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Estimating shark body sizes from fins as the future monitoring strategy for shark fin trade in Indonesia

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ABSTRACT

High market demand for shark products makes sharks more threatened due to targeted exploitation, bycatch and intensive utilisation. As the top producer and exporter of shark fins, Indonesia must have accurate and detailed trade data as well as proper monitoring of shark utilisation for implementing better management. This study aimed to estimate the body size of sharks based on their fin measurements. Data collection was done in one of the major shark landing sites at Tanjung Luar Fishing Port (Lombok, West Nusa Tenggara) during 2018-2020. Morphological measurements were taken for economically important and CITES-listed shark species, *i.e. Sphyrna lewini, Sphyrna mokarran, Carcharhinus longimanus, Alopias pelagicus, Alopias superciliosus, Isurus oxyrinchus* and *Isurus paucus* caught by both longlines and gillnets. Linear correlations were found in the relationships between body size (total length) and fin sizes (dorsal fin length, dorsal fin height and pectoral fin length), with variations among species. The results of this study will be useful for fishery and quarantine officers in predicting the body size of sharks caught from Indonesian waters and entering the fin trade, as an alternative approach in monitoring sharks as traded commodity, based on fin products.

Keywords: CITES, Fins, Monitoring, Sharks, Threatened species, Utilisation

Introduction

Sharks have specific characteristics such as slow growth, late maturation, low fecundity and long gestation period, which lead to low productivity and population-enhancing capacity (Cortes, 2000; Stevens *et al*., 200). Therefore, sharks are more vulnerable to overexploitation than other fishes. Numerous global and national fisheries management measures have been implemented to overcome this issue, including listing several shark species in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 2002 (CITES, 2021).

Sharks are caught as both target and bycatch in artisanal, recreational or commercial fisheries (Bonfil, 1994; Oliver *et al*., 2015). Shark exploitation is increasingly high due to the high demand for its fins from Asian markets and demand for its meat from Europe and South America (Dents and Clarke, 2015). Almost all body parts of sharks are traded, including fins, cartilage, teeth, meat and skin. Nevertheless, fins have the highest economic value among all shark products. Dharmadi *et al*. (2015) suggested that the sustainability of shark resources in Indonesia will be threatened if the international trade of shark fins is not controlled effectively.

Indonesia has been the top catcher of elasmobranch fishes globally for over a decade, with an average annual catch of 110,737 t, including all sharks and rays (FAO, 2019). The Indonesian Fisheries Statistics also reported that the total shark catch was 46,272 t annually, on average, from 2005 to 2016 (DGCF, 2017). The catches fluctuated but tended to decline during the last decade, similar to the global catch trend, which showed a decrease since the 2000s (Okes and Sant, 2019).

Indonesia has developed several policies and legal instruments to manage its fisheries. However, only a few regulations specifically address shark fisheries (Fahmi and Dharmadi, 2013; Dharmadi *et al*., 2015). Since 2019, the Indonesian Government issued regulations to limit shark exploitation by implementing annual catch and export quotas for CITES Appendix II listed species such as silky shark (*Carcharhinus falciformis*), three species of hammerhead sharks (*Sphyrna* spp.) and two species of mako sharks (*Isurus* spp.). The quotas were set using the precautionary approach, based on recommendations of the Indonesian Scientific Authority to support and implement the CITES provisions. The annual catch quota was also accompanied by the minimum capture size, which varied for each species (DGNREC, 2019; 2020; 2021; MMAF, 2021).

Nevertheless, monitoring of the quota implementation, for both catch and export, faced many challenges. Jaiteh *et al*. (2017a) found that shark finning practice still occurs in eastern Indonesia, in which only the fins were taken, while the rest of the bodies were dumped back into the sea. In many areas where the whole shark body is utilised, sharks were often landed finless (only part carcasses) as the fins were cut on the boat and landed separately (Fahmi and Dharmadi, 2013). Therefore, fisheries officers often found it difficult to identify the species, monitor the legal minimum size and estimate the number of the CITES-listed sharks landed. Another problem was the difficulty to evaluate the quota implementation through the traded products, as only a few skilled officers are capable of differentiating species based on products, especially fin products.

Considering shark fins being intensively exported, it is crucial to ensure that the fins traded come from mature individuals and follow the minimum capture size. To date, there are no regulations regarding the minimum size of shark fin for export and they can be exported no matter whether they come from juveniles or adults. Oktaviyani *et al*. (2020) recommended a size of 23 cm for the first dorsal fin and 35 cm for pectoral fin length as the minimum shark fin size for silky shark. Those values were obtained from the linear equations that related the body size (total length) to the fin size and compared the body size with the length at maturity. The equation can estimate the fin size from body size and *vice versa*. However, the previous equation to determine fin size for *C. falciformis* did not consider body size variability at a given fin size.

At present, the relationship of fin size and body size of other CITES-listed shark species is unknown. Therefore, this study aimed to find out these relationships for seven threatened shark species listed in Appendix II of CITES and occurring in Indonesian waters, including the oceanic whitetip shark (*Carcharhinus longimanus*), two species of hammerhead sharks (*Sphyrna lewini* and *S. mokarran*), two species of thresher sharks (*Alopias pelagicus* and *A. supercilious*) and two species of mako sharks (*Isurus paucus* and *I. oxyrinchus*). The fin sizes include dorsal fin length (DFL), dorsal fin height (DFH) and pectoral fin length (PFL), while the body size used is the total length (TL). In addition, this study also incorporated the variability of body size at fin sizes. The results of this study may help the management authority to regulate the minimum fin size for the trade of these species in the future and assist the officers in predicting the shark's body size based on their fin products as an alternative approach in monitoring shark utilisation.

Materials and methods

Time and location

This study was conducted at the largest landing site for shark-targeting fisheries in Indonesia, *i.e.* Tanjung Luar Fish Landing Port, West Nusa Tenggara, from April 2018 to November 2020 (Fig. 1). The fishers caught sharks mainly using drift and set bottom longlines within

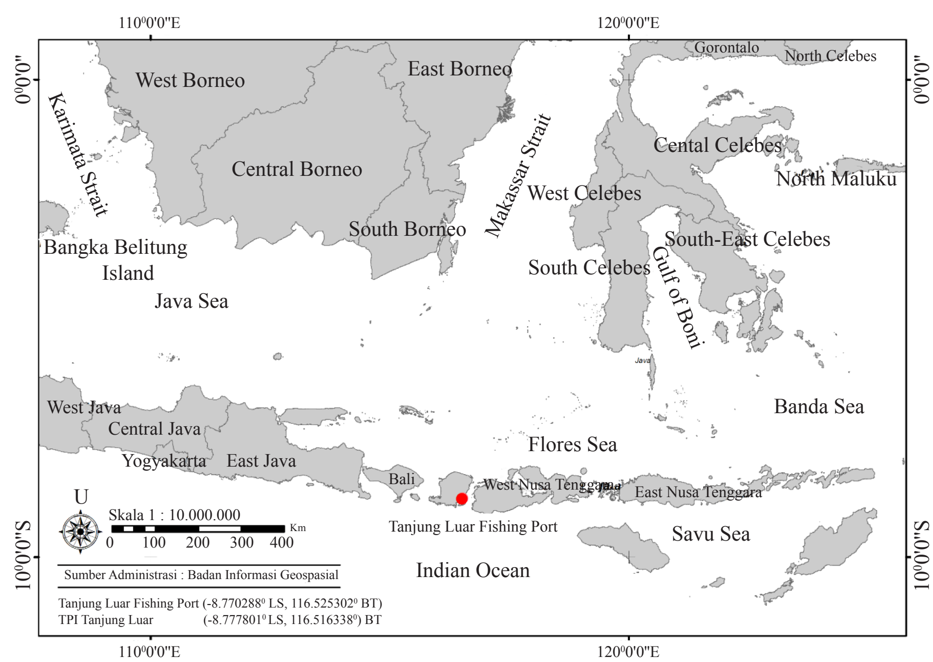


Fig. 1. Map showing sampling location

the Indonesian Fisheries Management Area (FMA) 573 and FMA 713, including the Eastern Indian Ocean, the Savu Sea, the Flores Sea and Makassar Strait.

Data collection

Data were collected daily and included identification of sex, measurements of the fin sizes *viz*. dorsal fin length (DFL), dorsal fin height (DFH) and pectoral fin length (PFL) and total body length (TL). The sex could be distinguished based on the presence/absence of claspers as a male reproductive organ. The TL was a straight measure from the tip of the snout to the tip of the upper caudal lobe. The first DFL was measured from the first dorsal fin origin to the tip of the fin, whereas DFH was measured from the fin apex perpendicular to the dorsal fin base and PFL was measured between the origin of the pectoral fin to the apex (Fig. 2). All measurements were done to the nearest cm using a measuring tape.

Data analysis

The relationships of fin size and body size were modeled using the following linear equations:

$$TL = a + b \times DFL \quad (1)$$

$$TL = c + d \times DFH \quad (2)$$

$$TL = e + f \times PFL \quad (3)$$

$$DFL = g + h \times DFH \quad (4)$$

$$DFL = i + j \times PFL \quad (5)$$

where a, b, c, d, e, f, g, h, i and j are parameters estimated using linear regressions assuming the covariates as fixed (measured without error) and the response variables were normally distributed with constant variance. Using t critical value, 95% confidence interval (CI) of each parameter was derived. Assuming TL and fin sizes are both random, correlation coefficients (r) were also computed and further analysed using a t-test to determine whether the correlation between each two variables is significant for the given sample size. To incorporate the variability of TL given fin sizes, the equations were constructed to compute the 95% prediction intervals (PI). The equations were based on the resultant linear equations and t critical value. All analyses were done using MS Excel.

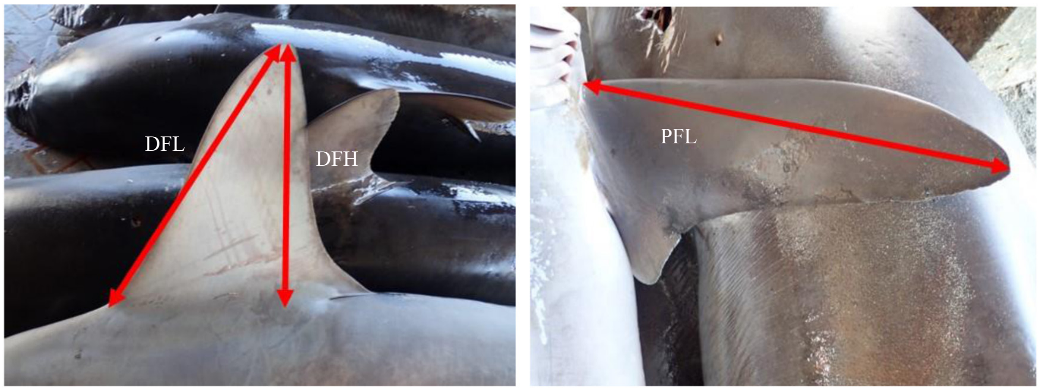
Different intervals of TL across its ranges and the associated fin sizes are presented in tables derived using equations (1) to (3) and represented the mean TL for the given DFL, DFH or PFL. Also, similar intervals of TL that already considered its variability at fin sizes are presented utilising the resulting equations of 95% PI.

Results and discussion

Data of 2,484 sharks representing eight threatened species were collected (Table 1). Of all eight species, *S. zygaena* had the narrowest TL ranges (152-189 cm) and had the lowest sample size, followed by *C. longimanus* (174-233 cm). In contrast, *A. superciliosus* showed the widest range of TL, despite not having a large sample size (140-419 cm TL) (Table 1).

Among eight shark species studied, only seven of them could be analysed for the relationships between fin size and body size, *i.e. C. longimanus*, *S. lewini*, *S. mokarran*, *A. pelagicus*, *A. superciliosus*, *I. oxyrinchus* and *I. paucus*. The data of the smooth hammerhead shark (*S. zygaena*) could not be analysed due to its low sample size. The relationships between fin size and body size are presented in Tables 2 to 4, the relationships between DFH and DFL in Table 5 and that between PFL and DFL in Table 6.

Fin size and total length (TL) relationships were found to be linearly related, generally with a high degree of correlation. Notwithstanding, t-test results show that



(a) (b)

Fig. 2. The measures of first dorsal fin length (DFL), first dorsal fin height (DFH) and pectoral fin length (PFL)

Table 1. The total number and size ranges of eight threatened species of sharks

Species	Total No. (ind)	Males (ind)	Females (ind)	Size range (cm TL)	Maximum of total length (cm TL)
Carcharhinidae					
C. longimanus	18	3	15	174-233	350-395 (White *et al*., 2006)
Sphyrnidae					
S. lewini	1,246	224	1,022	70.5-321	430 (Smith, 1997)
S. mokarran	45	22	23	114-353	610 (Compagno, 1984)
S. zygaena	3	1	2	152-189	500 (Muus and Nielsen, 1999)
Alopiidae					
A. pelagicus	452	295	157	122-334	428 (Weigmann, 2016)
A. superciliosus	178	65	113	140-419	461 (White *et al*., 2006)
Lamnidae					
I. oxyrinchus	373	138	235	83-330	445 (Weigmann, 2016)
I. paucus	177	65	112	143.5-382	427 (Weigmann, 2016)

Table 2. The first dorsal fin length- total length (DFL-TL) relationships of seven threatened shark species. [*a* and *b* are parameters with 95% confidence interval (CI) in parentheses, *r* is correlation coefficient]

Species	DFL range (cm)	TL range (cm)	Parameters and 95% CI		*r*	p value
			a	*b*		
C. longimanus	30-36	174-233	-58.45 (-142.50, 25.59)	7.78 (5.18, 10.39)	0.85	0.00
S. lewini	9-52	70.5-321	12.73 (10.24, 15.22)	6.05 (5.98, 6.13)	0.98	0.00
S. mokarran	20-70	114-353	32.83 (14.55, 51.12)	4.33 (3.93, 4.73)	0.96	0.00
A. pelagicus	8-27	122-334	59.11 (52.29, 65.93)	10.82 (10.46, 11.18)	0.94	0.00
A. superciliosus	11-39	140-419	74.76 (59.24, 90.28)	9.69 (9.09, 10.29)	0.92	0.00
I. oxyrinchus	7-41	83-330	41.48 (37.30, 45.66)	6.74 (6.56, 6.92)	0.97	0.00
I. paucus	18-52	143.5-382	45.45 (35.61, 55.28)	6.38 (6.04, 6.73)	0.94	0.00

Table 3. The first dorsal fin height-total length (DFH-TL) relationships of seven threatened shark species [*c* and *d* are parameters with 95% confidence interval (CI) in parentheses, *r* is correlation coefficient]

Species	DFH range (cm)	TL range (cm)	Parameters and 95% CI		*r*	p value
			c	*d*		
C. longimanus	22-29	174-233	65.24 (-37.12, 167.60)	5.01 (0.98, 9.03)	0.55	0.02
S. lewini	7-48	70.5-321	18.62 (15.93, 21.31)	7.05 (6.95, 7.15)	0.94	0.00
S. mokarran	16-60	114-353	35.98 (17.42, 54.54)	5.24 (4.74, 5.74)	0.96	0.00
A. pelagicus	6-23	122-334	71.15 (64.70, 77.60)	11.33 (10.95, 11.71)	0.94	0.00
A. superciliosus	8-33	140-419	82.14 (67.69, 96.59)	10.94 (10.29, 11.60)	0.94	0.00
I. oxyrinchus	5-37	83-330	59.77 (55.69, 63.80)	6.99 (6.78, 7.19)	0.96	0.00
I. paucus	13-42	143.5-382	48.10 (35.42, 60.77)	7.53 (7.00, 8.07)	0.90	0.00

Table 4. The pectoral fin length-total length (PFL-TL) relationships of seven threatened shark species [*e* and *f* are parameters with 95% confidence interval (CI) in parentheses, *r* is correlation coefficient]

Species	PFL range (cm)	TL range (cm)	Parameters and 95% CI		*r*	p value
			e	*f*		
C. longimanus	42-51	174-233	-45.17 (-103.76, 13.40)	5.22 (3.94, 6.51)	0.91	0.00
S. lewini	6-48	70.5-321	23.44 (20.012, 26.87)	7.12 (6.99, 7.25)	0.95	0.00
S. mokarran	14-55	114-353	41.82 (22.72, 60.92)	5.91 (5.31, 6.51)	0.95	0.00
A. pelagicus	18-68	122-334	65.02 (58.99, 71.05)	4.33 (4.20, 4.46)	0.95	0.00
A. superciliosus	27-77	140-419	9.67 (-9.44, 28.79)	5.43 (5.10, 5.77)	0.93	0.00
I. oxyrinchus	11-56	83-330	44.35 (38.93, 49.77)	4.69 (4.52, 4.85)	0.95	0.00
I. paucus	35-74	143.5-382	-29.24 (-47.81, -10.66)	5.01 (4.65, 5.38)	0.90	0.00

Table 5. The first dorsal fin length and height (DFH-DFL) relationships of seven threatened shark species [*g* and *h* are parameters with 95% confidence interval (CI) in parentheses, *r* is correlation coefficient]

Species	DFH range (cm)	DFL range (cm)	Parameters and 95% CI		*r*	p value
			g	*h*		
C. longimanus	22-29	30-36	19.89 (8.29, 31.49)	0.49 (0.03, 0.94)	0.49	0.04
S. lewini	7-48	9-52	1.59 (1.19, 1.99)	1.14 (1.13, 1.16)	0.97	0.00
S. mokarran	16-60	20-70	2.23 (-1.49, 5.95)	1.17 (1.07, 1.27)	0.96	0.00
A. pelagicus	6-23	8-27	1.46 (1.13, 1.79)	1.03 (1.01, 1.05)	0.98	0.00
A. superciliosus	8-33	11-39	1.77 (0.79, 2.74)	1.08 (1.04, 1.13)	0.97	0.00
I. oxyrinchus	5-37	7-41	3.07 (2.61, 3.53)	1.02 (1.00, 1.04)	0.98	0.00
I. paucus	13-42	18-52	1.20 (-0.36, 2.75)	1.15 (1.08, 1.21)	0.93	0.00

Table 6. First dorsal fin length and pectoral fin length (PFL-DFL) of seven threatened shark species [*i* and *j* are parameters with 95% confidence interval (CI) in parentheses, *r* is correlation coefficient]

Species	PFL range (cm)	DFL range (cm)	Parameters and 95% CI		*r*	p value
			i	*j*		
C. longimanus	42-51	30-36	11.08 (0.97, 21.18)	0.47 (0.24, 0.69)	0.74	0.00
S. lewini	6-48	9-52	2.67 (2.09, 3.25)	1.14 (1.12, 1.16)	0.94	0.00
S. mokarran	14-55	20-70	4.09 (-0.33, 8.51)	1.30 (1.16, 1.44)	0.95	0.00
A. pelagicus	18-68	8-27	1.59 (1.07, 2.11)	0.38 (0.37, 0.39)	0.95	0.00
A. superciliosus	27-77	11-39	-3.88 (-5.83, -1.93)	0.51 (0.48, 0.55)	0.91	0.00
I. oxyrinchus	11-56	7-41	1.16 (0.38, 1.94)	0.67 (0.65, 0.70)	0.95	0.00
I. paucus	35-74	18-52	-10.01 (-12.52, -7.50)	0.75 (0.70, 0.80)	0.92	0.00

all correlations are significant ($p < 0.05$). Tables 5 and 6 show that the fin sizes are linearly related to each other as well. The *r* values were high, similar to the previous relationships. These results indirectly confirm the linear relationships between fin sizes and body size.

Using the information from the data as well as the results of linear regression between TL and fin sizes, the 95% prediction interval (PI) of TL given particular value of DFL, DFH or PFL were also derived as follows:

$$95\%\ \text{PI of TL} = (a + b \times DFL - \sqrt{(p + q \times (DFL - r)^2)},\ a + b \times DFL + \sqrt{(p + q \times (DFL - r)^2)}) \quad (6)$$

$$95\%\ \text{PI of TL} = (c + d \times DFH - \sqrt{(s + t \times (DFH - u)^2)},\ c + d \times DFH + \sqrt{(s + t \times (DFH - u)^2)}) \quad (7)$$

$$95\%\ \text{PI of TL} = (e + f \times PFL - \sqrt{(v + w \times (PFL - x)^2)},\ e + f \times PFL + \sqrt{(v + w \times (PFL - x)^2)}) \quad (8)$$

where a, b, … , x are parameters whose values are listed in Table 7.

Equations 6-8 along with Table 7 provides the means to compute 95% prediction intervals (PI) of TL for the seven shark species and shows the likely interval in which a future value of TL will fall for a given DFL, DFH or PFL.

Using equations in Table 2 to 4, some intervals of DFL, DFH and PFL were converted into the TL of sharks (Table 8). These TL values represent the expected (mean) TL values for the given DFL, DFH or PFL. Along with the TL values, total length at first maturity (TL_m) obtained

Table 7. Parameters of 95% prediction intervals (PI) of total length (TL) given first dorsal fin length (DFL), first dorsal fin height (DFH) and pectoral fin length (PFL)

Species	Formula for 95% PI of TL														
	Given DFL					Given DFH					Given PFL				
	a	b	p	q	r	c	d	s	t	u	e	f	v	w	x
C. longimanus	-58.45	7.78	300	6.03	32.22	65.24	5.01	7.33	14.39	25.39	-45.17	5.22	187	1.47	45.50
S. lewini	12.73	6.05	577	0.01	31.20	18.62	7.05	707	0.01	25.94	23.44	7.12	1,155	0.02	25.02
S. mokarran	32.83	4.33	637	0.15	44.60	35.98	5.24	674	0.24	36.30	41.82	5.91	749	0.34	31.19
A. pelagicus	59.11	10.82	1,245	0.13	18.24	71.15	11.33	1,252	0.14	16.35	65.02	4.33	1,050	0.02	44.21
A. superciliosus	74.76	9.69	1,651	0.36	25.22	82.14	10.94	1,536	0.42	21.66	9.67	5.43	1,594	0.11	56.96
I. oxyrinchus	41.48	6.74	379	0.03	22.53	59.75	6.99	447	0.04	19.12	44.35	4.69	631	0.03	31.78
I. paucus	45.45	6.38	601	0.12	27.85	48.09	7.53	951	0.28	23.25	-29.24	5.01	992	0.13	50.35

from previous studies are also shown as references to evaluate whether the observed fin sizes on average are from mature or immature individuals.

Table 8 shows intervals of mean total lengths for given intervals of observed fin sizes in seven species of threatened sharks. For instance, *C. longimanus* with

Table 8. Intervals of mean total lengths for given intervals of observed fin sizes in seven threatened shark species

Species	DFL (cm)	DFH (cm)	PFL (cm)	TL (cm)	L_m	
					Estimated TL_m (cm)	Sources
C. longimanus	<20	<7	<28	<100	195	190-200 (Male), 180-200 (Female) (White *et al.,* 2006) 180-190 (Mixed) (Lessa *et al.,* 1999)
	20-27	7- 17	28-37	100-150		
	27-33	17-26	37-46	150-195		
	33*	26*-27	46*-47	195-200		
	33-40	27-37	47-57	200-250		
	40- 46	37-47	57-66	250-300		
	46-52	47-57	66-76	300-350		
	>52	>57	>76	>350		
S. lewini	<14	<12	<11	<100	225	165-175 (Male), 220-230 (Female) (White *et al.,* 2006)
	14-23	12-19	11-18	100-150		
	23-31	19-26	18-25	150-200		
	31-35	26-29	25-28	200-225		
	35*-39	29*-33	28*-32	225-250		
	39-47	33-40	32-39	250-300		
	47-56	40-47	39-46	300- 350		
	>56	>47	>46	>350		
S. mokarran	<16	<12	<10	<100	275	234-269 (Male), 250-300 (Female) (White *et al.,* 2006) 210- 238 (Female) (CMFRI, 2017)
	16-27	12-22	10-18	100-150		
	27-39	22-31	18-27	150-200		
	39-50	31-41	27-35	200-250		
	50-56	41-46	35-39	250-275		
	56*-62	46*-50	39*-44	275-300		
	62-73	50-60	44-52	300-350		
	>73	>40	>52	>350		
A. pelagicus	< 4	< 3	<8	<100	287	267- 276 (Male), 282- 292 (Female), (Liu *et al.,* 1999)
	4- 8	3 – 7	8-20	100-150		
	8- 13	7 – 11	20-31	150-200		
	13-18	11 – 16	3-43	200-250		
	18-21	16 – 19	43-51	250-287		
	21*-22	19* – 20	51*-54	287-300		
	22-27	20 – 25	54-66	300-350		
	>27	>25	>66	>350		
A. supercilliosus	<3	<2	<17	<100	336	270-287 (Male), 332-341 (Female) (Chen *et al.,* 1997)
	3-8	2-6	17-26	100-150		
	8-13	6-11	26-35	150-200		
	13-18	11-15	35-44	200-250		
	18-23	15-20	44-53	250-300		
	23-27	20-23	53-60	300-336		
	27*-28	23*-24	60*-63	336-350		
	> 28	> 24	> 63	> 350		
I. oxyrinchus	< 9	< 6	< 12	< 100	303	196-201 (Male), 298-308 (Female), (Francis and Dulvy, 2005)
	9-16	6-13	12-23	100-150		
	16-24	13-20	23-33	150-200		
	24-31	20-27	33-44	200-250		
	31-38	27-34	44-55	250-300		
	38-39	34-35	55	300-303		
	39*-46	35*-42	55*-65	303-350		
	> 46	> 42	> 65	> 350		
I. paucus	< 9	< 7	< 26	< 100	216	205- 228 (Male) (White *et al.,* 2006)
	9-16	7-14	26-36	100-150		
	16-24	14-20	36-46	150-200		
	24-27	20-22	46-49	200-216		
	27*-32	22*-27	49*-56	216-250		
	32-40	27-33	56-66	250-300		
	40-48	33-40	66-76	300-350		
	> 48	> 40	> 76	> 350		

DFL between 20 and 27 cm will be estimated to have TL between 100 and 150 cm. Also, fish with DFL greater than 33 cm is categorised as mature based on the equation in Table 2 and the estimated mean length at first maturity at 195 cm TL (a mid-value of interval 190-200 cm) (White *et al.*, 2006). However, the TL intervals presented here will hold good for the species on an average, not for all single individuals. An individual shark may have TL deviating from the above value. For example, some *C. longimanus* with DFL between 20 and 27 cm will have TL less than 100, but others will have TL greater than 150 cm due to individual TL variations at DFL.

Consequently, some individuals with DFL greater than 33 cm can be immature, but others with DFL less than 33 cm may be mature. The same things apply to other fin sizes and other shark species. The intervals of TL values derived by the DFL, DFH and PFL were also given the 95% prediction intervals to anticipate these variations. The resulting TL intervals for the given intervals of fin sizes which have incorporated variations of TL at fin sizes along with the values of TL_m are shown in Table 9.

Discussion

The relationships between fin sizes and body size were positively correlated (Table 2-6), with the fins' size increasing with increase in total length. The correlation coefficients (*r*) for almost all shark species were more than 0.7, except for *C. longimanus,* with *r* values of the DFH-TL

Table 9. Intervals of likely total lengths (TL) for the given intervals of observed fin sizes derived using 95% prediction intervals.

Species	DFL-TL		DFH-TL		PFL-TL		TL_m
	DFL (cm)	TL (cm)	DFH (cm)	TL (cm)	PFL (cm)	TL (cm)	
C. longimanus	<20	<132	<10	<179	<30	<135	195
	20-30	63-193	10-20	51-199	30-40	88-179	
	30-35	157-233	20-30	131-248	40-48.7	148-223	
	35*-40	195-279	30-35	183-286	48.7*-50	195-231	
	40-50	227-378	35*-40	195-327	50-60	201-290	
	>50	>283	>40	>204	60-70	246-353	
					>70	>288	
S. lewini	<10	<97	<10	<116	<10	<129	225
	10-20	49-158	10-20	63-186	10-20	61-200	
	20-30	110-218	20-30	133- 257	20-30	132-271	
	30-39	170-273	30-33	203-278	30-33.1	203-293	
	39*-40	225-279	33*-40	225-327	33.1*-40	225-342	
	40-50	231-339	40-50	274-398	40-50	274-413	
	50-60	291-400	>50	>345	>50	>345	
	>60	>352					
S. mokarran	<10	<105	<10	<117	<10	<131	275
	10-20	48-146	10-20	59-168	10- 20	71-188	
	20-30	92-187	20-30	114-219	20-30	132-246	
	30-40	137-231	30-40	167-271	30-40	192-306	
	40-50	181-275	40-50	219-325	40-44.3	250-332	
	50-60	224-319	50-50.8	271-329	44.3*-50	275-367	
	60-62	267- 328	50.8*-60	275-379	50-60	308-428	
	62*-70	275-363	60-70	322-433	60-70	364-491	
	70-80	309-408	70-80	372-488	70-80	420-554	
	80-90	351-454	80-90	421-544	>80	>475	
	90-100	392-499	>90	>470			
	>100	>433					
A. pelagicus	<10	<203	<10	<220	<10	<141	287
	10-20	132- 311	10-20	149-333	10-20	76-184	
	20-24.3	240-357	20-22.2	262-358	20-30	119-227	
	24.3*-30	287-419	> 22.2*	> 287	30-40	162-271	
	>30	>348			40-50	206-314	
					50-58.8	249-352	
					58.8*-60	287- 357	
					60-70	292-401	
					>70	>336	

Contd.........................

Species	DFL-TL		DFH-TL		PFL-TL		TL_m
	DFL (cm)	TL (cm)	DFH (cm)	TL (cm)	PFL (cm)	TL (cm)	
A. superciliosus	<10	<213	<10	<231	<10	<107	336
	10-20	130-309	10-20	152-340	10-20	21-160	
	20-30	228-406	20-26.8	262-415	20-30	77- 214	
	30-31.2	325-418	>26.8*	>336	30-40	132-267	
	>31.2*	>336			40-50	187-321	
					50-60	241-376	
					60-67.5	296-417	
					>67.5*	>336	
I. oxyrinchus	<10	<128	<10	<151	<10	<117	303
	10-20	89-196	10-20	108-221	10-20	66-163	
	20-30	157-263	20-30	178-291	20-30	113-210	
	30-40	224-331	30-37.9	248-346	30-40	160-257	
	40-41.8	291-343	37.9*-40	303-361	40-50	207-304	
	41.8*-50	303 - 399	40 -50	318-431	50-60	253- 351	
	>50	>358	>50	>387	60-60.7	300-354	
					60.7*-70	303-398	
					70-80	347-445	
					>80	>393	
I. paucus	<10	<135	<10	<155	<20	<104	216
	10-20	84-198	10-20	92-230	20-30	37-153	
	20-30	148-261	20-26.4	168-278	30-40	89-203	
	30-30.6	212-265	26.4*-30	216-305	40-50	140-253	
	30.6*-40	216-326	30-40	243-381	50-55.3	190-280	
	40-50	276-390	>40	>317	55.3*- 60	216-303	
	>50	>339			60-70	240-354	
					70-80	289-405	
					>80	>339	

and DFH-DFL relationships being <0.7 (Tables 2-4). Other relationships in *C. longimanus* also had lower *r* values than other shark species (Tables 5-6). The limited sample size may have resulted in these low *r* values. The lowest *r* happens when the relationships involve the DFH variable. So, another reason for the low degree of correlation in *C. longimanus* might be the inaccuracy of measuring DFH for some fish. However, the low total number of observations in *C. longimanus* makes the outliers not clearly noticeable.

The relationships of fin size and body size are specific for each shark species (Tables 2-6). These depend on the characteristics and shapes of the fins, which are different from one species to another. For instance, among all seven sharks, *S. mokarran* has the longest dorsal fins in proportion to its body, while *I. paucus* has the longest pectoral fins. Other shark species have different sizes of dorsal and pectoral fins as well. The high *r* for the relationships in most shark species were equivalent to the high coefficients of determinations (R^2) values, indicating high goodness of fit in linear models. It means that the equations generated (Table 2-6) have strong predictive powers. Therefore, based on Tables 2-4, the body size of sharks can be accurately predicted from their dorsal fin lengths, dorsal fin heights or pectoral fin lengths.

Shark fin sets in the trade chain consist of one dorsal fin, a pair of pectoral fins and one lower caudal fin (Suzuki, 1997), except for giant guitarfishes and wedgefishes that have only two dorsal fins and caudal fin. The pectoral fin length (PFL) is the benchmark for shark fin sizes in the shark fin trade and determines the economic value (Djunaidi *pers. com*., 2018). Dewi *et al*. (2018) explained that the shark fins landed and traded In East Nusa Tenggara had various sizes, in the range of 10-65 cm, depending on the species. The fin sizes of *S. mokarran* ranged from 16 to 65 cm with a predominance of 40-45 cm. Meanwhile, the fin sizes of *S. lewini* and *S. zygaena* ranged from 10-40 cm with a predominant size of 20-25 cm (Dewi *et al*., 2018). Based on the conversion in Table 4, *S. mokarran* were primarily caught at large sizes, >278 cm TL on average, by which length, the sharks would be sexually mature (Table 8). Nevertheless, the fin trade of *S. lewini* was dominated by individuals with TL less than 201 cm and predicted that most of the sharks were still immature.

Threatened and CITES-listed shark species are commonly caught in Indonesian waters. Based on DNA barcoding analysis, Sembiring *et al*. (2015) revealed that those species were traded domestically in Indonesia. Most CITES-listed shark species are targeted primarily for trade in their fins (Okes and Sant, 2019) and marketed globally. Those species listed in Appendix II of CITES are legally traded, but the utilisation must be controlled in order to reduce the threat of extinction due to incompatible utilisation with their survival (CITES, 2022). All seven species considered in the present study were recorded as the common shark fins traded in Hong Kong SAR, the world's largest shark fin entrepot (Clarke *et al*., 2006). Hong Kong SAR, together with China, is not a producer; the shark fins are imported mostly from shark-catching countries, including Indonesia, which is the third-largest exporter in the world (Dents and Clarke, 2015).

Indonesian scientific authority recommended implementing quota following the minimum capture size for threatened and CITES-listed species, including the seven shark species studied (DGNREC, 2019; 2020; 2021; MMAF, 2021). The quarantine agency, fisheries officers or other institutions with duties and functions to monitor and evaluate shark products can use the results of this study as a guide to estimate the shark body size from fin products and *vice versa*. Therefore, they will be able to monitor the implementation and obedience of all stakeholders towards scientific recommendations. Identifying fin products at the species level is a crucial requirement for officers to avoid misidentification and miscalculation.

In tuna fisheries, sharks are often caught as bycatch, their bodies are often discarded when the target catch is abundant, but the shark fins are kept. For such cases, knowing the fin size-body size relationships can estimate the size composition of sharks caught from the fishery. Information on the size composition of shark catch generated from fin products will help evaluate the sustainability of shark species and the level of threat caused by the fishery. Fishing activities will be unsustainable if the products being taken are mostly juveniles or sexually immature, which indicated that the young fish would not have had a chance to grow and reproduce (Oktaviyani *et al*., 2019), which would be detrimental to its sustainability in nature.

Ferretti *et al*. (2019) suggested that the ban of shark fin sales is an effective practical step for reducing the global decline of shark populations and it will work for many nations around the world. Unfortunately, this is not easy to implement in Indonesia, particularly for coastal communities whose livelihoods depend on fishing sharks for their fins (Suzuki, 1997; Jaiteh *et al*., 2017b). Implementing shark fisheries management will be imperative to minimise any negative impacts on small-scale fishers that derive economic benefits from shark fisheries (Fahmi and Dharmadi, 2015). Results of this study can be an alternative approach in shark fisheries management strategy in Indonesia. The government may develop regulations regarding the allowable fin size for trade, mainly for export purposes, accounting for the maturity status of the sharks from where the fins originate. Whether to ban shark fins or protect all immature individuals, or conserve part of them, the government can choose using Table 7 or 8 as the references. Nevertheless, fin size regulation needs to be accompanied by directly restricting the body sizes allowed for the catch that should be implemented correctly in advance. If both options are implemented successfully, the sustainable utilisation of shark resources can be achieved.

These recommendations are also in line with one of the nine primary strategies of the Indonesian National Plan of Actions for shark and ray 2016-2020, on developing and implementing national regulations to support sustainable shark and ray management. The NPOA of shark and ray has been in place since 2010 with the remaining eight strategies or programmes, including (1) Review of shark and ray fisheries status at national, regional and international levels; (2) Strengthening of shark and ray fisheries data and information; (3) Development of shark and ray research; (4) Strengthening of conservation efforts for endangered sharks and rays; (5) Strengthening of management steps; (6) Awareness-raising on sharks and rays; (7) Institutional empowerment; and (8) Human resource capacity building (Sadili *et al*., 2015). In order to implement those management actions effectively, it is necessary to have the support and participation of all stakeholders involved in the shark and ray fisheries business chain.

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