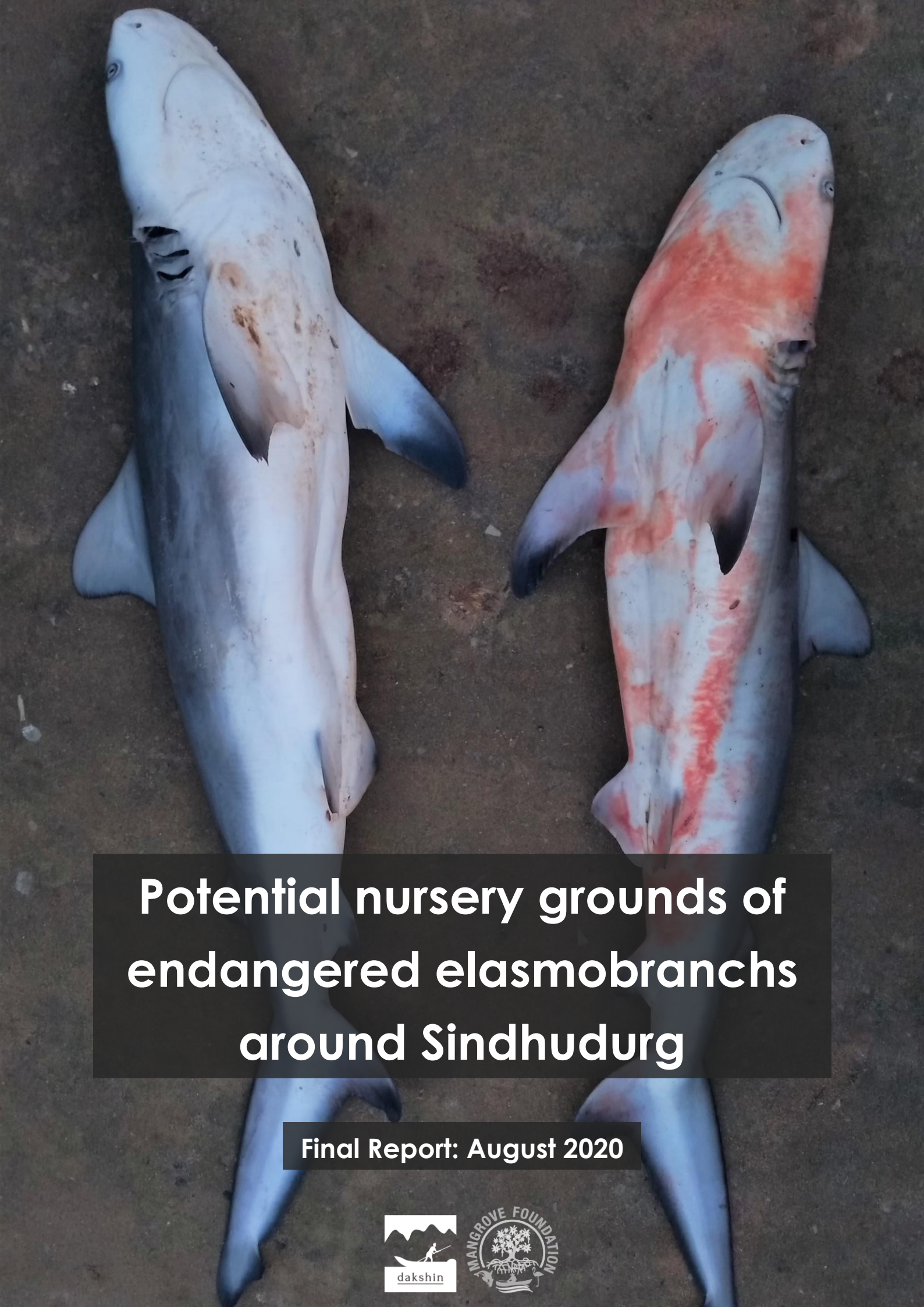

Potential nursery grounds of endangered elasmobranchs around Sindhudurg

Final Report: August 2020

dakshin

MANGROVE FOUNDATION

This report has been prepared by Trisha Gupta, Kaustubh Warde, Chetan Rao, Muralidharan Manoharakrishnan, and Kartik Shanker from Dakshin Foundation, in collaboration with the Mangrove Foundation of Maharashtra.

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About Dakshin Foundation

Dakshin Foundation is a non-profit, non-governmental organisation. Our mission is to inform and advocate conservation and natural resource management, while promoting and supporting sustainable livelihoods, social development, and environmental justice. We adopt interdisciplinary and transdisciplinary approaches in our research and conservation interventions, drawing from the fields of ecology, conservation biology, sociology, economics, and law. Our work aims at building community capacities for conservation and enhancing community stakes and rights in environmental decision-making, towards strengthening networks and supporting advocacy campaigns. Our goal is to promote ecologically and socially appropriate approaches to conservation and management in coastal, marine and mountain ecosystems in India.

Background

Elasmobranchs (sharks and rays) play an important ecological role as top and meso predators, and their survival is integral to healthy marine trophic dynamics (Dulvy *et al*., 2017; Martins *et al*., 2018). These species are particularly vulnerable to exploitation due to their slow growth and low fecundity (Bonfil, 1997) and are one of the most threatened marine faunal groups across the globe. India is amongst the top 3 elasmobranch fishing nations in the world (Dent & Clarke, 2015). However, steady declines in elasmobranch landings despite increasing fishing effort (Kizhakudan *et al*., 2015) indicate a severe crisis in the country. Lack of scientific information on their ecology has been a major hindrance to the formulation of meaningful conservation strategies (Kizhakudan *et al*., 2015).

Most shark and ray species display a viviparous or ovo-viviparous mode of reproduction (Cortés, 2000). These species tend to use specific habitats as pupping and nursery grounds in order to ensure survival of juveniles. Elasmobranch nurseries are defined by the following criteria: (1) newborns or young-of-the-year are more commonly encountered in the area than other areas; (2) they have a tendency to remain or return for extended periods; and (3) the area or habitat is repeatedly used across years (Heupel *et al*., 2007; Martins *et al*., 2018). In tropical waters, elasmobranchs may use shallow coastal habitats such as sheltered bays, coral reefs and mangrove forests as nursery grounds, as they offer abundant food resources and/or protection from predators (Springer, 1967). Gravid females and neonates are regularly harvested in India, indicating an overlap between pupping, nursery and fishing grounds (Kizhakudan *et al*., 2015). Signs of growth overfishing have also been reported in Indian waters (Karnad *et al*., 2019). Juvenile survival is particularly critical in maintaining elasmobranch populations; however, there has been little research on nursery grounds and other critical habitats in Indian waters.

Our monitoring of elasmobranch fisheries in the Sindhudurg district of Maharashtra found that a number of endangered and threatened species were captured regularly in this region (Gupta *et al*., 2020). Occurrence of neonates and gravid females of some of these species indicates that they are likely to be breeding in this region (Figure 1). Protection of juveniles and the habitats they use can be crucial for their conservation and sustainable harvest. Understanding the breeding and pupping of elasmobranchs, particularly their use of nursery habitats, can therefore guide improved regional fisheries management (Yokota & Lessa, 2006). However, there is currently an absence of long-term scientific data that is needed to identify nursery habitats as per the criteria listed by Huepel *et al* (2007).

This pilot study aimed to characterize the breeding biology of threatened elasmobranch species in Sindhudurg, in terms of occurrence, biological characteristics and catch locations of their juveniles. These findings will help identify potential nursery areas for these species to guide future research and conservation efforts.

Figure 1: A gravid female blacktip shark (*Carcharhinus limbatus*, **A**) captured by a gillnet, carrying 8 pups (**B**). Pictures by Aloknath Baral.

Study Area

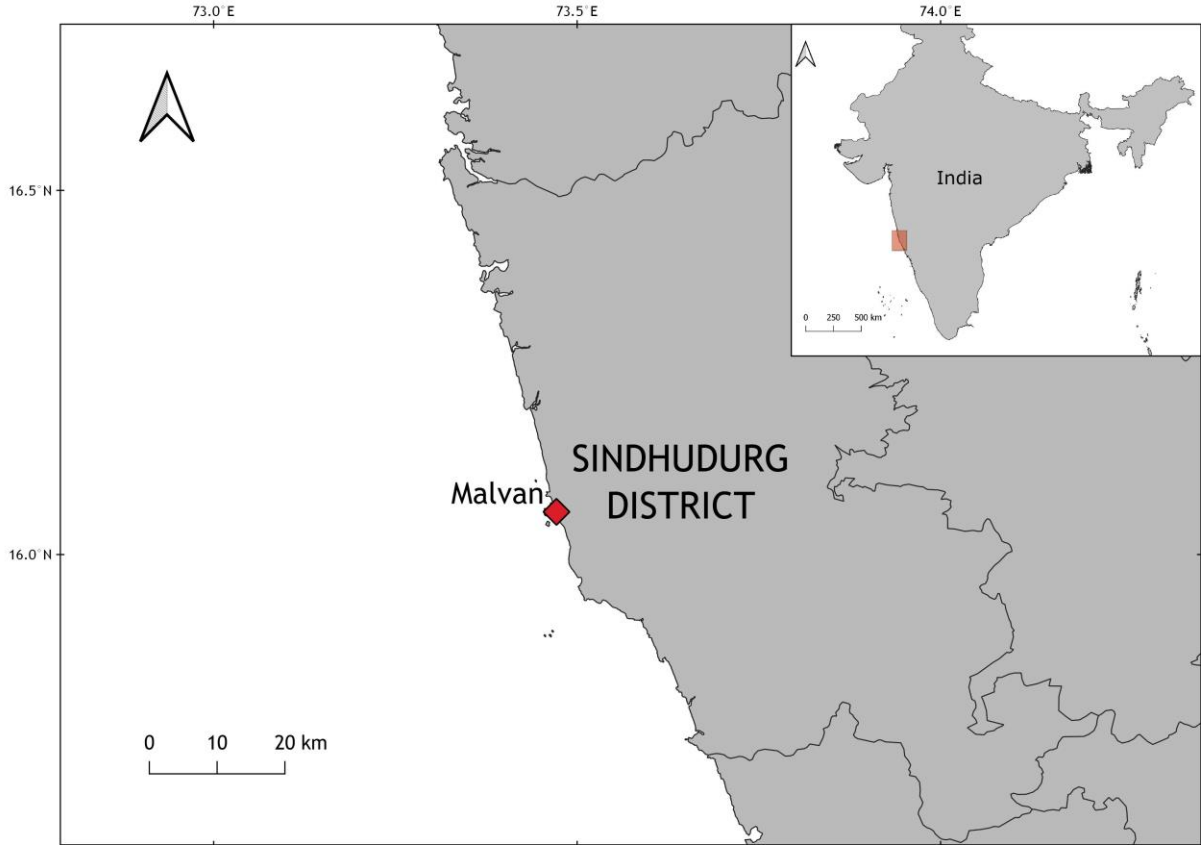


Figure 2: The Malvan region of Sindhudurg district, Maharashtra

Sindhudurg is a coastal district in the south of Maharashtra, bordering Goa. Sindhudurg has a shallow coastline interspersed with a range of marine habitats such as corals, mangrove forests and estuaries, and is a hotspot for marine biodiversity (UNDP, 2013). These waters also host the Malvan Marine Sanctuary, one of India's marine protected areas (UNDP, 2013). Sampling for this study was carried out in Malvan (Figure 2), which is the main fishing centre in this region. Fisheries in Malvan can be classified as trawlers, gillnets and artisanal (Figures 3A, B and 4A). There are about 80-100 trawlers operating from Malvan, constituting a multi-species fishery targeting prawns, crabs, and pelagic fish like pomfret (*Pampus sp.*) and mackerel (*Rastrelliger kanagurta*). There are at least 500 gillnets in and around Malvan, and are highly diverse in their target species and mesh sizes of their nets. Artisanal fisheries include shore seines (*Rampan*), hook and lines, cast nets and others. Trawlers usually landed and sold their catch in the evenings (Figure 4B), whereas gillnets and artisanal fisheries landed and sold their catch in the morning. Fishing trips are generally undertaken in relatively shallow waters (<100m depth) in the region, from Panaji in the south to Ratnagiri in the north. Elasmobranchs are frequently captured by all the different fisheries and gear.

Figure 3: **A**: A trawler boat, **B**: A non-motorised gillnet boat. Pictures by Manini Bansal.

Figure 4: **A**: Artisanal shore seine fishery, **B**: The evening fish auction at Malvan. Pictures by Kaustubh Warde (A) and Manini Bansal (B).

Landing surveys

Landing surveys for all elasmobranch species were conducted at Malvan between March 2018 and May 2019 (see Gupta *et al*., 2020 for methodology). Through these surveys, we identified the following threatened species (IUCN, 2019) that appeared to be breeding in this region: scalloped hammerhead shark (*Sphyrna lewini*), common blacktip shark (*Carcharhinus limbatus*, Figure 1), bull shark (*Carcharhinus leucas*), longheaded eagle ray (*Aetobatus flagellum*), widenose guitarfish (*Glaucostegus obtusus*) and sharpnose guitarfish (*Glaucostegus granulatus*).

Hence, the present study focused on these six elasmobranch species. Landings surveys were conducted three times a week, on alternate days, between November 2019 and March 2020. On each day, both the morning fish auction (catch from gillnets and artisanal fisheries) and evening auction (catch from trawlers) were sampled. Catch of each landed boat was surveyed for the study species; if present, biological data was recorded, and fishing data was noted through informal interviews with fishers (Table 1). Sharks with an open umbilical scar were considered as neonates (i.e. newly born individuals; Yokota & Lessa, 2006; Figure 5A). For rays, as umbilical scars could not be clearly distinguished, neonates were identified based on sizes of birth from literature. Gravid females were identified by presence of emerging embryos or if these could be clearly observed by pressing the stomach (Tyabji *et al*., 2020; Figure 5B). Embryos were removed and measured wherever possible.

Data collected during the present study were combined with the landings data for these species from our previous study (Gupta *et al*., 2020). This dataset was then analysed to generate descriptive statistics of the study species. Occurrence of neonates and gravid females was used to gain insights into the breeding and pupping seasons. Broad capture locations of neonates were plotted using QGIS (Version 3.12.3; QGIS, 2020) to indicate potential nursery grounds for these species. All other data analyses were conducted on RStudio (Version 1.2.5033; RStudio 2015; R Core Team 2017).

Challenges

Our study initially intended to conduct surveys onboard fishing vessels to record precise catch locations and environmental data of the study species. However, we faced considerable challenges in conducting this as fishers were not comfortable taking researchers on board their vessels. Instead, we conducted landing surveys focusing on these species, collecting data on catch locations and gear through interviews with fishers. This baseline data will guide future research in terms of which fishing grounds, season, vessels, and gear need to be focused on for onboard surveys and other data collection methods.

Figure 5: **A**: An open umbilical scar on a shark, indicating a neonate. **B**: A gravid eagle ray. Pictures by Trisha Gupta.

Table 1: Data collected during the landing surveys for elasmobranchs

Data	Type	Description
Fishing Behaviour and Gear		
Date of Sample	Categorical	
Fishing type	Categorical	Trawler, Gillnet or Artisanal
Boat ID	Categorical	
Trip length	Numeric	Number of fishing days
Fishing grounds	Categorical	Main location of fishing
Fishing depth	Numeric	Average depth of fishing (m)
Gear	Categorical	Benthic or Pelagic nets for trawlers, Mechanised, Motorised or Non-motorised for gillnets
Species Biology		
Species ID	Categorical	
Abundance	Numeric	Total number of the species per vessel
Size	Numeric	Total Length (TL) for sharks and guitarfish, Disc Width (DW) for rays
Weight	Numeric	To the nearest 5 grams
Sex	Categorical	Male or female
Male Maturity	Categorical	Immature, Maturing or Mature, based on clasper calcification (Tyabji *et al*., 2020)
Umbilical Scar	Categorical	Open or Closed

Scalloped hammerhead shark (*Sphyrna lewini*)

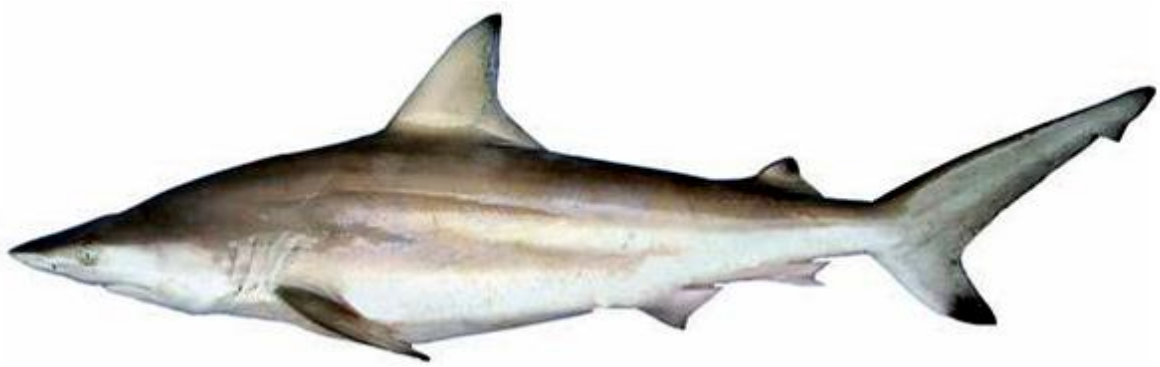
Sphyrna lewini, by Australian National Fish Collection, CSIRO

S. lewini was captured by both trawlers (52.4%) and gillnets (47.1%), with very few sharks captured in artisanal gear. Within trawlers, 84.4% were captured in pelagic nets whereas within gillnets, 72.3% were captured by mechanised boats. Nearly all the caught individuals of this critically endangered species were juveniles (i.e. below the size of maturity; Jabado & Ebert, 2015; Table 2). One gravid female (246.5cm TL) was encountered in December 2018; however, the number and size of pups could not be determined. Low occurrence of adults in the catch can be attributed to the fishing behaviour; large sharks (>1m) are not presently targeted and captured by the fisheries in Malvan. Adult hammerheads are likely to occur seasonally around Sindhudurg; anecdotal evidence indicates that large adults, including gravid females, are occasionally captured between September to December.

The breeding season for this species in Indian waters has been reported to be between August and October, with a high density of juveniles recorded in nearshore waters from August to December (Zacharia *et al.*, 2018). These records correspond with the present study, where neonates (identified by an open umbilical scar) were frequently encountered between November and January (Table 2). This suggests that along the Konkan coast, the post monsoon period is likely to be the pupping season of *S. lewini*, with gravid females coming close to shore to give birth.

S. lewini neonates appeared to be captured from fishing grounds across Sindhudurg. The highest catches were recorded from the Malvan fishing grounds, followed by Vengurla in the south and Aachra in the north (Figure 6). Depth of capture ranged from 13 to 91m, with highest catches recorded between 25-35m. *S. lewini* juveniles are known to use muddy benthic habitats in estuarine bays as nursery habitats (Brown *et al.*, 2016; Duncan & Holland, 2006). In Sindhudurg, it is likely that *S. lewini* uses a number of sandy estuarine habitats present along the coastline as pupping and nursery grounds.

Common blacktip shark (*Carcharhinus limbatus*)



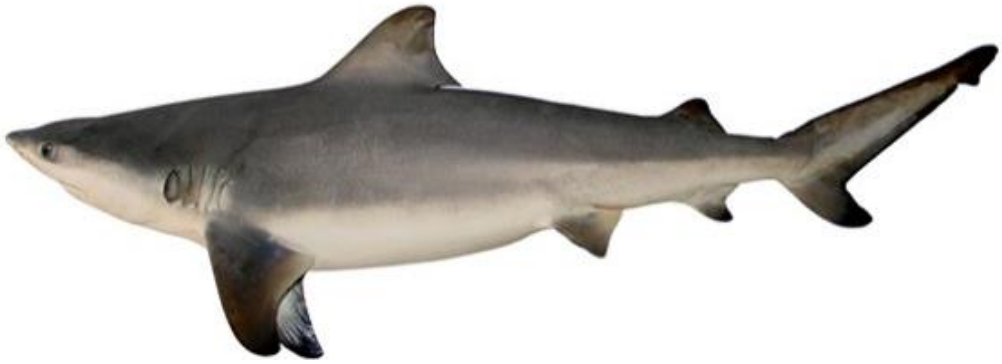
Carcharhinus limbatus, by Wikimedia Commons

Gillnets accounted for most of the *C. limbatus* catches (96.9%), as these species are sometimes targeted by gillnetters. Both mechanised and motorised gillnets captured these species. Like *S. lewini*, nearly all *C. limbatus* sharks captured were juveniles (Jabado & Ebert, 2015; Table 2). Only two adults were encountered over the course of the study, of which one was a gravid female (242cm TL) encountered in February 2020. The female was found carrying 8 near-term pups, averaging 68cm TL in size. We recorded at least 129 neonates of this species, having a wide range and variation in the sizes at birth (Table 2).

Relatively high abundance of neonates over the months of January and February, as well as occurrence of the gravid female, suggested that pupping occurs over these months (Table 2). In addition, anecdotal evidence indicates abundant catch of juvenile *C. limbatus* in the monsoon period (June – August) in Sindhudurg.

Pups of *C. limbatus* are known to occupy seasonal nursery grounds in shallow coastal waters away from the adult population, for 2-3 month after birth (Simpfendorfer & Milward, 1993; Yokota & Lessa, 2006). In the present study, *C. limbatus* neonates were captured across Sindhudurg, with the highest catches were recorded from Malvan waters followed by Vengurla in the south (Figure 6). Depth of capture ranged from 9–73m, with highest catches recorded between 25-30m. Like *S. lewini, C. limbatus* may be using multiple habitats in this region as seasonal nursery grounds.

Bull shark (*Carcharhinus leucas*)

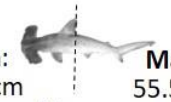
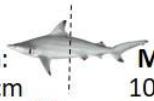
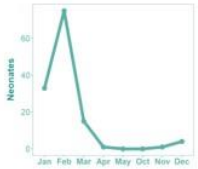
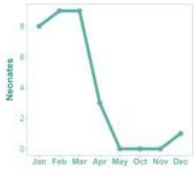


Carcharhinus leucas, by Australian National Fish Collection, CSIRO

C. leucas were encountered in low numbers in the present study. Like *C. limbatus*, this species was also occasionally targeted by gillnetters (particularly motorised vessels) with most sharks captured by this fishery (70.3%). All captured sharks were juveniles below 1m in length. Most of these were neonates with open umbilical scars (Table 2). Although we did not sample any gravid females of *C. leucas* in Malvan, gravid females have been recorded in landing centres in other parts of Sindhudurg and in Goa, strongly suggesting that bull sharks breed in this region. Pupping season may be between February and March, as neonates were frequently captured during this period (Table 2).

This species is known to frequently enter rivers to feed and to give birth, and neonates use rivers and estuaries as nursery grounds (Simpfendorfer & Burgess, 2009). We found similar patterns in the present study, where at least 8 (of the 28 cases where catch location was known) neonates were captured in rivers and creeks around Malvan (Figure 6). The remaining 20 sharks were captured in the sea, in relatively shallow waters as compared to the other shark species (between 7-44m, with an average of 22.2m). Their use of rivers and shallow estuarine habitats makes juveniles of these species vulnerable to capture in the small-scale fisheries operating in these areas.

Table 2: Summary of biological data of the shark species in the present study

	Scalloped hammerhead shark  *Sphyrna lewini*	**Common blacktip shark**  *Carcharhinus limbatus*	**Bull shark**  *Carcharhinus leucas*
IUCN Status	Critically Endangered	Near Threatened	Near Threatened
Total encountered (No. sampled)	**653** sharks (357)	**338** sharks (245)	**49** sharks (40)
No. of neonates	**102** neonates	**129** neonates	**30** neonates
Size (TL) of neonates	**Min:** 42.7cm  **Max:** 55.5cm **Mean:** 47.9cm	**Min:** 43.2cm  **Max:** 100cm **Mean:** 71.7cm	**Min:** 72cm  **Max:** 92cm **Mean:** 81.4cm
No. of gravid females	**1** gravid female (Dec)	**1** gravid female (Feb)	**0** gravid females
Potential pupping season	 **Nov -Dec**	 **Jan - Feb**	 **Feb - March**

Longheaded eagle ray (*Aetobatus flagellum*)

Aetobatus flagellum, by William T. White, *Zootaxa*

Trawlers accounted for 89.3% of the *A. flagellum* catch in Malvan, with most of it coming from pelagic nets (82.5%). A wide size range of this endangered species was sampled, from 23cm to 129cm DW. Although Last *et al*. (2016) suggest that this species grows up to about 93cm DW, 8 individuals (all females) larger than this size were recorded in Malvan.

89.3% percent of males and 90.3% percent of females were immature (i.e. below the size of maturity known from literature, Last *et al*., 2016). While we did not identify any gravid females, two spent females were recorded in the months of April (93.5cm DW) and October (109.5cm DW) respectively. Neonates (classified as individuals within 30cm DW, close to the size at birth; Last *et al*., 2016) were predominantly encountered in the months of May and October (Table 3). This coincides with the occurrence of the spent females, suggesting that pupping may occur during this period, in the monsoon. Juveniles were predominantly captured in fishing grounds in Malvan and Aachra, between 25-30m depth (Figure 6).

Little is known about the breeding behaviour and ecology of this species (White, 2006). Findings of this study provide some insights into understanding the breeding of this species and habitat use of juveniles.

Widenose guitarfish (*Glaucostegus obtusus*)

Glaucostegus obtusus, by Trisha Gupta

Gillnets, particularly motorised and non-motorised vessels, contributed to most of the catch (75.8%) of this critically endangered species. This is likely because *G. obtusus* is known to aggregate in shallow waters, especially at night, where they are sometimes targeted by small-scale gillnetters. A wide size range of this species was sampled, from 26.5cm to 119cm TL (Table 3). Previous records have suggested that this species grows up to 93cm TL (Last *et al*., 2016); however, the present study recorded 15 guitarfish larger than this maximum size (ranging from 94.5 to 119cm TL, all female).

7 gravid females were recorded over the study duration. Embryos were measured for two females; the first was 90cm TL with 5 embryos measuring an average of 13cm, and the second was 96.8cm TL with 5 embryos as well, measuring 8.5cm on average. The gravid females were encountered in the months of November, January and March (Table 3). Size at birth for this species is unknown; based on similar species (Last *et al*., 2016), neonates would likely be up to 45cm TL. Only 11 neonates were recorded in this study, largely in the month of January (Table 3). These findings suggest that pupping may occur in the first half of the year; however, sample size for this species was low. Neonates were predominately captured in fishing grounds in Malvan and Talashil (to the north), in shallow waters between 4-9m (Figure 6).

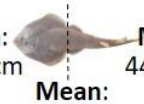
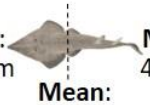
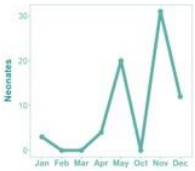
Sharpnose guitarfish (*Glaucostegus granulatus*)

Glaucostegus granulatus, by Frederik H. Mollen, *shark-references.com*

Unlike *G. obtusus*, most of the landed *G. granulatus* were from trawlers (76.4%), almost entirely from benthic nets. *G granulatus* is known to inhabit offshore continental shelves up to 120m depth (Last *et al*., 2016), where it may be more susceptible to capture in trawl nets. As with the other rays, a wide size range was observed for this species from 20.6cm to 166.4cm TL. Although no gravid females were identified, 3 individuals <30cm were recorded, significantly smaller than the size at birth reported from literature (39cm; Kyne *et al*., 2020). These rays may have been aborted embryos from gravid females captured by fisheries (Wosnick *et al*., 2019).

Little is known about the breeding and pupping of this species. Neonates (categorised as individuals <50cm TL, close to the size at birth) were recorded between December and January, which may be the pupping season; however, sample size for this species was low (Table 3). Malvan and Aachra reported relatively high catches of *G. granulatus* neonates over a depth range of 8-46m (Figure 6). *G. granulatus* and *G. obtusus* are known to co-occur (Last *et al*., 2016), and may be using the same nursery habitats.

Table 3: Summary of biological data of the ray species in the present study.

	Longheaded eagle ray  *Aetobatus flagellum*	**Widenose guitarfish**  *Glaucostegus obtusus*	**Sharpnose guitarfish**  *Glaucostegus granulatus*
IUCN Status	Endangered	Critically Endangered	Critically Endangered
Total encountered (No. sampled)	**309** rays (178)	**278** rays (132)	**74** rays (64)
No. of neonates	**70** neonates	**11** neonates	**18** neonates
Size of neonates	 **Min:** 23cm **Max:** 29.8cm **Mean:** 27.6cm	 **Min:** 26.5cm **Max:** 44.5cm **Mean:** 40.7cm	 **Min:** 20.6m **Max:** 49cm **Mean:** 39cm
No. of gravid females	**0** gravid, but **2** **spent** females (April, Oct)	**7** gravid females (Nov, Jan, March)	**0** gravid females
Potential pupping season	 **Nov, May**	 **Jan** (small sample size)	 **Dec - Jan** (small sample size)

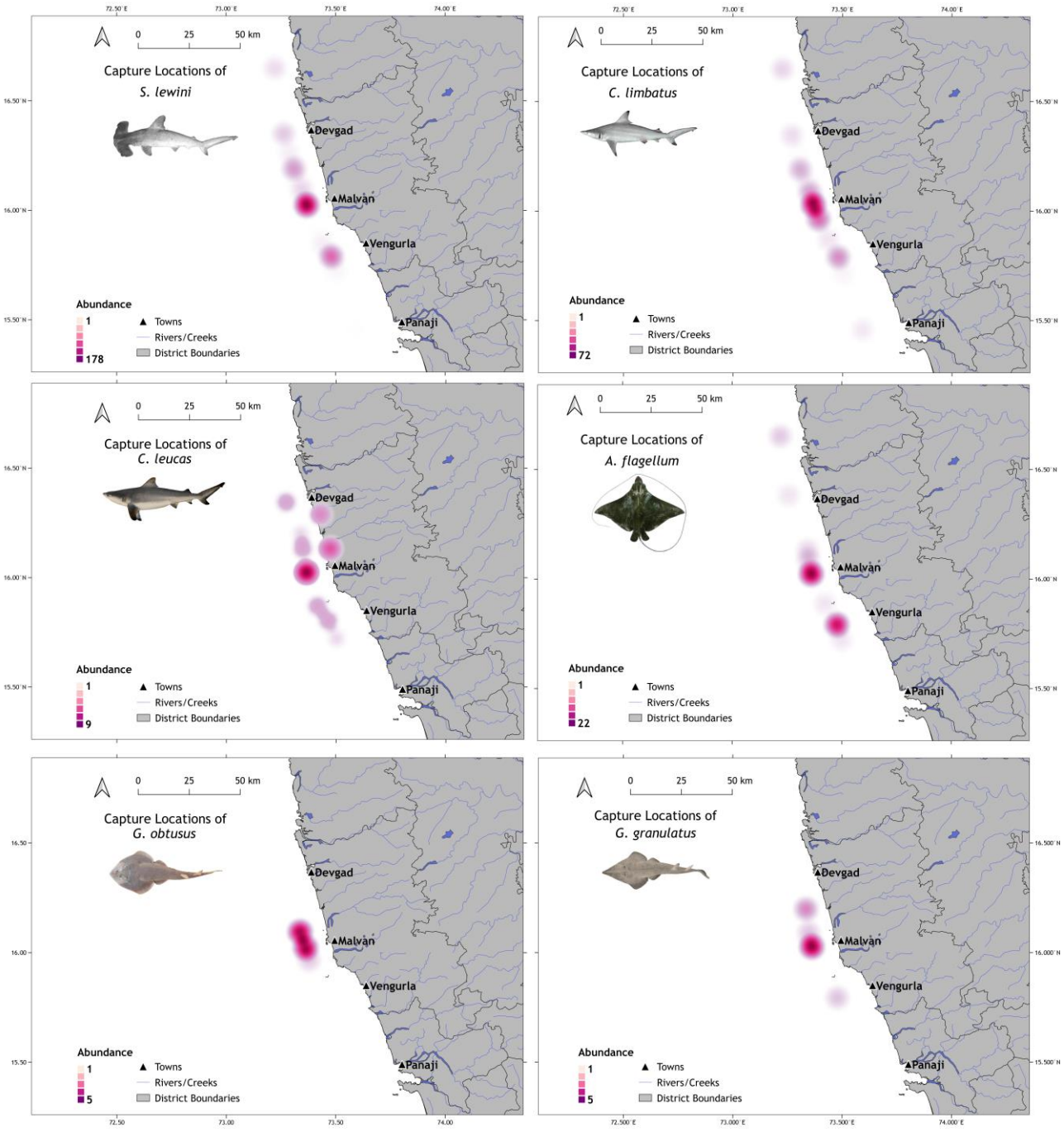


Figure 6: Capture locations of neonates of the study species in Sindhudurg waters, indicating potential nursery grounds. Map locations are representative only, plotted based on the broad catch locations and depths as told by fishers through informal interviews. The exact capture position and distance from shore are unknown.

Discussion

The present study was a preliminary investigation into the biology and nursery grounds of six threatened elasmobranch species in Sindhudurg. Although it is limited in terms of having a small dataset, collected through fisheries-dependent surveys only, we do provide much-needed insights into these poorly studied species in Indian waters. Furthermore, our data serves as a baseline to guide future research and conservation efforts in this region.

Carcharhinid and Sphyrnid sharks have been generally well researched in terms of their reproductive characteristics and nursery grounds in regions like North America and Australia (Duncan & Holland, 2006; Simpfendorfer *et al*., 2005; Simpfendorfer & Milward, 1993). However, little to no data exists for these genera in Indian waters. For the ray species, little is known about their breeding and pupping even globally (Last *et al*., 2016). Observations from our study aid in addressing some of these data gaps at the regional level.

Higher catches of neonates of the study species were recorded in the shallow waters around Malvan, Vengurla and Aachra in particular (Figure 6), indicating that these areas may serve as nursery grounds for elasmobranchs. Although our study did not assess fine-scale movement and habitat use, it is likely that elasmobranchs show some degree of spatial segregation within these nursery grounds (Yokota & Lessa, 2006). This is supported by differences in craft and gear of capture between species in the present study. Furthermore, we found variations in the breeding and pupping seasons between the elasmobranch species under study; for example, *S. lewini* may pup between November and January, whereas *C. leucas* may pup during February and March. Hence, broad conservation measures like seasonal or spatial closures will not be effective for all elasmobranchs. It is important that both research techniques and conservation efforts are nuanced and species-specific.

Our findings also emphasize the importance of Sindhudurg waters for marine biodiversity. We show that both coastal elasmobranch species like bull sharks (*C. leucas*) and guitarfish (*Glaucostegus sp.*), and oceanic, migratory species like the scalloped hammerhead shark (*S. lewini*) use these waters as breeding and nursery grounds. Sindhudurg is also known to be an aggregation site of the endangered whale shark (*Rhincodon typus*; Premjothi *et al*., 2016). Continued unregulated exploitation of elasmobranch juveniles can be detrimental to the long-term survival of these populations (Stobutzki *et al*., 2002). Long-term fisheries monitoring needs to be established for threatened species such as these, to generate robust data on their capture and interaction with fisheries. More importantly, research through fisheries-independent methods on the movement and habitat use of these species is crucial for identifying nursery grounds and other critical habitats. This is essential for both conservation and long-term sustainability of the fisheries.

Participation and inclusion of the fishing community is vital for the conservation of elasmobranchs and management of their fisheries. We developed an outreach book on sharks and rays of Malvan, in the local language *Marathi* (Figure 7). The book contains information regarding the importance of sharks and rays in local ecosystems. It also disseminates the findings of our study regarding species diversity, biology, and breeding of elasmobranchs.

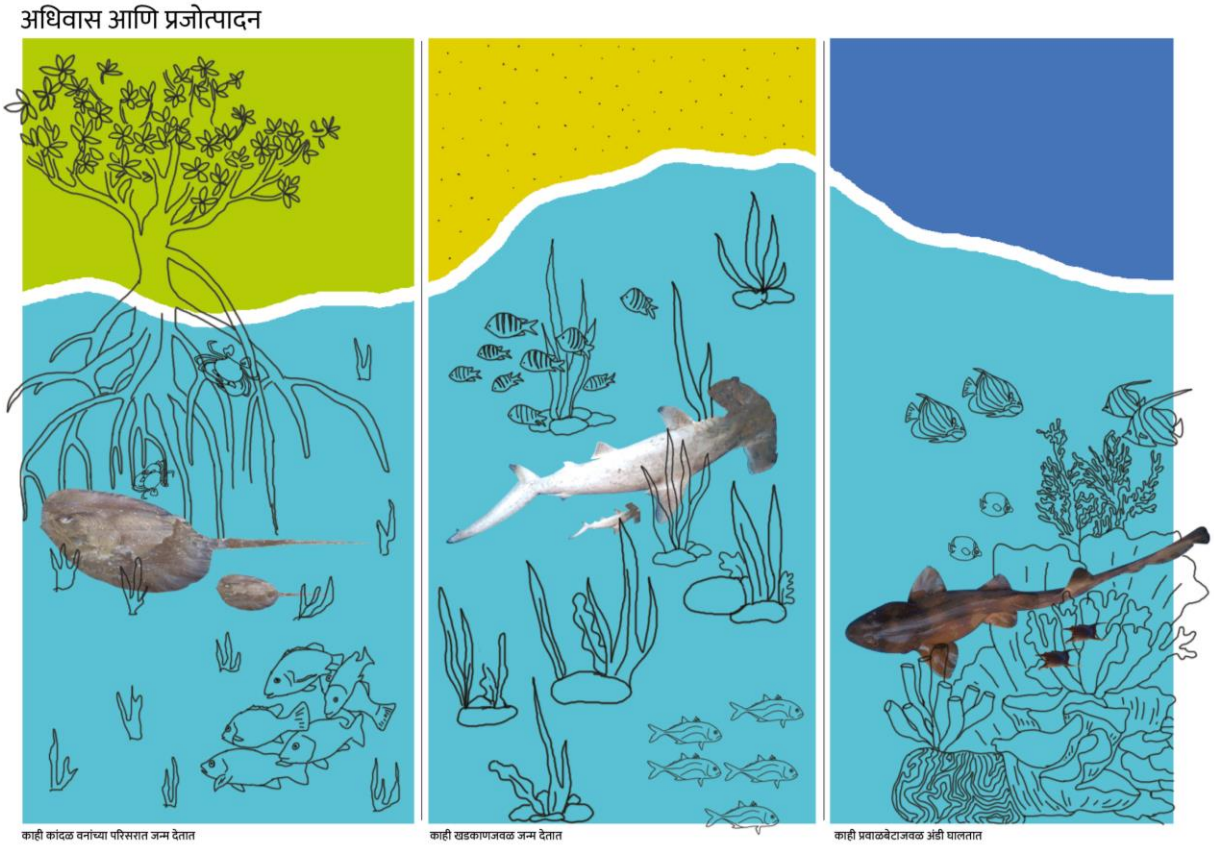


Figure 7: Outreach material on the breeding and habitat of sharks and rays, in Marathi

During this field study, we also supported the dissertation studies of two master's students from TERI University, New Delhi, working on post-capture survival and population genetic structure of elasmobranchs, respectively (Figure 8). Their work has been submitted for publication in peer-reviewed journals. We have also conducted a short study on elasmobranch capture in shore seine fisheries in Malvan, which has also been submitted for publication.

Figure 8: Sampling for post-capture survival of bamboo sharks (*Chiloscyllium sp.*). Picture by Kaustubh Warde.

Acknowledgements

We express our gratitude to the Mangrove Foundation of Maharashtra for funding and supporting this study. We thank Shruthi Kottillil, Sudha Kottillil, Aloknath Baral, Nikhil Thomas, Gaurav Patil and Harshitha Mohan for their assistance with the fieldwork. Finally, we are grateful to the fishing community of Malvan for participating in and supporting this work.

References

Bonfil, R. (1997). Trends and Patterns in World and Asian Elasmobranch Fisheries. Elasmobranch Biodiversity, Conservation and Management: Proceedings of the International Seminar and Workshop, 57(3), 476–494.

Brown, K. T., Seeto, J., Lal, M. M., & Miller, C. E. (2016). Discovery of an important aggregation area for endangered scalloped hammerhead sharks, *Sphyrna lewini*, in the Rewa River estuary, Fiji Islands. Pacific Conservation Biology, 22(3), 242.

Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Cortés, E. (2000). Life History Patterns and Correlations in Sharks. Reviews in Fisheries Science, 8(4), 299–344.

Dent, F., & Clarke, S. (2015). *State of the global market for shark products. In FAO technical paper 590*. Retrieved from http://www.fao.org/docrep/field/003/ab825f/AB825F00.htm#TOC%5Cnhttp://www.fao.org/3/a-i4795e.pdf

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N. K., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and Priorities in Shark and Ray Conservation. Current Biology, 27(11), R565–R572.

Duncan, K. M., & Holland, K. N. (2006). Habitat use, growth rates and dispersal patterns of juvenile scalloped hammerhead sharks *Sphyrna lewini* in a nursery habitat. Marine Ecology Progress Series, 312, 211–221.

Gupta, T., Booth, H., Arlidge, W., Rao, C., Manoharakrishnan, M., Namboothri, N., … Milner-Gulland, E. J. (2020). Mitigation of elasmobranch bycatch in trawlers: A case study in Indian fisheries. Frontiers in Marine Science, 7 (July), 571.

Heupel, M. R., Carlson, J. K., & Simpfendorfer, C. A. (2007). Shark nursery areas: Concepts, definition, characterization and assumptions. Marine Ecology Progress Series, 337 (Nmfs 2006), 287–297.

IUCN (2019). The IUCN Red List of Threatened Species. Version 2019-2. http://www.iucnredlist.org. Downloaded on 18 July 2020

Jabado RW and Ebert DA (2015). *Sharks of the Arabian Seas: an identification guide*. The International Fund for Animal Welfare, Dubai, UAE. 240 pp.

Karnad, D., Sutaria, D., & Jabado, R. W. (2019). Local drivers of declining shark fisheries in India. Ambio. 49(2), 616-627.

Kizhakudan, S. J., Zacharia, P. U., Thomas, S., Vivekanandan, E., & Menon, M. (2015). *Guidance on National Plan of Action for Sharks in India*. p. 104. Retrieved from http://eprints.cmfri.org.in/10403/1/NPOA_SHARKS.pdf

Kyne, P.M. & Jabado, R.W. (2019). *Glaucostegus granulatus*. *The IUCN Red List of Threatened Species* 2019: e.T60166A68623788. Downloaded on 13 July 2020.

Last, P., White, W., de Carvalho, M., Séret, B., Stehmann, M. and Naylor, G. (2016). *Rays of the World*. CSIRO Publishing, Clayton.

Martins, A. P. B., Heupel, M. R., Chin, A., & Simpfendorfer, C. A. (2018). Batoid nurseries: Definition, use and importance. Marine Ecology Progress Series, 595, 253–267.

Premjothi PVR, Choudury BC, Kaul R, Subburaman S, Matwal M, Joshi D, Louise J, Menon V. *An assessment of the past and present distribution status of the whale shark (Rhincodon typus) along the west coast of India*. QScience Proceedings (The 4th International Whale Shark Conference) (2016): iwsc4.43 http://dx.doi.org/10.5339/qproc.2016.iwsc4.43

QGIS.org (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org

Rigby, C.L., Dulvy, N.K., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B. & Winker, H. (2019). *Sphyrna lewini*. *The IUCN Red List of Threatened Species* 2019: e.T39385A2918526. Downloaded on 06 August 2020.

RStudio Team (2015). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL: http://www.rstudio.com/.

Simpfendorfer, C. & Burgess, G.H. (2009). *Carcharhinus leucas*. *The IUCN Red List of Threatened Species* 2009: e.T39372A10187195. Downloaded on 13 July 2020.

Simpfendorfer, C. A., Freitas, G. G., Wiley, T. R., & Heupel, M. R. (2005). Distribution and habitat partitioning of immature bull sharks (*Carcharhinus leucas*) in a Southwest Florida estuary. Estuaries, 28(1), 78–85.

Simpfendorfer, C. A., & Milward, N. E. (1993). Utilisation of a tropical bay as a nursery area by sharks of the families Carcharhinidae and Sphyrnidae. Environmental Biology of Fishes, 37(4), 337–345

Springer, S. (1967). *Social organization of shark populations*. pp. 149-174. In: P.W. Gilbert, R.F. Matheson & D.P. Rall, (eds.), Sharks, Skates and Rays, John Hopkins Press, Baltimore.

Stobutzki, I. C., Miller, M. J., Heales, D. S., & Brewer, D. T. (2002). Sustainability of elasmobranchs caught as bycatch in a tropical prawn (shrimp) trawl fishery. Fishery Bulletin, 100(4), 800–821.

The Noun Project (2014). Available online at: www.thenounproject.com (accessed June 25, 2020).

Tyabji, Z., Wagh, T., Patankar, V., Jabado, R. W., & Sutaria, D. (2020). Catch composition and life history characteristics of sharks and rays (Elasmobranchii) landed in the Andaman and Nicobar Islands, India. *bioRxiv*. doi**:** https://doi.org/10.1101/2020.03.17.995217

UNDP (2013). *Mainstreaming Coastal and Marine Biodiversity Conservation into Production Sectors in the Sindhudurg Coast, Maharashtra. Progress Report 2013.* Maharashtra: United Nations Development Programme (UNDP), 116.

White, W.T. (2006). *Aetobatus flagellum*. *The IUCN Red List of Threatened Species* 2006: e.T60119A12306888. Downloaded on 06 August 2020.

Wosnick, N., Awruch, C. A., Adams, K. R., Gutierre, S. M. M., Bornatowski, H., Prado, A. C., & Freire, C. A. (2019). Impacts of fisheries on elasmobranch reproduction: high rates of abortion and subsequent maternal mortality in the shortnose guitarfish. Animal Conservation, 22(2), 198–206.

Yokota, L., & Lessa, R. P. (2006). A nursery area for sharks and rays in Northeastern Brazil. Environmental Biology of Fishes, 75(3), 349–360.

Zacharia, P. U., Kizhakudan, S. J., Thomas, S., Manojkumar, P. P., Nair, R. J., Najmudeen, T. M., Purushottama, G. B., Muktha, M., Dash, S. S., Akhilesh, K. V. and Remya, L. (2017). *CMFRI Marine Fisheries Policy Series No-6; Non-Detriment Findings (NDF) for the export of Shark and Ray species listed in Appendix II of the CITES and harvested from Indian waters.* Marine Fisheries Policy Series (6). Central Marine Fisheries Research Institute, Kochi, pp. 1-102. ISBN ISSN 2394-8019