Research prioritisation to manage sharks and rays in South African Fisheries

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The National Plan of Action for Sharks South Africa II was finalised in 2022 and serves as a pivotal strategy for addressing the conservation concerns of the ~100 species of chondrichthyans caught as by-catch and target in South African fisheries. Globally chondrichthyes are experiencing severe population declines attributable to a combination of conservative life-history traits, unmonitored fishing practices, poor data collection, and insufficient management. Despite their ecological significance and contributions to economies through fisheries, trade, and tourism, existing management interventions often fall short in ensuring their sustainability. The NPOA-Sharks South Africa II, aligned with the FAO Code of Conduct for Responsible Fisheries, outlines a framework to improve conservation and management efforts in South Africa. Implicit in the NPOA Sharks South Africa II is a list of actions, timeframes, and responsibilities to be completed by the end of the 5-year plan. This prioritization exercise represents an action as required by the NPOA Sharks II, to determine which chondrichthyans in South Africa warrant urgent research. By prioritizing species for research, the plan aims to gather crucial information on the risks associated with shark exploitation and guide effective management within fisheries. The prioritization is done separately for three marine ecosystems roughly separating three fishery systems, namely coastal, demersal, and pelagic. The prioritization emphasises research gaps, while acknowledging challenges in data collection, identification, and observer coverage. Recommendations include resolving species composition issues, updating catch lists, immediate sample collection, and fostering international collaboration for pelagic species. The NPOA-Sharks underscores the complexity of managing chondrichthyan species affected by fisheries and highlights the importance of bridging the gap between scientific research, policy implementation, and international cooperation to secure their future.

1. *Introduction*

Sharks and their cartilaginous relatives are among the most endangered species worldwide (Dulvy *et al.* 2014). This is primarily due to their conservative life-history traits, coupled with unknown catches and unmonitored fishing practices. As a result, many shark populations have experienced rapid declines, with a quarter of shark species now facing extinction (Dulvy *et al.* 2014). Despite their significance in terms of ecosystem function (Stevens *et al.* 2000; Ferretti *et al.*2010; Dulvy *et al.* 2017). and their contribution to national economies through fisheries, trade, and tourism (O'Malley *et al*. 2013; Leeney *et al.* 2018), their importance is seldom reflected in management interventions that would ensure their long-term survival (Lack and Sant, 2011). Exacerbating this situation is that many species are categorised as by-catch or joint-product and simply lumped into generic categories like "shark" and "ray", resulting in poor quality data that cannot easily used in population assessments (DFFE, 2021, da Silva et al. 2015). As data from fisheries are disaggregated, of variable quality and not readily available in form of species- specific time series, little is known about their

threat status. Moreover, the incidental nature of the capture of some of these species make dedicated studies on their life history challenging. This dearth of information further complicates efforts to draft legislation aimed at protecting them. Given the diversity and ecological importance of chondrichthyan species and the challenges they face, research into their life histories and ecological requirements is critical for their conservation.

The southern African chondrichthyan fauna includes representatives from all 13 orders of cartilaginous fishes with 50 families and 105 genera, representing 20% of all known chondrichthyans. There are 111 shark, 72 batoid and 8 chimaera species, of which 13% are endemic to the region. Just over half of the 191 chondrichthyan species that occur in southern Africa are impacted by fisheries, ranging from recreational angling to industrialised fishing such as trawling and pelagic longline fishing (Ebert *et al.* 2021). Of the 103 species of chondrichthyans that are impacted by South African fisheries, catches in excess of 11 t are reported for only 22 species (DEFF, 2020).

South Africa is a signatory of the FAO Code of Conduct for Responsible Fisheries. Under its framework an International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) was developed in 1998, which encourages maritime states to develop a Shark Assessment Report (SAR) and adopt a National Plan of Action for Sharks (NPOA-Sharks, 2013).The first South African National Plan of Action for sharks (NPOA-Sharks) was finalised in 2013 and provided baseline information on the status of chondrichthyans in South Africa and assessed research, management, monitoring, and enforcement frameworks associated with shark fishing and trade of shark product in the South African context. The NPOA-Sharks went through an internal review and a comprehensive external review by an international panel of experts appointed by the Minister in 2020. The panel recognised South Africa's achievements, in the discipline of scientific assessments, but also identified areas where improvements are still needed. Emanating from this review, after an extensive stakeholder consultation phase, the revised NPOA (NPOA-Sharks II, 2022) builds on the achievements and lessons learned from NPOA-Sharks I, and closely follows the recommendations of the Shark Expert Panel. The NPOA-Sharks II details 41 actions that need to be completed within the 5-year life-span of the plan and essentially is a roadmap towards improved shark fisheries in South Africa. Within the action plan speaking towards research goals, the first task is to prioritise sharks, rays and chimaeras that occur in the catch of South African fisheries for scientific research. Priority is determined by the extent of anthropogenic pressure through fishing, knowledge of species' life history parameters and abundance trends in relation to the these.

2. *Methods*

The list of Chondrichthyes impacted by South African Fisheries, both as intentional target or unintended bycatch or by-product was obtained and modified from da Silva *et al.* (2015) and DFFE (2020). Information on the most recent IUCN Red List assessment status was collated and appended to this list. Additionally, we gathered crucial life-history information from Cliff and Olbers (2022) needed for conducting basic assessments and making scientific recommendations for the management of specific areas. This information encompassed maximum length, size at maturity, reproductive output, generation length, age-at-length, length at birth, and data on nursery grounds. Recognising the broad difference in abundance, fishery systems, capture rates and logistics in obtaining samples, we categorized the species into three groups: coastal, demersal, and pelagic.

Based on the available information a scoring system was developed to rapidly differentiate the 103 species in terms of selected criteria, in the following manner: Six criteria (i) abundance trend;(ii) level

of knowledge; (iii) endemicity; (iv) relative exploitation and (v) ease of identification and (vi) availability of assessments were used to derive an overall prioritization score. Each of the criteria was individually scored such that the final score fell between zero and 100. Individual scoring schemes are detailed below:

(i) Abundance trend

Abundance trend was scored according to the latest regional IUCN status of the species under consideration. The most recent set of IUCN assessments included abundance data from South Africa, allowing for consistent scoring across species with different quality of abundance trend information. IUCN status score was interpreted broadly aligning with the A1 criteria for listing, the IUCN Red list criteria were scored as follows: Critically Endangered species (90), Endangered species (70), Vulnerable (50), Near Threatened (20) and Least Concern (5). As a precautionary measure, with species grouped under genus; the most severe IUCN rating was chosen to represent the status of the group.

(ii) Level of knowledge

We used the information recently compiled *Sharks, rays and chimaera status report for South Africa* (Cliff and Olbers 2022) for scoring the knowledge of each species. For species not included in the report, additional literature reviews were completed (Table 1). Life-history criteria included: maximum length, size at maturity, reproductive output, generation length, age at length, length at birth and information on nursery grounds. Each was scored for existing literature in category: Yes (0) and no (1). The review was not quantitative and any reference to known literature was used. To determine each score, the number of known factors was summed and normalised such that a maximum score equalled 100.

(iii) Endemicity

Species endemic to southern Africa received a score of 100, non-endemic cosmopolitan ones scoring 0. Endemism was extended to the southern African region due to the relative lack of information and formal protection for chondrichthyans in the region. South Africa remains one of few places in Africa where Chondrichthyes are afforded a degree of protection from fisheries.

(iv) Relative exploitation

Estimated catches (t) of chondrichthyans caught by South African fisheries, detailed in Appendix 2 of the NPOA- Sharks II, originally described in da Silva *et al.* 2015, were used to infer relative exploitation. Catch scores were allocated as follows: Catches < 1 t were allotted a score of 5, catches >10 t a score of 20, catches >100 t a score of 50, catches > 200 t a score of 75, whilst catches of more than 400 t achieved a score of 100.

(v) Ease of identification

The ability to identify sharks to the species level can vary significantly among different types of fisheries, and this can be influenced by several factors, including education, time constraints, and available resources. This was considered for each species depending on the major fishery or combination of fisheries contributing >75% of the mortality for the species (NPOA Sharks II). The following scores applied; no certainty in identification 100, certainty to family 75, certainty to genus 50, and certainty to species 10.

(iv) Availability of assessments.

To ensure that assessments were included in overall scoring, the following penalties applied; no assessments: 100, risk assessments: 50 and comprehensive stock assessments: 10.

Scores were combined, and an overall rank was calculated for each species.

3. *Results*

The results of the aggregation of rank and scores for coastal species are shown in Table 1. These ranged between 60 and 16.6 with the top five ranked species bluntnose guitarfish *Acroteriobatus blochii* (LC, 2019, endemic), diamond ray *Gymnura natalensis* (LC,2019, regionally endemic), dusky shark *Carcharhinus obscurus* (EN, 2018), blacktip shark *Carcharhinus limbatus* (VU,2021), soupfin shark *Galeorhinus galeus* (CR, 2020).

The results of the aggregations for demersal species are shown in Table 2. Scores from Chondrichthyes accessible from demersal surveys ranged between 73.6 to 27.1 with the top five ranked species: twineye skate *Raja ocellifera* (EN, 2020, endemic), munchkin skate *Rajella caudaspinosa* (LC, 2019, regionally endemic), blackspotted torpedo ray *Torpedo fuscomaculata* (DD, 2019, regionally endemic), smith's spurdog *Squalus margaretsmithae* (DD, 2019, regionally endemic) and yellowspotted skate *Leucoraja wallacei* (VU, 2019, regionally endemic).

The results of the aggregations for pelagic species are shown in Table 3. Scores from pelagic Chondrichthyes ranged between 56.67 to 77.62 with the top five priority species: scalloped hammerhead *Sphyrna lewini* (CR, 2018), great hammerhead *Sphyrna mokarran* (CR, 2018), pelagic thresher *Alopias pelagicus* (EN, 2018), longfin mako *Isurus paucus* (EN, 2019) and blue shark shortfin mako *Isurus oxyrinchus* (EN, 2018).

Discussion

The work presented here is the first comprehensive research prioritisation of South African Chondrichthyes impacted by fisheries. This exercise was identified as one of the actionable tasks within the NPOA-sharks II and necessitated by the vast diversity of sharks caught by fisheries around South Africa. The particular methodology was geared towards conservation and management of fished species in the South African context and hence doesn't include other anthropogenic impacts such as habitat loss, susceptibility to pollution and climate change. The final aim of this exercise was to structure efforts to gather information towards a better understanding of the risk associated with shark exploitation, to ultimately improve their management within the fisheries that exploit them.

Overall, the top five demersal species scored and ranked higher, surpassing coastal and pelagic Chondrichthyes of importance, owing to their high degree of endemism, lack of dedicated sampling effort and high degree of exploitation. It is worth noting that Chondrichthyes grouped into genus or orders have not been assigned specific ranks, such as the ~600 ton of rays reported by the trawl fisheries per annum. Nevertheless, it is crucial to prioritise research efforts aimed at determining the species composition of these groups. Once species composition is clarified, these findings should be incorporated into species lists and considered in mid-term research initiatives and future prioritisation exercises.

To address these concerns, it is imperative to develop methods to enable fishers to identify Chondrichthyes to the level of order and genus in the field or onboard fishing vessels and to increase coverage and improve design of current observer programmes. This will enable the inclusion of these species and others not currently on the list in the existing species list and enhance future prioritisation exercises and research endeavours.

Coastal species

In terms of research prioritization for coastal species, specific attention should be given to the following: namely the bluntnose guitarfish, diamond ray, dusky shark, blacktip shark and soupfin shark. The bluntnose guitarfish and diamond ray are relatively unstudied, occur close inshore where they are accessible to multiple fisheries. Dusky and blacktip sharks overlap with multiple fisheries, while dusky sharks have been taken off the permitted list for multiple fisheries; identification issues remain. Both species have recently been CITES Appendix II listed in 2022. Soupfin sharks remain one of the most threatened sharks in South Africa, given almost a century of concentrated fishing on this species. Of importance is the fact that samples of these species can be collected with small boats or from the shore. The establishment of research collaborations among South African research institutes and potentially collaboration with recreational and even small-scale fisheries might to facilitate collection efforts around the coast.

Demersal species

The collection of data and species-specific samples from demersal Chondrichthyes poses significant challenges. Fisheries data is seldom disaggregated to species level or to catch area, as many the majority of species are considered incidental bycatch, and observer programmes are industry driven and have insufficient coverage and stratification across vessels and areas... To overcome these challenges and gather valuable biological samples, a multi-faceted approach is necessary. Collection of samples from both the National Demersal Surveys (DFFE) and observers on industry vessels for prioritised species needs to be coordinated and significantly increased.

Pelagic species

International collaboration plays a pivotal role in advancing research on pelagic sharks. This importance stems from the inherent transboundary nature of pelagic shark populations, their extensive migratory patterns, and the global threats they encounter. By working together on an international scale, the conservation and management needs of these species could be effectively addressed. The significance of international collaboration is underscored by the harmonization of research methods and data standards. This ensures comparability and accuracy across studies, facilitating the pooling of resources and efforts across the distribution range of these oceanic species. Active participation in scientific working groups at the Regional Fisheries Management Organization (RFMO) level is essential for effective international collaboration. Through engagement with RFMO scientific working groups, researchers can contribute their expertise, exchange knowledge, and collaborate on sample collection and analysis for regional and global species. This engagement fosters cooperation, facilitates data sharing, and enables the development of evidence-based conservation measures for pelagic Chondrichthyes.

The state of knowledge for prioritised Chondrichthyes are shown in Table 4. Information on the life-history for these species is often insufficient, this is especially pertinent for those species overlapping in distribution with offshore trawl fisheries where they are incidentally caught in large

quantities (mostly unmonitored and seldom identified to species level). Pelagic species are overall well-studied with most of the required life-history categories known. However, little research is focus on the South African stocks, which are important components of the Southern Hemisphere populations of these species.

Conclusion and Recommendations:

As stated by the NPOA Sharks II, Chondrichthyes highlighted in this study should be prioritised for research, conservation, and management. Research at both a National and Departmental level should be directed towards these listed species. The following recommendations should be put forward:

1) ***Species composition of Chondrichthyes lumped into genera or orders needs to be resolved.***
2) ***Species catch lists need to be updated where names have changed.***
3) ***Immediate collection of biological samples and abundance data for the top 3 coastal and demersal Chondrichthyes as available.***
4) ***Continued data collection on movement, genetics, stock structure of pelagic Chondrichthyes.***

Table 1: The prioritised coastal Chondrichthyes, showing ranks and scores. Colour reflects IUCN status no colour = Data Deficient/ Least Concern, pink = Near Threatened, yellow = Vulnerable, orange= Endangered, red = Critically Endangered

Scientific name	Common name	Rank	Score
Acroteriobatus blochii	Bluntnose guitarfish	*1*	60.0
Gymnura natalensis	Diamond ray	*2*	56.6
Carcharhinus obscurus	Dusky shark	*3*	40.0
Carcharhinus limbatus	Blacktip shark	*4*	39.1
Galeorhinus galeus	Soupfin shark/tope	*5*	38.2
Carcharhinus plumbeus	Sandbar shark	*6*	37.5
Carcharhinus brevipinna	Spinner shark	*7*	36.7
Carcharhinus leucas	Zambezi shark, bull shark	*8*	36.7
Bathytoshia brevicaudata	Shorttailed stingray	*9*	36.7
Sphyrna zygaena	Smooth hammerhead shark	*10*	36.7
Carcharhinus amboinensis	Java shark	*11*	36.6
Mustelus mosis	Hardnose smoothhound/houndshark	*12*	36.4
Carcharhinus melanopterus	Blacktip reef shark	*13*	34.2
Carcharhinus brachyurus	bronze whaler shark	*14*	33.3
Acroteriobatus annulatus	Lesser guitarfish	*15*	33.3
*Triakis megalopterus**	Spotted gully shark	*16*	33.2
Notorynchus cepedianus	Broadnose sevengill shark	*17*	32.4
Carcharias taurus	Spotted raggedtooth shark	*18*	28.3
Mustelus mustelus	Common smoothhound/houndshark	*19*	28.3
Galeocerdo cuvier	Tiger shark	*20*	25.0
Carcharodon carcharias	Great white shark	*21*	24.1
Dasyatis chrysonota	Blue stingray	*22*	16.6

Table 2: The prioritised demersal Chondrichthyes, showing ranks and scores. Colour reflects IUCN status no colour = Data Deficient/ Least Concern, pink = Near Threatened, yellow = Vulnerable, orange= Endangered, red = Critically Endangered

Scientific name	Common name	Rank	Score
Raja ocellifera	*Twineye skate*	1	73.6
Rajella caudaspinosa	*Munchkin skate*	2	73.5
Torpedo fuscomaculata	*Blackspotted electric ray*	3	71.0
Raja spp.	*Rays unidentified*		70.0
Squalus margaretsmithae	*Smith's spurdog*	4	66.1
Leucoraja wallacei	*Yellowspotted skate*	5	65.5
Centrophorus spp.	*Gulper sharks*		62.5
Chlamydoselachus africana	*Southern African frilled shark*	6	61.8
Holohalaelurus regani	*Izak catshark*	7	60.4
Scyliorhinus capensis	*Yellowspotted catshark*	8	60.2
Cruriraja spp.	*Legskates*	9	59.2
Deania spp.	*Dogfish*		59.2
Centroscymnus spp.	*Dogfish*		59.2
Holohalaelurus favus	*Honeycomb Izak catshark*	10	58.3
Narke capensis	*Onefin/Cape Sleeper Ray*	11	57.1
Dipturus springeri	*Roughbelly skate*	12	56.8
Rajella leoparda	*Leopard Skate*	13	56.8
Dipturus pullopunctatus	*Slime Skate*	14	55.6
Raja straeleni	*Biscuit Skate*	15	55.1
Halaelurus lineatus	*Lined catshark*	16	54.6
Bathyraja smithii	*Softnose skate*	17	54.4
Torpedo sinuspersici	*Marbled Electric Ray*	18	54.3
Etmopterus spp.	*Lanternsharks*		54.2
Squalus bassi	*African longnose spurdog*	19	53.0
Haploblepharus edwardsii	*Puffadder shyshark*	20	52.5
Hydrolagus or *Chimaera* spp.	*Chimaera*		51.7
Rhinochimaera spp.	*Longnose chimaera*		51.7
Apristurus spp.	*Catshark*		51.7
Haploblepharus fuscus	*Brown shyshark*	21	51.4
Heteronarce garmani	*Natal Sleeper Ray*	22	50.6
Holohalaelurus punctatus	*Whitespotted Izak catshark*	23	50.0
Rostroraja alba	*Spearnose Skate*	24	49.8
Mustelus palumbes	*Whitespotted smoothhound shark*	25	49.6
Malacoraja spinacidermis	*Prickle skate*	26	49.4
Neoharriotta pinnata	*Sicklefin chimaera*	27	49.4
Halaelurus natalensis	*Tiger catshark*	28	49.1
Pliotrema warreni	*Sixgill sawshark*	29	48.1
Haploblepharus pictus	*Dark shyshark*	30	47.5
Rajella barnardi	*Bigthorn skate*	31	47.0
Tetronarce cf.nobiliana	*Great torpedo ray*	32	47.0
Rajella ravidula	*Smoothbackskate*	33	46.9
Harriotta raleighana	*Narrownose chimaera*	34	46.9
Aetomylaeus bovinus	*Duckbill eagle ray*	35	45.7
Squalus acanthias	*Spotted spiny dogfish*	36	44.9
Cirrhigaleus asper	*Roughskin spurdog/dogfish*	37	44.6
Callorhinchus capensis	*St Joseph*	38	44.2
Oxynotus centrina	*Angular roughshark*	39	44.1
Squatina africana	*African angelshark*	40	43.9

Acroteriobatus ocellatus	*Speckled guitarfish*	*41*	43.5
Rhinobatos holcorhynchus	*Slender guitarfish*	*42*	43.5
Dalatias licha	*Kitefin shark*	*43*	42.5
Taeniura lymma	*Bluespotted lagoon ray*	*44*	42.1
Himantura uarnak	*Coach whipray*	*45*	41.7
Aetobatus ocellatus	*Spotted eagle ray*	*46*	41.4
Squalus acutipinnis	*Bluntnose spurdog*	*47*	41.4
Heptranchias perlo	*Sharpnose sevengill shark*	*48*	40.5
Acroteriobatus leucospilus	*Greyspot guitarfish*	*49*	39.9
Echinorhinus brucus	*Bramble shark*	*50*	39.9
Rhizoprionodon acutus	*Milk shark*	*51*	38.3
Himantura leoparda	*Leopard whipray*	*52*	38.3
Myliobatis aquila	*Common eagle ray*	*53*	37.4
Centroscyllium fabricii	*Black dogfish*	*54*	37.4
Rhynchobatus djiddensis	*Whiespotted wedgefish*	*55*	34.2
Hexanchus griseus	*Bluntnose sixgill shark*	*56*	33.9
Cetorhinus maximus	*Basking shark*	*57*	33.3
Poroderma africanum	*Pyjama shark*	*58*	30.8
Poroderma pantherinum	*Leopard catshark*	*59*	30.7
Isistius brasiliensis	*Cookiecutter shark*	*60*	27.1

Table 3: The prioritised pelagic Chondrichthyes, showing ranks and scores. Colour reflects IUCN status no colour = Data Deficient/ Least Concern, pink = Near Threatened, yellow = Vulnerable, orange= Endangered, red = Critically Endangered

Scientific name		Rank	Score
Sphyrna lewini	*Scalloped hammerhead shark*	*1*	43.3
Sphyrna mokarran	*Great hammerhead shark*	*2*	40.8
Alopias pelagicus	*Pelagic thresher shark*	*3*	39.9
Isurus paucus	*Longfin mako shark*	*4*	39.9
Isurus oxyrinchus	*Shortfin mako shark*	*5*	38.3
Alopias vulpinus	*Common thresher shark/thresher shark*	*6*	36.7
Carcharhinus falciformis	*Silky shark*	*7*	36.7
Alopias superciliosus	*Bigeye thresher shark*	*8*	34.2
Carcharhinus longimanus	*Oceanic whitetip shark*	*9*	34.2
Lamna nasus	*Porbeagle shark*	*10*	34.2
Mobula spp.	*Mobulid rays*	*11*	30.8
Prionace glauca	*Blue shark*	*12*	30.0
Pteroplatytrygon violacea	*Pelagic stingray*	*13*	27.3
Pseudocarcharias kamoharai	*Crocodile shark*	*14*	22.4

Table 4: Chondrichthyes prioritised for research, indicating life-history characteristics required for assessments. Colour reflects IUCN status no colour = Data Deficient/ Least Concern, pink = Near Threatened, yellow = Vulnerable, orange= Endangered, red = Critically Endangered. Fishery/fisheries responsible for > 75% of the mortality are indicated; TF Inshore and offshore trawl fisheries, RecL recreational linefish, LF commercial linefish, RL rocklobster, BG beach and seine net fisheries, PT prawn trawl, KZNS bather protection nets run by the KwaZulu Natal Sharksboard, SP small pelagic fishery and PL pelagic longline. *Indicates that species is suspected to be caught by a particular fishery but not frequently reported.

Scientific name	Catch	Maximum size	Size at maturity	Reproductive output	Generation length	Age at length	Size at birth	Nursery	Fishery/ies responsible for > 75% mortality
Acroterioba tus blochii		1							BG*,RecL*
Gymnura natalensis		10	1	1	1	1	1		BG*,TF
Carcharhinu s obscurus		10	1	1	1	1	1	1	LF*, RecL*,DSL,B G*
Carcharhinu s limbatus		10	1	1	1	1	1		LF, RecL*, KZNS*
Galeorhinus galeus		200	1	1	1	1	1		TF,LF,DSL
Raja ocellifera		100	1				1		TF
Rajella caudaspinos a		100	1						TF
Torpedo fuscomacul ata		10	1						TF
Squalus margaretsm ithae		10	1				1		TF
Leucoraja wallacei			1						TF
Sphyrna lewini		10	1	1	1	1	1	1	RecL, KZNS, SP
Sphyrna mokarran		1	1	1	1	1	1	1	KZNS
Alopias pelagicus		1	1	1	1	1	1		PL, SP
Isurus paucus		1	1	1	1	1	1	0	PL
Isurus oxyrinchus		700	1	1	1	1	1	1	PL

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