Indian J. Fish., 72 (2): 27-32, 2025 doi:10.21077/ijf.2025.72.2.155057-04
Available online at: epubs.icar.org.in/index.php/IJF

Length-based population dynamics of the near threatened shark *Scoliodon laticaudus* Muller and Henle, 1838 from north-eastern Arabian Sea, India

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Abstract

Spadenose shark *Scoliodon laticaudus* is a common shark species landed as a bycatch from various gears used in the north-eastern Arabian Sea, India. Length-based stock assessment was done for *S. laticaudus* landed from trawl nets operated from New Ferry Wharf and Versova and trawled at 20-50 m depths from August 2016 to May 2018. Altogether 2237 specimens of *S. laticaudus* were sampled for the study, of which males contributed 46.80% (n= 1047) and females 53.20% (1190) with a sex ratio of 1:1.3. Length range observed was 170 to 590 mm for males and 163 to 610 mm for females. *S. laticaudus* has a relatively faster growth rate with a K value of 0.64 yr^{-1}, t_0 of -0.364 yr and an asymptotic length (L_∞) of 674 mm.

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Keywords:
Carcharhinid sharks, Exploitation, Maharashtra, Spadenose shark, Stock assessment

Received : 13.08.2024
Accepted : 20.06.2025

Introduction

Elasmobranchs are born as well-developed young individuals of relatively large size as compared to teleost fishes. Natural mortality due to predation is less among elasmobranchs; hence fishing mortality is the leading factor for stock depletion. The recovery rate of these fishes is abysmal due to their physiology and life history parameters (Cortes, 1999; Heppell *et al*., 1999; Cortes, 2002; 2004; Musick, 2005; Morgan and Burgess, 2007; Mandelman *et al*., 2008). Most of the species in the Indian Ocean are categorised under the threatened categories of IUCN (Akhilesh *et al*., 2014; Dulvy *et al*., 2014; Jabado *et al*., 2017; Jabado *et al*., 2018).

Stock assessment studies evaluate the status of fish stock and predict the possible outcomes under different management scenarios. They provide information on whether the abundance of a stock is below a given reference point, helping determine if the stock is overexploited. They also indicate whether a particular catch level will maintain or alter the abundance of the stock (Bonfil, 2005). The main objective of stock assessment of exploited fish stocks is to predict future yields, biomass levels (sustainability) and the value of the catch constant or varying levels of fishing effort changes. Progress in stock assessment of elasmobranchs is critically hampered due to the lack of species-specific catch data (Camhi *et al*., 2008). The size, structure, biological parameters and spatial dynamics of most stocks of elasmobranchs are unknown due to the non-availability of data (Bonfil, 2005).

The spadenose shark *Scoliodon laticaudus* Muller and Henle, 1838 is a small carcharhinid shark species distributed in tropical waters of the Western Pacific and Indian Oceans. The species forms large shoals in neritic waters and is usually found in a depth range of 10 to 13 m. It is an apex predator preying on large varieties of other fishes, crustaceans and molluscs (Compagno, 1984: Reide, 2004). Like all other carcharhinid sharks, *S. laticaudus* exhibits viviparity, with 4-6 months of gestation and complex placental connection. The species is often caught in different gears operated in the tropical seas, as bycatch.

Unlike other larger and slow growing shark species, this species has fast-growing life history parameters which helps to sustain the stock from overfishing (Sen *et al*., 2018). However, the lower fecundity of 1 to 19 per female in a season and intense recruitment overfishing of the species may make them one of the most vulnerable groups in the ecosystem (Compagno and Niem, 1998, Fowler and Cavanagh, 2005; Sen *et al*., 2018). Similarly, habitat degradation in inshore waters may affect the species in estuaries (Sen *et al*., 2018). The IUCN Red List has categorised this species as Near Threatened.

The species is more common in the Maharashtra coast of India and contributed 87% to the total shark fishery (Thakurdas and Sundaram, 2011). On account of their importance in fisheries, several studies have been conducted in India on taxonomy, length-weight relationship feeding and breeding biology, stock and population parameters from different parts of the Indian coast (Aiyar and Mahadevan, 1938; Setna and Sarangdhar, 1949; Nair *et al*., 1974; Nair, 1976; Devadoss, 1979, 1984; Kulkarni *et al*., 1988; Devadoss *et al*., 1989; Kasim, 1991; Chakraborty *et al*., 1997; Mathew and Devaraj, 1997; Abdurahiman *et al*., 2004; Raje and Sundaram, 2012; Fofandi *et al*., 2013; Sen *et al*., 2018; Thomas *et al.,* 2020).

The present study was carried out to update the available information on the stock status of *S. laticaudus* along the Maharashtra coast.

Materials and methods

A total of 2237 specimens of *S. laticaudus* were collected from the shrimp trawlers of the New Ferry Wharf and Versova fish landing centres of Mumbai from August 2016 to May 2018, which comprised 1047 males and 1190 females. The vessels operated trawl nets (with cod end mesh size of 17-30 mm) in the depth range of 20-50 m. The total length (TL) range observed was 170 to 590 mm for males and 163 to 610 mm for females. The total length (TL) frequency data of *S. laticaudus* were recorded weekly from the two landing centres. Length-weight relationship (LWR) was calculated using log-transformed data, log W= log a+ b log L (Le Cren, 1951; Froese, 2006), where W is total weight (g), L is the total length (cm), log a is the intercept and b is the slope. The log-transformed data was applied to linear regression, and values of "a" and "b" were used for loading data into FiSAT II software. The frequency was raised to that of the day and the month following Sekharan (1962). Growth, mortality and exploitation parameters were estimated using FiSAT II programme developed by ICLARM (Gayanilo *et al.,* 1988; Gayanilo *et al*., 2005). The von Bertalanffy growth parameters (von Bertalanffy, 1934) *viz*. asymptotic length (L_∞) and growth co-efficient (K) were estimated using monthly raised frequency data in the ELEFAN- I module of FiSAT II. Age-at-length zero (t_0) was back-calculated using a modified von Bertalanffy growth equation suggested by Alagaraja (1984) *i.e.,* t_0= -1/K loge [1-(L_0/L_∞), where, t_0 is theoretical age at which the length of the shark is zero, K is the growth co-efficient, L_0 is length at birth and L_∞ is asymptotic length. For the calculation of t_0, 140 mm was used as the total length at birth (L_0), which was assumed from the length of the largest embryo and smallest free-swimming individuals observed from the fishery. Mortality and exploitation parameters were derived from the growth parameters. According to Cushing (1968), natural mortality, M was calculated as M = ln 100/(T_{max} - 1) where, T_{max} denotes longevity of the fish; M was also calculated by the method of Rikhter and Effanov (1976), M = 1.521/($T_{m50\%}$ $^{\wedge}_{0.720}$) - 0.155 per year which showed a close association between M and $T_{m50\%}$, the age when 50% of the population is mature (also called "the age of massive maturation"). Total mortality, Z was calculated based on the length-converted catch curve with the help of FiSAT II (Pauly, 1983; 1984). The selection curve was created from the cumulative length-frequency data and L_{C50} was obtained.

The relative yield per recruit (Y/R) and relative biomass per recruit (B/R) at different exploitation levels (Beverton and Holt, 1966) were estimated by the FiSAT II package. Exploitation rate (E) = F/Z and Exploitation ratio (U) = (F/Z) * [1- exp $^{-z}$] were calculated, where F is fishing mortality and Z is total mortality. Total stock = Y/U, where Y is the yield (annual catch) of the fish in tonnes; U the exploitation ratio, standing stock (B_V) = Y/F, where Y is the yield (annual catch) of the fish in tonnes and F is fishing mortality. Maximum sustainable yield (MSY) was estimated with the help of Cadima's formula, MSY = 0.5 x Z x Bv, where, Bv is virgin biomass (Average standing stock), Y is yield and M is natural mortality.

Results and discussion

Length-based population studies are considered robust methods for fish stock assessment in tropical waters (Pauly and Morgan, 1987). The length-based model is advantageous due to its fast and easily reliable data collection approach than age data collected from the hard parts. For tropical fishes, hard parts ageing methods are difficult due to lack of clear-cut seasonal demarcation (Morgan, 1987). Hence the present study focused on length-based data collection and estimation of stock parameters.

The L_∞ and K values of 674 mm and 0.64 yr-1, respectively obtained using t_0 of $^-$0.36 yr^{-1} were selected as the best fitting estimates of growth parameters for *S. laticaudus*. The von Bertalanffy growth curve (Fig. 1) constructed using the above parameters gave an L_0 of 140 mm. The growth performance index and t_{max} of *S. laticaudus* were estimated to be 3.46 and 4.69 yr, respectively. The growth curve constructed using these parameters showed that *S. laticaudus* grows to a TL of 225 and 437 mm at the end of 1st and 2nd year respectively after which the growth slows down considerably registering a TL of 550 mm in 3rd yr, 601 mm in 4th year and 640 mm in 5th year.

The length at birth (L_0) for *S. laticaudus* in the present study was estimated at 140 mm. Since direct estimation of L_0 was difficult, the largest embryo and smallest free-swimming individuals taken out from the pregnant female were used to arrive at the L_0. The value recorded is similar to that reported by Setna and Sarangdhar (1948), Nair (1976), Chakraborty *et al*. (1997), Mathew and Devaraj (1997) from Mumbai waters and Devadoss (1979; 1998) from Calicut waters.

The natural mortality rate (taken for further calculation) (M), the total mortality rate (Z), the fishing mortality rate (F), current exploitation rate (E) and exploitation ratio (U) for *S. laticaudus* were 0.98 yr^{-1}, 2. 39 yr^{-1}, 1.41 yr^{-1}, 0.58 and 0.54 respectively (Table 1). The length-based cohort analysis showed that F exceeded M after the shark attained 384 mm TL (Fig. 1) From the length-frequency data, a cumulative frequency curve was constructed to find the L_{C50} (Length at which 50% of the fish became vulnerable to the gear). The value of L_{C50} obtained as 350 mm (Fig. 1) is slightly nearer to the length at first maturity of the species (344 mm) (Sen *et al.,* 2018). *i.e.* 50% of fish get an opportunity to breed once in its life span.

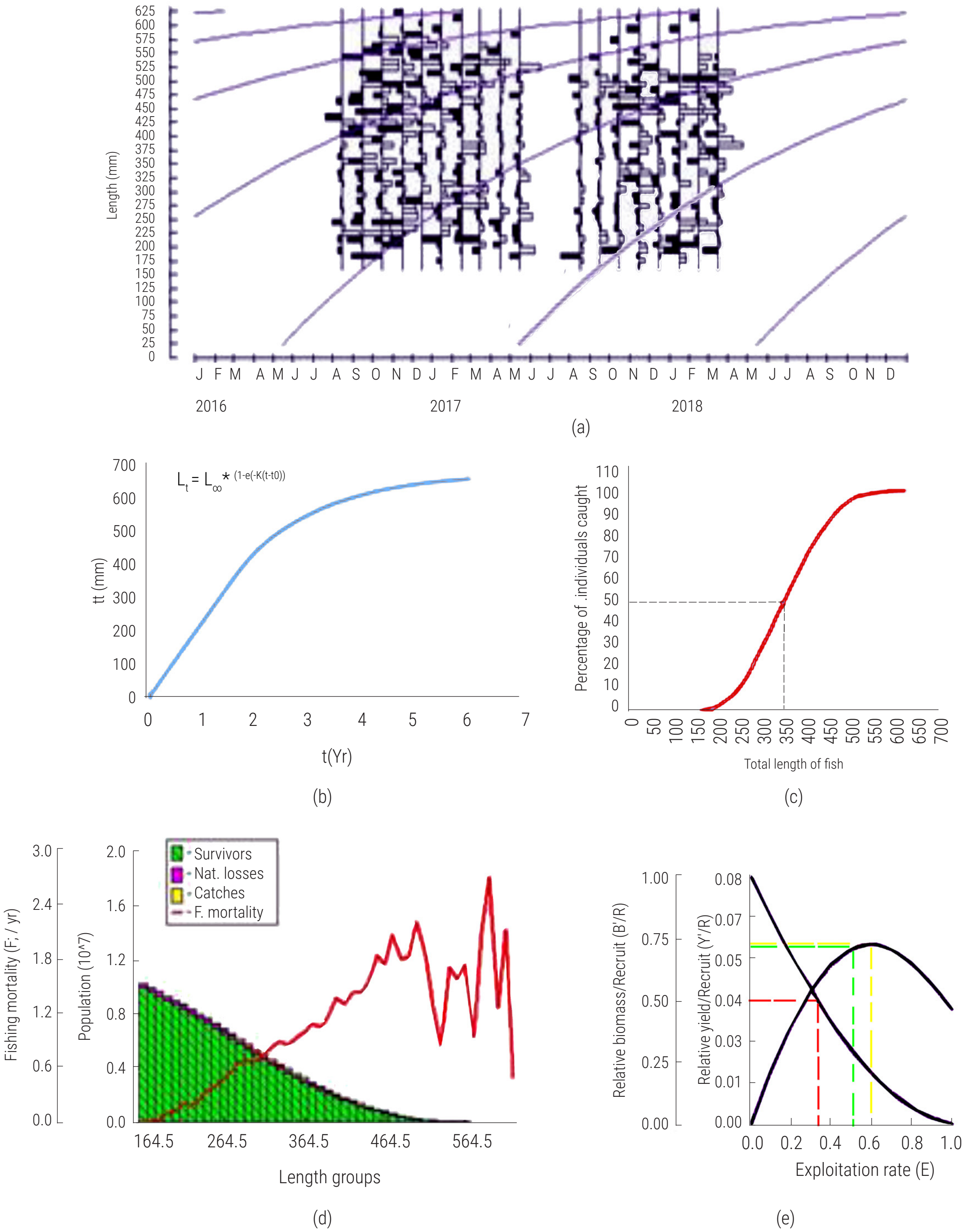

Fig. 1. Growth, mortality and exploitation parameters of *S. laticaudus* in north-eastern Arabian Sea, (a) and (b) von Bertalanffy growth curve, (c) Selection ogive of fish landed in trawl net (d) Length structured virtual population analysis, (e) Relative yield per recruit and relative biomass per recruit analysis using knife edge selection

The coefficient of growth (K) estimated as 0.64 yr^{-1} in the present study closely matches the values 0.68 and 0.63 yr^{-1} respectively, reported by Mathew and Devaraj (1997) and Chakraborty *et al*. (1997) from Mumbai waters, while the growth rates recorded by Devadoss (1998) from Calicut waters were 0.41 yr^{-1} (male) and 0.36 yr^{-1} (female). Kasim (1991) recorded the fastest growth rate of 0.88 yr^{-1} from Veraval, Gujarat. Branstetter and Musick (1994) also endorsed a fast growth rate for this species. The value of t_0 of the fish was calculated from the L_0 by using the inverse Bertalanffy's equation and was estimated as -0.364 yrs, while Devadoss (1988)

Table 1. Growth, mortality and exploitation parameters of *S. laticaudus*

Parameters	Value
L_∞ (mm)	674
K ($yr^{-1)}$	0.64
t_0 (yr)	0.36
L_0 (mm)	140
t_{max} (yr)	4.69
Φ'	3.46
M (yr^{-1})	0.98
F (yr^{-1})	1.41
Z (yr^{-1})	2. 39
E	0.58
E_{max}	0.57
$E_{0.1}$	0.50
$E_{0.5}$	0.33
U ($yr^{-1)}$	0.54
Total stock ,Y/U (t)	1146.78
Standing stock ,B_V = Y/F (t)	439.19
MSY = 0.5*Z*B (t)	524.83

ELEFAN I: Electronic Length Frequency Analysis - I method; VBGF: von Bertalanffy growth curve (equation); DW_∞: Maximum theoretical disk width, the animal can reach; K: Growth coefficient; t_0: Time when length of the animal is theoretically zero; DW_0: Disk width of animal at birth and t_{max}: Longevity of the fish, Φ' :Growth performance index, M: Natural mortality, F: Fishing mortality, Z: Total mortality, E: Exploitation rate (current), E_{max}: Maximum exploitation rate of the fishery, $E_{0.1}$: The exploitation level at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase, $E_{0.5}$: The exploitation level that could result in the reduction of B/R to 50% compared to virgin biomass, U: Exploitation ratio

recorded 0.59 yrs. The asymptotic length (L_∞) calculated is 674 mm *i.e.* it is one of the smallest groups of sharks. Similar studies in Mumbai recorded a size range of 726 to 755 mm as L_∞ (Nair,1986; Chakraborty *et al*., 1997; Mathew and Devaraj, 1997). The smaller size of L_∞ in the present study may be the result of increasing fishing pressure over the years. A comparison of growth, mortality and exploitation parameters obtained from the present study and previous studies are given in Table 2.

The estimation of M appears to be reasonable and M/K value is 1.53 which is within the range of 1 to 2.5 as suggested by Beverton and Holt (1957). The analysis indicated that the exploitation rate that maximises the yield per recruit (E_{max}) was 0.57 for *S. laticaudus*. However, exploitation of the stock at E_{max} can decrease the biomass to a critically low level and hence should not be necessarily used as a target reference point (TRP). Therefore, as a precautionary approach, it is recommended that the exploitation should be reduced to a level where the yield per recruit reaches 1/10 of the marginal increase computed at a very low level of exploitation ($E_{0.1}$) which was found to be 0.50 for *S. laticaudus,* and therefore this value may be used as a relatively safer TRP.

Acknowledgements

The authors are thankful to the Director, ICAR-CIFE, Mumbai, for necessary support to conduct this study. We are also thankful to the Scientist-in-charge and technical staff, Mumbai Regional Station of ICAR-CMFRI, for their valuable help during this study. Support of Mr. Om Pravesh Kumar Ravi and Mr. Sudhanshu Raman in the field is duly acknowledged.

References

Abdulrahiman, K. P., Harishnayak, T., Zacharia, P. U. and Mohamed, K. S. 2004. Length-weight relationships of commercially important marine fishes and shellfishes of the southern coast of Karnataka, India. *Naga, World fish Center Quarterly*, 27(1-2): 9-14.

Aiyar, R. G., and Mahadevan, G. 1938. On a collection of elasmobranch embryos obtained from Madras Coast. In: *Proceedings of the Twenty-Sixth Indian Science Congress,* Lahore*,* Pakisthan , 134 p.

Akhilesh, K. V., Bineesh, K. K., Gopalakrishnan, A., Jena, J. K., Basheer, V. S. and Pillai, N. G. K. 2014. Checklist of Chondrichthyans in Indian waters. *J. Mar. Biol. Assoc. India*, 56(1): 109-120. https://doi.org/10.6024/jmbai.2014.56.1.01750s-17.

Alagaraja, K. 1984. Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, 31(2): 177-208.

Beverton, R. J. H. and Holt, S. J. 1966. Manual of methods for fish stock assessment Part II, Tables of yield function, *FAO Fish. Biol. Tech. Pap.* 38(4), Ver. 1, Food and Agriculture Organisation of the United Nations, Rome, Italy, 67 p.

Bonfil, R. 2005. Fishery stock assessment models and their application to sharks. *Management techniques for elasmobranch fisheries*, *FAO Fisheries Technical Paper No. 474,* Food and Agriculture Organisation of the United Nations, Rome, Italy, 154 p.

Camhi, M. D., Lauck, E., Pikitch, E. K., and Babcock, E. A. 2008. A global overview of commercial fisheries for open ocean sharks. *Sharks of the open ocean: Biology, fisheries and conservation*, pp. 166-192. https://doi.org/10.1002/9781444302516.

Chakraborty, S. K., Deshmukh, V. D., and Khan, M. Z. 1998. Estimates of growth, mortality, recruitment pattern and maximum sustainable yield

Table 2. Comparison of growth, mortality and exploitation parameters of *S. laticaudus* recorded from different parts of the Indian coast

Authors	Year	Sex	Region	L_∞ (mm)	K (yr^{-1})	t_0 (yr)	L_0 (mm)	Z (yr^{-1})	F (yr^{-1})	M (yr^{-1})	E	Lc (mm)
Nair	1976	Pooled	Mumbai	755	0.27	-0.566	140					
Kasim	1991	Female	Gujarat	749	0.88	0.012	-	3.32	1.79	1.53	0.54	288.7
		Male		680	1.08	-0.012	-	3.39	1.63	1.76	0.48	335
Chakraborty *et al.*	1997	Female	Mumbai	726	0.48	-	-	3	2.1	0.9	0.7	559
		Male		740	0.63	-	-	3	2.1	0.9	0.7	340
Mathew and Devaraj	1997	Pooled	Mumbai	740	0.68	-0.01	140	4.15	2.2	1.95	0.53	270
Devadoss	1998	Female	Calicut	715	0.36	0.59	140	1.45	0.73	0.72	0.5	185
		Male		676	0.41	0.59	140					
Present study	2018	Pooled	Mumbai	674	0.64	-0.364	140	2.39	1.41	0.98	0.58	350

of important fishery resources of Maharashtra coast. *Oceanogr. Lit. Rev.*, 1(45): 151.

CMFRI 2018. *Annual report 2017-2018.* ICAR-Central Marine Fisheries Research Institute, Kochi, India, 304 p. http://eprints.cmfri.org.in/13044/1/CMFRI%20AR%202018.pdf.

Compagno, L. J. 1984. *Sharks of the world: An annotated and illustrated catalogue of shark species known to date . FAO Fisheries Synopsis No. 125, Vol. 1, Part 4.* Food and Agriculture Organisation of the United Nations, Rome, Italy, 249 p.

Compagno, L. J. V. and Niem, V. H. 1998. Squalidae. Dogfish sharks. In: Carpenter K. E. and Niem V. H. (Eds.), *FAO Identification guide for fishery purposes. The living marine resources of the Western Central Pacific, Vol. 2, Cephalopods, crustaceans, holothurians and sharks.* Food and Agriculture Organisation of the United Nations, Rome, Italy, pp. 1213-1232.

Cortes, E. 1999. Standardised diet compositions and trophic levels of sharks. *ICES J. Mar. Sci., 56*(5): 707-717. https://doi.org/10.1006/jmsc.1999.0489.

Cortes, E. 2002. Incorporating uncertainty into demographic modeling: Application to shark populations and their conservation. *Conserv. Biol.,* 16(4): 1048-1062. https://doi.org/10.1046/j.1523-1739.2002. 00423.x.

Cortes, E. 2004. Life history patterns, demography and population dynamics. In: Carrier, J. C., Musick, J. A., and Heithaus, M. R. (Eds.), *Biology of sharks and their relatives*, *CRC Marine Biology Series,* CRC Press, Boca Raton, Florida, USA, 598 p.

Cushing, D. H. 1968. *Fisheries biology: A study in population dynamics*. University of Wisconsin Press, Madison, USA, 200 p.

Devadoss, P. 1979. Observations on the maturity, breeding and development of *Scoliodon laticaudus* Muller and Henle off Calicut coast. *J. Mar. Biol. Assoc. India*, 21(1&2): 103-110.

Devadoss, P., Kuthalingam, M. D. K. and Thiagarajan, R. 1989. The present status and future prospects of elasmobranch fishery in India. In: *CMFRI Bulletin, Vol. 44(1), National Symposium on Research and Development in Marine Fisheries Sessions I&II 1987.* ICAR-Central Marine Fisheries Research Institute, Kochi, India, pp. 88-199.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison L. R., Carlson, J. K., Davidson, L. N., Fordham, S. V., Francis, M. P. and Pollock, C. M. 2014. Extinction risk and conservation of the world's sharks and rays. *eLife*, 1-34. https://doi.org/10.7554/eLife.00590.

Fofandi, M., Zala, M. S. and Koya, M. 2013. Observations on selected biological aspects of the spadenose shark (*Scoliodon laticaudus* Muller and Henle, 1838), landed along Saurashtra coast. *Indian J. Fish.*, 60(1): 51-54.

Fowler, S. L., and Cavanagh, R. D. 2005. *Sharks, rays and chimaeras: The status of the Chondrichthyan fishes, status survey, Vol. 63*. International Union for Conservation of Nature, Switzerland and Cambridge, UK.

Gayanilo, F. C., Soriano, M. and Pauly, D. 1988. *A draft guide to the complete ELEFAN. ICLARM Software 2*. International Center for Living Aquatic Resources Management, Manila, Philippines.

Gayanilo, F. C., Sparre, P., and Pauly, D. 2005. *FAO-ICLARM stock assessment tools II: User's guide No. 8*. Food and Agriculture Organisation of the United Nations, Rome, Italy,

Heppell, S. S., Crowder, L. B., and Menzel, T. R. 1999. Life table analysis of long-lived marine species with implications for conservation and management. In: *American Fisheries Society Symposium,*, 23: 137-148.

Jabado, R. W., Kyne, P. M., Pollom, R. A., Ebert, D. A., Simpfendorfer, C. A., Ralph, G. M. and Dulvy, N. K. 2017. *The conservation status of sharks, rays and chimaeras in the Arabian Sea and adjacent waters*. Environment Agency-Abu Dhabi, UAE and IUCN Species Survival Commission Shark Specialist Group, Vancouver, BC, Canada, 236 p.

Jabado, R. W., Kyne, P. M., Pollom, R. A., Ebert, D. A., Simpfendorfer, C. A., Ralph, G. M., Al Dhaheri, S. S., Akhilesh, K. V., Ali, K., Ali, M. H. and Al Mamari, T. M. 2018. Troubled waters: Threats and extinction risk of the sharks, rays and chimaeras of the Arabian Sea and adjacent waters. *Fish Fish*., 19(6): 1043-1062. https://doi.org/10.1111/faf.12311.

Kasim, H. M. 1991. Shark fishery of Veraval coast with special reference to population dynamics of *Scoliodon laticaudus* (Muller Andhenle) and *Rhizoprionodon acutus* (Ruppell). *J. Mar. Biol. Assoc. India*, 33(1): 213-228.

Kulkarni, G. N., Shanbhogue, S. L. and Udupa, K. S. 1988. Length-weight relationship of *Scoliodon laticaudus* Muller and Henle and *Carcharhinus limbatus* (Muller and Henle), from Dakshina Kannada Coast. *Indian J. Fish.*, 35(4): 300-301.

Mandelman, J. W., Cooper, P. W., Werner, T. B. and Lagueux, K. M. 2008. Shark bycatch and depredation in the US Atlantic pelagic longline fishery. *Rev. Fish Biol. Fish.*, I(4): 427. https://doi.org/10.1007/s11160-008-9084-z.

Mathew, C. J. and Devaraj, M. 1997. The biology and population dynamics of the spadenose shark *Scoliodon laticaudus* in the coastal waters of Maharashtra State, India. *Indian J. Fish.*, 44(1): 11-27.

Morgan, G. R. 1987. Incorporating age data into length-based stock assessment methods. In: Pauly, D. and Morgan, G. R. (Eds), *Length-based methods in fisheries research*. International Center for Living Aquatic Resources Management, Metro Manila, Philippines and Kuwait Institute for Scientific Research, Safat, Kuwait, pp. 137-146.

Morgan, A. and Burgess, G. H. 2007. At-vessel fishing mortality for six species of sharks caught in the Northwest Atlantic and Gulf of Mexico. *Gulf and Caribbean Research*, 19(2): 123-129. https://doi.org/10.18785/gcr.1902.15.

Musick, J. A. 2005. Introduction: Management of sharks and their relatives (Elasmobranchii). *FAO Fisheries Technical Paper*, *1*. Food and Agriculture Organisation of the United Nations, Rome, Italy, 474 p.

Nair, K. P. 1976. Age and growth of the yellow dog shark *Scoliodon laticaudus* Muller and Henle from Bombay waters. *J. Mar. Biol. Assoc. India*, 18(3): 531-539.

Nair, R. V., Appukuttan, K. K. andRajapandian, M. E. 1974. On the systematics and identity of four pelagic sharks of the family Carcharhinidae from Indian Region. *Indian J. Fish.*, 21(1): 220-232.

Pauly, D. 1983. Length converted catch curves. A powerful tool for fisheries research in tropics (Part I). *ICLARM Fishbyte,* 1(2): 9-13.

Pauly, D. 1984. Length converted catch curve. A powerful tool for fisheries research in tropics (Part II). *ICLARM Fishbyte,* 2(3): 9-10.

Pauly, D. and Morgan, G. R. 1987. *Length-based methods in fisheries research Vol. 13*. *ICLARM Conference Proceedings, 13*. International Center for Living Aquatic Resources Management, Metro Manila, Philippines and Kuwait Institute for Scientific Research, Safat, Kuwait, 468 p.

Raje, S. G. and Sundaram, S. 2012. Relationship between body size and certain breeding behavior in selected species of Elasmobranchs off Mumbai. *J. Mar. Biol. Assoc. India*, 54(2): 85-89.

Riede, K. 2004. *Global register of migratory species: From global to regional scales. Final report of the R&D-Projekt 808 05 081*. Federal Agency for Nature Conservation, Bonn, Germany, 330 p.

Rikhter, V. A. and Efanov, V. N. 1976. *On one of the approaches to estimation of natural mortality of fish populations, ICNAF Res.Doc. 76/vr/B*. International Commission for the Northwest Atlantic Fisheries, Halifax, Nova Scotia, Canada.

Sekharan, K. V. 1962. On the oil sardine fishery of the Calicut area during the years 1955-56 to 1958-59. *Indian J. Fish.*, 9(2): 679-700.

Sen, S., Chakraborty, S. K., Zacharia, P. U., Dash, G., Kizhakudan, S. J., Bharadiya, S. A. and Gohel, J. K. 2018. Reproductive strategy of spadenose shark, *Scoliodon laticaudus* Muller and Henle, 1839 along north-eastern Arabian Sea. *J. Appl. Ichthyol.*, 34(6): 1304-1313.

Setna, S. B. and Sarangdhar, P. N. 1949. Breeding habits of Bombay elasmobranchs. *Rec. Indian Mus.*, 47(1): 107-124.

Sparre, P. and Venema, S. C. 1998. Estimation of growth parameters. In: *Introduction to ttropical fish stock assessment, Part 1: Manual. FAO Fisheries Technical Paper*, Food and Agriculture Organisation of the United Nations, Rome, Italy, pp. 81-92.

Thakurdas and Sundaram, S. 2011. First record of tawny nurse shark, *Nebrius ferrugineus* (Lesson, 1830) from the north-west coast of India. *Mar. Fish. Infor. Serv., T&E Ser.*, 209: 16-16.

Thomas, S., Purushottama, G. B., Nataraja, G. D. and Kizhakudan, S. J. 2020. Fishery and biological characteristics of the spadenose shark *Scoliodion laticaudus* Muller and Henle, 1838 from the Eastern Arabian Sea. *Reg. Stud. Mar. Sci.*, 34: 1-9.

von Bertalanffy, L. 1934. Studies on the legality of growth. I. General principles of theory; mathematical and physiological regularities of growth in aquatic animals. *Arch Entwickungsmech*, 131: 613-652.