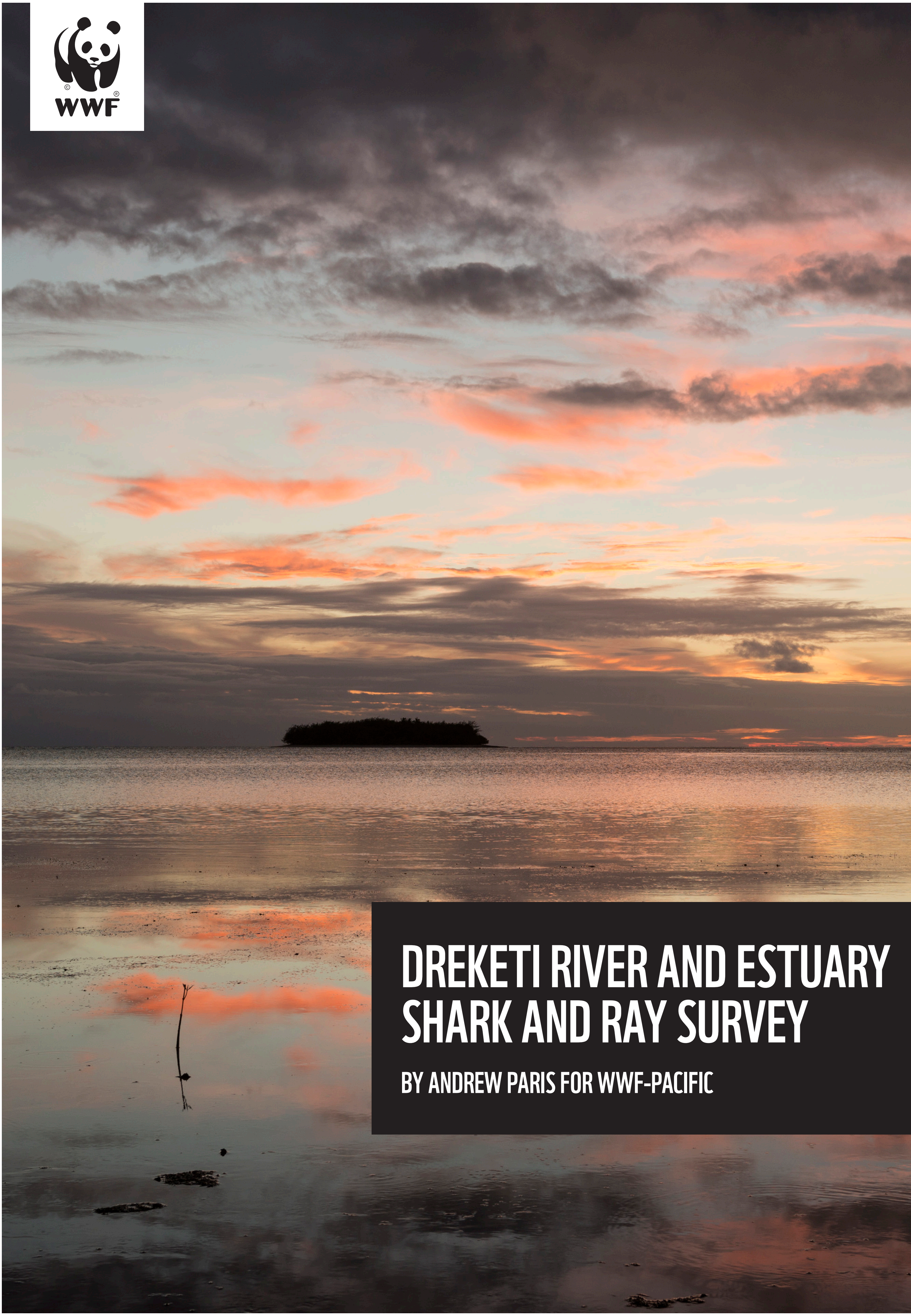

# DREKETI RIVER AND ESTUARY SHARK AND RAY SURVEY

BY ANDREW PARIS FOR WWF-PACIFIC


**Picture Caption**

Cover page - Evening sunset view from the mouth of the Dreketi River with Nukuci island in the background. © WWF-Pacific

Page 2-3 - Bull shark (*Carcharhinus leucas*). © Shutterstock / Carlos Aguilera / WWF

Page 4-5 - Researcher Andrew Paris holds a blacktip shark upside down to induce a state of tonic immobility while community representative Tomasi Bula obtains a fin clip for DNA analysis. © Opeti Vateitei / WWF-Pacific

Page 6-7 - Blacktip shark (*Carcharhinus limbatus*). © Daniel Versteeg / WWF

Pages 14-15 - The side view of a bull shark (*Carcharhinus leucas*). © Shutterstock / Fiona Ayerst / WWF

Page 16 - The Dreketi River with Mt. Nararo in the background, on the boarder of the Macuata and Cakaudrove Province. © Andrew Paris / WWF-Pacific

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# SUMMARY


- Fishery-independent survey undertaken over a period of 20 days, comprised of 75 hours of gill net soak time, yielded a total of 85 elasmobranch captures and a total elasmobranch catch per unit effort (CPUE) of 1.13 captures per hour.

- Of the total captures there were 4 species of shark; 47 scalloped hammerhead sharks (55%), 14 blacktip sharks (16%), 8 great hammerhead sharks (9%) and 8 bull sharks (9%) and 3 species of ray; 6 ocellated eagle rays (7%), 1 pink whipray (1%) and 1 bottlenose wedgefish (1%).

- Of the total captures, 3 species (the great hammerhead shark, the scalloped hammerhead shark and the bottlenose wedgefish) or 66% of all captures are listed on the IUCN Red List of Threatened Species as **Critically Endangered**. Two species (the bull shark and blacktip shark) or 26% of total captures are listed as **Near Threatened**. Two species (the ocellated eagle ray and the pink whipray) or 8% of total captures are listed as **Vulnerable**.

- The high proportion of sharks with either a healed or semi-healed umbilical scar indicates parturition and early life residency in the Dreketi Estuary and River and spatial data indicates a degree of species segregation with different species tending to utilize or remain in distinct areas within the study site. Based on anecdotal information the area is known to have a higher concentration of sharks than surrounding coastal areas and the presence of juvenile sharks has been an annual occurrence for many years.

- Elasmobranchs have been noted to have a geospatial affinity to certain areas that can allow the species increased access for food and protection. The identification of such areas can be particularly vital for migratory species such as the scalloped hammerhead shark, the great hammerhead shark and the bull shark which are intrinsically difficult to manage and may warrant marine protected area status.

# 1. INTRODUCTION

## 1.1 GENERAL INFORMATION

Conservation efforts for elasmobranchs require a clear understanding of the ecological processes they support and depend on. Given the complex movement ecology of many sharks and rays, data on the spatio-temporal distribution of critical life-history stages are especially needed. Many species exhibit philopatry, whereby individuals often return to or remain in specific locations for mating, parturition and maturation, making certain areas essential for population survival (Chapman et al., 2015; Hueter et al., 2005; Tillett et al., 2012).

Elasmobranch species which exhibit philopatry within coastal embayments and estuaries are subject to a plethora of threats both natural and anthropogenic. Estuaries in particular face heavy pressures, such as fishing, an increase in coastal development, declining water quality and habitat loss owing to their close proximity to human populations (Lotze et al., 2006). It has been suggested that several shark species use estuaries as nursery areas.

Shark nurseries are critical areas where gravid females give birth and where early life residency occurs. Such areas can offer a steady source of food and protection from predators to juvenile cohorts (Froeschke et al., 2010; Heupel and Simpfendorfer, 2011). By definition, sharks visit such nursery areas repeatedly across years, spend a significant amount of time in these areas and inhabit them at higher densities than surrounding areas (Heupel et al., 2007). They are hence considered critical habitats and their identification is key to understanding elasmobranch ecology and improving current management approaches, in particular in countries with large tropical coastlines that are home to many elasmobranch species.

## 1.2 ELASMOBRANCHS IN FIJI

Fiji is home to at least 40 species of sharks and rays (Sykes et al., 2018) and has a responsibility to ensure their long-term survival. In line with this, the Fijian government has made 17 voluntary commitments at the 2017 United Nations Ocean Conference in New York, including the protection of all shark and ray habitats in Fijian waters under the Sustainable Development Goal 14. Considering the rapid decline of elasmobranch populations throughout the world (Dulvy et al., 2014, 2017; Ferretti et al., 2010) and their ecological importance for marine ecosystems (Bornatowski et al., 2014; Heithaus et al., 2008; Heupel et al., 2014) as well as economic potential (Gallagher and Hammerschlag, 2011; Simpfendorfer and Dulvy, 2017), a better management approach for local shark and ray populations is urgently needed.

Essential fish habitats for sharks have been identified in Fiji waters with potential nursery areas for bull sharks located in the Rewa, Navua, Sigatoka and Ba Rivers and for the critically endangered scalloped hammerhead sharks in the Rewa and Ba Estuary (Marie et al., 2017; Vierus et al., 2018; Glaus et al., 2019b). Research by Rasalato et al. (2010) utilized the potential of local and traditional ecological knowledge to identify shark river habitats in seven riverine areas on Viti Levu and Vanua Levu. Interviews conducted by Rasalato elicited information on the presence of a species of hammerhead in the Dreketi River mouth and an unidentified shark species with a rounded snout, most likely bull sharks, in the lower catchment of the Dreketi River from Nabavatu to Batiri village. Initial observations coupled with brief interviews with community members indicate lower artisanal fishing pressures in the Dreketi Estuary however gear selectivity is a concern with most fisher folk opting to use gill nets.

## 1.3 DREKETI RIVER AND ESTUARY

At 84,928ha, the Dreketi River catchment is one of the largest in Fiji. The Dreketi River runs 65km mostly from east to west and drains a large section of central Vanua Levu. The Dreketi River is considered to be the deepest river in Fiji and one of the few remaining rivers in Fiji that has not yet been dredged (Atherton et al., 2005). The Dreketi Estuary spans a width of approximately 7km and extends 3km to the seaward margins with an alluvial fan that covers 15km$^2$. For the purpose of the report the estuary is the shallow alluvial fan that begins where the river terminates and this stretches the length of the continental shelf, in a semi-circle, to where the depth increased to 8m and more. Sampling sites were established across the estuary and up to 18km upriver.

## 1.4 AIM AND OBJECTIVES

The aim of the project is to conduct shark and ray sampling survey in the Dreketi River and Estuary.

Objectives:

1. Design and undertake fishery independent survey of juvenile elasmobranch species in the Dreketi River and Estuary.
2. Collate data and carry out analysis for development of draft report.

# 2. METHODOLOGY

## 2.1 SAMPLING METHODS

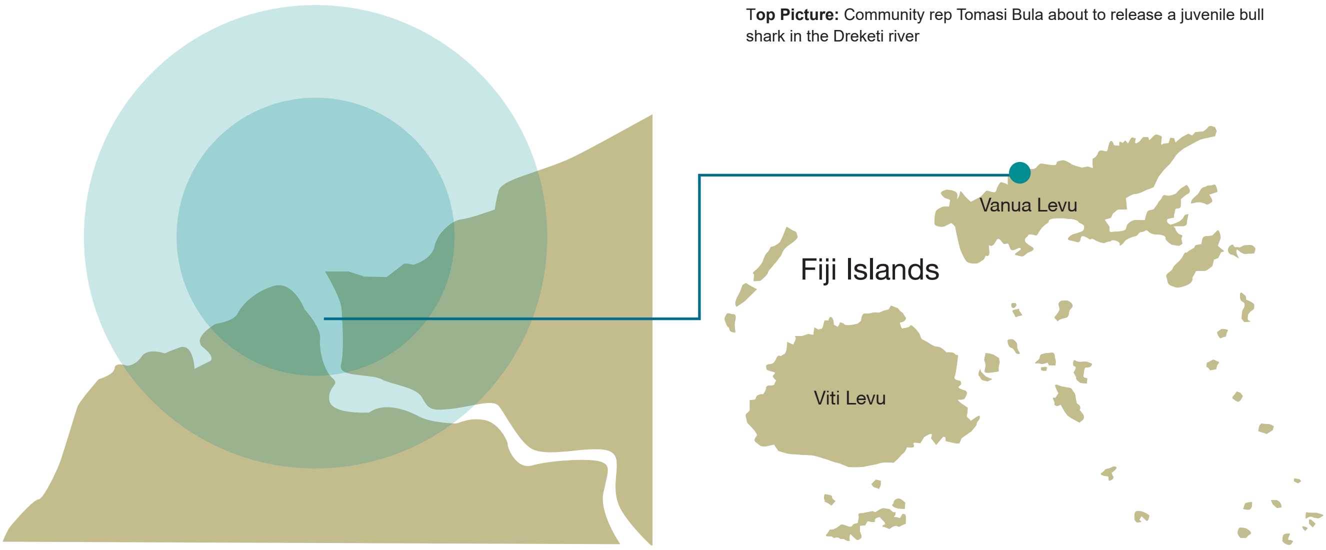
Fishery-independent survey were undertaken over a period of 20 days from 8 January to 18 February 2020 and were comprised of a total of 75 bottom-set gillnet deployments across the estuary with 20 bottom-set gillnet deployments in the river. Sampling times were between 6pm and 4am and the time window was based on scientifically determined periods of high activity. Up to two monofilament gillnets (100m total length and 3m height, ~10cm mesh size) were deployed simultaneously with a soak time of 40 minutes per deployment. The sampling effort was divided into two discrete components; estuary and river sampling.

## 2.2 SHARK AND RAY HANDLING

Captured individuals were freed from the net, processed and released back into the water on the opposite end of the boat. Processing involved taking a photograph, recording species, sex, umbilical scar condition and total length. For ray species disc width was taken. Tissue samples for future DNA analyses were collected using Whatman Elute DNA cards. The umbilical scar condition was categorized based on the degree of healing; open, semi-healed, healed. Open and semi-healed umbilical scars are characteristic for the neonate period with a duration of approximately 15 days until healed. Healed scars are indicative of an age more than 15 days and these specimens are classified as young-of-the-year (Duncan and Holland, 2006). A YSI 85 multimeter device was used to collect water parameter readings at 2m depths.


**Top Picture:** Community rep Tomasi Bula about to release a juvenile bull shark in the Dreketi river

Dreketi River and Estuary



# 3. RESULTS

## 3.1 CATCH COMPOSITION

Between the 8 January and the 18 February 2020, a total of 75 gillnet deployments were conducted totaling 75 standardized hours of fishing. A standardized hour was defined as a period of one-hour fishing with a 100m long, 3m high gill net of 10cm mesh size. The fishery-independent survey led to the capture of a total of 85 elasmobranchs consisting of 4 shark species: scalloped hammerhead shark (*Sphyrna lewini;* N = 47), blacktip shark (*Carcharhinus limbatus*; N = 14), great hammerhead shark (*Sphyrna mokarran;* N = 8), bull shark (*Carcharhinus leucas,* N = 8) and 3 ray species: ocellated eagle ray (*Aetobatus ocellatus;* N = 6), pink whipray (*Pateobatus fai;* N = 1) and bottlenose wedgefish (*Rhynchobatus australiae,* N = 1). Catch per unit effort (CPUE) was calculated by dividing the total captures by total of standardized hours of net soak time which corresponding to a total pooled CPUE of 1.13 captures per hour.

**Table 1.** Sampling effort and average CPUE per area (estuary/river) and survey month. 'SE' refers to sampling effort in hours and 'CPUE' refers to standardized CPUE.

| | | SE | Captures | CPUE |
|---|---|---|---|---|
| January | Estuary | 44 | 61 | 0.71 |
| | River | 8 | 7 | 1.14 |
| February | Estuary | 11 | 10 | 1.10 |
| | River | 12 | 7 | 1.71 |

Comparing the differences in standardized CPUE in the two distinct areas, the estuary and the river along with the month of survey, it can be noted that the highest CPUE was observed in the river for the month of February followed by the river in the month of January, then the estuary in January and finally the estuary in January, see Table 1. It has to be noted that sampling effort was concentrated in the month of January and ideally a period of several months with equal sampling effort will provide a better indication of temporal CPUE variations. A reduced sampling effort in the river was due to unfavorable weather conditions, high rainfall at the beginning of the month of February hindered sampling in the river due to a large volume of debris being swept downstream.

## 3.2 BIOLOGICAL SHARK DATA

The scalloped hammerhead shark *S. lewini* (N = 47) was the most common species encountered during the survey with a mean size of 52.83cm. The majority of the scalloped hammerhead shark captures exhibited a healed umbilical scar condition. The male: female ratio of the scalloped hammerhead shark was 1:0.8. The blacktip shark *C. limbatus* (N = 14) was the second most numerous species encountered with a mean total length of 73.21cm. The majority of blacktip sharks exhibited a healed umbilical scar condition with an even male to female ratio. The third most commonly encountered species was the great hammerhead shark *S. mokarran* (N = 8) with a mean total length of 78.29cm. All great hammerhead shark captures showed a healed umbilical scar condition with a male: female ratio of 3:1. The bull shark *C. leucas* (N = 8) was the third most encountered shark with most of the individuals exhibiting an open umbilical scar condition and a mean total length of 79.25cm. The male to female ratio of the species was even. The ocellated eagle ray *A. ocellatus* (N = 6) was the most encountered ray species with a mean disc width of 61cm and a male to female ratio of 2:1. One individual each of the pink whipray *P. fai* and the bottlenose wedgefish *R. australiae* was captured with a disc width of 53cm and a total length of 140cm respectively, see Table 2.

Community representative Solomone Tuqara deploying gill nets in the estuary of the Dreketi River.

**Table 2.** Overview of elasmobranch species caught in the Dreketi Estuary with information on sex, length and umbilical scar condition ('O' for open, 'SH' semi healed, 'H' healed and 'A' for absent) for those where measurement was possible.

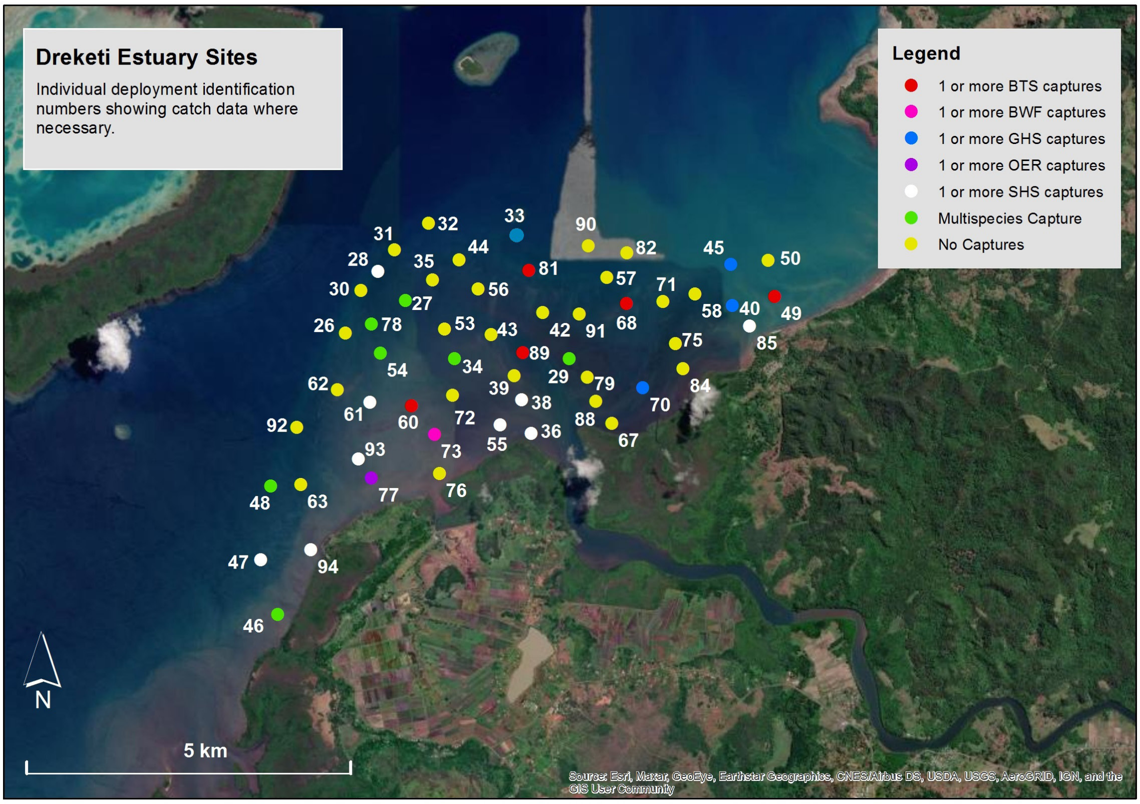
| Species | N | Sex | | Length | | | | Umbilical scar condition | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | F | Mean | SD | Max | Min | O | SH | H | A |
| *S. lewini* | 47 | 26 | 21 | 52.83 | 2.12 | 58 | 49 | 0 | 14 | 33 | 0 |
| *C. limbatus* | 14 | 7 | 7 | 73.21 | 2.74 | 120 | 64 | 0 | 1 | 12 | 1 |
| *S. mokarran* | 8 | 6 | 2 | 78.29 | 3.19 | 83 | 73 | 0 | 0 | 8 | 0 |
| *C. leucas* | 8 | 4 | 4 | 79.25 | 7.98 | 100 | 74 | 6 | 1 | 0 | 1 |
| *A. ocellatus* | 6 | 4 | 2 | 61.00 | 17.74 | 80 | so | - | - | - | - |
| *P. fai* | 1 | 0 | 1 | 53.00 | 0.00 | 53 | 53 | - | - | - | - |
| *R. australiae* | 1 | 1 | 0 | 140 . 00 | 0. 00 | 140 | 140 | - | - | - | - |

## 3.3 SPATIAL DISTRIBUTION

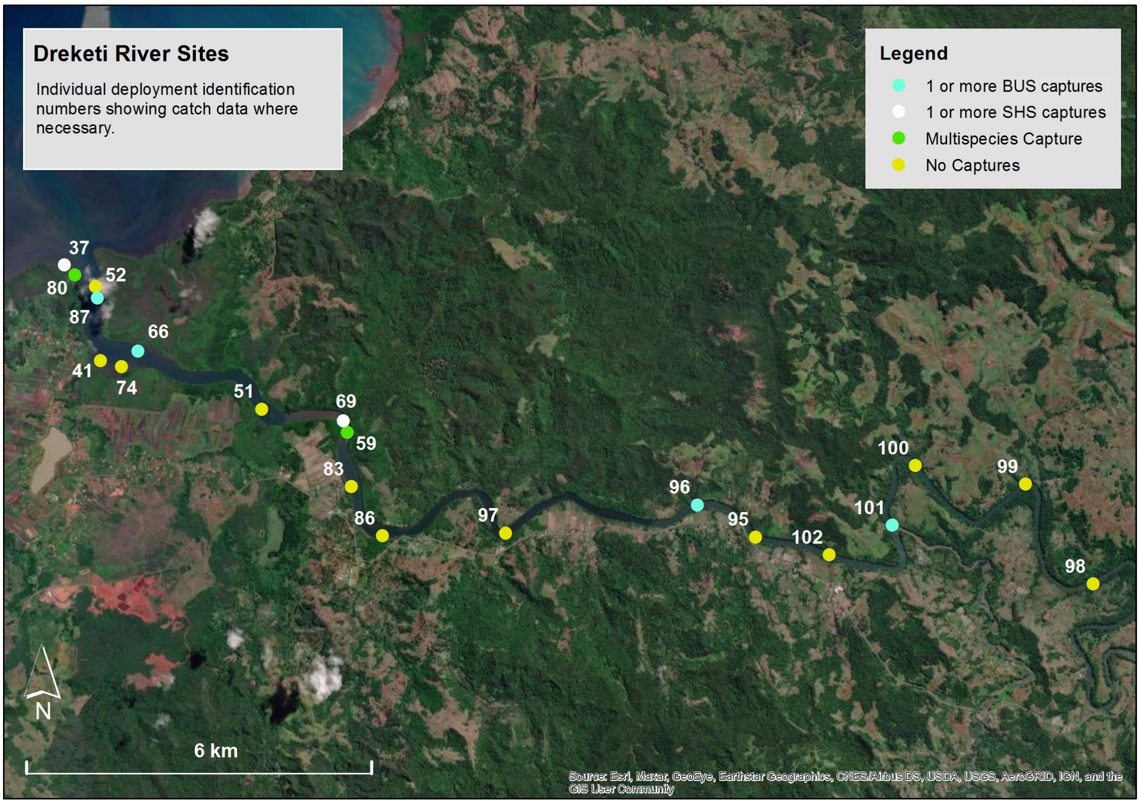
Elasmobranch captures spanned the length and breadth of the Dreketi Estuary with captures also recorded up to 18km upriver. Spatial analysis indicates a degree of species segregation with scalloped hammerhead sharks found mainly in the shallower (less than 1.5m) waters to the west of the river mouth with the exception of 6 individuals caught 6km upstream and one individual recorded to the eastward margins of the estuary. All captures of the great hammerhead sharks were in deeper waters (1.5 to 3m) to the northeast of the river mouth. All bull shark captures were in the river while the blacktip sharks were found throughout the estuary. All 8 individual rays were documented to the west of the river mouth where the substrate is a fine silt.

A bottlenose wedgefish listed as Critically Endangered on the IUCN Red List is caught by the mangroves at the mouth of the Dreketi river

Net retrieval while the sun sets over the mouth of the Dreketi river. (L-R) Pictured Andrew Paris, Solomone Tuqara and Tomasi Bula.




**Map 1.** Map of the Dreketi Estuary showing geotagged deployments with deployment identification numbers also indicating sites with zero, single and multiple species captures. 'BTS' refers to blacktip shark, 'BWF' to bottlenose wedgefish, 'OER' to ocellated eagle ray and 'SHS' to scalloped hammerhead shark.




**Map 2.** Map of the Dreketi River showing geotagged deployments with deployment identification numbers also indicating sites with zero, single and multiple species captures. 'BUS' refers to bull shark and 'SHS' to scalloped hammerhead shark.

## 3.4 PHYSICAL WATER PARAMETERS

The physical water parameters were disaggregated to the estuary and the river due to high differential for certain parameters between the two areas. In the estuary, the sea surface temperatures ranged from 28.80 to 31.60°C, salinity values ranged from 13.30 to 31.70 parts per thousand and levels of dissolved oxygen were between 3.80 to 6.20mg per liter. The depth ranged from between 1.00 to 3.50m. In the river, the water temperatures ranged from between 27.40 and 31.50°C, the levels of dissolved oxygen ranged from 4.80 to 7.70mg per liter, the salinity ranged from 0.00 to 30.60 parts per thousand and the water depth ranged from 1.50 to 4.50m. A comparison of the averages showed a slightly increased water temp in the estuary compared to the river; 29.93 and 29.51°C respectively. The average salinity readings were elevated for the estuary (26.92 parts per thousand) compared to the average salinity readings in the river (18.44 parts per thousand). The average levels of dissolved oxygen were lower for the estuary at 5.57mg per liter compared with 6.14mg per liter for the river sites. The sampled sites in the river were on average deeper than the sites in the estuary at 2.40m and 2.05m respectively.

| | Estuary | | | | River | | | |
|---|---|---|---|---|---|---|---|---|
| | Depth | Salinity | DO | Temp | Depth | Salinity | DO | Temp |
| average | 2.05 | 26.92 | 5.57 | 29.93 | 2.40 | 18.44 | 6.14 | 29.51 |
| max | 3.50 | 31.70 | 6.20 | 31.60 | 4.50 | 30.60 | 7.70 | 31.50 |
| min | 1.00 | 13.30 | 3.80 | 28.80 | 1.50 | 0.00 | 4.80 | 27.40 |

**Table 3.** Depth (m), dissolved oxygen (mg/l), salinity (parts per thousand) and temperature (°C) water conditions for all deployments in the estuary and the river.


The eastern edge of the Dreketi estuary by the village of Navidamu.

# 4. DISCUSSION

## 4.1 ELASMOBRANCHS OF THE DREKETI ESTUARY AND RIVER

The study evaluated the catch composition of a fishery-independent survey of elasmobranch species in the Dreketi River and Estuary and confirmed the presence of 7 species of elasmobranchs; the scalloped hammerhead shark (*Sphyrna lewini*; N = 47), blacktip shark (*Carcharhinus limbatus*; N = 14), great hammerhead shark (*Sphyrna mokarran*; N = 8), bull shark (*Carcharhinus leucas,* N = 8) and 3 ray species: ocellated eagle ray (*Aetobatus ocellatus*; N = 6), pink whipray (*Pateobatus fai*; N = 1) and bottlenose wedgefish (*Rhynchobatus australiae*, N = 1). The results validate the findings by Rasalato et al. (2010) who drew upon local knowledge to report the presence of a species of hammerhead and what was most likely bull sharks in the Dreketi River and Estuary. The corresponding total pooled CPUE was 1.13 captures per hour and is noted to be higher than the Ba Estuary for the corresponding months (Paris et al., 2019). A closer examination of CPUE data showed a higher rate of shark and ray captures in the Dreketi River for the month of February.


Juvenile pink whipray is caught, processed and released by the mouth of the Dreketi river.

## 4.2 THE DREKETI RIVER AND ESTUARY PUPPING AREA

The population structure was found to be dominated by neonates and young of the year as these were caught throughout the study period. The categorization of neonates and young of the year was done on the basis of total length as well as the status of the umbilical scars. The metric for determining relative age from umbilical scar condition was based on a previous study by Duncan and Holland (2006) which showed that a period of 5 days is required for open umbilical scars to advance to semi-healed and a further 14 days to develop to a healed condition. An assessment of biological catch data (Table 1) showed a high proportion of recently born sharks (open and semi-healed umbilical scar condition) which is indicative of parturition along with neonate and young of the year residency (healed and absent umbilical scar condition) in the estuary and river. Size ranges for the scalloped hammerhead shark, the great hammerhead shark, the blacktip shark and the bull shark were in accordance with size ranges of neonate and young of the year from earlier studies in Fiji by Brown et al. (2016), Marie et al. (2017), Veirus et al. (2018) and Glaus et al. (2019). The majority of scalloped hammerhead sharks (70%) exhibited a healed umbilical scar condition which is indicative of residency in the area after birth. A similar trend was observed for both the blacktip and great hammerhead shark. Interestingly, 75% of bull sharks exhibited an open umbilical scar condition which is very likely indicative of birth in the area.

## 4.3 THE DISTRIBUTION OF SPECIES IN THE DREKETI RIVER AND ESTUARY

Spatial data (Map 1 & Map 2) is indicative of captures throughout the estuary and up to 18km upriver. The data also indicates species segregation to some degree which could be attributed to either habitat selection (Yates et al, 2015) for biotic factors such as competition for space and resources (White et al, 2004) or abiotic factors such as ideal water conditions. The smaller sized scalloped hammerhead sharks were found to cluster in the shallower waters just to the west of the Dreketi River mouth (see Map 1) which is likely to be attributed to a preference for high water temperature, moderate salinity and high turbidity (Yates et al., 2015). Studies on populations of juvenile scalloped hammerheads in Hawaii documented the use of core areas within a coastal embayment with daily long distance excursions of up to 5km (Duncan and Holland, 2006). This could be the case in Dreketi with the defined cluster to the west of the river mouth comparable to the core areas documented by Duncan and Holland. Daily excursions out of the core area would likely be the reason that 6 individuals were recorded approximately 6km upriver. The blacktip shark was documented to have a pan-estuarine distribution with a high tolerance for a range of water parameters, this has been previously noted in studies of the species in the Caribbean (Legare et al., 2018). Previous findings by Heupel et al. (2004) on populations in the Gulf of Mexico has asserted that juvenile blacktip shark populations expand home range sizes as individuals transition from neonate to young of the year. The majority of blacktip individuals were young of the year and therefore we could expect a relatively large home range. The bull shark is a euryhaline species able to tolerate extreme salinity fluxes (Glaus et al., 2019) and therefore has adapted to residency in the Dreketi River, up to 18 kilometers. Neonate and young of the year have been recorded to tolerate lower levels of salinity compared with adults and sub adults (Heithaus et al., 2009), this observation is in line with the recording of only neonates and young of the year in the Dreketi River. Great hammerhead sharks have been documented to give birth offshore and then migrate into coastal areas shortly thereafter (Harry et al., 2011). The documentation of young of the year great hammerhead sharks suggests that parturition is likely to occur offshore before migration into the fringes of the estuary where 80% of the captures occurred. A small sample size for the remaining estuarine elasmobranchs meant a low degree of confidence for inferences on spatial distribution in the area although all species of ray were found in the fine silt substrate to the west of the river mouth in close proximity of mangrove stands.

The presence of an extensive mangrove system at the estuary and lower reaches of the Dreketi River provides an ideal habitat for elasmobranchs. Mangrove forests are areas of high ecological utility and are characterized by having high primary and secondary productivity, as well as the presence of a large number of microhabitats, which play a major role in the life stages of many tropical elasmobranchs (Beck et al., 2001). Coastal areas dominated by mangrove stands have been shown to serve as nursery grounds for a large number sharks providing a rich source of food and protection against predation (e.g., Robertson & Duke, 1987; Simpfendorfer & Milward, 1993; Ashton et al., 2003; Knip et al., 2010). The seagrass beds which underlie large swathes of the Dreketi Estuary also serve as an ideal habitat for a variety of marine invertebrates and bony fishes. A study by Brown (2016) on the preferred prey items of scalloped hammerhead sharks found the most numerous prey items to be Decapods (prawn and shrimp).

# 5. CONCLUSION

This study is the first fisheries independent survey on elasmobranch occurrence on the island of Vanua Levu. The survey of the Dreketi Estuary and River was conducted over a period of 20 days and yielded a total catch of 85 elasmobranchs. Of the shark and ray species that have been documented in the study area, 3 species are listed on the IUCN Red List of Threatened Species as Critically Endangered namely the scalloped hammerhead shark *S. lewini*, the great hammerhead shark *S. mokarran* and bottlenose wedgefish *R. austaliae*. The bull shark *C. leucas* and blacktip shark *C. limbatus* are listed as Near Threatened. The pink whipray *P. fai* and ocellated eagle ray *A. ocellatus* are listed as Vulnerable.

The total elasmobranch CPUE calculated for the Dreketi River and Estuary was 1.13 captures per hour. The high proportion of sharks with either a healed or semi-healed umbilical scar indicates parturition and early life residency in the Dreketi Estuary and River. The documentation of 85 individuals of shark and ray species across 20 sampling days from January to February 2020 indicates the area could provide an important habitat for elasmobranchs. Based on the initial data collected for this report, the Dreketi Estuary and River does serve as an important habitat for several elasmobranch species including at least two critically endangered species. Further to this, based on anecdotal information the area is known to have a higher concentration of sharks compared to surrounding coastal areas and the presence of juvenile sharks has been an annual occurrence for many years. The four species of shark identified in the study area are known to exhibit philopatry behavior; the bull shark (Tillett et al., 2012), the blacktip shark (Keeney et al., 2005), the scalloped hammerhead (Chapman et al., 2009) and the great hammerhead (Guttridge et al., 2017). A geospatial affinity to certain areas can allow such species increased access to food and protection and it seems that the Dreketi Estuary and River is continually selected as a pupping area by adult sharks. The identification of such areas can be particularly vital for migratory species such as the scalloped hammerhead shark, the great hammerhead shark and the bull shark which are intrinsically difficult to manage and may warrant marine protected area status

There is a plethora of threats that the Dreketi River and Estuary faces and these pressures are expected to increase in intensity and duration. Pollution and destructive fishing practices such as overnight gill-netting are two of the main threats identified. Coupled with bad land use management and extractive industries in the Dreketi catchment increases sediment load and run-off which will drastically alter the health of the lower reaches of the river. Any impact on the physical condition of the river and estuary will inadvertently lessen the carrying capacity and decrease the diversity and abundance of species which are suited to conditions here.

More research on the abundance, diversity, fine-scale distribution and population structure is required to clearly understand the utilization of the Dreketi River and Estuary by elasmobranchs for parturition, and post-natal residency. Although low fishing pressures were observed by the author, it is highly recommended that temporal closures during peak parturition periods be considered to protect the elasmobranch species listed. Effective management of elasmobranch species in Fiji needs to be on the basis of sound scientific discourse. An improved knowledge of species-habitat and species-species interactions can inform decisions such as temporal closures and no-take tabu areas.

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# 6. REFERENCES


Ashton, E. C., Macintosh, D. J., & Hogarth P. J. (2003) A baseline study of the diversity and community ecology of crab and molluscan macrofauna in the Sematan mangrove forest, Sarawak, Malaysia. Journal of Tropical Ecology 19 (02):127-142.

Atherton, J., Olsen, D., Farley, L., Qauqau, I. (2005). Fiji Watersheds at Risk Watershed Assessment for Healthy Reefs and Fisheries. Wildlife Conservation Society–South Pacific.

Beck, M. W., Heck, K. L., Able, K. W., Childers, D. L., Eggleston, D, B., Gillanders, B. D., Halpern, B., Hays, C. J., Hoshino, K., Minello, T. J., Orth, R. J., Sheridan, P. F., & Weinstein, M. P. (2001) The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. BioScience 51(8):633-641.

Bornatowski, H., Navia, A.F., Braga, R.R., Abilhoa, V., and Corrêa, M.F.M. (2014). Ecological importance of sharks and rays in a structural foodweb analysis in southern Brazil. ICES Journal of Marine Science 71, 1586–1592.

Brown, K.T., Seeto, J., Lal, M.M., and 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, 242–248.

Chapman, D.D., Pinhal, D., Shivji, M.S., 2009. Tracking the fin trade: genetic stock identification in western Atlantic scalloped hammerhead sharks Sphyrna lewini. Endangered Species Research. 9 (3), 221–228.

Chapman, D.D., Feldheim, K.A., Papastamatiou, Y.P., and Hueter, R.E. (2015). There and Back Again: A Review of Residency and Return Migrations in Sharks, with Implications for Population Structure and Management. Annual Review of Marine Science 7, 547–570.

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., et al. (2014). Extinction risk and conservation of the world's sharks and rays. ELife 3, e00590.

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

Duncan, K.M., and 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.

Ferretti, F., Worm, B., Britten, G.L., Heithaus, M.R., and Lotze, H.K. (2010). Patterns and ecosystem consequences of shark declines in the ocean. Ecology Letters 13, 1055–1071.

Froeschke, J., Stunz, G.W., and Wildhaber, M.L. (2010). Environmental influences on the occurrence of coastal sharks in estuarine waters. Marine Ecology Progress Series 407, 279–292.

Gallagher, A.J., and Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism 14, 797–812.

Glaus, K.B.J., Adrian-Kalchhauser, I., Burkhardt-Holm, P., White, W.T., and Brunnschweiler, J.M. (2015). Characteristics of the shark fisheries of Fiji. Scientific Reports 5, 17556.

Glaus, K.B.J., Brunnschweiler, J.M., Piovano, S., Mescam, G., Genter, F., Fluekiger, P., and Rico, C. (2019b). Essential waters: Young bull sharks in Fiji's largest riverine system. Ecology and Evolution 9, 7574–7585.

Guttridge, T. L., Van Zinnicq Bergmann, M.P.M., Bolte, C., Howey, L.A., Finger, J.S., Kessel, S.T., Brooks, J.L., Winram, W., Bond, M.E., Jordan, L.K.B., Cashman, R.C., Tolentino, E.R., Grubbs, R,D., Gruber, S.H. (2017). Philopatry and Regional Connectivity of the Great Hammerhead Shark, Sphyrna mokarran in the U.S. and Bahamas. Frontiers in Marine Science 4(3).

Harry, A. V., Macbeth, W. G., Gutteridge, A. N. & Simpfendorfer, C. A. (2011). The life histories of endangered hammerhead sharks (Carcharhiniformes, Sphyrnidae) from the east coast of Australia. Journal of Fish Biology 78, 2026–2051.

Heithaus, M.R., Frid, A., Wirsing, A.J., and Worm, B. (2008). Predicting ecological consequences of marine top predator declines. Trends Ecology Evolution (Amst.) 23, 202–210.

Heithaus, M.R., Delius, B.K., Wirsing, A.J. and Dunphy□ Daly, M.M. (2009). Physical factors influencing the distribution of a top predator in a subtropical oligotrophic estuary. Limnology and Oceanography, 54(2), 472–482

Heupel, M.R., Simpfendorfer, C.A. and Hueter, R. (2004). Estimation of Shark Home Ranges using Passive Monitoring Techniques. Environmental Biology of Fishes. 71. 135-142

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

Heupel, M.R., and Simpfendorfer, C.A. (2011). Estuarine nursery areas provide a low-mortality environment for young bull sharks Carcharhinus leucas. Marine Ecology Progress Series 433, 237–244.

Hueter, R., Heupel, M., Heist, E., and Keeney, D. (2005). Evidence of philopatry in sharks and implications for the management of shark fisheries. Journal of Northwest Atlantic Fishery Science 35, 239–247.

Keeney, D.B., Heupel, M.R., Hueter, R.E., Heist, E.J., (2005) Microsatellite and mitochondrial DNA analyses of the genetic structure of blacktip shark (Carcharhinus limbatus) nurseries in the northwestern Atlantic, Gulf of Mexico, and Caribbean

Sea. Molecular Ecology 14, 1911–1923

Knip, D., Heupel, M., & Simpfendorfer, C. (2010) Sharks in nearshore environments: models, importance, and consequences. Marine Ecology Progress Series 402:1-11.

Legare, B., Skomal, G. & DeAngelis, B. Diel movements of the blacktip shark (Carcharhinus limbatus) in a Caribbean nursery. (2018) Environ Biol Fish 101, 1011–1023. https://doi.org/10.1007/s10641-018-0755-x

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H., and Jackson, J.B.C. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312, 1806–1809.

Marie, A.D., Miller, C., Cawich, C., Piovano, S., and Rico, C. (2017). Fisheries-independent surveys identify critical habitats for young scalloped hammerhead sharks ( Sphyrna lewini ) in the Rewa Delta, Fiji. Scientific Reports 7, 1–12.

Paris, A., Vierus, T., Gehrig, S. (2019). Vanua o Votua Shark and Ray Survey Report: Activity 1.1.1.2. Fiji Ridge to Reef Project. University of the South Pacific Institute of Applied Science. Suva, Fiji.

Rasalato, E., Maginnity, V. & Brunnschweiler, J. M. (2010). Using local ecological knowledge to identify shark river habitats in Fiji (South Pacific). Environmental Conservation, 37, 90–97.

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

Simpfendorfer, C.A., and Dulvy, N.K. (2017). Bright spots of sustainable shark fishing. Current Biology 27, R97–R98.

Tillett, B.J., Meekan, M.G., Field, I.C., Thorburn, D.C., and Ovenden, J.R. (2012). Evidence for reproductive philopatry in the bull shark Carcharhinus leucas. Journal of Fish Biology 80, 2140–2158.

Vierus, T., Gehrig, S., Brunnschweiler, J.M., Glaus, K., Zimmer, M., Marie, A.D., and Rico, C. (2018). Discovery of a multispecies shark aggregation and parturition area in the Ba Estuary, Fiji Islands. Ecology Evolution 8, 7079–7093.

White, W., T., Platell, M.E. & Potter, I.C. (2004). Comparisons between the diets of four abundant species of elasmobranchs in a subtropical embayment: Implications for resource partitioning. Marine Biology, 144, 439–448.

Yates, P. M., Heupel, M. R., Tobin, A. J. & Simpfendorfer, C. A. (2015). Ecological drivers of shark distributions along a tropical coastline. PLoS One, 10, 1–18.

# 7. APPENDIX

**Table 4.** Overview of elasmobranch species in the Dreketi Estuary and River with national and international obligations.

| Scientific Name | Endangered and Protected Species Act 2002 | Endangered and Protected Species (Amendment) Act 2017 | Offshore Fisheries Management Regulation 2014 | CITES | Convention on Migratory Species of Wild Animals | IUCN Red List |
|---|---|---|---|---|---|---|
| *Sphyrna lewini* | × | ✓ | II | II | II | Critically Endangered |
| *Carcharhinus limbatus* | × | × | × | × | × | Near Threatened |
| *Sphyrna mokarran* | × | ✓ | II | II | II | Critically Endangered |
| *Aetobatus ocellatus* | × | × | × | × | × | Vulnerable |
| *Carcharhinus leucas* | × | ✓ | × | × | × | Near Threatened |
| *Pateobatus fai* | × | × | × | × | × | Vulnerable |
| *Rhynchobatus australiae* | × | × | II | II | II | Critically Endangered |

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