Title:
High overexploitation risk and management shortfall in highly traded requiem sharks

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ABSTRACT

While some sharks are subject to trade regulations, much of the international trade in fins (and likely meat too) is derived from requiem sharks (*Carcharhinus spp*). Here, we quantify catch, trade, and the shortfall in fisheries management (M-Risk) for 18 requiem shark species based on 230 assessments across 27 countries and four Regional Fisheries Management Organisations (RFMOs). Requiem sharks comprise one-third (~240,000 of 740,000 mt) of the annual global chondrichthyan catch and two-thirds (64%) of the fin trade of coastal sharks. They are inadequately managed, with an average M-Risk of 49% of an ideal score, consequently 71% of species are threatened globally. The high catch and trade volume and shortfall in management of these iconic species requires a global integrated improvement in fisheries management, supported by regulating international trade to sustainable levels.

1 | INTRODUCTION

The strength of management for internationally traded seafood is poorly understood. Most fisheries assessed as sustainable that target teleosts or sharks are in Regional Fisheries Management Organisations (RFMOs) and developed countries in North America, Europe as well as South Africa, Australia, and New Zealand (Hilborn et al. 2020; Simpfendorfer and Dulvy 2017). While fisheries subject to quantitative stock assessments remain the gold standard – it is unclear how well managed fisheries are elsewhere in the world.

Three approaches to infer fisheries status have been used to date: expert surveys (Melnychuk et al. 2017), counterfactual analyses of progress toward policy commitments (Juan-Jordá et al. 2018), and statistical analyses of macroeconomic and socioecological correlates of catch trends and abundance estimates (Davidson et al. 2016; MacNeil et al. 2020). Notwithstanding these promising approaches, it remains unclear the degree to which nation-by-nation fisheries management is adequate, especially in the face of international trade demand, particularly across the less developed countries of the world.

We focus on understanding fisheries management of sharks, rays, and chimaeras (Class Chondrichthyes, hereafter 'sharks') because they are highly threatened, in part due to international trade demand for meat, fins, gills, skins and livers (Dent and Clarke 2015; Niedermüller et al. 2021). However, the latest Red List assessment reveals many other families, notably tropical sharks and rays, are at a very high risk of extinction (Dulvy et al. 2021).

The requiem sharks (family Carcharhinidae) are a recent radiation found throughout the tropical coastal waters, with some pelagic species, which have historically dominated the shark catches of coastal fisheries (Lam and Sadovy de Mitcheson 2011). Indeed, this is one of seven priority shark taxa based on the high volume of fisheries catches taken in poorly documented and poorly regulated tropical multispecies fisheries (Dulvy et al. 2017). Further, many species of the family, and specifically the type genus of requiem sharks (*Carcharhinus;* D.A. Ebert pers. comm.), are highly prevalent in the international fin trade (Cardeñosa et al. 2020; Fields et al. 2018).

Here, we ask whether fisheries management is adequate to halt declines and reverse the status of the requiem sharks. We estimate the risk due to overexploitation based on the current state of global fisheries management for 18 species from the *Carcharhinus* genus using a novel rapid assessment of management risk (M-Risk) (Lack et al. 2014; Sherman et al. 2022). Specifically, we ask three questions: (1) are requiem sharks adequately managed across their geographic range?, (2) which (if any) species are adequately managed?, and (3) which forms of management are most prevalent and which are lacking?

2 | METHODS

2.1 | Selection of management units

Country management units were selected based on their proportional contribution to global shark catch, (2010–2019, inclusive) (FAO 2019). We include the 21 countries that cumulatively report >80% of global Chondrichthyan catch as well as the six countries with the highest catch in each FAO fishing region (total = 27). In addition to countries, all tuna Regional Fisheries Management Organisations (RFMOs) were included as management units due to the high volume of shark catch in Areas Beyond National Jurisdictions (Murua et al. 2021; Tolotti et al. 2015).

2.2 | Selection of species

Species of the genus *Carcharhinus*, hereafter requiem sharks, were chosen based on their inclusion in global trade, regardless of the products (e.g., meat, fins, skins) based on: (1) FAO global catch per species from the most recent decade 2010-2019, (2) the Sea Around Us project (Pauly et al. 2021), and (3) species composition at a shark fin market in Hong Kong (Fields et al. 2018) (*Carcharhinus* spp.: **Table S1**).

2.3 | M-Risk: Management risk assessment

Species assessments were completed by scoring management risk against 21 measurable attributes, as fully documented in Sherman *et al.* (2022). The 21 Attributes were split into five classes, three scored for all management units (2.3.1. Management System [*n*=5 Attributes], 2.3.2 Fishing Practises & Catch [*n*=5], 2.3.3. Compliance, Monitoring & Enforcement [*n*=5]) and two that were specific to either a country (2.3.5.; *n*=4) or RFMO (2.3.6; *n*=2).

2.3.1 | Management System

This group of five attributes considers the foundational requirements for a sustainable fishery. including: (1) whether there is a regulatory body (i.e., fishery department), (2) the presence and structure of fishing permits, (3) the existence and depth of stock assessments for target species, (4) the existence and outcome of a risk assessment for the species being assessed, and (5) efforts to reduce shark catch (if not targeted).

2.3.2 | Fishing Practices & Catch

These five attributes consider efforts to minimise fishing mortality through management of at-sea fishing operations. First, the landing limits attribute considers the taxonomic resolution of landing limits. Second, the post-release survival (PRS) attribute evaluates both the understanding of PRS for each species and regulations in place to increase PRS, thus reducing fishing mortality. Third, the high-value product attribute evaluates the effectiveness of finning regulations, as well as *Mobula* gill rakers and deep-sea shark livers. The last two attributes in this group consider the presence and purpose (i.e., for target species, sharks overall, or species-specific) of spatial and temporal closures in-place

2.3.3 | Compliance, Monitoring, & Enforcement

This class of five attributes considers how fishing activity is examined, including: the taxonomic resolution of reported catch, how catch is validated, and any additional compliance measures not considered in other attributes. One attribute evaluates the consideration of illegal, unregulated, and unreported (IUU) in management decisions. The last attribute considers enforcement methods including electronic surveillance, boarding of vessels by fisheries officers and port presence of fishery officers for monitoring of catch unloading, logbook validation, and checking for illegal and mis-sized catch.

2.3.4 | Country Attributes

These four attributes indicate the importance of sustainable fisheries to a country's government. Having a National Plan of Action for Sharks (Shark Plans) indicates a country's interest in ensuring sustainable fishing mortality for sharks, with higher scores awarded for more thorough Shark Plans. Two country-level attributes consider engagement with international treaties and agreements, with higher scores awarded to countries that are CITES members with no reservations on sharks in one and higher scores for member countries of CMS and/or MOU-Sharks signatories. The final attribute in this class evaluated the national spending on fisheries subsidies and the proportion of deleterious "capacity-enhancing" subsidies compared to beneficial subsidies.

2.3.5 | RFMO Attributes

This class of two attributes scored at the RFMO-level had similar intentions to the Country Attributes. The first considers the proportion of member countries involved in international

treaties and agreements (i.e., CITES and CMS). The second scored the implementation of Ecosystem Based Fisheries Management as per a 2017 study by Juan-Jordá et al.

2.4 | Scoring of Attributes

All attributes were scored in an ordinal manner with a narrow range of scores to ensure consistency (i.e., 0–3, 0–4, or 0–5) such that higher scores indicated management with a higher likelihood of sustainable outcomes (for full details see Sherman et al. 2022)). Assessments were completed through exhaustive internet searches and national fisheries department websites. Where English was not the official language, searches were completed in the official language and documents were translated using Google translate. To accommodate the potential for ambiguous translations, points were generously awarded. However, if no information for an attribute was found, a precautionary score of zero was given. The final 'Management Score' was expressed as a percentage of the total possible points. This score indicates progress towards the ideal management, therefore, a score greater than 75% could be considered a well-managed fishery for sharks.

2.5 | Additional Catch, Trade, and Species Data

Fin trade data were obtained from Table 2 of Cardeñosa et al. (2020). Sample totals from the Guangzhou shark fin market and Hong Kong retail markets were combined to estimate the full representative species list involved in international trade. Species were split into their primary habitat (coastal, pelagic, or deepwater) to determine the proportion of species from the *Carcharhinus* genus in each grouping.

To determine threat level of the *Carcharhinus* genus, the IUCN Red List Status of all species and species distribution maps were sourced after the 2021-03 update of the IUCN Red List website (www.iucnredlist.org), which was the final update from the Global Shark Trends reassessment of all 1,199 species as summarised here (Dulvy et al. 2021).

3| RESULTS

3.1 | What is the scale of catch and trade of requiem sharks (*Carcharhinus* spp)

This single genus likely comprises one-third of the global reported catch of all Chondrichthyans (approximately 736,000 mt per year (FAO 2019)). Based on the FAO global catch data from 2010–2019, inclusive, 89.4% of Chondrichthyan catch was reported only as Class (Chondrichthyes) or superorder (Selachimorpha). The *Carcharhinus* genus accounted for 12.5% of shark catch reported below Order, and 20.3% of reported coastal shark catch. *Carcharhinus* species comprise 32.8% of the fin trade in Guangzhou and Hong Kong (Cardeñosa et al. 2020). Assuming the taxonomically aggregated FAO data have the same species composition as these Chinese markets, then the potential unknown global catch of *Carcharhinus* spp. amounts to 236,143 metric tonnes per year.

3.2 | Are requiem sharks adequately managed across their geographic range?

Requiem sharks (genus *Carcharhinus*) are inadequately managed worldwide, both by nations and RFMOs and are distributed globally with hotspots in northern Australia and Southeast Asia (**Figure 1a**). Across 230 M-Risk assessments from 27 countries spanning all six inhabited continents and four RFMO fishing grounds, the average management risk was high (49.2%), with only half of the necessary management in place for requiem sharks. Regionally, the management shortfall for requiem sharks was greatest in Africa (mean management score 34.6% ± 1.8) and Asia (39.3% ± 0.8; **Figure 1b,c**). Both regions were much lower than the remaining regions: North America (66.8% ± 4.0), Oceania (65.8% ± 3.1), Europe (62.2% ± 1.3), and South America (56.1% ± 1.1). The four RFMOs had an average score of (60.1% ± 0.3), similar to that of the countries in the better managed regions of the world (**Figure 1b,c**).

Some of the biggest fishing nations of the world have the lowest fisheries management scores. The countries with the lowest average management score of requiem sharks were Nigeria (21.9% ± 10.1), India (27.2% ± 1.6), Taiwan (30.9% ± 2.0), and Yemen (31.7% ± 7.2) (**Figure 1b,d**). These countries are all among the top 10 shark catching countries globally (Okes and Sant 2019). Much of their catch is exported through non-standardized commodity codes, masking catch details (Shea and To 2017). The countries with the highest scores, and assessments on more than 3 species, were the USA (78.7% ± 7.1), Australia (73.7% ± 3.8), Spain (67.3% ± 7.0), and Brazil (60.4% ± 4.3), respectively (**Figure 1b,d**). Interestingly, these

four countries represent four different continents, indicating there are ‘pockets’ with better management scores (above 60%) for requiem sharks on each continent.

3.2 | Which species are adequately managed?

Strictly speaking any species with an M-risk score of less than 100% is likely to be undermanaged, by that criterion, all species are undermanaged. The species with the highest mean management score are Blacknose Shark (*C. acronotus*: 61.7% ± 7.0), Smalltail Shark (*C. porosus:* 58.8% ± 4.1) and Australian Blacktip Shark (*C. tilstoni:* 58.0% ± 8.4) (**Figure 2**). All three of these species have relatively small distributions when compared to many of the requiem sharks assessed. The first two species occur in the Western Central and Southwest Atlantic Ocean and are both threatened according to the IUCN Red List (Endangered-EN and Critically Endangered-CR, respectively). The Australian Blacktip Shark is endemic to the country with one of the highest average management scores, and is Least Concern (LC). However, status is a function not only of management, but also total catch volume, therefore, in regions with higher fishing effort and catch, like the Western Atlantic (Bell et al. 2017), even higher management scores are not currently effective at ensuring sustainable catch levels for these species.

The lowest scoring species (i.e. the *least* managed) were the Smoothtooth Blacktip Shark (*C. leiodon:* 39.5% ± 6.7), followed by the Blacktip Reef Shark (*C. melanopterus*: 40.1% ± 3.2), and Whitecheek Shark (*C. dussumieri:* 40.9% ± 4.2) (**Figure 2**). All three of these species are listed in threatened categories (EN, Vulnerable-VU, and EN, respectively), and they occur in the heavily fished waters of the Western Pacific and Indian Oceans (Blaber et al. 2009; Pauly et al. 2021).

The variation between the highest and lowest management scores were 21.9% for all six species in Nigeria and 85.0% for Copper Shark (*C. brachyurus*) in the USA, indicating highly variable management for species (over 60%). When considered as an average management score for species, there is just over a 20% difference in management of the highest and lowest scoring requiem sharks, indicating a mixture of good and bad management across a species’ distribution.

3.3 | Which aspects of management are most prevalent and lacking?

Across all assessed management units, the attributes with the highest average scores were lower resolution structural attributes, related to general fisheries management, such as: if a regulatory body was present (95.2% ± 2.8), the country's engagement with CITES (93.9% ± 2.9) or Ecosystem Based Fisheries Management (EBFM) for the RFMOs (91.7% ± 3.0), followed by IUU management (82.8% ± 5.1) (**Figure 3a**). Attributes with lower average scores were the harder to implement, species-specific fisheries operational attributes including: understanding of the species' stock status (17.6% ± 5.1), taxonomic resolution of landing limits in place or if any limits existed (23.0% ± 5.2), and species-specific compliance measures to reduce fishing mortality (26.9% ± 4.3) (**Figure 3a**). These attribute scores indicate that while countries and RFMOs have the foundations in-place to incorporate management, this is not yet being directed towards significant catches of threatened species, like the requiem sharks. The pattern of attribute scoring of species was similar to that for management units, with greater scores for structural attributes and lower scores for fisheries operational attributes (**Figure 3b**). For some species, like the CITES listed Oceanic Whitetip and Silky Sharks (*C. longimanus* and *C. falciformis*), landing limits existed more often, and at higher resolution than the average requiem shark (60.1% ± 9.1 and 41.9% ± 9.8, respectively, vs. 20.1% ± 3.5 for all requiem sharks).

4 | DISCUSSION

We have three key findings. First, the global catch of requiem sharks is one-third of the global reported catch of all sharks, rays, and chimaeras (~240,000 of 730,000 mt/yr). Second, we estimate that requiem sharks comprise one-third of the trade volume of coastal sharks. Third, the management risk scores for 18 species of requiem sharks from 27 nations and four RFMOs demonstrate they are undermanaged with only half of the ideal management in place. M-Risk is lower in Africa and Asia and higher in Oceania, but there are better managed countries found on each continent, representing pockets of hope. Taken together these three catch, trade, and management shortfall issues have resulted in high levels of overfishing of the *Carcharhinus* genus and an elevated risk of extinction. We next consider the following issues (1) how to improve domestic management, (2) improving global fisheries management, (3) the emerging opportunity that trade regulation presents, and (4) the benefits of trade regulation of requiem sharks.

Globally, requiem sharks have minimal species-specific fisheries regulations, including a lack of landing limits, and catch reporting generalised to the genus, class, or often not reported at all. The recognition that many shark species, including requiem sharks, are threatened by overfishing, has resulted in increasing national and international efforts to improve their management, but there is little evidence that these efforts have been able to address the issue in a significant way (Davidson and Dulvy 2017). In addition to a lack of domestic measures, documentation meant to ensure internationally traded species are caught in a sustainable manner, like catch documentation schemes, are not used for requiem sharks (Mundy-Taylor et al. 2014). Domestic and international regulations have increased in the past decade for shark finning, the act of removing fins and discarding the body at sea (Ferretti et al. 2020; Lawson and Fordham 2018), but appear to have had little effect on reducing the volumes of fins traded. In addition to the fin trade, there has been a recent increase in the international shark meat trade (Dent and Clarke 2015; Liu et al. 2021). This may be adding to demand and, therefore, incentive for fishers to land sharks, thus additional constraints are urgently needed to ensure catches are sustainable.

Globally widespread species of sharks are subject to fragmented management, requiring a coherent response (Dulvy et al. 2017). The wide-ranging requiem sharks suffer from a patchwork of management and might have lower extinction risk only if a significant part of their range lies within the waters of better managed countries like Australia and the USA, e.g., Blacktip Reef Shark, which is well-managed in Australia, but less so in other parts of its range. Smaller range species may be at very high risk of extinction if a significant fraction of their range lies in countries with moderate to high management risk, such as the Smoothtooth Blacktip Shark. The broad distributions of many species, and the large volume of requiem sharks in the global trade means the need for well-managed fisheries is pertinent to all range states. Traded shark products often travel through several different countries being aggregated at regional entrepôts before moving to the final destination for processing and reimport and finally sold to the general public. This results in issues of traceability and species identification (Haque and Spaet 2021; Niedermüller et al. 2021). The onus should be on both importers and exporters to ensure traded products are fished sustainably and legally acquired. Introducing national and/or fishery landing limits for requiem sharks would have a further reaching benefit, due to the volume of this species group in international trade. These types of measures can only be regulated at a domestic scale, making them difficult to implement due to the area covered by fishing operations. However, this must be completed coherently in all countries to ensure future sustainability of requiem shark catches. There is an immediate need for global cooperation in the monitoring, sustainable catch, and trade of these species, which can be achieved through international agreements such as CITES, CMS, and adherence to the FAO Guidelines for Responsible Fish Trade.

Listing species on Appendix II of CITES ensures that specimens cannot be traded unless they are legally acquired and from a sustainable fishery (i.e., have a positive Non-Detriment Finding (NDF))(Fernando et al. 2022). However, a lack of global standards and requirements for NDFs, in addition to the lack of consideration of cumulative effects across the full range of a species, may reduce the usefulness of NDFs. The development of tools to assess whether a fishery is detrimental or otherwise has driven investment in monitoring and management of CITES Appendix II listed sharks and rays. There are promising signs of progress, even though measuring effectiveness is challenging and the listings have been comparatively recent relative to the long generation lengths and recovery times of sharks and rays (Friedman et al. 2018). Appendix II CITES listings have led to detectable progress in governance, particularly in major shark fishing nations like Indonesia and Malaysia (Friedman et al. 2018). Implementation of

listings resulted in reduced catch and trade of manta rays (*Mobula alfredi* and *M. birostris*) in Tanjung Luar, Indonesia (Booth et al. 2020). Here, we identify lower management risk scores for the CITES-listed Oceanic Whitetip and Silky Sharks (*C. longimanus* and *C. falciformis*), landing limits existed more often, and at higher resolution than the average requiem shark (60.1% ± 9.1 and 41.9% ± 9.8, respectively, vs. 20.1% ± 3.5 for all requiem sharks). For less easily identifiable species, like the requiem sharks, their trade from Indonesia, the top shark catching country in the world, is reported to Family, combining all Carcharhinidae, which contribute 51% to shark production (Prasetyo et al. 2021). This broad level of reporting may be masking serial depletions. However, both the obligations, created through CITES listing, to have species-specific positive NDFs, and to report species-specific trade data would greatly improve our ability to discern species-specific fishing mortality using trade volume data (Janssen and Leupen 2019). Evidence of improved species status after CITES listings is minimal, but has been observed for mammals (Mialon, 2022 #8457). However, in some cases, anticipation of CITES listing and ratification may spur traders to increase trade volume prior to the need for an NDF (Mialon et al. 2022). Despite this initial increase, regulations moving forward would allow for species control and recovery, therefore, long-term sustainability is only possible through immediate action.

Policy relevance

Requiem sharks are heavily fished and traded, with at least 23 species of the genus *Carcharhinus* and at least 39 species of the family Carcharhinidae documented in fin clippings in Hong Kong and Guangzhou markets in China (Cardeñosa et al. 2020). Most requiem sharks are threatened and indeed the whole family Carcharhinidae is in the top ten most threatened families of sharks and rays, with two-thirds (68.4% 39 of 57) of species threatened. The genus *Carcharhinus* is the largest of the Family with 35 species, of which nearly three-quarters (71.4%, *n*=25) are threatened [IUCN: CR(PE), CR, EN, VU] (Dulvy et al. 2021). Here, we show that this high level of threat, from overfishing and unregulated international trade, results from a shortfall in national and international management. We conclude that listing requiem sharks on CITES Appendix II provides a mechanism for tackling the management deficits for requiem sharks.

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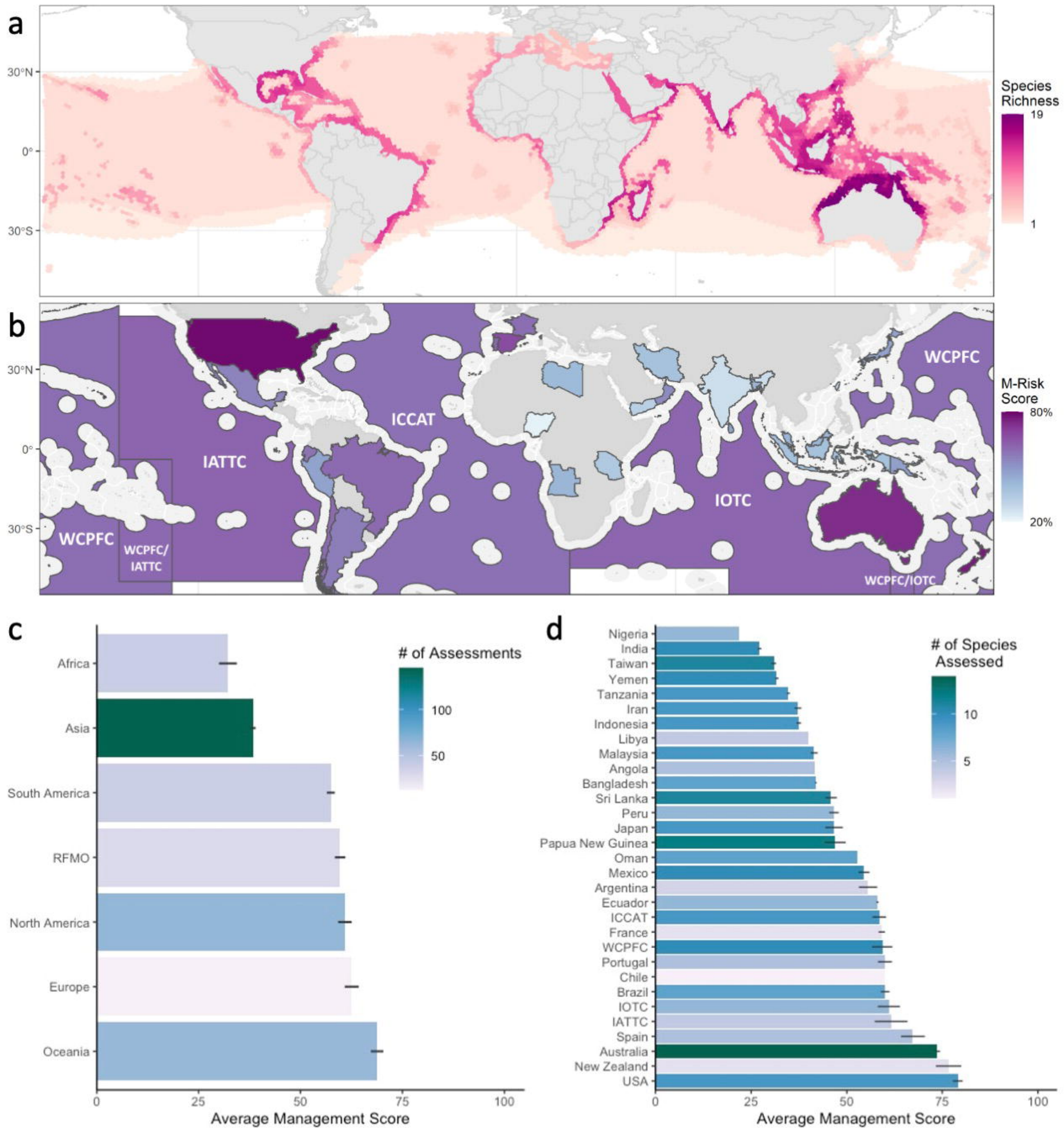
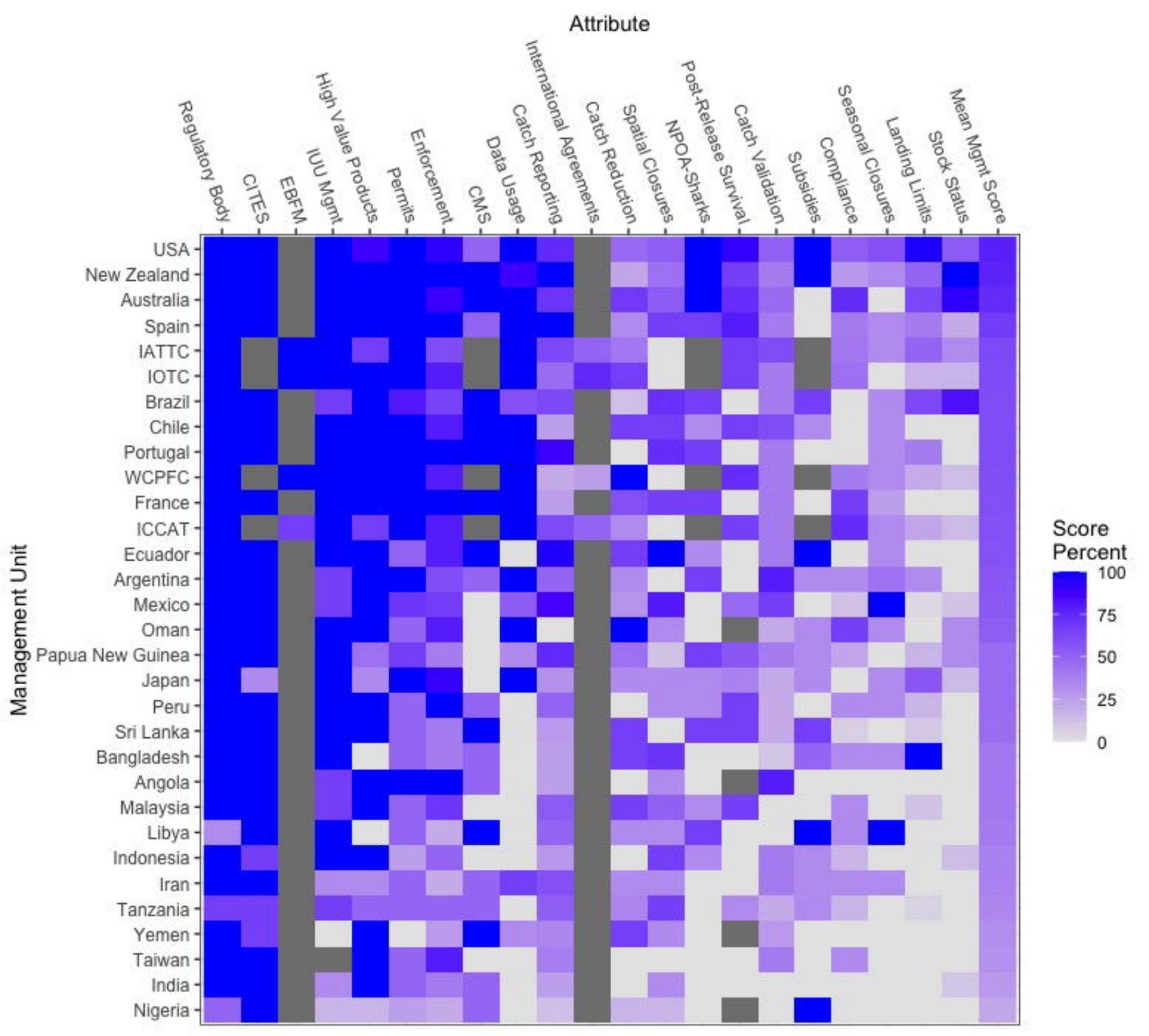
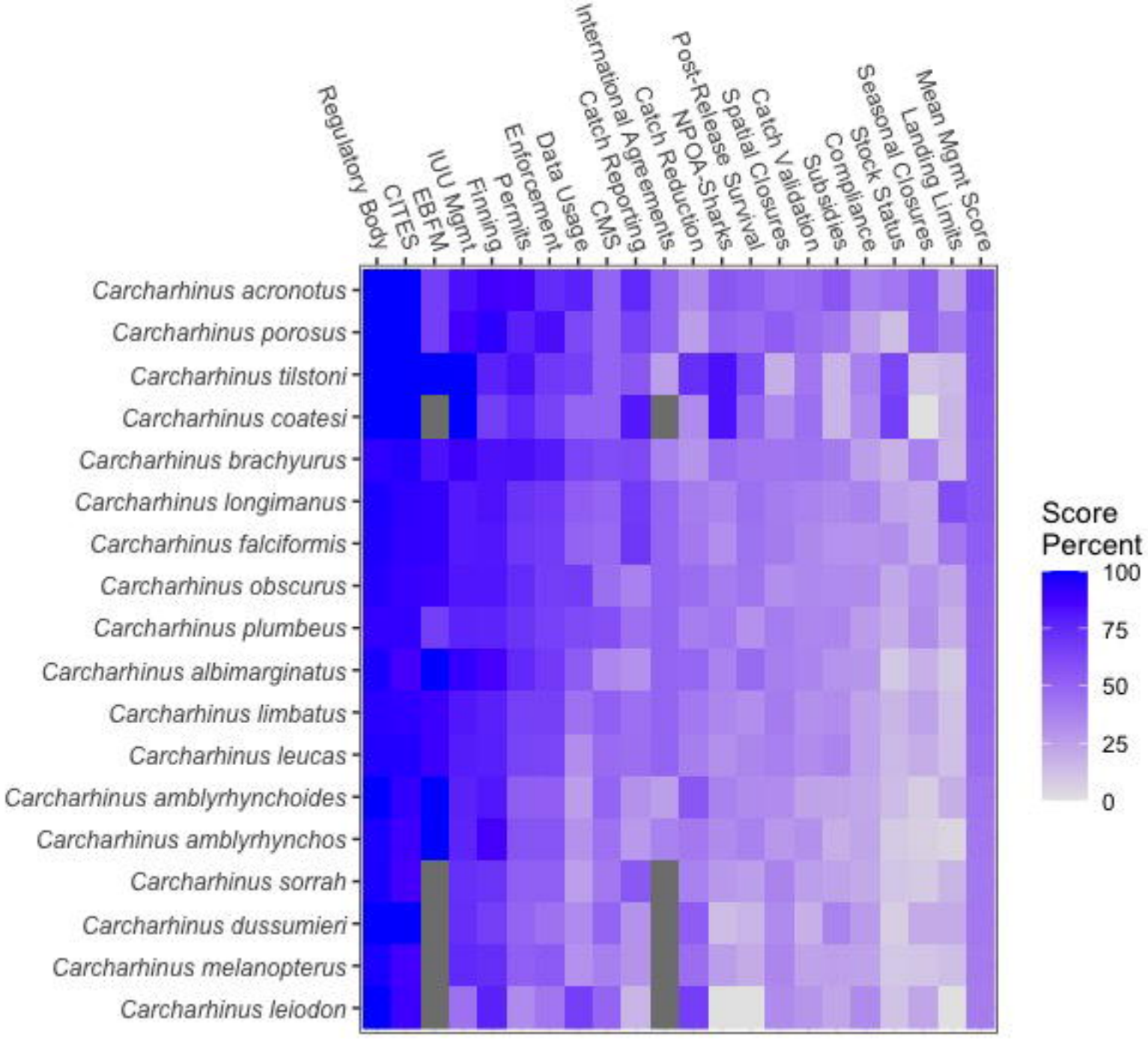

a
30°N
0°
30°S
Species Richness
19
1
b
30°N
0°
30°S
WCPFC
ICCAT
IATTC
IOTC
WCPFC
WCPFC/ IATTC
WCPFC/IOTC
M-Risk Score
80%
20%
c
Africa
Asia
South America
RFMO
North America
Europe
Oceania
# of Assessments
100
50
0
25
50
75
100
Average Management Score
d
Nigeria
India
Taiwan
Yemen
Tanzania
Iran
Indonesia
Libya
Malaysia
Angola
Bangladesh
Sri Lanka
Peru
Japan
Papua New Guinea
Oman
Mexico
Argentina
Ecuador
ICCAT
France
WCPFC
Portugal
Chile
Brazil
IOTC
IATTC
Spain
Australia
New Zealand
USA
# of Species Assessed
10
5
0
25
50
75
100
Average Management Score

Carcharhinus leiodon
Carcharhinus melanopterus
Carcharhinus dussumieri
Carcharhinus sorrah
Carcharhinus amblyrhynchos
Carcharhinus amblyrhynchoides
Carcharhinus leucas
Carcharhinus limbatus
Carcharhinus albimarginatus
Carcharhinus plumbeus
Carcharhinus obscurus
Carcharhinus falciformis
Carcharhinus longimanus
Carcharhinus brachyurus
Carcharhinus coatesi
Carcharhinus tilstoni
Carcharhinus porosus
Carcharhinus acronotus
# of Management Units Assessed
20
10
0
25
50
75
100
Average Management Score


Attribute
Regulatory Body
CITES
EBFM
IUU Mgmt
High Value Products
Permits
Enforcement
CMS
Data Usage
Catch Reporting
International Agreements
Catch Reduction
Spatial Closures
NPOA-Sharks
Post-Release Survival
Catch Validation
Subsidies
Compliance
Seasonal Closures
Landing Limits
Stock Status
Mean Mgmt Score
Management Unit
USA
New Zealand
Australia
Spain
IATTC
IOTC
Brazil
Chile
Portugal
WCPFC
France
ICCAT
Ecuador
Argentina
Mexico
Oman
Papua New Guinea
Japan
Peru
Sri Lanka
Bangladesh
Angola
Malaysia
Libya
Indonesia
Iran
Tanzania
Yemen
Taiwan
India
Nigeria
Score Percent
100
75
50
25
0


Regulatory Body
CITES
EBFM
IUU Mgmt
Finning
Permits
Enforcement
Data Usage
CMS
Catch Reporting
International Agreements
Catch Reduction
NPOA-Sharks
Post-Release Survival
Spatial Closures
Catch Validation
Subsidies
Compliance
Stock Status
Seasonal Closures
Landing Limits
Mean Mgmt Score
Carcharhinus acronotus
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Carcharhinus amblyrhynchoides
Carcharhinus amblyrhynchos
Carcharhinus sorrah
Carcharhinus dussumieri
Carcharhinus melanopterus
Carcharhinus leiodon
Score Percent
100
75
50
25
0