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Overfishing and climate change elevate extinction risk of endemic sharks and rays in the southwest Indian Ocean hotspot and adjacent waters

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Abstract

The southwest Indian Ocean (SWIO) is a hotspot of endemic and evolutionarily distinct sharks and rays. We summarise the extinction risk of the sharks and rays endemic to coastal, shelf, and slope waters of the SWIO and adjacent waters (Namibia to Kenya, including SWIO islands). Thirteen of 70 species (19%) are threatened: one is Critically Endangered, five are Endangered, and seven are Vulnerable. A further seven (10%) are Near Threatened, 33 (47.1%) are Least Concern, and 17 (24.2%) are Data Deficient. While the primary threat is overfishing, there are the first signs that climate change is contributing to elevated extinction risk through habitat reduction and inshore distributional shifts. By backcasting their status, few species were threatened in 1980, but this changed soon after the emergence of targeted shark and ray fisheries. South Africa has the highest national conservation responsibility, followed by Mozambique and Madagascar. Yet, while fisheries management and enforcement have improved in South Africa over recent decades, drastic improvements are urgently needed elsewhere. To avoid extinction and ensure robust populations of the region's endemic sharks and rays and maintain ecosystem functionality, there is an urgent need for the strict protection of Critically Endangered and Endangered species and sustainable management of Vulnerable, Near Threatened, and Least Concern species, underpinned by species-level data collection and reduction of incidental catch.

Keywords: marine conservation, Convention on Biological Diversity, elasmobranch, IUCN Red List Index, biodiversity indicator, Sustainable Development Goals.

85

86 **Introduction**

87 Anthropogenic pressures are mounting in the global oceans, and extinction risk appears
88 to be increasing mainly through overfishing. Over 1,500 marine species that are
89 threatened globally; more than two-thirds of these are threatened due to overfishing, more
90 than double the risk caused by the next most-cited threat (residential and commercial
91 development)¹. The international community has formally agreed through the Convention
92 on Biological Diversity that extinctions need to be prevented. Although society failed to
93 meet the 2020 marine targets, namely Aichi Targets 6 (fisheries sustainability), 11
94 (avoiding extinction risk), and 14 (life under water), work is well underway to establish a
95 more effective post-2020 Global Framework for Biodiversity with goals for 2030 and
96 beyond. The IUCN Red List of Threatened Species provides a robust view of fisheries
97 sustainability and extinction risk, especially when tracked over time through the Red List
98 Index (<https://www.iucnredlist.org/assessment/red-list-index>). To date, the only Red List
99 Index on the status of marine life is that for the hard stony corals (Family Scleractinia),
100 which are threatened primarily by global climate change². There is, therefore, a need to
101 expand the Red List Index for marine species that are threatened by overfishing, which
102 is the primary cause of population reductions in the oceans^{3,4}.

103

104 Marine taxa particularly threatened by fisheries include the sharks and rays (subclass
105 Elasmobranchii), many of which are captured incidentally in fisheries targeted at more
106 productive species or are directly targeted⁴. Sharks and rays represent an ancient lineage
107 of over 400 million years of evolution⁵. Further, they often function as apex and
108 mesopredators in pelagic, benthic, and nearshore environments⁶. Understanding how
109 changes in fisheries management are affecting sharks and rays through the Red List
110 Index is crucial to gauging progress towards international biodiversity targets. The first
111 comprehensive assessment of this unique radiation of fishes, published in 2014,
112 estimated that over one-quarter are threatened⁷; recent work reflecting new information
113 reveals that over one third are in fact threatened⁴. Globally, some progress has been
114 made with taxonomic and regional species subsets to track change through
115 reassessment and Red List Index development^{8,9,10}.

116

117 The southwest Indian Ocean (SWIO) and adjacent waters (including the Benguela
118 current, waters off East Africa, and SWIO islands, hereafter SWIO+) have one of the most
119 distinctive shark and ray faunas globally, comprised of high richness and endemism with
120 a large number of evolutionarily distinct species^{11,12}. This area exhibits a rich diversity of
121 over 250 species from at least 47 families, in part due to the variety of habitats, including
122 warm-water tropical coral reefs, kelp and mangrove forests, and warm-temperate and
123 cool-water rocky reefs and sand flats^{12,13}. This biogeography is influenced in the south by
124 the unique ecological conditions created by the confluence of the warm southward-flowing
125 Agulhas Current along the east and south coasts of South Africa and the cold northward-
126 flowing Benguela Current on the west coast of South Africa and Namibia¹⁴.

127

128 Coastal regions of SWIO+ are under considerable fishing pressure. Approximately one-
129 quarter of the human population lives within 100 km of the coast; population growth is
130 among the highest worldwide, with a projected doubling of the human population by
131 2050¹⁵. Coastal communities in the region are heavily dependent on fisheries as the
132 primary source of protein, livelihoods, and food security¹⁶. The pressure and scale of
133 artisanal fisheries are significant and could pose an equivalent if not greater threat than
134 industrialized fleets to sharks in the region. For example, in Mozambique, the total small-
135 scale fisheries catch is estimated to be as much as three times that of the industrial
136 sector¹⁷. Several nations in the SWIO+ region face significant socio-economic challenges
137 and rank in the lowest quartile of the Human Development Index (HDI)¹⁸, limiting their
138 ability to manage marine resources effectively. This includes sharks and rays, which are
139 subject to generally unregulated take in parts of SWIO+, particularly in artisanal fisheries.

140

141 Here, we provide an assessment of extinction risk status of 70 sharks and rays endemic
142 to SWIO+. Specifically, we: (1) assess the extinction risk of these sharks and rays using
143 the IUCN Red List Categories and Criteria, (2) compare the change in extinction risk over
144 ~40 years against a retrospective assessment for 1980 using the Red List Index, and (3)
145 determine the countries with the most significant national conservation responsibility.

Finally, we propose some general policies that, if implemented, will help to safeguard shark and ray populations in SWIO+.

Methods

We first describe the geographic and taxonomic scope of the regional endemic elasmobranch extinction risk assessment, followed by the application of the IUCN Red List Categories and Criteria, species mapping and spatial analyses, and the calculation of a Red List Index.

Geographic and taxonomic scope. We focus on the assessment of extinction risk in endemic sharks and rays of the SWIO+ that inhabit the continental and insular shelves and slopes off Africa from the Angola–Namibia border, around the Cape of Good Hope, and east and north to the Kenya–Somalia border. The region also includes Madagascar and the islands of the southwest Indian Ocean. The geographic scope thus comprised nine range countries: Namibia, South Africa, Mozambique, Tanzania, Kenya, Madagascar, Comoros, Seychelles, and Mauritius. The Namibia–Angola border was chosen as the western boundary of the region because of the oceanographic and faunal break at the interface between the Benguela and Guinea Currents¹⁴. The Kenya–Somalia border was chosen as the northeastern-most limit of this assessment as it abuts the boundary of the Arabian Sea and its adjacent waters region, the subject of a separate recent extinction risk assessment¹⁹. Reunion is not included here because no regionally endemic sharks or rays exist there. We collectively refer to this region as SWIO+ for accuracy and simplicity.

A comprehensive list of all elasmobranch species known to occur in the region was based on the work of Ebert and van Hees²⁰. We evaluated 70 shark and ray species considered endemic to the region and did not include those that inhabit wider-ranging coastal, pelagic, or deepwater areas. For nomenclature and taxonomy, we followed the online electronic version of the Catalog of Fishes²¹ for sharks and *Rays of the World*²² for rays.

Application of the IUCN Red List Categories and Criteria. We assessed species at the global level by applying the IUCN Red List Categories and Criteria (Version 3.1) and the associated guidelines^{23,24}. Existing data and information on each species, including taxonomy, geographic distribution, population trends, habitat and ecology, significant threats, and conservation measures were compiled by the IUCN Species Survival Commission Shark Specialist Group (SSG) and regional experts. Information was obtained from published peer-reviewed scientific literature, government reports, unpublished fisheries data, grey literature, anecdotal information, and expert observations and data.

A four-day workshop was convened at the National Research Foundation's South African Institute for Aquatic Biodiversity (SAIAB) in Grahamstown in April 2018, facilitated by the SSG. Workshop participants included regional fisheries, biodiversity, and taxon-specific experts, including representatives of non-governmental organizations, fisheries agencies, and government staff from countries across the region. During the workshop, participants shared data, reports, and anecdotal information for each species and threats from the region. This group systematically assessed 70 species against each of five quantitative IUCN Red List Criteria A–E: A, population reduction; B, geographic range; C, small population size and decline; D, very small or restricted population; and, E, quantitative analysis²³.

Each species was assigned to one of the following Red List Categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), or Data Deficient (DD) (for definitions, see⁴⁹). The categories CR, EN, and VU are collectively termed 'threatened' categories. A species qualifies for one of the three threatened categories by meeting the quantitative threshold for that category within one of the five criteria (A–E). The NT category is applied to species that come close to, but do not meet, a threshold for a threatened category. The LC category is applied to species that have been assessed against the Red List criteria but do not qualify for CR, EN, VU, or NT. There were two ways species were assessed as LC: i) data show that the species has a stable or increasing population size over 3 GL, or

ii) because they inhabit remote or deepwater areas that are not subject to threats and therefore it can be inferred that the population is not undergoing reduction. The DD category is applied to a species when there is inadequate information to make a direct or indirect assessment of the risk of extinction based on its distribution and/or population status²³. The Red List assessment process includes a structured approach to classifying threats into 11 primary classes, such as *human intrusions and disturbance*, *pollution*, *biological resource use*, and *climate change and severe weather*²⁵ and appropriate threats were selected for each species.

Red List Criterion A uses a set of quantitative thresholds to classify population reduction scaled over three generation lengths (3 GL)²³. One primary source of long-term abundance data for 17 species was demersal research trawl surveys conducted in South Africa during summer along the west coast and autumn and spring along the south coast by the Fisheries Branch of the South African Department of Agriculture, Fisheries and Forestry²⁶. All datasets underwent extensive checks before analyses, and their reliability was reviewed by experts during the workshop. Annual density estimates (kg per nm² area swept) were estimated using the geostatistical delta-generalized linear mixed model (GLMM) developed by Thorson *et al.*²⁷. Applications of the delta-GLMM to South African trawl survey index standardization have been described elsewhere^{28,29} and the spatial patterns in density over time are shown for species for which there were data available. Although demersal trawl surveys commenced in 1984, we only considered the period from 1991 onwards due to improvements in species identification following the initial survey years. For the analysis, each survey season was treated as an individual index *i*. To analyze trend data, we used a Bayesian population state-space model designed specifically for IUCN Red List assessments (Just Another Red List Assessment, JARA)^{30,31}, which builds on the Bayesian state-space tool for averaging relative abundance indices³² and is available open-source on GitHub (www.github.com/henning-winker/JARA). Each relative abundance index (or time-series) was assumed to follow an exponential growth defined through the state process equation:

$$\mu_{t+1} = \mu_t + r_t$$

where μ_t is the logarithm of the expected abundance in year t , and r_t is the normally distributed annual rate of change with mean $\bar{r}$, the estimable mean rate of change for a time-series, and process variance σ^2 . We linked the logarithm of the observed relative abundance indices to the logarithm of the true expected population trend using the observation equation (eqn. 16) from Winker *et al.*³². We used a non-informative normal prior for $\bar{r} \sim N(0, 1000)$, and an approximately uniform prior on the log scale for the process variance $\sigma^2 \sim \frac{1}{\text{gamma}(0.001, 0.001)}$.

We ran two Monte Carlo Markov chains for each dataset with different initial values. Each Markov chain was initiated by assuming a prior distribution on the initial condition centred around the first data point in each abundance time-series. In each chain, the first 1,000 iterations were discarded ('burn-in'), and of the remaining 10,000 iterations, 5,000 were selected for posterior inference ('thinning rate' = 2). Thus, posterior distributions were estimated from 20,000 iterations. Convergence was diagnosed using Geweke's diagnostic³³ with thresholds of $p = 0.05$ via the 'coda' library (v0.19-1)³⁴. Analyses were performed using R Statistical Software v3.5.0³⁵ and via the interface from R ('R2jags' package v0.5-7)³⁶ to JAGS ('Just Another Gibbs Sampler' v4.3.0)³⁷. The Highest Posterior Density interval was used as the interval estimator of 95% credible intervals.

While there are many demographic approaches to calculating generation length²⁴, these are generally data-intensive and have been applied to relatively few sharks and rays. Therefore, to derive generation length (GL), a simple measure that requires only female age-at-maturity and maximum age was used:

$$GL = \text{maximum age} + ([\text{maximum age} - \text{age-at-maturity}] * z),$$

where z depends on the mortality rate of adults and is typically around 0.3 for mammals but we assume z is 0.5 to account for the truncation of age-structure due to overfishing and underestimation of age in chondrichthyans. This value represents the median age of parents of the current cohort. To derive population reduction over 3 GL, the proportional decline over the x years of available catch rate or landings datasets was calculated, and this was used to calculate annual proportional change, which was then scaled across the 3 GL period.

If a species qualified for a change in conservation status from a previously published assessment (a 'downlisting' or 'uplisting' in status), changes were classified as either *Genuine* or *non-genuine* changes. Genuine changes are assigned due to actual increases or decreases in the level of extinction risk that a species faces based on changes in the threatening processes. In contrast, non-genuine changes are assigned due to new information, taxonomic changes, and/or errors in the application of criteria or incorrect data used in the previous assessment²⁴.

Assessments were drafted after the workshop's conclusion and the category and criteria, and the assessment rationale sections were initially sent to all workshop participants to solicit feedback before circulation to the full membership of the SSG comprising 177 members from 55 countries for their input. Each assessment was peer-reviewed by at least two experts with knowledge of the species and the IUCN Red List Categories and Criteria. Completed assessments were submitted to the IUCN Red List Unit in Cambridge, UK, for final review and publication on the IUCN Red List¹.

Species distribution mapping. Draft species range maps were primarily based on the original maps published in the previous Red List assessments augmented by revised distributions from those in *Sharks of the World*⁸⁸ and *Rays of the World*²² and maps were reviewed and validated by regional experts and taxonomists. The final distribution maps were prepared using ArcGIS 10.6. The ranges of each species were clipped to their known depth range based on the highest-resolution bathymetry dataset available across the region (15 arc seconds)³⁹. One species, Kaja's Sixgill Sawshark (*Pliotrema kaja*), was excluded from all spatial analyses, as it was not possible to map its range due to a lack of data.

Red List Index. We derived retrospective assessments for two earlier periods, 2005 and 1980 (with the current assessments set at 2020), in order to calculate a Red List Index (RLI)⁴⁰. Before this current reassessment, all except 15 newly described species had assessments published on the IUCN Red List. All changes in Red List category except

one were considered non-genuine changes due to new information²⁴. In other words, if what is currently understood was known during the previous assessments, the assigned status of those species would likely have been different. For example, if a species was assessed as DD in 2005 but is now LC in the current assessment, the older status would be retrospectively corrected to be LC. For species assessed as NT or in one of the threatened categories, ‘backcasting’ was undertaken by retrospectively assigning status based on current understanding of the spatial and temporal pattern of coastal human population growth, the development of general fishing pressure, the availability of fishing gear capable of capturing sharks and rays, and the development of the international trade demand for shark and shark-like ray fins⁷.

The RLI for all 70 endemic species was also disaggregated to each of the nine SWIO+ range countries. The disaggregation of RLI to country level, which considers the relative proportions of all species’ ranges occurring in each country, allows a more nuanced understanding of which range countries contribute most to the change in Red List statuses across all species and the region. This is an important consideration because different range countries can potentially contain highly differing proportions of an individual species’ distribution range, impacting driving or preventing extinction risk in this species. For calculating country-specific RLI values, the equation is amended such that:

$$RLI_{(t,u)} = 1 - \left[\frac{\sum \left(W_{(t,s)} \times \frac{r_{su}}{R_s} \right)}{WEX \times \sum \left(\frac{r_{su}}{R_s} \right)} \right]$$

where t is the year of assessment, u is the country and $W_{(t,s)}$ is the Red List threat at year t for each species, multiplied by $\frac{r_{su}}{R_s}$, representing the proportion of each species’ total range found within the Exclusive Economic Zone (EEZ) of each country⁴¹. This is summed across all species that occur in each country’s EEZ and divided by the maximum threat score ($WEX = 5$), multiplied by the sum of proportional species’ ranges. The final country-specific RLI value is derived by subtracting from 1. Higher RLI values indicate fewer negative changes in Red List status across species and vice versa (as with the global RLI). Finally, we calculated national conservation responsibilities for all range

countries, which are based on the sum of all threat scores across species within a country, multiplied by each of the species' proportional ranges for that country⁴².

RESULTS

Taxonomic diversity and species richness

This study comprised 70 endemic species (38 sharks and 32 rays, the latter comprising guitarfishes, electric rays, and skates) from 7 orders, 20 families, and 39 genera (Table 1). Families with the highest species richness were Rajidae (hardnose skates, $n = 12$, 17.1% of all species) and Pentanchidae (deepwater catsharks, $n = 15$, 21.4%), collectively comprising more than a third (38.5%) of the regional endemic fauna. Species richness was greatest along the South African and southern Mozambican coastlines, with a maximum number of 19 species occurring in each country (Fig. 1a). The richness of threatened (Critically Endangered, CR; Endangered, EN; or Vulnerable, VU) shark and ray species reflects this inverse latitudinal gradient ($n = 13$; Fig. 1b). The high concentration of threatened endemics in South Africa is driven by the sharks ($n = 8$), whereas threatened rays ($n=5$) were more disparately distributed across the region (Fig. 1c & d).

Taxonomic patterns in extinction risk

Nearly one-fifth ($n = 13$, 19%) of assessed endemic sharks and rays in the region are threatened with extinction (Table 1). One species, the Shorttail Nurse Shark (*Pseudoginglymostoma brevicaudatum*), is CR and at an *extremely high* risk of extinction. It is assessed under Criterion A2cd as it has undergone a suspected population reduction of >80% over the past three generations (30 years) due to a decline in habitat quality and actual and potential levels of exploitation. Five species (7%) are EN and face a *very high* risk of extinction, and seven species (10%) are VU, facing a *high* risk of extinction (Table 1). A further seven species (10%) are Near Threatened (NT), indicating they may become threatened soon if countries don't implement management and conservation.

Most threatened and NT species were assessed as such using Criterion A (population reduction). For example, the Tiger Catshark (*Halaelurus natalensis*) declined by 39% in the commercially fished area in the last 27 years, consistent with a population reduction of 56.5% (CI: -97.3, 83.3) in 3 GL (60 years); however, there has been an expected range shift away from trawl grounds reducing catchability in the surveys, and experts agreed that the appropriate Category for this species is VU. The Twin-eye Skate (*Raja ocellifera*) declined by 65.5% in the commercially fished area in the last 27 years, consistent with a population reduction of 65.5% (CI: -89.2, -17.1) in 3 GL (27 years) and is EN (Fig. 2).

There were two cases of small-range species endemic only to South Africa, found in few locations and undergoing a continuing decline, which met threatened categories under criterion B: the Natal Shyshark (*Haploblepharus kistnasamyi*) and the Flapnose Houndshark (*Scylliogaleus queckettii*), are assessed as VU.

Nearly half of species showed slight increases or did not decrease substantially enough to meet the threatened or NT thresholds and were thus assigned a status of Least Concern (LC; $n = 33$, 47%) (Table 2). For example, the Softnose Skate (*Bathyraja smithii*) occurs primarily in Namibia, where fishing pressure is low. The Whitecheek Lanternshark (*Etmopterus alphas*) occurs between 472 and 792 m depth along a narrow strip of the Mozambique coastline, and it has depth refuge in the absence of deepwater fishing activities. There were eight species for which indices of abundance were available and revealed either stability or an increase in population index (Fig. 2, left column) and these are assessed as LC.

Finally, almost a quarter of species are Data Deficient (DD; $n = 17$, 24%) because there is insufficient information to accurately assess their extinction risk (i.e., data are so sparse for these species that assessors were not able to determine whether they are CR, LC, or somewhere between). Three of the six species of guitarfishes from the family Rhinobatidae require further information to assign a risk category. One of five endemic scyliorhinid catsharks and three of 15 pentanchid catsharks are DD. There are fewer data available regarding the status of rays overall, and nearly one-third are DD (10 of 32

species). Three species previously assessed as DD are now LC due to new information: the Saldanha Catshark (*Apristurus saldanha*), the Black Legskate (*Indobatis ori*), and the Whitespotted Smoothhound (*Mustelus palumbes*).

All changes in Red List status since the previous assessments are *non-genuine changes* except for the Shorttail Nurse Shark (which had its population further reduced since the 2005 assessment). These non-genuine changes are due to new information becoming available since the previous assessments. This new knowledge can be used to retrospectively correct previously published assessments for the development of a Red List Index. Thus, the newly stated retrospective statuses can be considered more accurate than the previously published assessments (Table 1).

Key threats

Red List assessments for all 13 threatened and seven NT species reported 'Biological Resource Use' and, more specifically, 'Fishing and Harvesting Aquatic Resources' as threatening processes, while other threats (habitat loss and degradation, pollution) caused reductions or a continuing decline in population size in fewer species (Fig. 3). Climate change was reported in the threat rationale for seven threatened and NT species. Although not the leading cause of population reductions, it has induced a significant distributional shift in the populations of six of these seven species²⁹ (grey bar, Fig. 3). Coastal development and pollution contributed to localized extinction risk for three species, but overfishing is the primary threat for all of them.

Overfishing is the main threat

Overfishing is the primary threat to all threatened elasmobranchs in the SWIO+ region through targeted and incidental catches (bycatch), including commercial, recreational, and artisanal fisheries using fishing gears such as gillnets, longlines, handlines, trawls, and seine nets. Furthermore, all 20 threatened and NT species are exposed to overfishing through incidental catches, where fisheries target other species such as teleost fishes or shrimps but catch and retain other valuable species such as sharks and rays.

Overfishing is compounded by climate change

There are two impact pathways by which climate change may be elevating extinction risk of sharks and rays. Firstly, the increasing frequency and severity of coral bleaching are implicated in the elevated extinction risk of the Shorttail Nurse Shark. This tropical shark has declined significantly over the past 15 years, resulting in a *genuine* change in status from VU to CR. This population reduction is suspected to be caused by a combination of overfishing, destructive fishing practices, and a continuing decline in habitat quality due to coral bleaching and rising sea temperatures. Live capture for the aquarium trade may further exacerbate risk. Secondly, there has been a north-easterly shift in the distribution of thermal habitat across the southern Cape of South Africa. This shift has resulted in simultaneous northeastward shifts of many teleost and elasmobranch species' distributions toward the narrower shelf area off the Eastern Cape and KwaZulu-Natal²⁹. Three species undergoing notable range shifts are the Lesser Guitarfish (*Acroteriobatus annulatus*), Bluntnose Spurdog (*Squalus acutipinnis*), and Twin-eye Skate (*Raja ocellifera*) (Fig. 4).

In addition to fishing pressure and climate change, habitat degradation from coastal development and pollution further exacerbates overfishing for two South African endemic catsharks. The Brown Shyshark (*Haploblepharus fuscus*) and the Natal Shyshark both inhabit nearshore waters at depths of less than 50 m. They are endemic to South Africa and occur near several large urban centers (Port Elizabeth, East London, and Durban) and are thus subject to associated localized urban development and pollution.

The Red List Index and national conservation responsibilities

Almost all species were retrospectively assessed as LC ($n = 52$) or DD ($n = 17$) in 1980 (Table 1), except one NT species (Natal Sleeper Ray *Heteronarce garmani*), resulting in a regional Red List Index (RLI) value of 0.996 (where a value of 1 represents all assessed species being LC; Fig. 5a). The regional RLI decreased slightly to 0.917 by 2005 and further to 0.849 in the most recent assessment (2020) presented here. This decreasing trend in RLI results from the increased numbers of species in threatened and NT

categories by 2005 and 2020 (13 and 20, respectively; Table 1). When disaggregating the RLI down to country-level, the most significant decline in RLI is from 1980 to 2005 in Madagascar (a decline from 0.999 to 0.672; Fig. 5b). Between 2005 and 2020, the greatest decline in country-level RLI also occurred in Madagascar (0.672 to 0.558; Fig. 5c). Nine range countries bear some responsibility for conserving the 70 endemic SWIO+ species that have been assessed using the IUCN Red List Categories and Criteria (Table 3). Consistent with the inverse latitudinal richness trend, South Africa had the highest national conservation responsibility (NCR) of all nine range countries (NCR = 1), followed by relatively high responsibilities for Mozambique (NCR = 0.442) and Madagascar (NCR = 0.407; Fig. 6). Collectively, these three countries represent 93% of all conservation responsibility for endemic sharks and rays in the region, largely reflective of the species richness found in their waters.

Discussion

Here, we provide the first comprehensive reassessment of extinction risk in sharks and rays that are endemic to waters of SWIO+. Of 70 species herein assessed for the IUCN Red List, nearly one-fifth are threatened and thus have a high to extremely high risk of extinction (1 CR, 5 EN, 7 VU). Despite a lack of data from parts of the region, it is clear that excessive fishing activity and limited management capacity are substantial barriers to ensuring robust shark and ray populations into the future. A further quarter of species are DD and could potentially be listed as threatened as additional data become available. Furthermore, this assessment of endemic species belies the overall status of sharks and rays in the region. If we include the wider-ranging coastal, pelagic, and deepwater species, there are 75 additional globally threatened sharks and rays that occur in the region, including 26 that are EN and 12 that are CR. Including these groups would also add another 21 DD species. We next (1) compare these findings to threat patterns globally and in other regions, and identify measures to (2) avoid extinctions, (3) ensure sustainability, (4) maintain robust functional populations, (5) drive down data deficiency gaps, and (6) cope with prevalent and emerging threats.

The percentage of threatened endemic species in this region (19%) is considerably lower than that observed globally (37%)¹. At the regional level, 42% of species ($n=50$) are threatened or predicted to be threatened in the Northwest Atlantic and two-thirds of species (67%, $n=48$) in the Mediterranean Sea⁹. A regional assessment (including all species, not only endemics) of the Arabian Sea and its adjacent waters region found 50.9% of species are threatened¹⁹. Although we find extinction risk in SWIO+ to be lower than in these other regions, many of the most threatened families found in this region are not included in this assessment, including the sawfishes, wedgefishes, hammerheads, and thresher sharks^{8,10,43,44}, because they are not endemics. If they are included, there are 82 of 227 species (36% threatened). Nevertheless, endemism adds a further layer of threat to a species and we show here that there are at least six endemic species that are endangered (EN or CR) and require urgent conservation action to prevent further declines and extinction.

The most severe and prevalent threat to the endemic species assessed in this region is heavy fishing pressure and bycatch mortality, resulting in population reductions for threatened and NT species. This threat is particularly problematic for species inhabiting shallow inshore and continental shelf waters to approximately 200 m depth, such as the Shorttail Nurse Shark (the only CR species), and the Happy Eddie Catshark (*Haploblepharus edwardsii*), Greyspot Guitarfish (*Acroteriobatus leucospilus*), and Twin-eye Skate (all EN). In the specific case of the Shorttail Nurse Shark, extensive landings surveys in Madagascar (2007–2012)⁴⁵ have not recorded any individuals, and only one individual has been observed there in 270 hours of baited remote underwater video (BRUV) surveys⁴⁶. although since this assessment, its range has been extended to include Mozambique⁴⁷. Further, no sightings of this species have been reported from extensive visual census surveys in Tanzania, Mozambique, or Madagascar (2009–2015)⁴⁸.

We recommend that governments implement management interventions for CR and EN species without delay. These interventions should involve strict prohibitions on landings where they are not yet in place and capacity for enforcement of laws. Highly impactful

fishing gears, such as large-mesh (shark-directed) gillnets and longlines, should be regulated, and legislation against destructive fishing practices such as reef nets and blast fishing, which damage habitats such as coral reefs, should be enforced to ensure the continued presence of these threatened species in the wild. If threats are not mitigated rapidly, species such as the Shorttail Nurse Shark could become extinct in the very near future. This situation could follow that of at least one, possibly two, sawfish species that are already considered locally extinct in South Africa (Largetooth Sawfish *Pristis pristis* and Green Sawfish *P. zijsron*). Although they are the first rays protected in the region, protection was implemented too late, two years before the last sighting of a sawfish⁴⁹.

For species in this region that are VU due to small geographic range sizes, occurring in few locations, and inferred to have declining populations (e.g., Flapnose Houndshark *Scylliogaleus queckettii*, Natal Shyshark), there is an opportunity to implement spatial closures of important habitat to complement catch and fishing effort reduction approaches. Establishing closures will require the identification of overlap between the existing protected area network and key habitat features and understanding movement behaviour and potential aggregation sites^{50,51}. Marine Protected Areas might prove to be a suitable approach for conserving threatened endemic sharks⁵². Even a modest expansion of the protected areas network has significant potential to contribute to the conservation of these species⁵³.

Madagascar, South Africa, and Seychelles are the only nations with a National Plan of Action (NPOA) for the Conservation and Management of Sharks^{54,55}, although most countries in the region are developing these. From our analyses, Mozambique and Madagascar had the most significant national conservation responsibility after South Africa, with these three nations representing 93% of all responsibility in the region. These are therefore priority nations to effectively implement NPOAs to set the stage for sustainable catch of species in their national waters. Further, such plans should include legislative mechanisms for protection of CR and EN species, explicit actions on catch limits for VU or NT species, strategies for managing bycatch in fisheries and, where needed, actions on protecting habitats or areas known as important during critical life

history stages⁵⁴. Increased efforts to accurately assess fishing pressure are also paramount. Underreporting and discrepancies in fisheries data are prevalent in reports provided to Regional Fisheries Management Organisations (RFMOs) and the Food and Agriculture Organization of the United Nations (FAO). Furthermore, where data are collected, discards are not reported, and post-release mortality is unknown, even in South Africa, where data collection is relatively robust⁵⁴.

Encouragingly, almost half of the species assessed here are LC, which means their populations are stable or declining slowly such that population reduction thresholds are not triggered. In many cases, these species are not exposed to the pressures to which threatened species are. For example, the geographic or bathymetric ranges of some species mean they are sparsely or never fished. Where a species is fished, resilience to this pressure is indicated by relatively stable population trends over time. For example, the Whitespotted Smoothhound *Mustelus palumbes* has shown a modest estimated increase of 8% over 27 years across the South African hake trawl grounds (Fig. 2). Whitespotted Smoothhounds are caught in trawl, line, and demersal shark longline fisheries, but given their increase in abundance, they appear robust to moderate levels of fishing activity (< 50 t per annum), although further management measures will be needed to ensure sustainability if catches increase. Some other targeted or retained bycatch species (e.g., Bluntnose Spurdog *Squalus acutipinnis*, Slime Skate *Dipturus pullopunctatus*) also exhibit some level of resilience to fishing pressure. However, it is essential that these LC species be monitored in terms of abundance and catch to maintain robust, ecologically functional populations that yield ecosystem services to humanity and contribute to food security.

A quarter of the species assessed had insufficient data available for an accurate assessment and were evaluated as DD. Many countries are still reporting catches simply as “sharks”, and species-level monitoring of rays has been particularly neglected in the region. Catch reconstructions reveal serious discrepancies where reported catches are far lower than the reconstructions, around 200% in Madagascar and Mauritius^{56,57}, and >75% in Tanzania⁵⁸. While there has been progress in assessing the species composition

and monitoring of fisheries, there remains a lack of species-specific population trend and time-series data, other than South Africa. The lack of species-specific fisheries data means that declines in sensitive species (e.g., angelsharks, guitarfishes) could go unnoticed^{8,59}. More information may reveal other species that are threatened. Further, more detailed information will be needed to provide effective spatial planning and fisheries management while minimizing impacts and conflicts with resource users.

Emerging threats in this region include the expansion of deepwater fisheries and climate change impacts on sharks and rays. Two deepwater species affected by fishing pressure are EN catsharks: the Honeycomb Izak Catshark (*Holohaelurus favus*) and the African Spotted Catshark (*H. punctatus*), which occur in waters greater than 200 m. Despite the potential for refuge at depth, populations of these deepwater catsharks are suspected of having undergone reductions of more than 50% over the past three generations due to deepwater trawl and longline fisheries operating within their ranges. These declines will continue if deepwater fisheries are further developed in the absence of management⁶⁰. We caution that as deepwater fisheries increase, particularly in Mozambique, Madagascar, and Tanzania, including fishing by distant water nations, many of the deepwater LC species may be at greater risk of extinction⁶¹. Monitoring fisheries expansions into deeper or more remote waters overlapping with the geographic ranges of deepwater LC species will be important, along with species-level catch data.

Although declines in VU species are mainly due to fishing, one of these species, the Tiger Catshark, is unique in that it has undergone a population reduction (including a reduction in area of occupancy) that is at least partially related to an ecological shift in currents due to climate change^{29,62}. For this catshark, mortality due to fisheries does not appear substantial enough to be the only factor causing this reduction, highlighting the importance of considering climate change in future Red List assessments of sharks and rays. As species distribution models for sharks and rays become available⁶³, future assessments could consider using climate projections. Trait-based approaches are already available to evaluate the potential risk of climate change and will be helpful for future reassessment^{64,65}.

Conclusion

Here, we find that 13 of the 70 (19%) endemic shark and ray species in the SWIO+ region are threatened with a high risk of extinction. There is thus a need for a collaborative regional improvement in shark and ray conservation to reduce risk for these endemic species. The uniqueness of this SWIO+ endemic hotspot for sharks and rays is of global significance and requires international support. There is a great urgency to act to avoid further extinctions, ensure sustainability, maintain robust functional populations, reduce data deficiency, and secure livelihoods and food security for coastal people. On-going monitoring and data collection at the species level are essential, particularly for threatened and NT species. Species-specific annual fisheries-independent population monitoring needs to take place. In the absence of such data, species-specific monitoring of catches and landings (accounting for fishing effort) can provide a reliable index of the trend in abundance. Although there has been an improvement in fisheries management in South Africa, and it may well have maintained populations and prevented more severe declines than those observed, many other countries in the region lag far behind. These nations need to significantly improve their capacity to effectively monitor, manage, and protect their shark and ray species and play their part to ensure the global viability of elasmobranch fauna. Nations are currently negotiating new biodiversity and sustainability targets to bend the curve on biodiversity to halt and reverse declines in populations and minimize extinctions^{42,66}. This study provides evidence that extinction risk has increased in the SWIO+ region due to overfishing and climate change and that action is needed to bend the curve for elasmobranchs there.

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Author Contributions

RAP, PMK, and NKD designed the study and organized and led the workshop. RAP, KSG, and NKD wrote the manuscript. JC, NP, and NKD analyzed the data and produced the figures. KSG, DAE, RWJ, KBH, RHB, CDS, SF, BK, RL, MEM, MS and HW participated in the workshop and provided access to data and/or valuable insight into Red List assessments. KBH provided mapping support. SF provided data and insight electronically. CLR and CMP reviewed Red List assessments. All authors reviewed the manuscript and provided critical insight.

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Figure Captions

Figure 1. Endemic species richness of (a) sharks and rays ($n = 70$), (b) threatened (Critically Endangered, Endangered or Vulnerable, according to the IUCN Red List Categories) sharks and rays ($n = 13$), (c) threatened sharks ($n = 8$), and (d) individual distributions of threatened rays ($n = 5$) across the SWIO+ region.

Figure 2. Species population time-series (expressed as a proportion) modelled from demersal research trawl surveys in commercially fished areas (line) and shore-based research angling surveys (dashed line) off the west and south coasts of South Africa. Lines and dashed lines denote the mean, and shaded regions represent the 95% credible intervals. Time-series are divided by their initial values and start at one. Silhouette colours indicate Red List status: dark green is Least Concern, light green is Near Threatened, yellow is Vulnerable, orange is Endangered.

Figure 3. Count of reported threat categories in the 20 threatened (Critically Endangered, Endangered and Vulnerable) and Near Threatened SWIO+ shark and ray species.

Figure 4. Spatial and temporal change in density (ln kg per km⁻²) between 20°E and 27°E longitude for 1991 and 2016 for (a) Lesser Guitarfish (*Acroteriobatus annulatus*; Vulnerable), (b) Bluntnose Spurdog (*Squalus acutipinnis*; Near Threatened), and (c) Twin-eye Skate (*Raja ocellifera*; Endangered).

Figure 5. Red List Index (RLI) for SWIO+ endemic sharks and rays ($n = 70$). (a) The decline in RLI across assessment years 1980, 2005, and 2020. Country-specific declines in RLI from (b) 1980—2005 and (c) 2005—2020. Calculations of RLI exclude Data Deficient (DD) species.

Figure 6. National conservation responsibility of nine range countries for all 70 endemic shark and ray species in the SWIO+ region for which Red List Status is known.

711 **Tables**

712 **Table 1.** Original, retrospectively backcasted (for years 1980 and 2005), and current assessments of IUCN Red List categories for all
 713 endemic shark and ray species of the SWIO+ region ($n = 70$). Differences in original past assessments and backcast assessments
 714 arise due to new information about a species' status from the better informed, more recent assessments. (CR, Critically Endangered;
 715 EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient). Species marked with * have been
 716 recently described for which previously published assessments do not exist.

717

ORDER: Family	Common name	Original IUCN Red List status			Red List status for RLI		
<i>Species name</i>		2000	Mid-2000s	Late-2010s	1980	2005	2020
SHARKS							
PRISTIOPHORIFORMES: Pristiophoridae	Sawsharks						
<i>Pliotrema annae</i> *	Anna’s Sixgill Sawshark			DD ₂₀₂₀	DD	DD	DD
<i>Pliotrema kajae</i> *	Kaja’s Sixgill Sawshark			DD ₂₀₂₀	DD	DD	DD
<i>Pliotrema warreni</i> *	Warren’s Sixgill Sawshark			LC ₂₀₁₉	LC	LC	LC
SQUATINIFORMES: Squatinidae	Angel Sharks						
<i>Squatina africana</i>	African Angelshark		DD ₂₀₀₄	NT ₂₀₁₇	LC	LC	NT
SQUALIFORMES: Centrophoridae	Gulper Sharks						
<i>Centrophorus seychellorum</i>	Seychelles Gulper Shark		DD ₂₀₀₈	LC ₂₀₁₈	LC	LC	LC
SQUALIFORMES: Squalidae	Houndsharks						
<i>Squalus acutipinnis</i> *	Bluntnose Spurdog			NT ₂₀₁₉	LC	LC	NT
<i>Squalus bassi</i> *	African Longnose Spurdog			LC ₂₀₁₉	LC	LC	LC
<i>Squalus lalannei</i>	Seychelles Spurdog		DD ₂₀₀₈	LC ₂₀₁₈	LC	LC	LC
SQUALIFORMES: Etmopteridae	Lantern Sharks						
<i>Etmopterus alphas</i> *	Whitecheek Lanternshark			LC ₂₀₁₈	LC	LC	LC
<i>Etmopterus compagnoi</i> *	Brown Lanternshark			LC ₂₀₁₈	LC	LC	LC

ORDER: Family <i>Species name</i>	Common name	Original IUCN Red List status			Red List status for RLI		
		2000	Mid-2000s	Late-2010s	1980	2005	2020
<i>Etmopterus sculptus</i> *	Sculpted Lanternshark			LC ₂₀₁₈	LC	LC	LC
<i>Etmopterus sentosus</i> *	Thorny Lanternshark		LC ₂₀₀₆	LC ₂₀₁₈	LC	LC	LC
ORECTOLOBIFORMES: Ginglymostomatidae	Nurse Sharks						
<i>Pseudoginglymostoma brevicaudatum</i>	Shorttail Nurse Shark		VU ₂₀₀₄	CR ₂₀₁₈	LC	VU	CR
ORECTOLOBIFORMES: Hemiscylliidae	Longtailed Carpetsharks						
<i>Chiloscyllium caeruleopunctatum</i> *	Bluespotted Bambooshark			DD ₂₀₁₉	DD	DD	DD
CARCHARHINIFORMES:							
Pentanchidae	Deepwater Catsharks						
<i>Apristurus saldanha</i>	Saldanha Catshark		LC ₂₀₀₄	LC ₂₀₁₈	LC	LC	LC
<i>Bythaelurus clevai</i>	Broadhead Catshark		DD ₂₀₀₄	DD ₂₀₁₈	DD	DD	DD
<i>Bythaelurus lutarius</i> *	Mud Catshark			DD ₂₀₁₈	DD	DD	DD
<i>Bythaelurus tenuicephalus</i> *	Narrowhead Catshark			LC ₂₀₁₈	LC	LC	LC
<i>Halaelurus lineatus</i>	Lined Catshark		DD ₂₀₀₄	LC ₂₀₁₈	LC	LC	LC
<i>Halaelurus natalensis</i>	Tiger Catshark		DD ₂₀₀₄	VU ₂₀₁₈	LC	NT	VU
<i>Haploblepharus edwardsii</i>	Happy Eddie Catshark	NT	NT ₂₀₀₈	EN ₂₀₁₉	LC	NT	EN
<i>Haploblepharus fuscus</i>	Brown Shyshark	NT	VU ₂₀₀₈	VU ₂₀₁₉	LC	VU	VU
<i>Haploblepharus kistnasamyi</i>	Natal Shyshark		CR ₂₀₀₈	VU ₂₀₁₉	LC	NT	VU
<i>Haploblepharus pictus</i>	Dark Shyshark		LC ₂₀₀₈	LC ₂₀₁₈	LC	LC	LC
<i>Holohalaelurus favus</i>	Honeycomb Izak Catshark		EN ₂₀₀₈	EN ₂₀₁₉	LC	EN	EN
<i>Holohalaelurus grennian</i>	Grinning Izak Catshark		DD ₂₀₀₈	DD ₂₀₁₉	DD	DD	DD
<i>Holohalaelurus melanostigma</i>	Crying Izak Catshark		DD ₂₀₀₆	LC ₂₀₁₉	LC	LC	LC
<i>Holohalaelurus punctatus</i>	African Spotted Catshark		EN ₂₀₀₈	EN ₂₀₁₉	LC	EN	EN

ORDER: Family <i>Species name</i>	Common name	Original IUCN Red List status			Red List status for RLI		
		2000	Mid-2000s	Late-2010s	1980	2005	2020
<i>Holohalaelurus regani</i>	Izak Catshark		LC ₂₀₀₇	LC ₂₀₁₉	LC	LC	LC
CARCHARHINIFORMES: Scyliorhinidae	Catsharks						
<i>Cephaloscyllium sufflans</i>	Balloon Shark		LC ₂₀₀₄	NT ₂₀₁₉	LC	LC	NT
<i>Poroderma africanum</i>	Pyjama Shark	NT	NT ₂₀₀₅	LC ₂₀₁₉	LC	LC	LC
<i>Poroderma pantherinum</i>	Leopard Catshark		DD ₂₀₀₄	LC ₂₀₁₉	LC	LC	LC
<i>Scyliorhinus capensis</i>	Yellowspotted Catshark	NT	NT ₂₀₀₄	NT ₂₀₁₉	LC	LC	NT
<i>Scyliorhinus comoroensis</i>	Comoro Catshark		DD ₂₀₀₇	DD ₂₀₁₈	DD	DD	DD
CARCHARHINIFORMES: Proscylliidae	Finback Catsharks						
<i>Eridacnis sinuans</i>	African Ribbontail Catshark		LC ₂₀₀₄	LC ₂₀₁₈	LC	LC	LC
CARCHARHINIFORMES: Triakidae	Houndsharks						
<i>Mustelus palumbes</i>	Whitespot Smoothhound		DD ₂₀₀₆	LC ₂₀₁₉	LC	LC	LC
<i>Scylliogaleus queckettii</i>	Flapnose Houndshark	VU	VU ₂₀₀₅	VU ₂₀₁₈	LC	NT	VU
<i>Triakis megalopterus</i>	Spotted Gully Shark	NT	NT ₂₀₀₅	LC ₂₀₁₉	LC	LC	LC
RAYS							
RAJIFORMES: Anacanthobatidae	Legskates						
<i>Anacanthobatis marmorata</i>	Spotted Legskate		DD ₂₀₀₄	NT ₂₀₁₉	LC	LC	NT
<i>Indobatis ori</i>	Black Legskate		DD ₂₀₀₄	LC ₂₀₁₉	LC	LC	LC
RAJIFORMES: Arhynchobatidae	Softnose Skates						
<i>Bathyraja smithii</i>	Softnose Skate		DD ₂₀₀₈	LC ₂₀₁₉	LC	LC	LC
RAJIFORMES: Gurgesiellidae	Pygmy Skates						
<i>Cruriraja durbanensis</i>	Smoothnose Pygmy Skate		DD ₂₀₀₈	DD ₂₀₁₈	DD	DD	DD
<i>Cruriraja hulleyi</i>	Hulley's Pygmy Skate		LC ₂₀₀₇	LC ₂₀₁₈	LC	LC	LC

ORDER: Family <i>Species name</i>	Common name	Original IUCN Red List status			Red List status for RLI		
		2000	Mid-2000s	Late-2010s	1980	2005	2020
<i>Cruriraja parcomaculata</i>	Roughnose Pygmy Skate		DD ₂₀₀₇	LC ₂₀₁₈	LC	LC	LC
<i>Fenestraja maceachrani</i>	Madagascar Pygmy Skate		DD ₂₀₀₈	DD ₂₀₁₈	DD	DD	DD
RAJIFORMES: Rajidae	Hardnose Skates						
<i>Dipturus campbelli</i>	Blackspot Skate		NT ₂₀₀₄	NT ₂₀₁₉	LC	LC	NT
<i>Dipturus crosnieri</i>	Madagascar Skate		VU ₂₀₀₆	VU ₂₀₁₈	LC	VU	VU
<i>Dipturus lanceorostratus</i>	Rattail Skate		DD ₂₀₀₄	DD ₂₀₁₈	DD	DD	DD
<i>Dipturus pullopunctatus</i>	Slime Skate		LC ₂₀₀₄	LC ₂₀₁₉	LC	LC	LC
<i>Dipturus stenorhynchus</i>	Prownose Skate		DD ₂₀₀₄	DD ₂₀₁₈	DD	DD	DD
<i>Leucoraja compagnoi</i>	Tigertail Skate		DD ₂₀₀₄	DD ₂₀₁₈	DD	DD	DD
<i>Leucoraja wallacei</i>	Yellowspotted Skate		LC ₂₀₀₈	VU ₂₀₁₉	LC	LC	VU
<i>Neoraja stehmanni</i>	South African Dwarf Skate		DD ₂₀₀₄	LC ₂₀₁₈	LC	LC	LC
<i>Okamejei heemstrai</i>	Narrow Skate		DD ₂₀₀₄	LC ₂₀₁₈	LC	LC	LC
<i>Raja ocellifera</i>	Twineye Skate			EN ₂₀₁₉	LC	VU	EN
<i>Rajella caudaspinosa</i>	Munchkin Skate		NT ₂₀₀₄	LC ₂₀₁₈	LC	LC	LC
<i>Rajella paucispinosa</i>	Sparsethorn Skate			LC ₂₀₁₈	LC	LC	LC
TORPEDINIFORMES: Narkidae	Sleeper Rays						
<i>Electrolux addisoni</i>	Ornate Sleeper Ray		CR ₂₀₀₈	LC ₂₀₁₈	LC	LC	LC
<i>Heteronarce garmani</i>	Natal Sleeper Ray		VU ₂₀₀₇	NT ₂₀₁₉	NT	NT	NT
<i>Narke capensis</i>	Cape Sleeper Ray		DD ₂₀₀₇	LC ₂₀₁₈	LC	LC	LC
TORPEDINIFORMES: Torpedinidae	Torpedo Rays						
<i>Tetronarce cowleyi</i> *	South African Torpedo			LC ₂₀₁₈	LC	LC	LC
<i>Torpedo fuscomaculata</i>	Blackspotted Torpedo		DD ₂₀₀₄	DD ₂₀₁₈	DD	DD	DD
TORPEDINIFORMES: Narcinidae	Numbfishes						

ORDER: Family <i>Species name</i>	Common name	Original IUCN Red List status			Red List status for RLI		
		2000	Mid-2000s	Late-2010s	1980	2005	2020
<i>Narcine insolita</i>	Madagascar Numbfish		DD ₂₀₀₄	DD ₂₀₁₈	DD	DD	DD
RHINOPRISTIFORMES:							
Rhinobatidae	Guitarfishes						
<i>Acroteriobatus annulatus</i>	Lesser Guitarfish		LC ₂₀₀₆	VU ₂₀₁₉	LC	NT	VU
<i>Acroteriobatus blochii</i>	Bluntnose Guitarfish		LC ₂₀₀₆	LC ₂₀₁₈	LC	LC	LC
<i>Acroteriobatus leucospilus</i>	Greyspot Guitarfish		DD ₂₀₀₈	EN ₂₀₁₈	LC	VU	EN
<i>Acroteriobatus ocellatus</i>	Speckled Guitarfish		DD ₂₀₀₈	DD ₂₀₁₈	DD	DD	DD
<i>Rhinobatos austini</i>	Austin's Guitarfish			DD ₂₀₁₈	DD	DD	DD
<i>Rhinobatos holcorhynchus</i>	Slender Guitarfish		DD ₂₀₀₈	DD ₂₀₁₈	DD	DD	DD
MYLIOBATIFORMES: Gymnuridae							
<i>Gymnura natalensis</i>	Diamond Ray		DD ₂₀₀₆	LC ₂₀₁₈	LC	LC	LC

719 **Table 2.** Endemic SWIO+ shark and ray species and their observed and projected (over 3 GL) population trends (observed change in
720 % in fisheries trawl surveys and shore-based research angling surveys off the west and south coasts of South Africa), for which JARA
721 has been used as a decision-support tool to undertake extinction risk assessments based on the IUCN Red List Categories and Criteria.
722

Species	Common Name	RL Category	Survey	Years	GL	Population trend (%)	
						Observed	3GL
<i>Acroteriobatus annulatus</i>	Lesser Guitarfish	VU	trawl surveys	1991–2017	5	-87	-34.1 (-76.7, 62.7)
			angling surveys	1998–2017	5	26	16.7 (-26.3, 75.6)
<i>Dipturus pullopunctatus</i>	Slime Skate	LC	trawl surveys	1991–2017	11.5	71	110.1 (10.2, 288.6)
<i>Halaaelurus natalensis</i>	Tiger Catshark	VU	trawl surveys	1991–2017	20	-39	-56.5 (-97.3, 83.3)
<i>Haploblepharus edwardsii</i>	Happy Eddie	EN	trawl surveys	1991–2017	20	-59	-74.8 (-98.9, 36.2)
			angling surveys	1996–2017	20	-72	-92.3 (-99.6, -60.0)
<i>Haploblepharus fuscus</i>	Brown Shyshark	VU	angling surveys	1996–2017	20	-21	32.4 (-99.3, 550.6)
<i>Holohalaaelurus regani</i>	Izak Catshark	LC	trawl surveys	1991–2017	20	39	78.4 (-42.6, 199.4)
<i>Leucoraja wallacei</i>	Yellowspotted Skate	VU	trawl surveys	1991–2017	12	-37	-40.4 (-78.6, 32.4)
<i>Mustelus palumbes</i>	Whitespot Smoothhound		trawl surveys	1991–2017	14	15	26.7 (-36.8, 108.4)
<i>Pliotrema warreni</i>	Warren's Sixgill Sawhark	LC	trawl surveys	1991–2017	11	84	96.3 (-55.3, 405.4)
<i>Poroderma africanum</i>	Pyjama Catshark	LC	angling surveys	1996–2017	25	30	172.8 (-91.4, 702.0)
<i>Poroderma pantherinum</i>	Leopard Catshark	LC	angling surveys	1996–2017	18	64	332.6 (-87.4, 1425.1)
<i>Raja ocellifera</i>	Twineye Skate	EN	trawl surveys	1991–2017	9	-70	-65.5 (-89.2, -17.1)
<i>Scyliorhinus capensis</i>	Yellowspotted Catshark	NT	trawl surveys	1991–2017	21	-28	-36.3 (-93.4, 115.5)
<i>Squalus acutipinnis</i>	Bluntnose Spurdog	NT	trawl surveys	1991–2017	23.5	-12	-21.3 (-78, 95.5)

Species	Common Name	RL	Survey	Years	GL	Population trend (%)	
		Category				Observed	3GL
<i>Squalus bassi</i>	African Longnose Spurdog	LC	trawl surveys	1991–2017	23.5	124	146.3 (-33.7, 370.7)
<i>Triakis megalopterus</i>	Spotted Gully Shark	LC	angling surveys	1996–2017	20	64	117.7 (55.8, 195.7)

Table 3. Nine range countries in the SWIO+ region and their national conservation responsibilities for all 70 endemic shark and ray species across the region, where Red List statuses are known. Responsibility for each country is calculated based on the numbers of species occurring in the country's Exclusive Economic Zone (EEZ), the most recent Red List assessment category, and the proportion of each species' range area occurring in the EEZ (values were normalized to range from 0 to 1).

Country	National Conservation Responsibility
South Africa	1.000
Mozambique	0.442
Madagascar	0.407
Tanzania	0.057
Namibia	0.053
Kenya	0.014
Mauritius	0.002
Comoros	0.001
Seychelles	0.000

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Figures

Figure 1

Endemic species richness of (a) sharks and rays (n = 70), (b) threatened (Critically Endangered, Endangered or Vulnerable, according to the IUCN Red List Categories) sharks and rays (n = 13), (c)

threatened sharks (n = 8), and (d) individual distributions of threatened rays (n = 5) across the SWIO+ region.

Figure 2

Species population time-series (expressed as a proportion) modelled from demersal research trawl surveys in commercially fished areas (line) and shore-based research angling surveys (dashed line) off the west and south coasts of South Africa. Lines and dashed lines denote the mean, and shaded regions represent the 95% credible intervals. Time-series are divided by their initial values and start at one. Silhouette colours indicate Red List status: dark green is Least Concern, light green is Near Threatened, yellow is Vulnerable, orange is Endangered.

Figure 3

Count of reported threat categories in the 20 threatened (Critically Endangered, Endangered and Vulnerable) and Near Threatened SWIO+ shark and ray species.

Figure 4

Spatial and temporal change in density (ln kg per km²) between 20°E and 27°E longitude for 1991 and 2016 for (a) Lesser Guitarfish (*Acroteriobatus annulatus*; Vulnerable), (b) Bluntnose Spurdog (*Squalus acutipinnis*; Near Threatened), and (c) Twin-eye Skate (*Raja ocellifera*; Endangered).

Figure 5

Red List Index (RLI) for SWIO+ endemic sharks and rays (n = 70). (a) The decline in RLI across assessment years 1980, 2005, and 2020. Country-specific declines in RLI from (b) 1980–2005 and (c) 2005–2020. Calculations of RLI exclude Data Deficient (DD) species.

Figure 6

National conservation responsibility of nine range countries for all 70 endemic shark and ray species in the SWIO+ region for which Red List Status is known.