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Prioritizing global genetic capacity building assistance to implement CITES shark and ray listings

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ABSTRACT

The global demand for shark and ray products has fuelled a lucrative international trade, driving large population declines as a consequence. This high-volume trade exceeds the capacity of nations to monitor their trade and enforce international trade regulations, leaving them susceptible to international trade sanctions. Here, a multi-criteria decision analysis was used to examine global trade levels and regulatory controls associated with the world's shark and ray trade to prioritize international genetic capacity building assistance to implement the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II shark and ray listings. A total of 76 nations were identified as priority nations to collaborate in a genetic implementation program. Improving the capacity of nations to detect CITES Appendix II shark and rays bound for international markets using a genetic program can aid as an additional tool to enhance trade-monitoring and enforcement efforts to improve the conservation and management of commercially important and threatened shark and ray populations.

1. Introduction

The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) is a major international agreement between governments that bans the international trade of species that are threatened with extinction and affected by trade (Appendix I), and regulates the international trade of species that may become threatened with extinction unless trade is subject to strict regulations to avoid utilization that is incompatible with their survival (i.e., Appendix II [1,2]). Since 1973, CITES has listed over 35,000 wild species with the vast majority listed under Appendix II.

Since 2001, twelve shark species as well as all rays in the genus *Mobula* have been listed in Appendix II (*Cetorhinus maximus* [2001], *Rhincodon typus* [2001], *Carcharodon carcharias* [2004], *Lamna nasus* [2013], *Carcharinus longimanus* [2013], *Sphyrna lewini* [2013], *S. mokarran* [2013], *S. zygaena* [2013], *Mobula birostris* [2013], *M. alfredi* [2013], *C. falciformis* [2016], *Alopias superciliosus* [2016], *A. pelagicus* [2016], *A. vulpinus* [2016], *Mobula* spp. [2016]). CITES has become a key policy tool to ensure the legal and sustainable trade of these species [1], and there is momentum by parties to list more elasmobranchs under Appendix II, with 20 species being listed in the last six years. However, recent evidence suggests low compliance and reporting by CITES parties, possibly due to a lack of capacity to monitor and enforce these new shark trade regulations [3]. Moreover, the reporting, monitoring and enforcement requirements continue to increase as new CITES regulations become effective where nations are now required to identify the movement of shark products by species. For example, silky shark (*C. falciformis*), the second most common shark species in trade, was listed to Appendix II in October 2017, requiring nations to gather silky shark-specific landings and trade data, despite the lack of capacity to effectively do so [3].

Accurate species-specific data of landings and traded products is urgently needed to enforce CITES shark and ray listings to allow better quantification of catch and trade trends, and to provide more robust stock assessments, which are essential for sustainable fisheries management [4]. In order to improve enforcement at different governance levels, visual identification techniques (e.g., fin comparisons, morphometrics, distinguishable features) have been traditionally used to identify sharks and rays to species level when handled (e.g., dead or alive; [5], but these methods are often difficult to use when identifying sharks that have been landed without their fins attached, headless, or processed [5]. As a result, genetic techniques (e.g., DNA barcoding,

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species-specific assays, RNA sequencing) are increasingly being used to identify sharks or rays to the species level during any stage of the supply chain [6–10].

However, utilization of genetic techniques by CITES parties has been complicated due to lack of funding and expertise in most developing nations. Molecular techniques are a key tool for CITES parties and border control agents, in order to successfully enforce CITES regulations and avoid international trade sanctions [1]. Recently, a reliable, mobile, fast (< 4 h), and cost effective multiplex real-time PCR protocol was developed [11]. This novel technique is capable of detecting nine of the twelve sharks listed under CITES in a single reaction and presents new opportunities for CITES parties to enhance their enforcement and monitoring capabilities of processed and unprocessed products of past and future shark and ray listings [11].

The CITES Secretariat encourages capacity building and the transfer of knowledge and expertise between the parties to "efficiently, reliably and cost-effectively identify shark products in trade" (SC69 Doc. 50), including genetic methods such as the one described above. Therefore, the main objective of this study was to objectively identify and prioritize which CITES and FAO Parties (i.e., those that participate in shark and ray trade and are a CITES party) could benefit the most from receiving genetic capacity building assistance to implement the CITES Appendix II shark and ray listings by creating international partnerships and coordinated research.

2. Methodology

A Multi-Criteria Decision Analysis (MCDA [12]) was used to assess the importance of shark trade and the amount of regulation, monitoring, and control policies (hereafter RMCs) set in place for countries that both participate in CITES and/or have submitted shark trade statistics to the FAO (n = 129). Nine nations included in the analysis reported FAO shark landings but are not CITES parties (Cook Islands, Falkland Islands, Faroe Islands, French Polynesia, Nauru, Taiwan, Tonga, Kiribati, and Zanzibar). In the trade category, there were 24 attributes considered and in the RMCs category there were 21 (Table 1). For the trade category, attributes to be included were justified as those most important to shark trade and a country's reliance on agriculture including population size. With the exception of the Falkland Islands, nations that are more dependent on agriculture, as a percent of their GDP, have lower per capita income. Therefore, nations that have both a high agriculture dependence and low per capita income are two main metrics that justify nations that need more financial assistance. Population size was included because it was assumed that larger populations are likely to be involved in more extensive trade. Attributes in the RMCs category included different categories such as the nation's enforcement, environmental, and research agencies, regulatory and policy capacity, regional fishery management organization (RFMO) participation, and societal stability. For the latter, attributes such as proximity to assistance (i.e., financial, expertise, or equipment) was assessed based on proximity to Washington, D.C., one of the top locations in the world for global capacity building work, including providing nations with tools to enhance their ability to increase monitoring and data collection. The remaining attributes in the stability category included the percent of the population's access to internet where a low percent is assumed to represent an underdeveloped nation.

Scores of the 24 attributes for each nation in the trade category were calculated when each nation's individual attributes were taken as a percentage of the highest nation for that attribute; the nation with the highest value for that attribute was scored a 1. In other words, attributes were designated as relative (i.e. relative to the highest nation for that category). Using this approach, the summation of all 24 attributes for each nation were then ranked to allow an objective hierarchical rank (i.e., score) for each nation for that category. For the RMCs category, nations were scored mostly on the summation of attributes designated as absolute (i.e., present = 1 or absent = 0). The absolute scale was used in the RMCs category to reflect whether or not a nation had specific policies in place to manage their shark catch and/or trade. After scores were generated for the RMCs category for all CITES/FAO nations, they were classified using natural breaks [Jenks] classification scheme, in order to minimize variance within groups, but maximize variance between groups to differentiate nation groupings. Thereafter, in order to prioritize nations with the greatest need for genetic capacity building assistance to implement the CITES Appendix II shark and ray listings, nations in the highest class for the RMCs category (n = 32) were removed because these nations (e.g., the top 5: United Kingdom, United States, France, Canada and Japan) have a significant number of resources and therefore were assumed to not need financial assistance to implement the CITES shark and ray listings. Additionally, remaining nations were classified, using quantile classification scheme, to create equal groupings due to extreme outliers of relative annual per capita income (i.e., high $124,000 USD/yr, low $700 USD/yr). Nations in the top class were removed (n = 20; > $23,000 USD/yr), under the assumption that nations with higher per capita income have greater resources and a lower priority for capacity building assistance. After filtering, the final scores of the nations were plotted in R, ordered from high to low based on trade index, using the ggplot2 package.

3. Results

The MCDA ranked 76 nations based on priority to receive genetic capacity building assistance to implement the CITES Appendix II shark and ray listings (Supplementary Material 1). These nations represent nearly half of the shark fin product export market (49.8%), represent the smallest economies in the world (166,762,323.6 to 2.34×10^{12} USD) with the lowest per capita yearly income (average $8,091.33 USD/year), hold large population sizes (e.g. India, Indonesia, Brazil), and have the highest dependence on agriculture as a means to make a living (average: 16.8% agriculture to gross domestic product). In addition, international trade represents a large sector of the gross domestic product for identified nations, with 47% of the nations drawing greater than 20% of their GDP (Table 2). When examining historic chondrichthyan landings, identified nations represent nearly half of all landings reported to FAO from 1950 to 2013, more than half of non-species-specific shark landings, and nearly half of historic identified CITES species landed, yet only one nation (Morocco) has a supply chain program, defined as the commercial network between the production site and the final consumer, and 25% have implemented a shark finning ban (n = 10). However, when examining participation among top tuna RFMOs, identified nations record varied participation (ICCAT: 31 nations; IATTC: 13 nations; CCSBT: 1 nation; IOTC: 20 nations; WCPFC: 15 nations).

Of the 76 nations identified, both the current and historic shark trade data suggest the top 20 hold the greatest investment (i.e., shark product production) and dependence (i.e., import/export) on the shark fin and meat product trade market (Fig. 1; Table 3). In addition, these nations have the highest trade and regulatory control indices (Table 3) but also account for the majority of total shark landings (6,919,533 t vs. 3,219,556 t), non-species-specific landings reported (523,834 t vs. 290,909 t), and CITES species harvested (5,663 vs. 4,105 t). The top 20 nations also include four re-export nations (e.g., Sri Lanka, Mauritius, Fiji, Vanuatu) and hold broad participation in the major RFMOs. More than half of these nations have instituted shark finning bans (n = 13; Argentina, Belize, Brazil, Chile, Costa Rica, Honduras, India, Namibia, Nicaragua, Panama, Peru, Sri Lanka, Vanuatu), yet none have a chain of custody program.

4. Discussion

A MCDA was used to prioritize capacity building assistance among CITES and FAO cooperating Parties to implement the CITES Appendix II shark and ray listings using genetic identification techniques. The rank-

Table 1
Trade and regulatory criteria used in multi-criteria decision analysis (MCDA).

Trade Attribute	Attribute Type (Relative (highest entity)/Absolute)	Title and Source (URL)	Date Accessed (MM/DD/YYYY)
International Trade (% GDP)	Relative (Singapore)	UNDP International Human Development Indicators (http://hdr.undp.org/en/countries)	9.24.2015
Value Shark Trade Import (USD)	Relative (Singapore)	FAOSTAT FishStatJ (http://www.fao.org/fishery/statistics/software/fishstatj/en)	9.28.2015
Value Shark Trade Export (USD)	Relative (Singapore)		
Quantity Shark Trade Import (Tons)	Relative (Italy)		
Quantity Shark Trade Export (Tons)	Relative (Taiwan)		
Quantity Shark Production (Tons)	Relative (Taiwan)		
Re-export Nation since 2010	Absolute		
Total Fin Import (Tons)	Relative (China)		
Fin Import Since 2010 (Tons)	Relative		
Total Meat Import (Tons)	Relative (Italy)		
Meat Import Since 2010 (Tons)	Relative		
Total Other Product Import (Tons)	Relative (Korea)		
Other Product Import Since 2010 (Tons)	Relative		
Total Fin Export (Tons)	Relative (Thailand)		
Fin Export Since 2010 (Tons)	Relative		
Total Meat Export (Tons)	Relative (Spain)		
Meat Export Since 2010 (Tons)	Relative		
Total Other Product Export (Tons)	Relative (Portugal)		
Other Product Export Since 2010 (Tons)	Relative		
Import or Export Since 2010 CITES Species (Tons)	Relative (Spain)		
Percent Agriculture of Gross Domestic Product	Relative (Falkland Islands)	The World Factbook CIA (https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html)	10.14.2015
Population Size (millions)	Relative (China)	The World Factbook CIA (https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html)	10.14.2015
Exclusive Economic Zone (m^2)	Relative (United States)	ArcGIS v.10.4 World EEZs shapefile	9.28.2015
Length of coastline (Km)	Relative (Canada)	ArcGIS v.10.4 GSHHG v2.3.4 shapefile	9.28.2015

Regulatory and Monitoring Controls	Attribute Type (Relative (with highest entity)/Absolute)	Title and Source (URL)	Date Accessed
Fisheries Ministry Environment Ministry Customs Fisheries Legislation/Enforcement University Research Genetics/Fisheries International Research Collaboration Shark Chain of Custody Program Shark Quota/Fishing Ban Shark Finning Ban Shark Plan complete, draft, in progress Data collection protocols	Absolute	1. FAO CountryStat (http://www.fao.org/countryprofiles/en/) 2. Agricultural Science and Technology Indicators (http://asti.cgiar.org/) 3. United States Department of State List of Countries (http://www.state.gov/misc/list/index.htm) 4. FAO National and Regional Plans of Action (http://www.fao.org/fishery/topic/18123/en) 5. FAO Geographic Information (http://www.fao.org/fishery/geoinfo/en)	10.14.2015
Physical Distance between Country and U.S. Capitol	Relative (Singapore)	ArcGIS v.10.4 using geographic coordinates (http://www.csgnetwork.com/llinfotable.html)	10.14.2015
Participation in International Commissions for the Conservation of Atlantic Tunas	Absolute	International Commission on the Conservation of Atlantic Tuna (http://www.iccat.int/en/)	10.13.2015
Participation Inter-American Tropical Tuna Commission	Absolute	Inter-American Tropical Tuna Commission (http://www.iattc.org/HomeENG.htm)	10.13.2015
Participation in Commission for the Conservation of Southern Bluefin Tuna	Absolute	Commission for the Conservation of Southern Bluefin Tuna (www.ccsbt.org/site/)	10.13.2015
Participation in Indian Ocean Tuna Commission	Absolute	Indian Ocean Tuna Commission (http://www.iotc.org/)	10.13.2015
Participation in Western Central Pacific Fisheries Commission	Absolute	Western Central Pacific Fisheries Commission (http://www.wcpfc.int/)	10.13.2015
Human Development Index	Absolute	UNDP International Human Development Indicators (http://hdr.undp.org/en/countries)	9.24.2015
Gross Domestic Product in 2014 or 2013	Relative (United States)	The World Bank (http://data.worldbank.org/indicator/NY.GDP.MKTP.CD/countries?display=default)	10.5.2015

(*continued on next page*)

Table 1 (*continued*)

Regulatory and Monitoring Controls	Attribute Type (Relative (with highest entity)/ Absolute)	Title and Source (URL)	Date Accessed
Average per capita income in 2014	Relative (Qatar)	USAID (https://results.usaid.gov/)	10.14.2015
Percent of the Population with Internet access in 2014	Absolute	The World Factbook CIA (https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html)	10.14.2015

order of nations was based on past and present levels of trade activity, regulatory capacity, and need for financial assistance. Nations or entities were not identified as a priority if not a CITES Party (e.g., Taiwan, Falkland Islands, Faroe Islands, Cook Islands, French Polynesia, Kiribati, Nauru, and Tonga), despite having submitted shark landings and trade data to the FAO, or if determined that programs and policies are already in place (e.g., European Union countries, U.S.A., Canada, etc.) or could be initiated without outside financial assistance and guidance (e.g., Qatar, Bermuda, Singapore, etc.). While these nations were not identified to receive financial assistance, they represent the largest shark product trade markets and fleets targeting sharks and rays in the world (e.g., Hong Kong, Singapore, Taiwan), and therefore signify where species-specific shark landing and trade data is most needed to ensure long-term conservation and management of CITES Appendix II listed sharks and rays [13]. Nevertheless, most of the countries with the capacity to initiate stronger border controls using genetic tools, and therefore excluded from genetic capacity building priority list, do not currently implement such controls. It is possible that while financial assistance was not prioritized for these nations, expert and technical consultation may help initiate regulatory and trade controls. The basis of the idea developed in this manuscript is to prioritize where governments and/or entities can allocate financial resources, and expert help, to those nations that have the biggest hurdle to overcome to begin to monitor for CITES appendix II species in trade. Nations with financial resources and that have larger economies are not necessarily low hanging fruit. There may be larger bureaucratic hurdles to overcome with those nations while the poorer nations would allow for a swifter implementation of basic programs and policies to begin to tackle the

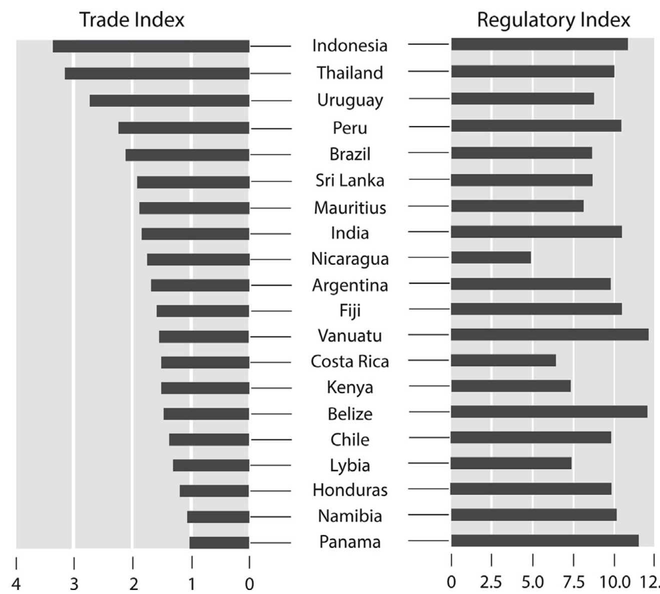

Fig. 1. Shark product trade and regulatory indices are plotted to provide a nation-based prioritization to implement genetic capacity building and the CITES Appendix II shark and ray listings. Nations are ranked according to relative level of shark product trade activity.

Table 2
Historic (1976–2013) and current (since 2010) shark product production, import, and export quantities for the 76 nations identified using the multi-criteria decision analysis.

Country	Quantity Shark Trade Production Fin/Meat/ Other (Tons)	Total Fin Import (Tons)	Fin Import since 2010 (% of Total)	Total Meat Import (Tons)	Meat Import since 2010 (% of Total)	Total Fin Export (Tons)	Fin Export since 2010 (% of Total)	Total Meat Export (Tons)	Meat Export since 2010 (% of Total)
Indonesia	17553/39759/0	2216	15.3	1053	31.9	24961	15.9	48158	6.8
Thailand	13805/0/0	4265	3.7	8873	16.9	39075	38.1	3968	40.6
Uruguay	395/55664/46	0	0	98927	34.2	627	3.5	91091	29.7
Peru	37501/0/0/	243	60.9	22228	40.6	2359	17.3	8168	21.4
Brazil	2338/0/0	8	0	146309	27.9	4109	2.6	1148	2.2
Sri Lanka	1968/19726/0	0	0	390	7.2	13393	0	164	15.9
Mauritius	0	0	0	1029	30	345	9.3	0	0
India	23499/0/0	6	0	122	67.7	5044	4.6	1201	15.2
Nicaragua	0	0	0	142	99.3	0	0	1001	33.9
Argentina	2718/0/0	0	0	25	0	336	39.3	63551	30.8
Fiji	1270/1100/0	0	0	520	0	302	0	1865	4.5
Vanuatu	0	3	0	0	0	0	0	1	0
Costa Rica	0	0	0	19162	14.4	1845	9.6	51651	6.2
Kenya	0	0	0	49	100	0	0	326	0
Belize	0	0	0	0	0	0	0	156	0.6
Chile	13070/0/0	0	0	409	0	253	1.6	42099	8.5
Libya	0	0	0	85	100	0	0	0	0
Honduras	0	0	0	87	70.1	0	0	4	0
Namibia	0	0	0	4236	0.3	0	0	18659	35.6
Panama	0	0	0	353	9.1	0	0	47736	1.9
Top 20 Nations	114117/116249/46	6741	8.9	303999	28.7	92649	21.2	380947	17.3
All Others (n = 56)	12336/1730/166	167	25.7	25786	3	11419	2.3	12973	11.1

Table 3
Trade and regulatory indices, annual per capita income, percent agriculture of each nation's gross domestic product, and United Nations Development Programme Human Development Indices are provided for the top 20 nations identified using the multi-criteria decisions analysis.

Country	Trade Index	Regulatory Index	Annual Per Capita	Percent Agriculture of GDP	HDI Index
Indonesia	3.40	10.88	10600	0.142	0.684
Thailand	3.19	10.04	14400	0.116	0.722
Uruguay	2.74	8.78	20600	0.075	0.79
Peru	2.25	10.40	11280	0.071	0.737
Brazil	2.13	8.73	16100	0.058	0.744
Sri Lanka	1.96	8.67	10400	0.102	0.75
Mauritius	1.91	8.17	18600	0.045	0.771
India	1.88	10.53	5900	0.179	0.586
Nicaragua	1.77	4.88	4700	0.149	0.614
Argentina	1.72	9.85	22600	0.104	0.808
Fiji	1.63	10.56	8200	0.127	0.724
Vanuatu	1.58	12.19	2600	0.251	0.616
Costa Rica	1.53	6.48	14900	0.06	0.763
Kenya	1.51	7.35	3100	0.293	0.535
Belize	1.48	12.14	8200	0.131	0.732
Chile	1.38	9.90	23000	0.035	0.822
Libya	1.31	7.43	15700	0.02	0.784
Honduras	1.18	9.93	4700	0.14	0.617
Namibia	1.05	10.23	10800	0.163	0.624
Panama	1.03	11.48	19500	0.029	0.765

issue at hand. Given the position of many of these countries as major shark exporting/importing nations, it is crucial that they invest in stronger border controls and their technical capacity in order to avoid potential international trade sanctions under CITES regulations [1].

The use of genetic techniques (e.g., species diagnostic PCR, real-time PCR, and DNA sequencing) to identify shark and ray products in trade should not be used to replace morphological identification [5] and identification of products by trade records and name [14], but rather serve as an additional tool when those techniques result in uncertainty (e.g., meat, processed fins, or false-labelling [7]). For example, the real-time PCR protocol described by Cardeñosa et al., 2018b, detects nine, out of twelve, CITES-listed species and presents the fastest (< 4 h), and cheapest ($0.94 USD per sample) enforcement molecular tool for shark CITES species to date. This protocol is based on the internal transcribed spacer 2 (ITS2) and could be adapted to include all CITES-listed batoids species and future elasmobranch CITES listings. In addition, it could aid with the enforcement of international trade of endangered shark and ray species regulations, by enhancing the traceability and verification of shark products at each step in the supply chain. In fact, Hong Kong has recently started a collaboration with scientists and NGOs to implement this real-time PCR protocol to monitor and enforce shark CITES regulations at the border, which is a major step forward and an international collaborative example at the largest shark fin trade hub in the world [11].

Therefore, this and other available tools and technologies [15] must be accompanied by collaborative initiatives between stakeholders such as governments, NGOs, and industry partners. Developed countries and international bodies should strive to transfer knowledge, the relevant technologies and techniques, and build the capacity of developing countries, on a case by case basis, to meet the challenge of improving the long term sustainability and conservation of sharks and rays [16]. Our study ranked countries where such capacity building and collaborative initiatives should take place in order to effectively increase local research capacity, data collection and ensure best monitoring practices for nations that are heavily engaged in shark trade.

Declaration of interest

None.

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Appendix A. Supplementary data

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