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Supplemental Information

Overfishing drives over one-third of all sharks and rays toward a global extinction crisis

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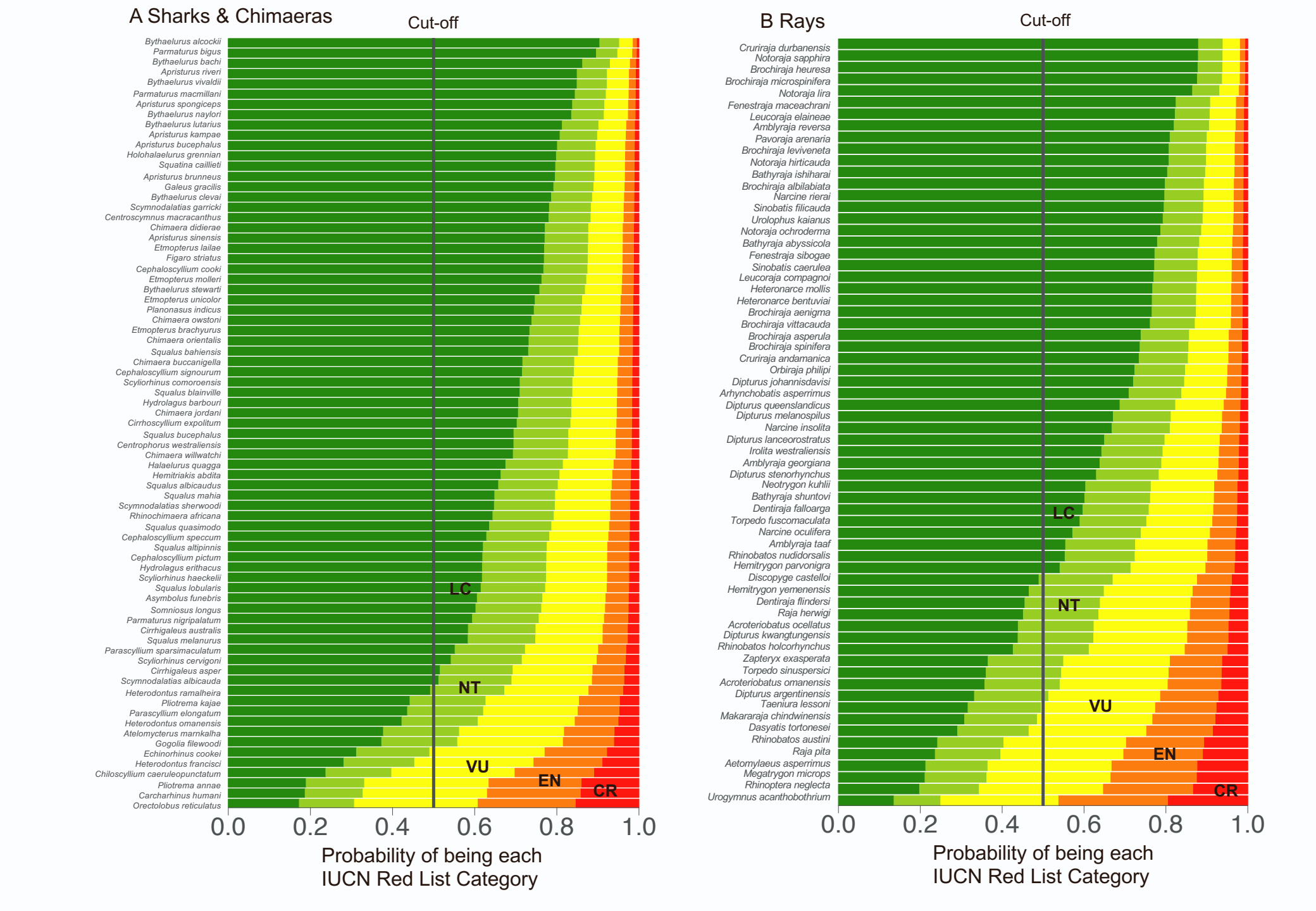
A Sharks & Chimaeras
Cut-off
Bythaelurus alcockii
Parmaturus bigus
Bythaelurus bachi
Apristurus riveri
Bythaelurus vivaldii
Parmaturus macmillani
Apristurus spongiceps
Bythaelurus naylori
Bythaelurus lutarius
Apristurus kampae
Apristurus bucephalus
Holohalaelurus grennian
Squatina caillieti
Apristurus brunneus
Galeus gracilis
Bythaelurus clevai
Scymnodalatias garricki
Centroscymnus macracanthus
Chimaera didierae
Apristurus sinensis
Etmopterus lailae
Figaro striatus
Cephaloscyllium cooki
Etmopterus molleri
Bythaelurus stewarti
Etmopterus unicolor
Planonasus indicus
Chimaera owstoni
Etmopterus brachyurus
Chimaera orientalis
Squalus bahiensis
Chimaera buccanigella
Cephaloscyllium signourum
Scyliorhinus comoroensis
Squalus blainville
Hydrolagus barbouri
Chimaera jordani
Cirrhoscyllium expolitum
Squalus bucephalus
Centrophorus westraliensis
Chimaera willwatchi
Halaelurus quagga
Hemitriakis abdita
Squalus albicaudus
Squalus mahia
Scymnodalatias sherwoodi
Rhinochimaera africana
Squalus quasimodo
Cephaloscyllium speccum
Squalus altipinnis
Cephaloscyllium pictum
Hydrolagus erithacus
Scyliorhinus haeckelii
Squalus lobularis
Asymbolus funebris
Somniosus longus
Parmaturus nigripalatum
Cirrhigaleus australis
Squalus melanurus
Parascyllium sparsimaculatum
Scyliorhinus cervigoni
Cirrhigaleus asper
Scymnodalatias albicauda
Heterodontus ramalheira
Pliotrema kajae
Parascyllium elongatum
Heterodontus omanensis
Atelomycterus marnkalha
Gogolia filewoodi
Echinorhinus cookei
Heterodontus francisci
Chiloscyllium caeruleopunctatum
Pliotrema annae
Carcharhinus humani
Orectolobus reticulatus
LC
NT
VU
EN
CR
0.0
0.2
0.4
0.6
0.8
1.0
Probability of being each
IUCN Red List Category
B Rays
Cut-off
Cruriraja durbanensis
Notoraja sapphira
Brochiraja heuresa
Brochiraja microspinifera
Notoraja lira
Fenestraja maceachrani
Leucoraja elaineae
Amblyraja reversa
Pavoraja arenaria
Brochiraja leviveneta
Notoraja hirticauda
Bathyraja ishiharai
Brochiraja albilabiata
Narcine rierai
Sinobatis filicauda
Urolophus kaianus
Notoraja ochroderma
Bathyraja abyssicola
Fenestraja sibogae
Sinobatis caerulea
Leucoraja compagnoi
Heteronarce mollis
Heteronarce bentuviai
Brochiraja aenigma
Brochiraja vittacauda
Brochiraja asperula
Brochiraja spinifera
Cruriraja andamanica
Orbiraja philipi
Dipturus johannisdavisi
Arhynchobatis asperrimus
Dipturus queenslandicus
Dipturus melanospilus
Narcine insolita
Dipturus lanceorostratus
Irolita westraliensis
Amblyraja georgiana
Dipturus stenorhynchus
Neotrygon kuhlii
Bathyraja shuntovi
Dentiraja falloarga
Torpedo fuscomaculata
Narcine oculifera
Amblyraja taaf
Rhinobatos nudidorsalis
Hemitrygon parvonigra
Discopyge castelloi
Hemitrygon yemenensis
Dentiraja flindersi
Raja herwigi
Acroteriobatus ocellatus
Dipturus kwangtungensis
Rhinobatos holcorhynchus
Zapteryx exasperata
Torpedo sinuspersici
Acroteriobatus omanensis
Dipturus argentinensis
Taeniura lessoni
Makararaja chindwinensis
Dasyatis tortonesei
Rhinobatos austini
Raja pita
Aetomylaeus asperrimus
Megatrygon microps
Rhinoptera neglecta
Urogymnus acanthobothrium
LC
NT
VU
EN
CR
0.0
0.2
0.4
0.6
0.8
1.0
Probability of being each
IUCN Red List Category

Figure S1. Predicted Red List category of 142 Data Deficient chondrichthyans from Cumulative Link Mixed-effects Models, related to Figure 4.

(A) Sharks and chimaeras.

(B) Rays. A 50% probability was used to classify species into IUCN categories, and this is shown with a grey line. The top model included maximum size (cm) and median depth (m) as fixed effects.

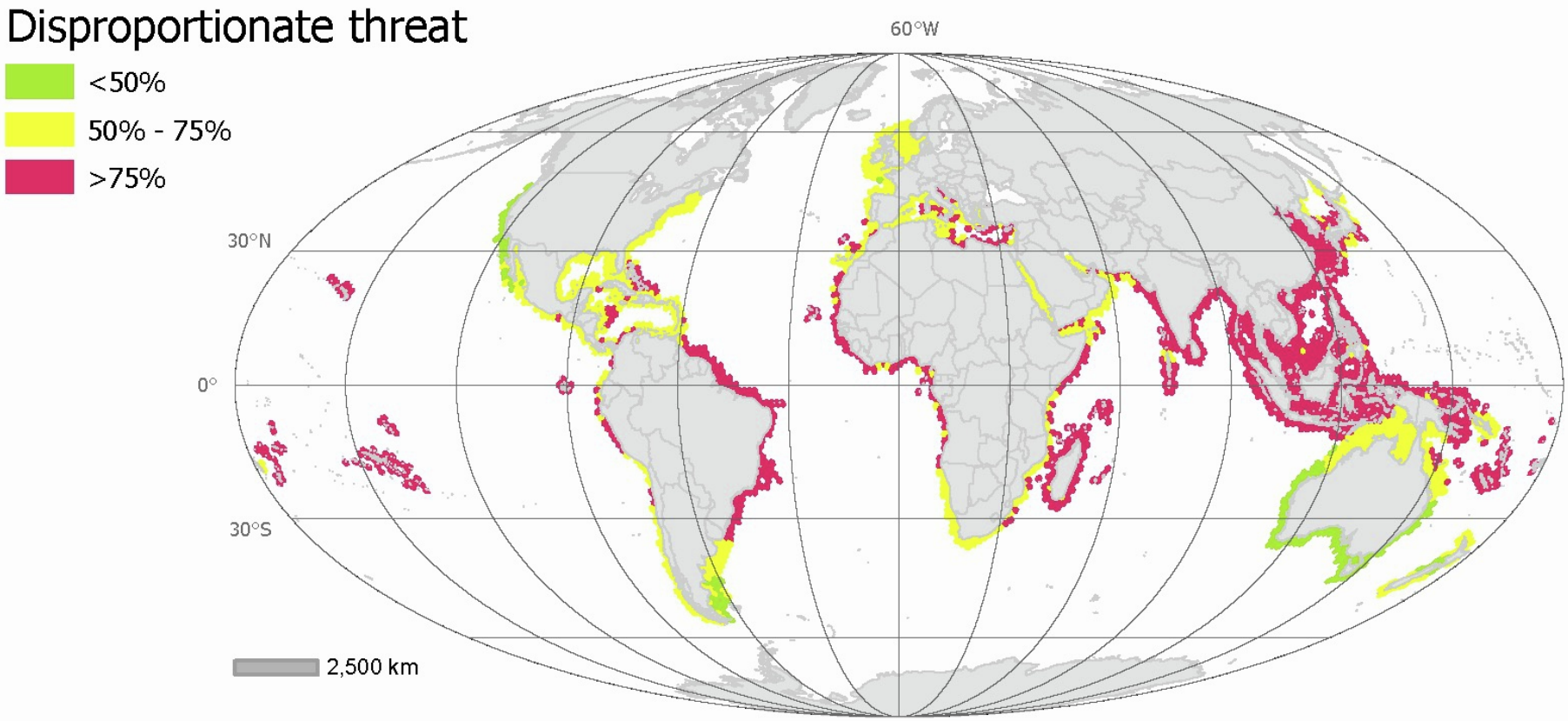

Figure S2 Coastal chondrichthyans are disproportionately threatened in the tropics and subtropics, related to Figure 5.

Disproportionate is defined by greater than 50% and greater than 75% of species are threatened per cell

Unique threat	Intentional (target catch)	Unintentional catch	Both intentional & unintentional	Scale total
Subsistence/small scale	0.4% (4)	1.9% (21)	1.7% (19)	4.0% (44)
Large-scale	0.6% (7)	34.5% (377)	1.4% (15)	36.5% (399)
Both subsistence & industrial	0.0% (0)	31.2% (340)		
Intentionality total	1.0% (11)	67.5% (738)		
Combined threats	Intentional (target catch)	Unintentional catch	Scale total	
Subsistence/small scale	28.0% (306)	62.4% (681)	63.6% (694)	
Large-scale	21.4% (233)	95.2% (1,040)	96.0% (1,049)	
Intentionality total	32.5% (355)	99.0% (1,082)		

For unique threats, species are scored only when coded for the unique threat or the column or row pairwise combination. For the combined threats, species can be coded for up to all four combinations.

Table S1. Percent of all 1,091 species under exploitation classified by intentionality (intentional vs. unintentional) and scale of the fishery (subsistence/small-scale vs. large-scale) separated by unique and pairwise, and combined threats, Related to Figure 3.

Fixed effects	logLik	AIC	ΔAIC	AIC weight	Coefficient estimates	Standard Error	Random effect variance / standard deviation
Data-sufficient Chondrichthyans (*n* = 1,178)							
Maximum Size	-1230.72	2473.44	87.42	9.01e-20	0.76	0.18	2.32 / 1.52
Median Depth	-1212.21	2436.42	50.39	9.87e-12	-1.50	0.20	2.15 / 1.47
Maximum Size + Median Depth + Geographic Range	-1185.01	2386.02	0.00	8.66e-01	1.09 -1.97 +0.45	0.19 0.20 0.19	1.02 / 1.01
Data-sufficient sharks (*n* = 528)							
Maximum Size	-529.30	1070.61	11.83	1.70e-03	0.91	0.29	1.68 / 1.30
Median Depth	-530.42	1072.84	14.06	5.56e-04	-0.74	0.27	2.26 / 1.50
Maximum Size +Median Depth	-522.39	1058.77	0.00	6.30e-01	1.21 -1.03	0.29 0.27	1.32 / 1.15
Maximum Size +Median Depth +Geographic Range	-521.94	1059.87	1.10	3.63e-01	1.08 -1.10 +0.29	0.32 0.28 0.31	1.30 / 1.14
Data-sufficient rays (*n* = 598)							

Maximum Size	-667.43	1346.85	76.71	1.61e-17	0.78	0.23	2.40 / 1.55
Median Depth	-647.75	1307.50	37.36	5.64e-09	-2.08	0.29	1.73 / 1.32
Maximum Size +Median Depth +Geographic Range	-627.07	1270.14	0.00	7.31e-01	1.26 -2.63 +0.49	0.22 0.27 0.25	0.31 / 0.55

LogLik = log likelihood, AIC = Akaike Information Criterion, ΔAIC = difference in AIC from top model.

Table S2. Cumulative Link Mixed-effects Models of the life history and distributional covariates of IUCN status, Related to Figure 4.

Separated for all data-sufficient chondrichthyans, sharks, and rays. The models are of the form *p*(IUCN status) = biological and ecological traits, random effect = taxonomic family.

Fixed Effects	**AUC values**						
	CR	EN	VU	NT	LC	thr	Mean
Size	0.703	0.650	0.554	0.456	0.816	0.675	0.636
Depth	0.717	0.669	0.656	0.505	0.831	0.755	0.676
Range	0.569	0.627	0.561	0.203	0.815	0.638	0.555
Size+Depth	**0.778**	**0.732**	**0.668**	**0.634**	**0.840**	**0.805**	**0.730**
Size+Range	0.699	0.653	0.557	0.458	0.815	0.676	0.637
Depth+Range	0.728	0.711	0.674	0.542	0.835	0.783	0.698
Size+Depth+Range	0.771	0.735	0.675	0.620	0.840	0.806	0.728
The Area Under the Curve (AUC) score represents the probability of a model predicting the correct category, with scores closer to 1 represent high accuracy and those closer to 0.5 representing low predictive accuracy. To choose the model with the highest overall predictive accuracy across categories, the mean AUC of all five categories was calculated. We also calculated the average AUC across the three threatened categories							

Table S3. Predictive model accuracy for chondrichthyan extinction risk, Related to Figure 4.
Each model included the IUCN category or as the response variable, and additive combinations of maximum linear dimension (cm), median depth (m) and geographic range as fixed effects, and taxonomic Family as a random effect to account for phylogenetic non-independence.

Common name	Latin name	Species number	Threatened species number	Threatened species (%)	p-value*
Devil Rays	Mobulidae	9	9	100.0	0.0001
Giant Guitarfishes	Glaucostegidae	6	6	100.0	0.0028
Pelagic Eagle Rays	Aetobatidae	5	5	100.0	0.0074
Sawfishes	Pristidae	5	5	100.0	0.0074
Wedgefishes	Rhinidae	10	9	90.0	0.0010
Hammerhead Sharks	Sphyrnidae	9	8	88.9	0.0023
Weasel Sharks	Hemigaleidae	8	7	87.5	0.0056
Gulper Sharks	Centrophoridae	15	11	73.3	0.0053
Eagle Rays	Myliobatidae	18	13	72.2	0.0030
Requiem Sharks	Carcharhinidae	57	39	68.4	0.0000
Guitarfishes	Rhinobatidae	34	23	67.7	0.0004
Angel Sharks	Squatinidae	22	13	59.1	0.0325
Stingrays	Dasyatidae	91	51	56.0	0.0002

**p*-value derived from a one-tailed binomial test of the probability that the percent threatened is significantly greater than for all chondrichthyans (37.5%) at the 0.05 level. The families with five or more species are in descending ordered with the greatest percent of threatened species uppermost.

Table S4. Most speciose threatened families of chondrichthyans, with species richness, the number and percent of species threatened, Related to Figure 5.

Theme	Scope	Participants	Dates	Location	Funding
Taxonomic	Sawfishes	28	21-24th May 2012	London, UK	NOAA Award NA12NMF4690058 from Fisheries Headquarters Program Office (FHQ); SOSF project #204, the Mohamed bin Zayed Species Conservation Fund, project #11252587. Further support was provided by IUCN SSC Sub-Committee for Species Conservation Planning, Environment Agency-Abu Dhabi, Chester Zoo, North West Group of Fauna and Flora International, Flying Sharks, Global Ocean, and Dallas World Aquarium.
Regional	Northeast Pacific wide-ranging	28	21st March 2014	Seattle, USA	Seattle Aquarium
Regional	Northeast Atlantic, Mediterranean Sea, & Black Seas	19	12-15th May 2014	Plymouth, UK	European Commission (Directorate General for the Environment Service Contract No. 070307/2011/607526/SER/B.3) and the IUCN Centre for Mediterranean Cooperation (IUCN-Med)
Taxonomic	Devil Ray	17	9-13th June 2014	Durban, South Africa	SOSF project #235; US State Department IUCN contribution
Regional	Australia	26	16-20th February 2015	Townsville, Australia	Fisheries Research and Development Corporation (FRDC)
Regional	Northeast Pacific endemics	11	15th July 2015	Reno, USA	N/A
Regional	Arabian Seas Region	25	5-11th Feb. 2017	Abu Dhabi, UAE	Environment Agency, Abu Dhabi, SOSF Grant # 370. Additional financial support was provided by IFAW, and CMS Sharks MoU

Regional	Sub-Equatorial Africa	17	23-25th April 2018	Grahamstown, South Africa	Shark Conservation Fund
Regional	Southwest Atlantic	21	31st May to 1st June 2018	João Pessoa, Brazil	Shark Conservation Fund
Taxonomic	Chimaeras	5	10-11th June 2018	João Pessoa, Brazil	Shark Conservation Fund
Habitat	Pelagic sharks & rays	15	5-9th Nov. 2018	Dallas, USA	Shark Conservation Fund
Regional	Eastern Central and Southeast Pacific	22	4-8th February 2019	Cali, Columbia	Shark Conservation Fund
Regional	Northwest & Western Central Atlantic	21	16-21 June 2019	The Bahamas	Shark Conservation Fund
Regional	Northwest Pacific	17	25-30th August 2019	Nagasaki, Japan	Shark Conservation Fund
Habitat	Deepsea	15	18-22 Nov. 2019	Vancouver, Canada	Shark Conservation Fund
Regional	Southeast Asia	29	13 2-hour calls, 15th April to 28th May 2020	Virtual	Shark Conservation Fund
Regional	West Africa	37	10 2-hour calls, 7th July to 5th August 2020	Virtual	Shark Conservation Fund
CMS Sharks MoU- Convention of Migratory Species Sharks Memorandum of Understanding, IFAW - International Fund for Animal Welfare, NOAA - US Department of Commerce, National Oceanic and Atmospheric Administration/National Marine Fisheries Service, SOSF - Save Our Seas Foundation.					

Table S5. Red List workshops by theme and scope detailing participant numbers, dates, location, and funding sources, Related to STAR Methods.

Aaron Carlisle	Dave Kulka	John Carlson	Momodou Jallow
Aaron Lobo	David Allen	Jonathan Smart	Momodou Sidibeh
Abdoulaye Ba	David Morgan	Joost Pompert	Monika Böhm
Abraham Basani Sianipar	David Ebert	Jorge Morales	Nathan Pacoureau
Adam Barnett	David Robinson	Jorge Nunes	Nicholas Dulvy
Adrian Guttridge	Dawit Tesfamichael	Juan Carlos Pérez Jiménez	Nikola Simpson
Adriana Cevallos	Dayv Lowry	Juan Martín Cuevas	Olaf Ormseth
Ahmad Ali	Dennis Tanay	Julia Lawson	Oscar Miguel Lasso-Alcalá
Alberto González	Dharmadi	Julia Spaet	Oscar Sosa-Nishizaki
Alec Moore	Diego Cardenosa	Julie Neer	Paola Mejía-Falla
Alejandra Briones	Dwi Ariyoga Gautama	Justin Cordova	Patricia Charvet
Alen Soldo	Dyhia Belhabib	Justine Dossa	Paula Carlson
Alessandro Ponzo	Ed Farrell	Karen Crow	Peter Kyne
Alex Tamo	Edwin Grandcourt	Kat Gledhill	Phil Doherty
Ali Hood	Elena Buscher	Katalin Csatadi	Rachel Cavanagh
Alifa Haque	Elisa Areano	Katelyn Hermann	Rachel Graham
Alistair Harry	Eloísa Espinoza	Kelly van Hees	Rachel Walls
Alvaro Abella	Emmanuel Chartrain	Kelsi Chiquillo	Ranny Yuneni
Amie Bräutigam	Enzo Acuña	Ken Graham	Rhett Bennett
Ana Nieto	Eric Schneider	Kerry Sink	Richard Sherley
Ana-Lucia Furtado Soares	Evgeny Romanov	Kerstin Forsberg	Riley Pollom
Andrea Launer	Fábio Motta	Khadeeja Ali	Rima Jabado

Andrea Marshall	Fabrizio Serena	KK Bineesh	Rob Leslie
Andrea Pauly	Fahmi	Kristian Metcalfe	Rodrigo Barreto
Andrés Felipe Navia	Fereidoon Owfi	Kristin Walovich	Romney McPhie
Andrew Chin	Framoudou Doumbouya	KV Akhilesh	Rory McAuley
Ania Budziak	Francesco Ferretti	Kwang-Ming Lui	Ryan Freedman
Annie Pek Kiok Lim	Francis Neat	Laura Paesch	Samantha Sherman
Antt Maung	Francisco Concha	Leontine Baje	Santiago Montealegre-Quijano
Aristide Takoukam	Francisco Marcante Santana	Lewis Barnett	Sara Ratão
Armelle Jung	George Burgess	Lindsay Davidson	Sarah Fowler
Ashkay Tanna	Getulio Rincon	Luc Badji	Sarah Gravel
Atsuko Yamaguchi	Gina Ralph	Lucy Harrison	Sarah Lewis
Bamikole Williams	Godefroy De Bruyne	Lucy Keith-Diagne	Sarika Singh
Baraka Kuguru	Grant Johnson	Luciana Ferreria	Shannon Barry
Barry Bruce	Guido Leurs	Ly Seyha	Shawn Larson
Beatriz Naranjo	Guillermo Porrinos	Lyle Squire	Sho Tanaka
Breanna Machuca	Giuseppe Notartolo-di-Sciara	Malcolm Francis	Simona Cló
Brendan Talwar	Gustavo Chiaramonte	Mamadou Dia	Sonja Fordham
Brit Finucci	Guy Stevens	Manuel Duriel	Sophy McCully Philips
Brooke Anderson	Hajime Ishihara	María del Pilar Blanco-Parra	Stela Fernando
Cameron Provost	Heather Koldeway	Marina Garcia	Stiven Pires
Carlos Bustamante	Helen Yan	Mario Espinoza	Susan Smith
Carmen Santos	Henning Winker	Mark Erdmann	Tariq Al Mamari
Cassie Rigby	Hollie Booth*	Mark Stanley-Price	Tassapon Krajangdara*

Catarina Pien	Hsuan-Ching (Hans) Ho	Martin Clark	Terry Walker
Chante Davis	Hua Hsun Hsu	Martin Hall	Thomas Farrugia
Charlene da Silva	Ian Jacobsen	Mary O'Malley	Tooraj Valinassab
Charlie Huveneers	Igbal ElHassan	Mathieu Ducroq	Van Quang Vo
Chip Cotton	Igor Volvenko	Matthew Gollock	Vicente Faria
Choong-Hoon Jeong	Isabelle Ender	Matt McDavitt	Vicky Vasquez
Chris Chabot	Issah Seidu	Maximin Djondo	Wade Smith
Chris Lowe	Itzigery Burgos	Meaghen McCord	Wade VanderWright
Chris Mull	James Kemp	Megan Van der Bank	Will White
Christine Dudgeon	Jean Utzurrum	Melissa Nehmans	William Smyth
Cindy Tribuzio	Jenny Bigman	Melita Samoilys	Xiao Chen
Colin Simpfendorfer	Jess Cheok	Mia Comeros-Raynal	Ximena Vélez-Zuazo
Connor White	Jessica Jang	Michelle Heupel	Yasuko Semba
Cristopher Avalos	Jie Zhang	Mika Diop	Yury Dyldin
Daniel Fernando	Jim Ellis	Moazzam Khan	Zoe Crysler
Danielle Derrick	Joe Bizzarro	Mohammad Hassan Ali	

*denotes significant contribution *in absentia*

We also thank these five volunteers: Shamsa Al Hameli, Karen K. Frazer, Sarah Gravel, Romney McPhie, and Pedro Warner. We ask forgiveness for any names that may have been inadvertently omitted or misspelled.

Table S6. List of 243 Red List Assessment workshop participants ordered alphabetically by first name, Related to STAR Methods.

Latin binomial	Previous taxonomic concept	Revised taxonomic concept
Aetobatus flagellum	EN (2006)	EN (2020)
Aetobatus narinari	NT (2006)	EN (2020)
Aetomylaeus nichofii	VU (2003)	VU (2015)
Bathytoshia brevicaudata	LC (2015)	LC (2020)
Bathytoshia centroura	LC (2007)	VU (2019)
Bathytoshia lata	LC (2007)	VU (2020)
Bythaelurus lutarius	DD (2004)	DD (2018)
Carcharhinus dussumieri	NT (2003)	EN (2018)
Carcharhinus porosus	DD (2006)	CR (2019)
Centrophorus granulosus	VU (2006)	EN (2019)
Cephaloscyllium fasciatum	DD (2010)	CR (2019)
Cephaloscyllium umbratile	DD (2007)	NT (2019)
Chiloscyllium plagiosum	NT (2006)	NT (2020)
Chimaera ogilbyi	VU (2015)	NT (2019)
Dipturus chilensis	VU (2007)	EN (2019)
Ginglymostoma cirratum	DD (2006)	VU (2019)
Glaucostegus cemiculus	EN (2007)	CR (2018)
Glaucostegus typus	VU (2003)	CR (2018)
Glyphis gangeticus	CR (2007)	CR (2021)
Gymnura micrura	DD (2006)	NT (2020)
Hexanchus nakamurai	DD (2008)	NT (2019)

Himantura uarnak	VU (2015)	EN (2020)
Hypanus americanus	DD (2006)	NT (2019)
Lamiopsis temminckii	EN (2008)	EN (2020)
Mobula hypostoma	DD (2008)	EN (2018)
Mobula mobular	EN (2014)	EN (2018)
Myliobatis tenuicaudatus	LC (2003)	LC (2015)
Narke japonica	VU (2019)	VU (2021)
Neotrygon kuhlii	DD (2015)	DD (2017)
Platyrhina sinensis	VU (2008)	EN (2019)
Pliotrema warreni	NT (2004)	LC (2019)
Pristis pristis	CR (2005)	CR (2013)
Psammobatis normani	LC (2019)	LC (2020)
Raja miraletus	LC (2003)	LC (2019)
Rajella fyllae	LC (2008)	LC (2019)
Rhinobatos schlegelii	DD (2004)	CR (2019)
Scoliodon laticaudus	NT (2005)	NT (2020)
Scyliorhinus canicula	LC (2008)	LC (2020)
Scyliorhinus haeckelii	DD (2004)	DD (2019)
Scyliorhinus torazame	LC (2008)	LC (2020)
Sinobatis borneensis	LC (2008)	LC (2020)
Squalus blainville	DD (2008)	DD (2020)
Squalus megalops	DD (2003)	LC (2019)
Squalus mitsukurii	DD (2007)	EN (2019)

Squatina dumeril	DD (2006)	LC (2017)
Squatina guggenheim	EN (2007)	EN (2018)
Taeniura lymma	NT (2005)	LC (2020)
Telatrygon zugei	NT (2006)	VU (2019)
Tetronarce nobiliana	DD (2004)	LC (2020)
Tetronarce tremens	LC (2019)	LC (2021)

Table S7. Species that underwent a revision in taxonomic concept since the first assessment, but that we have not classified as Not Evaluated because a species with this name was previously assessed, Related to STAR Method.