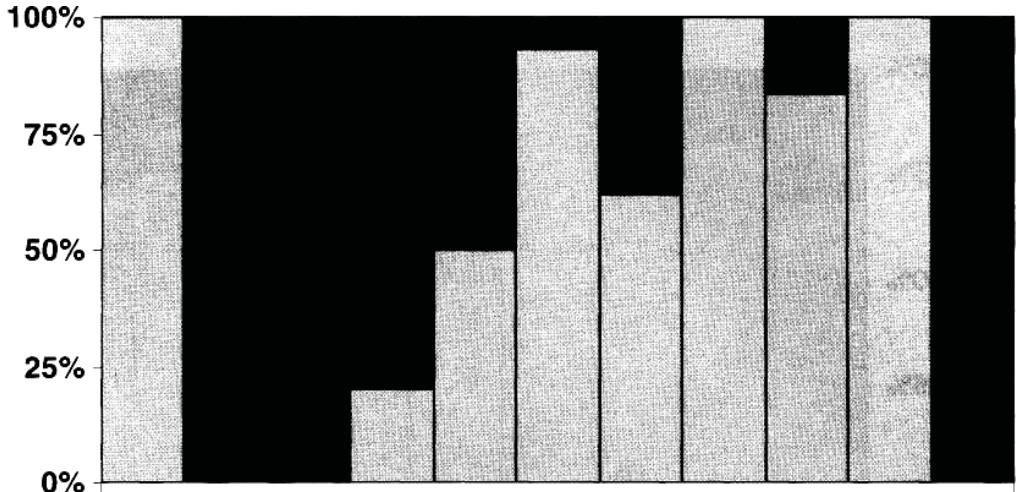
Male	1	5	1	8	6	8	0	14	3	0	2	12	59	33	6	8	2
Female	0	4	2	11	6	4	1	25	3	1	6	8	54	31	12	5	6
Chi Square	1.00	0.11	0.33	0.47	0.00	1.33	1.00	3.10	0.00	1.00	2.00	0.80	0.22	0.06	2.00	0.69	2.00

Figure 3. Comparisons between numbers of females and males of *C. brevipinna* from the South Java (SJv) and South Bali-Lombok (BalLmbk) regions at several occassions from March 2002 to December 2004. Table shows the numbers of males and females observed and chi-square values from each occassion.



Male	8	0	9	11	22	1	10	41	3	2	13	7	9	38	49	13	46	39	9
Female	6	4	6	5	27	5	12	36	0	2	18	18	10	39	52	14	45	38	4
Chi-square	0.28	4.00	0.60	2.25	0.51	2.67	0.18	0.32	3.00	0.00	0.81	4.84	0.05	0.01	0.09	0.04	0.01	0.01	1.92

Figure 4. Comparisons between numbers of females and males of *C. falciformis* from the South Java (SJv) and South Bali-Lombok (BalLmbk) regions at several occasions from March 2002 to December 2004. Table shows the numbers of males and females observed and chi-square values from each occassion



	Mar	Jun	Aug	Oct	Feb	Apr	Jun	Jul	Sep	Oct	Dec
■ Male	0	1	2	4	1	2	11	0	1	0	3
□ Female	1	0	0	1	1	28	18	3	5	1	0
Chi square	1.00	1.00	2.00	1.80	0.00	22.53	1.69	3.00	2.67	1.00	3.00

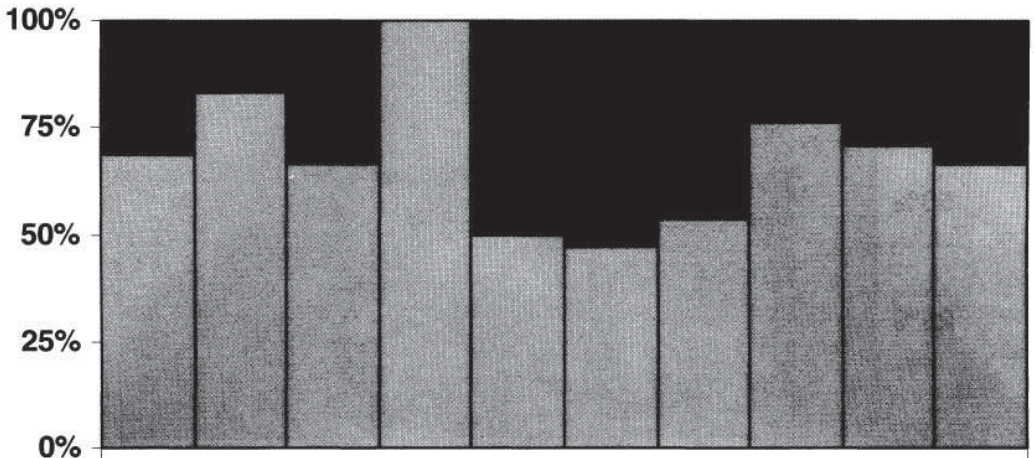
Figure 5. Comparisons between numbers of females and males of *C. sorrah* from the South Bali-Lombok (BalLmbk) region at several occassions from March 2002 to December 2004. Table shows the numbers of males and females observed and chi-square values from each occassion

ratio between males and females in the South Bali-Lombok was different (χ^2 = 19.93; P<0.05), numbers of females were much higher than males in October 2002 and September to October 2004 April 2004 (Fig. 6).

Length at maturity

Mature males of *C. brevipinna* that have fully calcified claspers were found at size between 1660 and 2499 mm TL. Generally, they were recorded at the South Bali-Lombok region, especially from the Tanjung Luar landing site. During the study, there was no mature male recorded at other regions in Java and Sumatra. When the size attained 1700 mm TL, there was a rapid increase in the length of claspers of male spinner sharks. The largest immature male (with not fully calcified claspers) was recorded at size 1777 mm TL (Fig. 7a). On the other hand, the mature females were found at size between 1700 and 2990 mm TL, indicating by the presence of the embryos inside the uteri. The largest female was recorded at size 2990 mm TL from the South Bali-Lombok region with nine embryos inside the uteri.

Mature males of silky shark *C. falciformis* with fully calcified claspers were recorded at size between 1830 and 2450 mm TL. Almost all mature males were recorded at Tanjung Luar landing site. Figure 7b shows an S-shape curve in the relationship between the length of claspers and the total length of male silky sharks. The length of clasper increased significantly when the male shark reached its maturity. There was an overlapping between immature and mature male sharks in their total length. The largest immature male (with uncalcified claspers) was recorded at size 2136 mm TL, while the smallest mature male was at 1830 mm TL. On the other hand, mature females were recorded at size between 2170 and 2800 mm TL, indicating by the enlarged ova or the presence of embryos. In this study, the pregnant females of silky shark were recorded with two to 28 embryos in their uteri. Pregnant females with embryos inside their uteri were recorded at size between 2360 and 2450 mm in total length. The



	Mar	Jun	Aug	Oct	Apr	Jun	Jul	Sep	Oct	Dec
Male	5	1	1	0	3	9	14	8	11	1
Female	11	5	2	10	3	8	16	26	27	2
Chi-square	2.25	2.67	0.33	10.00	0.00	0.06	0.13	9.53	6.74	0.33

Figure 6. Comparisons between females and males of *Sphyrna lewini* from the South Bali-Lombok (BalLmbk) region at several occassions from March 2002 to December 2004. Table shows the numbers of males and females observed and chi-square values from each occasion

embryos size was varied between 135 mm and 350 mm TL, depending on the reproductive stage of the mothers. The mature sharks were recorded only at Tanjung Luar (South Bali-Lombok) and Pelabuhan Ratu (South Java region). In Tanjung Luar landing site, the mature sharks (both females and males) represented for 22.47% of total silky sharks recording in this area. Conversely, there were no mature female sharks recorded at Pelabuhan Ratu landing site and mature males represented only 6.58% of the total silky sharks recorded during the study. In general, mature males and females of silky sharks from western Indonesia represented 10.13 and 4.02% of the total number of the species recorded during the study, respectively.

During the study, male spot-tail sharks reached their full maturity at size between 1030 and 1200 mm TL. There was a gap in the transition between the mature and immature male sharks because inadequate data of the mature males (Fig. 7c). However, there was a rapid increase in the length of claspers when this species reached its maturity. The largest immature male was recorded at 1030 mm TL and the smallest mature male spot-tail shark was also recorded at the same size. On the other hand, mature females were receded at size between 1328 and 1572 mm TL. The biggest female shark was recorded at Tanjung Luar landing site. Pregnant females were recorded at size between 1328 and 1348 mm TL. During this study, the number of embryos was varied from five to six embryos at size between 315 and 353 mm TL. Mature *C. sorrah* were only recorded at Tanjung Luar and Sibolga (West Sumatra region), representing 56.32% of the total number of spot-tail sharks recorded from those areas.

In general, males of 5. *lewini* attained their maturity at 1620 mm to 1812 mm TL. Figure 7d shows the relationship between the length of claspers and the total length of male scalloped hammerhead. The increase of claspers length of male 5. *lewini* when they reached maturity was not as rapid as other three carcharhinids in this study. The largest immature male was recorded at size 1700 mm TL, while the smallest mature male was at 1620 mm TL. Conversely, mature females attained their maturity from 2130 mm TL.

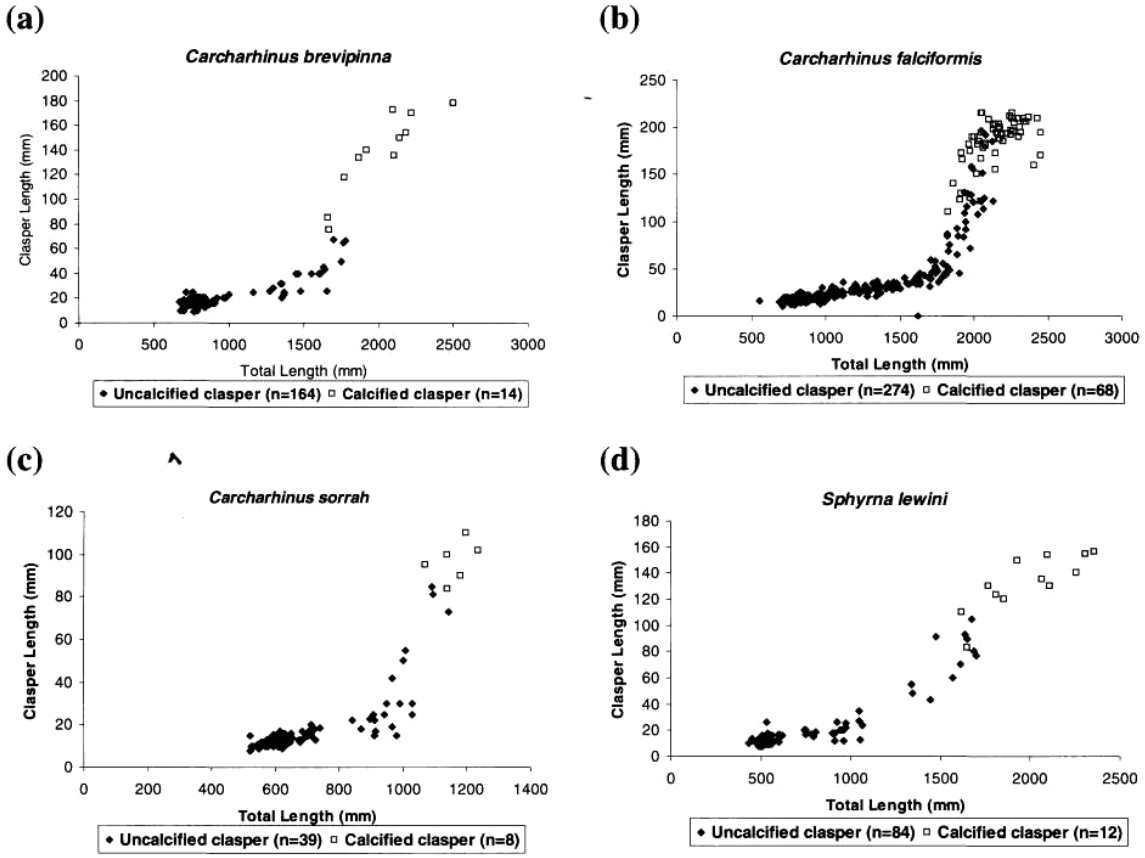


Figure 7. Relationship between clasper length and total length: (a) *Carcharhinus brevipinna*; (b) *Carcharhinus falciformis*; (c) *Carcharhinus sorrah*; and (d) *Sphyrna lewini*

During the study, pregnant females were recorded at size between 2830 mm and 3060 mm TL. The number of embryos in the uteri varied from 13 to 28 embryos and the sizes were between 174 mm and 415 mm TL, depending on the embryonal development stages. A 2830 mm female of scalloped hammerhead was recorded carrying embryos consisting of 18 males and 10 females at size between 320 and 370 mm TL. In addition, the mature hammerhead sharks were commonly caught only in the South Bali-Lombok region. They represented 19.62% of the total hammerheads that have been recorded in Indonesia during the study. On the other hand, the West Sumatra region only contributed for 3.77 % of the total mature hammerheads recording during the study.

DISCUSSION

According to the size distribution and sex ratio, the proportion between males and females of C *brevipinna* and *C. falciformis* were about equal. Conversely, the size and sex ratio *C. sorrah* and *S. lewini* were significantly different. Females were larger than males and the size distribution between both sexes was not equal. The range sizes of females were generally wider than males for *C. sorrah* and *S. lewini*. The maximum total length of females was also higher. This could be meant that the growth rate of females was higher than males. A study on age and growth of blue shark *Prionace glauca* in the North Atlantic Ocean concluded that when males and females attained five years old, the growth rate of males was getting slow while the growth rate of females remained constant (Skomal and Natanson, 2003). This condition might be happened to other shark species. During the study, a female *C. brevipinna* attained up to 2900 mm TL. This was a new record for the maximum size of this species in the world. The maximum total length of this species that has been recorded before was 2780 mm (Compagno, 1984; 1999).

Sex ratio between males and females showed that females were caught more frequent than males. There was an idea of segregation between females and males that occurred at different area, as suggested by Heithaus (2001). Another possibility was adult females may occur at shallower waters to give birth (Simpfendorfer, 1992). The difference of maximum size between males and females was also related to the difference in the length at maturity of each sex. Males were usually faster in attaining its maturity than females. According to Branstetter (1987), the size at maturity of females of *C. falciformis* from the north-western Gulf of Mexico was more than 2250 mm, with an estimated age of seven to nine years, while the size at maturity of males was between 2100 and 2200 mm with an estimated age of 6-7 years. Conversely, Oshitani *et al.* (2003) examined the age and growth rate of C. *falciformis* from the Pacific Ocean and found that males considered attaining its maturity in estimated age of five to six years, while females in age of six to seven years and had larger size. Males attained maturity at 1350 to 1400 mm (precaudal length) and females were at 1450 to 1500 mm. The range size at maturity of male *C. falciformis* in this study was presumably shorter than the size range mentioned by Branstetter (1987), Compagno (1999) and Oshitani *et al.* (2003). On the other hand the size at maturity of *C. sorrah* in western Indonesia was about equal in size at maturity of the same species from northern Australia (Davenport & Stevens, 1988). A condition when sharks attained their maturity in earlier time could be indicated as one of the species adaptation methods for the pressure such as over exploitation or natural selection (Lucifora *et al.,* 1999).

In this study, the size at maturity for female *S. lewini* from western Indonesia was much larger than those mentioned by Compagno (1999) or recorded from other region such as northeastern Brazil. The size of mature females of scalloped hammerhead sharks recorded in northeastern Brazil was from 2135 to 2550 mm TL, while the litter size ranged from two to 21 embryos (Hazin *et al.,* 2001). Due to inadequate data of mature females recorded in western Indonesia during the study, the result for length at maturity of female *S. lewini* was not representative.

Shark fishing activities in western Indonesia are faced to a fact that generally the Indonesian fishers tend to catch a large number of immature sharks. This situation is not a good sign for the sustainability of shark resource, regarding to the biological characteristics of these species. Due to their biology, sharks are more vulnerable to over-exploitation than other fishes. Sharks are long lived, have a long gestation periods (nine to 22 months), slow growth, late age at maturity (ten to twenty years for some species), low fecundity and low natural mortality (Coleman, 1996; Camhi *et al.,* 1998; Stevens *et al.,* 2000; Bonfil, 2002; Cavanagh *et al.,* 2003). There will be a small chance for these species to recover from their exploitation if the existence of female sharks in nature is threated. In addition, the exploitation on the immature sharks make they have no opportunity to get mature and reproduce. This will lead to the extinction for these species in the next decades if there is no control and assessment for the shark fishery in Indonesia.

In general, juveniles and sub adult sharks tend to occur in the coastal area and shallow waters. Larger sharks mostly occur in the deeper waters or open seas while coastal and shallow waters are known as nursery area for juveniles of some shark species (Castro, 1993; Carlson, 1999). This condition makes immature sharks can be caught easier than the adults. The tendency of catching immature sharks by Indonesian fishers was not only caused by lack of their knowledge but also it depends on several factors such as fishing gear type, size and capability of fishing boat and fishing areas.

Fishing gears became one of the main factors in determining this variation. Long lines and gill nets were the most common fishing gears that were used for shark fishing. Size variation of the captures was dependent on the hook size of the long lines or mesh size of the gill net. Hence, larger hooks or mesh size of the net will catch larger sharks ideally. Long lines were quite common to be used by fishers from Tanjung Luar (South Bali-Lombok region) and South Java region, while gill nets were common to be used in the Kedonganan (South Bali-Lombok region), West Sumatra, South Sumatra and Malacca Strait regions. The mesh size of the gill nets was also varied in each region. The gill net that is specialized for shark catching is called as 'Shark net' or tangle net, which has large mesh size (up to 20 inches) and it is operated by medium to large sized boat (more than 10 m in length). This fishing gear has ability to catch medium to large sharks (one meter in length or more) and rarely catch the smaller sharks (less

than one meter in total length). The type of gill nets like this was commonly used by fishers from Sibolga and Bengkulu (West Sumatra). On the other hand, other fishers from Kedonganan (South Bali-Lombok), Labuhan Maringgai (South Sumatra), Pelabuhan Ratu (South Java) and Tanjung Balai (the Malacca Strait) and other areas in Indonesia are using smaller mesh-size gill nets and long lines to catch teleost fish as target of fishing. They do not catch sharks as target species but only as by catch. Unfortunately, they often get small sharks in their catches and sometimes the number of sharks that are being caught is greater than the target fishes. Some of those fishers also make sharks as their main target in order to get their fins. Other factors related to the immature shark catching are fishing boat and the area of fishing. In general, local fishers or artisanal fishers cannot afford to have big boat for their effort. They only have small boats with simple instruments. This condition makes Indonesian fishers are fishing close to the shore and in shallow waters (less than 60 m depth). The daily-trip gillnetters usually get small sharks and rarely get large sharks in their fishing grounds, while their boats are also not designed to load large fishes (>200kg).

Shark Status

Even though spinner shark, silky shark, spot-tail shark and scalloped hammerhead are quite common in Indonesian waters, the World Conservation Union (IUCN) classifies three of them as "Near threatened (NT) status" species in the IUCN red list table for *C. brevipinna, C. sorrah* and *Sphyrna lewini* (IUCN, 2005). This status is given to these three species because they are more conducive to become endangered in the future if there is no management action for them. In addition, generally all sharks are vulnerable to over exploitation because of their characteristics. Those characteristics make elasmobranch fishes should be exploited wisely. A condition when sharks are caught in their immature stages and the vulnerability of females on *C. sorrah* and *S. lewini,* could threat the sustainability of both species in nature. Conversely, *C. falciformis* is not categorized as near threatened (NT) status because there is still not enough data to categorize this species. However, it is not impossible for *C. falciformis* to turn into threatened or even endangered species in the future if the exploitation keep continues without any management actions. Therefore, further studies should be taken to estimate the sustainable stock for those species and to make recommendation for preparing a better management and regulation of shark fishing in Indonesia.

CONCLUSION

The captures of young sharks and more females than males by Indonesian fishers can affect the recruitment process of shark recources and their ability to recover from the exploitation. Lack of facilities and abilities to catch fishes in the further areas from the coastal zones were the main reason why Indonesian fishers caught the young more frequent than the adults. Moreover, socio-economical factors and the acknowledgment of fishers about shark characteristics are also contributing on that condition. Therefore, Indonesian government should have a good management for sustainability of shark fisheries and find out a better solution for shark fisheries in this country.

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REFERENCES

Ali, A., Hilmi, A. H., A. C. Gambang, A. Sade and S.A.Razak, (eds.). 2004. *Elasmobranch resources, utilization, trade and management in Malaysia.* Malaysia: Marine Fishery Resources Development and Management Department Southeast Asian Fisheries Development Center. 46p.

Amorim, A. F., C. A. Arfelli, and L. Fagundes. 1998. Pelagic elasmobranchs caught by longliners off southern Brazil during 1974-97: an overview. *Mar. Freshwater Res.,y* 49:621- 632.

Bonfil, R. 2002. Trend and patterns in world and Asian elasmobranch fisheries. *In:* S. L. Fowler, T. M. Reed and F. A. Dipper (eds.) Elasmobrach biodiversity

conservation and management: Proceeding of the International Seminar and Workshop in Sabah, July 1997. Gland, Switzerland and Cambridge, UK: IUCN-The World Conservation Union, pp. 15-24.

Branstetter S. 1987. Age, growth and reproductive biology of the silky shark, *Carcharhinus falciformis,* and the scalloped hammerhead, *Sphyrna lewini,* from the northwestern Gulf of Mexico. *Environ. Biol Fish.,* 19:161-173.

Camhi, M. S., S. Fowler, J. Musick, A. Brautigam, and S. Fordham. 1998. *Sharks and Their Relatives - Ecology and Conservation.* Gland, Switzerland and Cambridge, UK: IUCN SSC Shark Specialist Group. 39p.

Carlson, J. K. 1999. Occurrence of neonate and juvenile of sandbar sharks *(Carcharhinus plumbeus)* in the north-eastern Gulf of Mexico. *Fisheries Bulletin.,* 97(2), 387-391.

Castro, J.I. 1993. The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern coast of the United States. *Environmental Biology of Fishes,* 38: 37-48.

Cavanagh, R. D., P. M. Kyne, S. L. Fowler, J. A. Musick and M. B. Bennett. 2003. *The conservation status of Australasian chondrichthyans.* Report of the IUCN Shark Specialist Group Australia and Oceania Regional Red List Workshop, Queensland, Australia, 7-9 March 2003. The University of Queensland. Brisbane. 170p.

Clarke, S. 2004. 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.

Coleman, N. 1996. *Australia's Sharks and Rays.* NSW Australia: National Book Distributors and Publishers. 61p.

Compagno, L. J. V. 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of sharks species known to date. Part 2. Carcharhiniformes. *FAO Fish. Synop.,* (125) Vol. 4: 251-655.

Compagno, L. J. V. 1999. Sharks. *In:* K E. Carpenter, and V. H. Niem (eds.). FAO Species Identification Guide for Fishery Purposes. The living marine resources of the Western Central Pacific. Volume 2. Cephalopods, crustaceans, holuthurians and sharks. FAO, Rome. pp. 1193-1366.

Daley, R. K., J. D. Stevens, P. R. Last, and G K. Yearsley. 2002. *Field Guide to Australian Sharks and Rays.* Australia: CSIRO Marine Research and Development Corporation. 84p.

Davenport, S. and J. D. Stevens. 1988. Age and growth of two commercially important sharks *(Carcharhinus tilstoni* and *C. sorrah)* from Northern Australia. *Aust. J. Mar. Freshwater Res.,* 39:417-433.

Demski, L. S. and J. P.Wourms. 1993. The Reproduction and Development of Sharks, Skates, Rays and Ratfishes Introduction, History, Overview, and Future Prospects. *In:* J. P. Wourms and L. S. Demski (eds.) The Reproduction and Development of Sharks, Skates, Rays and Ratfishes. Kluwer Academic Publishers. London. 299p.

DKP. 2003. *Statistik Perikanan Tangkap Indonesia, 2001.* Jakarta: Direktorat Jenderal Perikanan Tangkap, Departemen Kelautan dan Perikanan. Jakarta. 94p.

Gay, L.R. 1996. *Educational research: competences for analysis and application.* Prentice-Hall, Inc. New Jersey. 662p.

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

Heithaus, M. R. 2001. The biology of tiger sharks, *Galeocerdo cuvier,* in Shark Bay, Western Australia: sex ratio, size distribution, diet, and seasonal changes in catch rates. *Environmental Biology of Fishes,* 61: 25-36.

IUCN. 2005. *The IUCN Red List of Threatened Species - Summary Statistics.* Retrieved 9 May 2005, from http://www.redlist.org/info/tables/tarte3a.html.

Krogh, M. 1994. Spatial, Seasonal and Biological Analysis of Sharks Caught in the New South Wales Protective Beach Meshing Programme. *Aust. J. Mar. Freshwater Res.,* 45:1087-1106.

Lucifora, L. O., J. L. Valero, and V. B. Garcia. 1999. Length at maturity of the greeneye spurdog shark, *Squalus mitsukurii* (Elasmobranchii: Squalidae), from the SW Atlantic, with comparisons with other regions. *Mar. Freshwater Res.,* 50:629-632.

Motta, F S., O. B. F. Gadig, R. C. Namora, and F. M. S. Braga. 2005. Size and sex compositions, length-weight relationship, and occurrence of the Brazilian sharpnose shark, *Rhizoprionodon lalandii,* caught by artisanal fishery from southeastern Brazil. *Fisheries Research,* 74:116-126.

Oshitani, S., H. Nakano, and S. Tanaka. 2003. Age and growth of the silky shark *Carcharhinus falciformis* from the Pacific Ocean. *Fisheries Science,* 69: 456-464.

Pepperell, J. G. 1992. Trends in the distribution, species composition and size of sharks caught by gamefish anglers off South-eastern Australia, 1961-90. *Aust. J. Mar. Freshwater Res.,* 43: 213-225.

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.

Skomal, G B. and L. J. Natanson. 2003. Age and growth of the blue shark (*Prionace glauca)* in the North Atlantic Ocean. *Fishery Bulletin,* 101:627-639.

Stevens, J. D., R. Bonfil, N. K. Dulvy, and P. A.Walker. 2000. The effects of fishing on sharks, rays and chimaeras (chondrichthyans), and the implications for marine ecosystem. *ICES Journal of Marine Science,* 57:476-494.

TRAFFIC. 2002. *A CITES priorities: Sharks and the twelfth meeting of the conference of the parties to CITES.* Retrieved 6 February, 2004, from http://www.traffic.org/news/Sharks_CoP12.pdf.

Wetherbee, B. M., G L. Crow and C. G Lowe. 1997. Distribution, reproduction and diet of the gray reef shark *Carcharhinus amblyrhynchos* in Hawaii. *Mar. Ecol. Prog. Ser.,* 151:181-189.

White, W. T., N. G Hall, and I. C. Potter. 2002. Size and age compositions and reproductive biology of the nervous shark *Carcharhinus cautus* in a large subtropical embayment, including an analysis of growth during pre- and postnatal life. *Marine Biology,* 141:1153-1164.

White, W. T., P. R. Last, J. D. Stevens, G K. Yearsley, Fahmi, and Dharmadi. 2006. *Economically important sharks and rays of Indonesia.* ACIAR. Canberra. 329p.