AT THE INTERSECTION OF SCIENCE & POLICY: INTERNATIONAL SHARK CONSERVATION & MANAGEMENT

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I. INTRODUCTION

For the past few decades, global shark populations have been in a near-constant state of decline,[1] while extractive pressures from the world's fisheries have continued to reduce shark populations in the world's oceans. At least 28 different shark populations have been extirpated from portions of their historical ranges including the "now ironically-named and critically endangered . . . [c]ommon angel shark (*Squatina squatina*) [which is] regionally extinct from much of [its] former geographic range in European waters."[2] Other shark species have essentially disappeared altogether, such as the "[c]ritically [e]ndangered Pondicherry shark (*Charcharhinus hemiodon*) [which] . . . has not been seen [in the wild] since 1979."[3] Yet, despite decreasing global populations and an estimated one-quarter of all shark species threatened with extinction,[4] sharks are still regularly targeted or caught as bycatch in the world's fisheries, and the ever-increasing market price of shark fins and other products indicate that this trend is unlikely to stop anytime soon.[5]

As a result, numerous shark species have begun to receive attention from Regional Fisheries Management Organizations (RFMOs), international organizations that manage and protect high seas fisheries for a particular area.[6] RFMOs have passed numerous resolutions and conservation measures focused on the conservation of shark species, such as gear restrictions preventing the use of certain types of shark-specific fishing gear and retention bans prohibiting the catch of individual shark species. Seven different genera of shark have received particular attention.[7] RFMOs have also begun conducting

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1. *See infra* Section II.A.

2. Nicholas K. Dulvy et al., *Extinction Risk and Conservation of the World's Sharks and Rays*, ELIFE, Jan. 2014, at 9, 34.

3. *Id*.

4. *Id*. at 3.

5. *See infra* Section II.A; *see also, e.g.,* Felix Dent & Shelley Clarke, *State of the Global Market for Shark Products*, 590 FOOD & AGRICULTURE ORGANIZATION [FAO] FISHERIES AND AQUACULTURE TECH. PAPER, fig. 3 (2015) (depicting the rapid increase in market price of shark fins); INDIAN OCEAN TUNA COMM'N [IOTC], *Executive Summary: Blue Shark* (2015) [hereinafter IOTC] http://www.iotc.org/sites/default/files/documents/science/species_summaries/english/Blue%20shark%20Executive%20Summary.pdf (indicating that fishing pressure on blue sharks remains relatively high despite their near-threatened status).

6. *Infra*, notes 60–66, and accompanying text.

7. The blue shark (*Prionace glauca*), mako (genus *Isurus*), oceanic whitetip (*Carchathinus longimanus*), porbeagle (*Lamna nasus*), hammerhead (genus *Sphyrna*), silky shark (*Carcharhinus falciformis*), and thresher sharks (genus *Alopias*) have all been the subject of conservation measures and stock assessments. *See infra* Section III.B.

scientific analyses of shark populations in an attempt to gain a confident assessment of shark stocks.

Despite RFMOs' using a wide variety of strategies aimed at reducing bycatch mortality and ensuring the long-term survival of key shark species, shark populations continue to decline. This may be because many of the current conservation measures and resolutions fail to take into account shark species' key life-history and behavioral characteristics. RFMOs passed many of the current conservation measures before they had conducted scientific surveys of shark populations or attempted to make conclusions on the status of shark stocks.[8] In the future, using the best available scientific data on shark species to inform and improve conservation measures will provide RFMOs the best tool to conserve global shark stocks. In order to facilitate RFMOs' use of scientific data in conservation measures, I propose using a procedure that identifies key life-history and behavioral characteristics of sharks, both as individual species and generally, before translating that information into targeted conservation measures.[9] Conservation measures created using this approach are expected to better protect global shark species, while not being overly burdensome on fishery participants, because these measures are specifically tailored to address the most vulnerable aspects of sharks' biology, allowing for fewer, more effective conservation measures.

This paper begins by looking at RFMO conservation and management measures that address shark conservation.[10] It then discusses the effectiveness of those types of measures and examines why some measures are ineffective. This paper then analyzes the current scientific knowledge and stock assessments for key shark

8. For example, the IOTC conducted its first shark stock assessment in 2015. *See* IOTC, *Blue Shark Supporting Information* (Dec. 2016) http://www.iotc.org/sites/default/files/documents/science/species_summaries/english/Blue%20shark%20Supporting%20Information.pdf (despite having previously passed numerous conservation measures aimed at protecting shark species); IOTC, Res 05/05, *Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by IOTC* (2005), http://www.iotc.org/sites/default/files/documents/proceedings/2010/wpeb/IOTC-2010-WPEB-Inf07.pdf; IOTC, Res 12/09, *On the Conservation of Thresher Sharks (Family Alopiidae) Caught in Association with Fisheries in the IOTC Area of Competence* (2012), *archived at* http://www.iotc.org/sites/default/files/documents/compliance/cmm/iotc_cmm_12-09_en.pdf; IOTC, Res 13/05, *On the Conservation of Whale Sharks* (*RHINCODON TYPUS*) (2013), *archived at* http://www.iotc.org/sites/default/files/documents/compliance/cmm/iotc_cmm_13-05 _en.pdf.

9. *See infra* Section V.B.

10. The various RFMOs do not all use the same terminology in reference to regulations. The author will generally refer to all such measures as conservation measures, except when specifically addressing individual measures.

species. This paper limits its assessment of scientific information to RFMO scientific committee reports and analyses and does not include any outside scientific sources. This is done deliberately to ensure that the scientific information considered is the same scientific information that the RFMOs have available to them, thereby replicating the type of data that RFMOs are likely to utilize in the future.[11] Finally, this paper proposes a method for better incorporating the scientific data gleaned from RFMO scientific committee reports and analyses into future conservation measures in order to make those measures as effective and efficient as possible.

II. Global Declines in Shark Populations Driven Largely by Negative Interactions with the World's Fisheries

Globally, shark populations are in decline. Despite the characteristics that leave them highly vulnerable to overexploitation, sharks are still regularly targeted for valuable products or caught incidentally in the world's fisheries. Many shark species have traits that leave them particularly vulnerable to fishing pressures, such as low fecundity, late maturity, and slow growth rates.[12] While some researchers have suggested that some shark species can be harvested sustainably,[13] doing so would require strict management observation and low catch rates that are not present in global shark fisheries.[14] "For many [shark] species, the question is no longer about fishery sustainability, but rather extinction risk."[15] Currently, nearly one-quarter of all shark and shark-related species are at risk of extinction.[16] "[A]t least 28 populations of [sharks] are locally or regionally extinct .

11. *See, e.g.,* Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, pt. III, art. 10, ¶ 5, Sept. 5, 2000 ("The commission shall take into account the reports and any recommendations of the Scientific Committee . . . on matters within their respective areas of competence."); *see also*, WCPFC, CMM 2010-07, *Conservation and Management Measure for Sharks* ¶ 4 (2010), http://www.wcpfc.int/system/files/CMM%202010-07%20%5BSharks%5D.pdf (delegating, to the scientific committee, the responsibility of identifying which species of sharks are in need of protection by the WCPFC.)

12. John A. Musick & Sussana Musick, *Sharks*, FAO OF THE U.N., 2011, at 1; MARINE AND INLAND FISHERIES SERV., *Review of the State of World Marine Fishery Resources*, 569 FAO Fisheries and Aquaculture Technical Paper 245 (2011), http://www.fao.org/docrep/015/i2389e/i2389e.pdf.

13. *Id*. (citing C. Simpfendorfer, *Demographic Analysis of the Dusky Shark Fishery in Southwest Australia*, *Life in the Slow Lane: Ecology and Conservation of Long-Lived Marine Animals* (J.A. Musick ed. 1999)).

14. Musick & Musick, *supra* note 12 at 245.

15. *Id.* at 250.

16. Dulvy et al., *supra* note 2 at 3.

. . [and] [s]everal shark species have not been seen for many decades."[17] Further, shark species have "one of the highest rates of Data Deficiency[, 46 percent,] of any taxon to date,"[18] which has led researchers to conclude that they may be underestimating the level of threats to shark species.[19]

A. The Declining Conservation Status of Sharks

The main threat to shark species is overutilization through both incidental and directed fishing pressures.[20] Over the past seventeen years, the number of sharks that are killed annually by the world's fisheries is estimated to exceed 100 million.[21] Incidental interactions with the global tuna fishery[22] and the ever-increasing market price for shark fins are two of the most prevalent causes for this high level of mortality.[23] While shark fins are the most valuable shark product, shark meat, skin, cartilage, and livers are also able to gain a hefty price.[24] These high prices come from the products' valuable uses: shark fins are used primarily to make shark fin soup, a Chinese delicacy;[25] meat is consumed either fresh or salted and dried;[26] skin is used to make a durable and fashionable leather;[27] and while the claim that shark cartilage can cure cancer was scientifically debunked,[28] both shark cartilage and livers do have legitimate medicinal uses such as stopping tumor growth, treating arthritis, and as an antibiotic.[29]

Because of the many valuable uses for shark products, many shark populations are being fished without any realistic management strategies and without regard for sustainable levels of extraction.[30] As a result, global shark catches are being dramatically underreported.

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17. *Id*. at 9.

18. *Id*. (quoting M. Hoffmann et al., *The Impact of Conservation on the Statue of the World's Vertebrates*, 33 SCIENCE 1503, 1509 (2010)).

19. *Id.* at 10–11.

20. *Id.*2 at 4.

21. Boris Worm et al., *Global catches, exploitation rates, and rebuilding options for sharks*, 40 MARINE POL'Y 194, 204 (2013).

22. *See infra* Section IV.

23. Felix Dent & Shelley Clarke, *State of the Global Market for Shark Products*, 590 FAO FISHERIES AND AQUACULTURE TECH. PAPER, fig. 3 (2015).

24. Musick & Musick, *supra* note 12 at 245–46.

25. *Id.* at 246.

26. *Id.*

27. *Id.*

28. *Id.*

29. *Id.*

30. *Id.* at 250.

For example, one researcher estimated that the level of shark catches required to support the known level of trade in shark fins would annually exceed the reported levels of shark catches by as much as four times.[31]

B. Bycatch from the Global Tuna Fishery

The global tuna fishery regularly interacts with various shark species. Understanding how and where shark populations interact with the global tuna fishery is the first step in recognizing how to best protect these populations. The most prevalent gear types used in the world's tuna fisheries, and therefore one of the more common gear types that sharks encounter, are purse seine nets and longlines.[32] United Nations Food and Agriculture Organization (UN-FAO) data indicate that from 1990 through 2010,[33] more than 82 million tons of tuna and tuna-like species were caught by the world's fisheries.[34] The vast majority (75.9 percent) of that was caught using purse seine (59.5 percent) or longline (16.4 percent) gear.[35] The remainder was caught with pole and line (11.9 percent), troll lines (1.88 percent), or other (10.2 percent) gear types.[36]

Purse seine fishing involves encircling schools of fish with very large nets.[37] Often, two separate boats are involved in setting a purse seine net. One boat, the mothership, reels out the net. The second boat, the skiff, drives the net around the school of fish.[38] Recent technological advances have allowed this system to be more effective than ever before. Industrialized purse seiners, for example, sometimes have helicopter support in order to spot large schools of fish.[39] Purse seine nets can be extremely large, extending more than 2000 meters

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31. *Id.* at 247.

32. *See* UN-FAO FISHERIES AND RESOURCES MONITORING SYSTEM, *World Global Tuna Fisheries*, History, fig. C1-1, http://firms.fao.org/firms/fishery/459/en (last visited 21 May 2017) (stating that "[c]urrently, on the industrial scale, tuna and tuna-like species are mainly caught with purse-seine, longline, and to a less extent, pole-and-line over wide areas in oceans.")

33. 2010 was the last data set available from the FAO.

34. FAO, FISHERIES AND AQUACULTURE DEPARTMENT, *Global Tuna Catches by Stock: Quantity (t)*, http://www.fao.org/figis/servlet/SQServlet?file=/usr/local/tomcat/8.5.16/figis/webapps/figis/temp/hqp_1747831916817833157.xml&outtype=html (last visited Apr. 12, 2018).

35. *Id*.

36. *Id*.

37. *Tuna Purse Seining*, FAO, FISHERIES AND AQUACULTURE DEPARTMENT, http://www.fao.org/fishery/fishtech/40/en (last visited Apr. 12, 2018).

38. *Id.*

39. *Id*.

long and 200 meters deep.[40] Once the net is in place surrounding the school of fish, the bottom of the net will be cinched shut, and the net will either be hauled onto the deck of the mothership or brought alongside.[41]

One of the main ecological issues present with purse seine nets is that they indiscriminately entrap everything in that area.[42] Despite the fact that fishers may only desire to catch tuna, species such as sharks, marine turtles, birds, and marine mammals often become trapped in the net as well.[43] Further, a common fishing strategy used to be the deliberate setting of purse seine nets around easily spotted animals that are commonly associated with tuna schools, such as whale-sharks[44] and dolphins.[45]

Longlines, on the other hand, do not use nets at all.[46] Instead of entrapping the targeted fish in nets, longlines set out many thousands of baited hooks in order to catch fish.[47] Longlines are divided by similarly equipped units, often called baskets.[48] Each basket will start and end at a buoy with a vertical line extending into the water from the buoy to a main horizontal line.[49] Coming off of the main horizontal line are baited hooks.[50] Baskets are then attached to each other, forming a line of buoys at the surface of the water, and baited hooks at depth.[51] The main horizontal line can be anywhere from 250 to 800 meters

40. NOAA FISHERIES, *Purse Seine: Fishing Gear and Risks to Protected Species*, https://www.fisheries.noaa.gov/national/bycatch/fishing-gear-and-risks-protected-species (last visited Apr. 12, 2018).

41. *Tuna Purse Seining*, *supra* note 37.

42. *Id.*

43. NOAA FISHERIES, *supra* note 40; *see also Tuna Purse Seining*, *supra* note 37.

44. *See, e.g.*, WESTERN & CENTRAL PACIFIC FISHING COMM'N [WCPFC], CMM 2012-04, *Conservation and Management Measure for Protection of Whale Sharks from Purse Seine Fishing Operations* (2012), https://www.wcpfc.int/system/files/CMM-2012-04-Conservation-and-Management-Measure-protection-whale-sharks-purse-seine.pdf (prohibiting fishers from deliberately encircling whale sharks in order to catch the tuna commonly associated with the sharks).

45. *See generally*, Joel P. Trachtman, *United States-Restrictions on Imports of Tuna. No. DS21/R, 30 ILM 1594* (1991), 86 AMERICAN J. INT'L L., 142–51 (1992) (deciding a controversy between Mexico and the United States, in favor of Mexico, after the United States forbid the importation of tuna harvested from the Eastern Pacific Ocean using purse seine nets that were intentionally set around pods of dolphins).

46. *Industrial Tuna Longlining*, FAO, FISHERIES AND AQUACULTURE DEPARTMENT, http://www.fao.org/fishery/fishtech/1010/en (last visited Apr. 12, 2018).

47. *Id.*

48. *Id.*

49. *Id.*

50. *Id.*

51. *Industrial Tuna Longlining*, *supra* note 46.

long.[52] Often a single longline will consist of 200 or more baskets allowing more than 3000 baited hooks per longline.[53] While longlines are more easily made to target specific species of fish than purse seines, based on the depth at which they are set and the type of bait used,[54] they still indiscriminately catch whatever animals happen to be present in that area.[55] Further, longlines are not easily able to distinguish between ages and sizes of individuals caught, often catching more juveniles or smaller sized individuals than would otherwise be desired.[56]

III. REGIONAL FISHERIES MANAGEMENT ORGANIZATION CONSERVATION AND MANAGEMENT MEASURES CONCERNING GLOBAL KEY SHARK SPECIES

The world's high seas[57] have always been a relatively lawless place. For centuries, the fish of the high seas were exploited at the whim of daring sea-captains – fishing vessels were able to stay at sea for months at a time, exploring the world's oceans in search of the most valuable catches.[58] Then, in 1982, the United Nations Convention on the Law of the Sea (UNCLOS) was adopted in order to bring some law and order to the high seas.[59] UNCLOS was adopted in part to stop the unrestricted harvest of high seas fish[60] and mandated that "[s]tates cooperate with each other in the conservation and management of living resources in the areas of the high seas."[61] UNCLOS called upon

52. *Id.*

53. *Id.*

54. *Id.*

55. *Id.* (stating animals such as marine turtles, seabirds, marine mammals, billfish, and sharks can become entangled in longlines and either incidentally caught or killed as a result); *see generally,* U.S. DEPARTMENT OF COMMERCE, NOAA, NMFS, *Report of the U.S. Longline Bycatch Reduction Assessment and Planning Workshop*, NOAA Technical Memorandum NMFS-OPR-41, 4, 10, 13, 16, 19 (2008).

56. *Industrial Tuna Longlining*, *supra* note 46.

57. Today, nations are typically able to claim sovereign jurisdiction out to 200 nautical miles. The term high seas denotes those areas beyond the jurisdiction of any nation; *see generally,* United Nations Convention on the Law of the Sea Pt. VII, Sec. 1, Dec. 10, 1982 1833 U.N.T.S. 397.

58. *The United Nations Convention on the Law of the Sea: A historical perspective* UNITED NATIONS DIVISION FOR OCEAN AFFAIRS AND LAW OF THE SEA, http://www.un.org/depts/los/convention_agreements/convention_historical_perspective.htm (last visited Apr. 12, 2018).

59. *Id*.

60. *See generally* United Nations Convention on the Law of the Sea Pt. VII, Sec. 2, Dec. 10, 1982 1833 U.N.T.S. 397.

61. *Id*. at Art. 118. UNCLOS officially came into force on November 16th, 1994. Currently there are 157 signatory countries and 166 countries that have ratified UNCLOS. Notably, the United States has neither signed nor ratified UNCLOS. *See Chronological lists of ratifications of,*

States to "establish subregional or regional fisheries organizations,"[62] and to consider how their fisheries "[affect] . . . species associated with . . . harvested species with a view to maintain or restoring populations of such associated . . . species . . . ."[63] Therefore, by signing UNCLOS, nations agreed to participate in RFMOs and agreed to UNCLOS' mandate that RFMOs consider not just the targeted species (i.e., tuna) but also species associated and impacted by the tuna fisheries, such as sharks.

A. Regional Fisheries Management Organizations

The creation of RFMOs was the primary way that nations complied with UNCLOS' call for state cooperation. For example, the Western and Central Pacific Fisheries Commission draws much of its procedure and guidance from the United Nations Fish Stocks Agreement.[64] The Fish Stocks Agreement, in turn, implements UNCLOS provisions relating to the conservation and management of the high seas and "establishes that such management must be based on the precautionary approach and the best available scientific information."[65] Currently, there are a total of seventeen different RFMOs each managing a different area, species, or resource of concern.[66] Five of these RFMOs are primarily geared towards the

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accessions and successions to the Convention and the related Agreements, UNITED NATIONS DIVISION FOR OCEAN AFFAIRS AND LAW OF THE SEA, http://www.un.org/Depts/los/reference_files/chronological_lists_of_ratifications.htm#The%20United%20Nations%20Convention%20on%20the%20Law%20of%20the%20Sea (last visited Apr. 12, 2018).

62. United Nations Convention on the Law of the Sea art. 118, Dec. 10, 1982 1833 U.N.T.S. 397.

63. *Id*. at art. 119(b).

64. WCPFC, *About WCPFC*, https://www.wcpfc.int/about-wcpfc.

65. UNITED NATIONS OCEANS & LAW OF THE SEA, *The United Nations Agreement for the Implementation of Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (in force as from 11 December 2001) Overview*, http://www.un.org/depts/los/convention_agreements/convention_overview_fish_stocks.htm; *See generally,* United Nations General Assembly, Agreement for the Implementation of the Provision of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, art. 5, art. 6, Sept. 8, 1995, A/Conf. 164/37 (establishing that "States fishing on the high seas shall" participate in RFMOs and utilizing both the best scientific information available and the precautionary approach, "conserve and managing straddling . . . and highly migratory fish stocks," including non-target species that "belong[] to the same ecosystem or [are] associated with . . . the target stock.").

66. PEW CHARITABLE TRUST, *FAQ: What is a Regional Fishery Management Organization?*, http://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2012/02/23/faq-what-is-a-regional-fishery-management-organization.

management of the global tuna fishery[67] and have geographical ranges that cover the vast majority of the globe.[68]

All of the tuna-RFMOs have conservation and management measures in place to ensure that the tuna fishery is not negatively impacting shark species. Globally, shark species tend to interact more frequently with the tuna fishery than with any other fishery.[69] Tuna and sharks are often found in the same area or in large aggregations. Also, the tuna fleet typically exerts more fishing effort—meaning physically fishing more—than other high seas fisheries which causes it to encounter more highly migratory species than other fisheries.[70] Further, because of their common encounters with shark species and the rapidly increasing market prices for shark fins, some tuna fishers specifically target shark species in addition to tuna.[71] As a result of these interactions and targeting pressures, the tuna fisheries negatively impact shark species more than other fisheries, and therefore necessitates tuna-RFMOs to address these concerns.

B. RFMOs and their Current Conservation Measures

RFMOs have approached shark conservation and protection mainly through the use of seven different types of measures.

First, retention bans typically identify a specific species of shark and prohibit fishers from having any part of that species on board. This prevents the direct targeting of certain key shark species.[72]

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67. The five tuna-focused RFMOs are the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), Inter-American Tropical Tuna Commission (IATTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Indian Ocean Tuna Commission (IOTC), and the Western and Central Pacific Fisheries Commission (WCPFC); despite not being a tuna-specific RFMO, the Northwest Atlantic Fisheries Organization (NAFO) was also included in this article. *Id.*

68. *Regional Fisheries Management Organisations (RFMOs)* EUROPEAN COMM'N, https://ec.europa.eu/fisheries/cfp/international/rfmo_en (last visited Apr. 12, 2018).

69. *See* Musick & Musick, *supra* note 12 at 247 (explaining that "international longline fleets that target tunas and billfish . . . have a huge bycatch of sharks").

70. IOTC, OCEANIC WHITETIP SHARK SUPPORTING INFORMATION, 1 (2016). *See also*, FISHERIES AND RESOURCES MONITORING SYSTEM, *World Global Tuna Fisheries*, http://firms.fao.org/firms/fishery/459/en (last visited Apr. 12, 2018) (analyzing the high seas tuna fishery and depicting annual global catch rates as dramatically increasing from the year 1950 through 2009).

71. *See* Felix Dent & Shelley Clarke, *State of the Global Market for Shark Products*, 590 FAO FISHERIES AND AQUACULTURE TECH. PAPER, fig. 3 (2015) (depicting a rapidly increasing price and trade in shark fins, globally, from 1976 to 2011).

72. *See, e.g.*, WCPFC, CMM 2011-04, *Conservation and Management Measure for Oceanic Whitetip Shark* (Mar. 2012), https://www.wcpfc.int/system/files/CMM-2011-04-Conservation-and-Management-Measure-Oceanic-Whitetip-Sharks.pdf.

Second, fin-to-carcass ratios set a certain percent of the total weight of shark fins that fishers may have on board in relation to the weight of shark carcasses on board. For example, a common fin-to-carcass ratio prohibits fishers from having the total weight of shark fins on board be more than five percent of the total weight of shark carcasses on board. In theory, this strategy limits the overall number of sharks that a boat can catch by limiting the amount of cargo space on board.[73]

Third, body/carcass requirements are based on a similar theory as fin-to-carcass ratios. They mandate that fishers retain the entire carcass of certain species of shark, in an effort to reduce the total cargo space that fishers can fill with just shark fins, thereby, in theory, reducing the total number of sharks killed by the fishing industry.[74]

Fourth, catch quotas are a common management strategy found in fisheries management. Catch quotas restrict the overall amount of a given species that can be harvested from a particular area, by a particular boat, or by particular gear types.[75]

Fifth, gear restrictions or requirements are also a common management strategy found in fisheries, and either forbid or mandate the use of certain types of gear.[76]

Sixth, a combination of reporting and research requirements increase available information.[77] Reporting requirements mandate that fishers, or nations, include in their preexisting reporting obligations

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73. *See, e.g.*, INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNA [ICCAT], Rec. 04-10, *Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT* (Oct. 2004), https://iccat.int/Documents/Recs/compendiopdf-e/2004-10-e.pdf (preventing fishers from having shark fins on board with a total weight in excess of 5 percent of the total weight of shark carcasses on board).

74. *See,* NORTHWEST ATLANTIC FISHERIES ORGANIZATION [NAFO], Doc. 06/1, *Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures* Ch. I, art. 13 (2006), https://www.nafo.int/Portals/0/PDFs/fc/2006/fcdoc06-01.pdf?ver=2016-02-19-063243-417 (mandating that fishers have the entire shark carcass on board, with the exception of the head, gills, and skin).

75. *See, e.g.*, Inter-American Tropical Tuna Commission [IATTC], Res C-16-06, *Conservation Measures for Shark Species, with Special Emphasis on the Silky Shark (Carcharhinus falciformis), for the Years 2017, 2018, and 2019* (2016) (prohibiting longline fishermen from retaining juvenile silky sharks in excess of 20 percent of their total catch per trip).

76. *See, e.g.*, WCPFC, CMM 2012-04, *Conservation and Management Measure for Protection of Whale Sharks from Purse Seine Fishing Operations* (Apr. 2012) (preventing fishers from deliberately encircling whale sharks with purse seine nets), https://www.wcpfc.int/system/files/CMM-2012-04-Conservation-and-Management-Measure-protection-whale-sharks-purse-seine.pdf.

77. These two requirements are included in the same type of measure because the one inherently depends upon the other. For example, research requirements are often predicated upon vessels reporting accurate data. *Id*.

any interactions with key shark species. Research requirements can differ quite drastically from each other, with some mandating that research occurs on certain shark species, or in certain areas, while others allow otherwise prohibited activities to occur if in the furtherance of research activities. [78]

Seventh, a general other category which includes such requirements as the safe release of incidentally caught sharks, geographical or area restrictions, or requirements for how and where certain shark species, when retained, are transferred between vessels.[79]

These seven measures give RFMOs the ability to protect sharks with varied and evolving strategies.

i. Western and Central Pacific Fisheries Commission (WCPFC)

The Western and Central Pacific Fisheries Commission is the RFMO that governs most of the Pacific Ocean.[80] Its convention area––meaning the area of the globe that the WCPFC governs—extends west to the East Asian seaboard, not including the South China Sea, and south to 60°S. On the east, the WCPFC area ends where the Inter-American Tropical Tuna Commission (IATTC) area begins.[81] Currently, the WCPFC consists of twenty-six members, seven participants, and seven cooperating non-members.[82] The WCPFC is aimed at managing high seas fisheries, especially in regards to such

78. *See, e.g.*, ICCAT, Rec 95-2, *Resolution by ICCAT on Cooperation with the Food & Agriculture Organization of the United Nations (FAO) with Regards to Study on the Status of Stocks and Bycatches of Shark Species* (1995), https://iccat.int/Documents/Recs/compendiopdf-e/1995-02-e.pdf (creating a reporting structure that would allow researchers to gather data on certain shark species).

79. *See,* IOTC, Res 14/06, *On Establishing a Programme for Transshipment by Large-scale Fishing Vessels* (2014) (requiring all tuna, tuna-like species, and sharks to be transferred between vessels only in port where the catches can be tracked).

80. The WCPFC convention area covers nearly twenty percent of the earth. *See*, *WCPFC Brochure*, WCPFC, 1 (2010) https://www.wcpfc.int/system/files/WCPFC%20BROCHURE%20FEB%202010.pdf.

81. *See infra* Section III.B.3.

82. Members include: Australia, China, Canada, Cook Islands, EU, Federated States of Micronesia, Fiji, France, Indonesia, Japan, Kiribati, Republic of Korea, Republic of Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Chinese Taipei, Tonga, Tuvalu, United States of America, Vanuatu; Participants: American Samoa, Commonwealth of N. Mariana Islands, French Polynesia, Guam, New Caledonia, Tokelau, Wallis and Futuna; Cooperating non-members: Ecuador; El Salvador; Mexico; Panama; Liberia; Thailand; Vietnam.

issues as unregulated fishing, over-capitalization, vessel strategies to escape controls or management, and the conservation of highly migratory fish stocks.[83]

The WCPFC has attempted numerous different strategies in order to protect sharks. The WCPFC began its work towards shark conservation in 2006, starting with a multi-strategy measure similar to many of the other RFMOs.[84] Each year from 2006 through 2010, the WCPFC passed nearly identical conservation and management measures (CMMs), each replacing the last, with only minor changes in language.[85]

These CMMs each had five main components: 1) reporting requirements, which asked members to include shark species in their annual reports; 2) full utilization requirements, mandating that fishers retain the entire shark carcass with the exception of the head, guts, and skin, until the first point of landing or transshipment; 3) a fin-to-carcass-weight ratio, mandating that vessels have on board fins that weigh, in total, no more than five percent of the total weight of shark carcasses on board; 4) a retention ban against any shark caught in violation of WCPFC CMMs; and 5) the encouragement to release incidentally-caught sharks live.[86] The shark species included in the currently active CMM are the blue shark (*Prionace glauca*), species of Mako shark (genus *Isurus*), oceanic whitetip shark (*Carchathinus longimanus*), porbeagle (*Lamna nasus*), species of hammerhead shark (the winged, scalloped, great, and smooth hammerhead sharks, genus *Sphyrna*), silky shark (*Carcharhinus falciformis*), and thresher sharks (*Alopias vulpinus*).[87]

83. WCPFC, *About WCPFC*, http://www.wcpfc.int/about-wcpfc (last visited Nov. 10, 2016).

84. *Compare* WCPFC, CMM 2006-05, *Conservation and Management Measure for Sharks in the Western and Central Pacific Ocean* (Dec. 2006), *with* ICCAT, Rec. 04-10, *Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT* (2004), *and* IATTC, Rec. C-05-03, *Resolution on the Conservation of Sharks Caught in Association with Fisheries in the Eastern Pacific Ocean* (2005).

85. Each subsequent CMM in this series superseded the previous CMM.

86. WCPFC, CMM 2006-05, *Conservation and Management Measure for Sharks in the Western and Central Pacific Ocean* (Dec. 2006); WCPFC, CMM 2008-06, *Conservation and Management Measure for Sharks* (2008); WCPFC, CMM 2009-04, *Conservation and Management Measure for Sharks* (2009).

87. WCPFC, CMM 2010-07, *Conservation and Management Measure for Sharks* (2010), https://www.wcpfc.int/system/files/CMM%202010-07%20%5bSharks%5d.pdf/.

In 2011, the WCPFC continued its protection of sharks by passing its first true retention ban.[88] WCPFC members agreed to prohibit their vessels from retaining or storing on board any oceanic whitetip shark.[89] They further encouraged the live release of any incidentally-caught oceanic whitetip in such a manner as to minimize any potential harm to the shark.[90] This CMM also included a reporting requirement to estimate the number of oceanic whitetip sharks caught, and allowed biological samples to be taken if the specimen was dead upon haul-back.[91]

The WCPFC next switched to a gear restriction method of shark protection. In 2012, a CMM was passed which prevented fishers from setting a purse seine around any school of tuna associated with a whale shark (*Rhincodon typus*).[92] Before the enactment of this CMMs, fishers would deliberately set nets around whale sharks based on their belief that tuna and whale sharks often interact. Because of the extremely large size of whale sharks,[93] it often became difficult, if not impossible, to release the whale shark alive.[94] Under the 2012 CMM, if a whale shark is accidentally encircled by a purse seine vessel, the captain must ensure the safe release of the shark and report the incident.[95]

In 2013, the WCPFC passed a second true retention ban, prohibiting the landing or storing on board of any silky shark.[96] Similar

88. WCPFC, CMM 2011-04, *Conservation and Management Measure for Oceanic Whitetip Shark* (2012), https://www.wcpfc.int/system/files/CMM-2011-04-Conservation-and-Management-Measure-Oceanic-Whitetip-Sharks.pdf. This is a "true" retention ban in that it prohibits fishers from having any oceanic whitetip sharks on board as opposed to previous conservation measures that included "pseudo-retention bans" prohibited fishers from having any illegally caught sharks on board and not prohibiting the retention of a specific shark species. *See,* WCPFC, CMM 2010-07, *supra* note 87 (prohibiting fishers from retaining any sharks caught in violation of the WCPFC conservation measures).

89. WCPFC, CMM 2011-04 *supra* note 88 at ¶ 1.

90. *Id.* at ¶ 2.

91. *Id.* at ¶ 5.

92. WCPFC, CMM 2012-04, *Conservation and Management Measure for Protection of Whale Sharks from Purse Seine Fishing Operations* (Dec. 2012), https://www.wcpfc.int/system/files/CMM-2012-04-Conservation-and-Management-Measure-protection-whale-sharks-purse-seine.pdf.

93. S.J. PIERCE & B. NORMAN, RHINCODON TYPUS, THE IUCN RED LIST OF THREATENED SPECIES (May 21, 2017), http://www.iucnredlist.org/details/full/19488/0.

94. *Id*. (describing the suspected high whale shark mortality rate upon being encircled by purse seine nets because "[c]ommon release practices, such as being lifted or towed by the caudal peduncle[the tail], are likely to cause stress, injury and possibly death to the sharks.").

95. WCPFC, CMM 2012-04, *supra* note 92.

96. WCPFC, CMM 2013-08, *CONSERVATION AND INT'L UNION FOR THE CONSERVATION OF NATURE MANAGEMENT MEASURE FOR SILKY SHARKS* (2013), https://www.wcpfc.int/system/files/CMM%202013-08%20CMM%20for%20Silky%20Sharks_0.pdf.

to the 2011 CMM, the WCPFC also mandated vessels report any silky sharks that they released and allowed on-board scientific observers to take biological samples from individual silky sharks caught.[97]

The WCPFC established a second gear restriction in 2014 when it barred longline fishers targeting tuna and billfish from using or carrying on board shark lines.[98] Shark lines are set shallower than typical longlines and specifically target sharks because they are made of a stronger material that sharks cannot bite through. This is done to ensure that the sharks are attracted to these lines, instead of to the tuna that had previously been caught.[99] Further, the 2014 CMM required WCPFC members to develop a management plan that specifically includes a license structure and total allowable catch, in order to further protect sharks.[100]

ii. International Commission for the Conservation of Atlantic Tunas (ICCAT)

The International Commission for the Conservation of Atlantic Tunas (ICCAT) is the RFMO that governs fisheries in the Atlantic Ocean. It currently has fifty contracting parties and four cooperating non-parties,[101] most of which are countries with Atlantic Ocean coastlines. ICCAT governs the conservation of tuna and tuna-like

97. *Id*.

98. WCPFC, CMM 2014-05, *Conservation and Management Measures for Sharks* (Dec. 2014), https://www.wcpfc.int/system/files/CMM%202014-05%20Conservation%20and%20Management%20Measure%20for%20Sharks.pdf (prohibits boats from carrying wire trace, branch lines, or leaders).

99. Further, there is some indication that some sharks sit higher in the water column than the tuna schools they associate with. Therefore, in an effort to target these shallow swimming sharks, fishers will set metal or wire lines, stronger material than typical tuna lines in order to account for the stronger species, above the deeper set tuna lines. *See*, Stephen Brouwer et al., *The Western and Central Pacific Tuna Fishery: 2016 Overview and Status of Stocks*, 8 (2016) (reporting that the "shallow fishery has a higher proportion of non-tuna species in the catch, principally shark and billfish . . .").

100. WCPFC, CMM 2014-05, *supra* note 98.

101. Contracting Parties: United States, Japan, South Africa, Ghana, Canada, France, Brazil, Marco, Korea, Cote D'Ivoire, Angola, Russia, Gabon, Cape-Verde, Uruguay, Sao Tome E Principe, Venezuela, Guinea Equatorial, Guinee Rep., UK, Libya, China, EU, Tunisia, Panama, Trinidad & Tobago, Namibia, Barbados, Honduras, Algeria, Mexico, Vanuatu, Iceland, Turkey, Philippines, Norway, Nicaragua, Guatemala, Senegal, Belize, Syria, St. Vincent & the Grenadines, Nigeria, Egypt, Albania, Sierra Leone, Mauritania, Curacao, Liberia, El Salvador, Guinee-Bissau; Cooperators: Bolivia, Chinese Taipei, Suriname, Guyana. WCPFC, *About WCPFC,* https://www.wcpfc.int/about-wcpfc (last visited Mar. 10, 2018).

species within its convention area[102] through compiling fishery statistics, coordinating research activities, and developing science-based management.[103]

In contrast to the WCPFC, ICCAT has relied much more heavily on retention bans in order to protect sharks than on other types of measures. ICCAT started its shark conservation in 1995, ten years before any other international fishery organization, with a reporting requirement aimed at gathering global shark data.[104] ICCAT was also the first organization to pass a multi-strategy recommendation that has since been adopted by nearly every other international fishery organization.[105] This recommendation included a retention ban from sharks caught in violation of the convention, a reporting requirement for shark catches, a requirement for full utilization of sharks, and a five percent fin-to-carcass ratio.[106] Further, this recommendation encouraged fishers to release live sharks, especially juveniles, if incidentally caught.[107]

ICCAT then focused more heavily on shark retention bans. In 2007, it banned all retention of porbeagle (*Lamna nasus*) and North Atlantic shortfin Mako sharks (*Isurus oxyrinchus*).[108] In 2009, it added a retention ban on bigeye thresher sharks (*Alopias superciliosus*) and prohibited any directed fishery on *Alopias* species.[109] In 2010, ICCAT passed three more recommendations relating to shark conservation. First, it established a retention ban for all shortfin Mako sharks.[110]

102. ICCAT, https://iccat.int/en/ (last visited Nov. 10, 2016).

103. *Id*.

104. ICCAT, Rec 95-2, *Resolution by ICCAT on Cooperation with the FAO of the U.N. with Regards to Study on the Status of Stocks and Bycatches of Shark Species* (1995), https://iccat.int/Documents/Recs/compendiopdf-e/1995-02-e.pdf.

105. *Compare* ICCAT, Rec. 04-10, *Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT* (2004), https://iccat.int/Documents/Recs/compendiopdf-e/2004-10-e.pdf, *with* WCPFC, CMM 2010-07, *supra* note 87. This is particularly encouraging because it indicates that RFMOs either communicate with each other, or at least pay attention to what other RFMOs are doing. Therefore, if proposed CMMs are shown to be effective and beneficial in one RFMO, others are likely to adopt that same or substantially similar CMM.

106. ICCAT, Rec. 04-10, *Recommendation by ICCAT Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by ICCAT* (2004), https://iccat.int/Documents/Recs/compendiopdf-e/2004-10-e.pdf.

107. *Id*.

108. ICCAT, Supp. Rec. 07-06, *Supplemental Recommendation by ICCAT Concerning Sharks* (2007), https://iccat.int/Documents/Recs/compendiopdf-e/2007-06-e.pdf.

109. ICCAT, Rec. 09-07, *Recommendation by ICCAT on the Conservation of Thresher Sharks Caught in Association with Fisheries in ICCAT Convention Area* (2009), https://iccat.int/Documents/Recs/compendiopdf-e/2009-07-e.pdf.

110. ICCAT, Rec 10-06, *Recommendation by ICCAT on Atlantic Shortfin Mako Sharks*

Second, it prohibited the retention of any oceanic whitetip shark.[111] Finally, it added a retention ban for hammerhead sharks in the family *Sphyrnidae*.[112] This trend of using retention bans continued in 2011, with the inclusion of a retention ban on all silky sharks.[113]

In 2013, ICCAT passed a reporting and fishing-strategy recommendation.[114] This recommendation allowed the collection of biological samples from shark species, but only if in conjunction with a permitted scientific study, and only from specimens already dead upon haul-back.[115] The fact that ICCAT added a reporting requirement after having already established numerous retention bans indicates that something in the retention bans was not working. If the retention bans were successfully protecting sharks, then the reporting and fishing strategy recommendation would be unnecessarily cumulative. Instead, this additional measure suggests that the retention bans, at least on their own, were not successfully protecting shark species.[116]

iii. Inter-American Tropical Tuna Commission (IATTC)

The Inter-American Tropical Tuna Commission (IATTC) governs conservation and management of tuna and other marine resources in the eastern Pacific Ocean from 150°W towards the

Caught in Association with ICCAT Fisheries (2010), https://iccat.int/Documents/Recs/compendiopdf-e/2010-06-e.pdf.

111. ICCAT, Rec 10-07, *Recommendation by ICCAT on the Conservation of Oceanic Whitetip Shark Caught in Association with Fisheries in ICCAT Convention Area* (2010), https://iccat.int/Documents/Recs/compendiopdf-e/2010-07-e.pdf.

112. ICCAT, Rec 10-08, *Recommendation by ICCAT on Hammerhead Sharks (Family Sphyrnidae) Caught in Association with Fisheries Managed by ICCAT* (2010), https://iccat.int/Documents/Recs/compendiopdf-e/2010-08-e.pdf.

113. ICCAT, Rec 11-08, *Recommendation by ICCAT on the Conservation of Silky Sharks Caught in Association with ICCAT Fisheries* (2011), https://iccat.int/Documents/Recs/compendiopdf- e/2011-08-e.pdf.

114. ICCAT, Rec 13-10, *Recommendation on Biological Sampling of Prohibited Shark Species by Scientific Observers* (2013), https://iccat.int/Documents/Recs/compendiopdf-e/2013-10-e.pdf.

115. *Id*.

116. Likely because retention bans, alone, are ineffective to protect shark species based on the fact that many sharks who encounter fisheries at all perish as a result of that encounter, regardless of whether the fisher is able to retain that individual specimen or not. *See infra* Section IV.E.

American continental coast.[117] The IATTC consists of twenty-one members and four cooperating non-members.[118]

The IATTC has recently passed numerous shark conservation resolutions with new and innovative ideas for the protection of sharks. The IATTC passed its first shark-related resolution in 2005.[119] This resolution followed ICCAT's 2004 approach by requiring the full utilization of any sharks retained by fishers and mandated that shark specimens on board must include the shark's full bodies except head, guts, and skin.[120] Further, the IATTC instituted a fin-to-carcass ratio of five percent, imposed a reporting requirement on its members in relation to shark catches, and prohibited any retention of sharks caught in violation of IATTC regulations.[121]

From 2005 to 2016, the IATTC passed only one more shark-related resolution, a retention ban for all oceanic whitetip sharks, which also included a reporting requirement.[122] Then in 2016, the IATTC switched shark protection strategies by passing three more resolutions. First, IATTC amended its 2005 resolution to include gear selectivity requirements.[123] IATTC members now must identify ways to make gear less likely to catch sharks as bycatch.[124] Next, the IATTC prohibited longline vessels from using shark lines, which would target sharks despite the vessel fishing for tuna and billfish.[125] This measure also included a reporting requirement and safe release requirements for any incidental catch of silky sharks (*Carcharhinus falciformis*) and hammerhead sharks (i.e., *Sphyrna lewini*, *S. zygaena*, and *S. mokarran*).

Finally, the IATTC passed a much more aggressive protection measure for silky sharks than any other international fishery organization.[126] This resolution included three new strategies: a catch

117. IATTC, https://www.iattc.org/HomeENG.htm (last visited Nov. 10, 2016).

118. Members: Belize, Canada, China, Colombia, Costa Rica, Ecuador, El Salvador, EU, France, Guatemala, Japan, Kiribati, Korea, Mexico, Nicaragua, Panama, Peru, Chinese Taipei, U.S., Vanuatu, Venezuela; Cooperating non-members: Bolivia, Honduras, Indonesia, Liberia. *Id*.

119. IATTC, Res C-05-03, *Resolution on the Conservation of Sharks Caught in Association with Fisheries in the Eastern Pacific Ocean* (June 24, 2005).

120. *Compare id.*, *with* ICCAT, Rec 04-10, *supra* note 106.

121. IATTC, Res C-05-03, *supra* note 119.

122. IATTC, Res C-11-10*, Resolution on the Conservation of Oceanic Whitetip Sharks Caught in Association with Fisheries in the Antigua Convention Area* (July 8, 2011).

123. IATTC, Res C-16-04, *Amendment to Resolution C-05-03 on the Conservation of Sharks Caught in Association with Fisheries in the Eastern Pacific Ocean* (July 1, 2016).

124. *Id*.

125. IATTC, Res C-16-05, *Resolution on the Management of Shark Species* (July 1, 2016).

126. IATTC, Res C-16-06, *Conservation Measures for Shark Species, with Special Emphasis*

quota, an area restriction, and a monthly gear restriction. First, the resolution established a retention ban for all silky sharks.[127] It next adopted the first true catch quota for sharks by prohibiting longliners from having more than twenty percent of their total catch per trip consist of silky shark bycatch.[128] Further, any vessels using surface longlines are not allowed to catch more than twenty percent of their allowed silky shark bycatch of individuals less than 100 cm in total length, per trip.[129] Vessels are also prohibited from fishing in known silky shark pupping areas, and cannot use steel leaders during three consecutive months each year.[130]

iv. Indian Ocean Tuna Commission (IOTC)

The Indian Ocean Tuna Commission (IOTC) governs fishing for tuna, mackerel, billfish, and related species in the Indian Ocean from 20°E to 150°E.[131] The IOTC governance extends as far south as 45°S longitude in the western Indian Ocean, and 55°S in the eastern Indian Ocean.[132] The IOTC consists of 31 members, and four cooperating non-members.[133] The IOTC is responsible for the conservation and management of tuna and tuna-like species through the promotion of cooperation amongst nations, the optimal utilization of fish stocks, and the sustainable development of future fisheries.[134]

In recent years, the IOTC, similar to the IATTC, has adopted more aggressive shark conservation measures. The IOTC began its shark conservation in 2005 when it passed a measure, similar to the

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on the Silky Shark (Carcharhinus falciformis), for the Years 2017, 2018, and 2019 (July 1, 2016).

127. *Id*.

128. It is unclear why this measure was directed specifically at longliners as opposed to other fishers, or why it included such a high catch limit. *See*, IATTC, 90TH MEETING, MINUTES OF THE MEETING (July 1, 2016) ¶4(d)(v.1)–(v.2) (noting that while various members supported these recommendations, Costa Rica and the European Union thought that the recommendations did not go far enough and planned to submit additional proposals.). Perhaps this indicates that any weaknesses in the regulations were intended to be addressed by future proposals.

129. IATTC, Res C-16-06, *supra* note 126.

130. *Id.*

131. IOTC, *The Commission: Objectives*, http://www.iotc.org/about-iotc/competence (last visited May 22, 2017).

132. *Id*.

133. Members: Australia, Belize, China, Comoros, EU, France, Guinea, India, Indonesia, Iran, Japan, Kenya, Korea, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Oman, Pakistan, Philippines, Seychelles, Sierra Leone, Somalia, Sri Lanka, South Africa, Sudan, Tanzania, Thailand, UK, Yemen; Cooperating non-members: Bangladesh, Djibouti, Liberia, Senegal. *Structure of the Commission*, IOTC, http://www.iotc.org/about-iotc/structure-commission (last visited Feb. 15, 2018).

134. IOTC, *The Commission: Objectives*, http://www.iotc.org/ (last visited Nov. 10, 2016).

IATTC and ICCAT, which established a retention ban for sharks caught in violation of the IOTC regulations, a fin-to-carcass ratio of five percent, a body requirement for the full utilization of the shark, and a reporting and research requirement for shark catches.[135] From 2005 until 2012, the IOTC did not pass any other shark related resolutions.

In 2012, the IOTC prohibited the use of large scale driftnets on the high seas.[136] This was not directly in order to protect sharks, but was of benefit to shark populations that had previously been caught and killed by such nets.[137] That same year, the IOTC also passed a retention ban for thresher sharks (Family *Alopiidae*).[138] This measure required that vessels who had the potential to incidentally catch thresher sharks have proper equipment on board which would facilitate the safe release of any individual caught.[139]

In 2013, the IOTC passed a research and reporting measure in order to determine which shark species should be protected in the future.[140] This was to be done through the development of a full stock assessment on Indian Ocean sharks.[141] Further, while the stock assessments were being conducted, the IOTC established an interim retention ban on oceanic whitetip sharks.[142] The IOTC also passed a 2013 resolution aimed at protecting whale sharks.[143] This measure prohibited vessels from intentionally setting a purse seine around a whale shark, mandated the safe release of any whale shark encircled incidentally, and included reporting requirements for any such encounter with a whale shark.[144]

135. IOTC, Res. 05/05*, Concerning the Conservation of Sharks Caught in Association with Fisheries Managed by IOTC* (2005).

136. IOTC, Res. 12/12, *To Prohibit the Use of Large-Scale Driftnets on the High Seas in the IOTC Area* (2012).

137. *See* Simon P. Northridge, FAO of the U.N., *Driftnet Fisheries and their Impacts on Non-Target Species: A WorldwideRreview*, FAO Fisheries Technical Paper, No. 320, Ch. 2 (1991) (describing how driftnet fisheries in the Pacific, Indian, Atlantic, and Mediterranean oceans all report incidental catches of various shark species, sometimes at high levels).

138. IOTC, Res. 12/09, *On the Conservation of Thresher Sharks (Family Alopiidae) Caught in Association with Fisheries in the IOTC Area of Competence* (2012).

139. *Id*.

140. IOTC, Res. 13/06, *On a Scientific and Management Framework on the Conservation of Shark Species Caught in Association with IOTC Managed Fisheries* (2013) (passing the measure over the objection of India, who took a reservation on IOTC Res. 13/06).

141. *See generally, infra* Section IV.

142. IOTC, Res 13/06, *On a Scientific and Management Framework on the Conservation of Shark Species Caught in Association with IOTC Managed Fisheries* (2013).

143. IOTC, Res. 13/05, *supra* note 8.

144. *Id*.

In 2014, the IOTC passed a resolution to ensure that all tuna, tuna-like species, and shark transshipments occur in port.[145] This measure was aimed at preventing any shark fishing from occurring in violation of the IOTC provisions.[146] Then in 2015, the IOTC passed two more related resolutions. First, the IOTC mandated a reporting requirement for all shark catches.[147] Then, the IOTC significantly limited the use of Fish Aggregating Devices (FADs).[148] This measure was not specifically aimed at protecting sharks, but was also beneficial to them as sharks had been negatively impacted by FADs in the past.[149] This resolution set a maximum number of FADs that each vessel was allowed to follow and recommended what materials should be used in the construction of FADs.[150]

In 2016, the IOTC first mandated that all parties include shark catches in their annual reports to the IOTC.[151] Then, the IOTC passed a gear restriction strategy.[152] Vessels were prohibited from using artificial lights on the underside of their vessels. Artificial lights were used to aggregate fishes around boats, and caused an unnecessary increase in shark bycatch, as the sharks were also attracted to the lights.

145. *See* IOTC, *On Establishing a Programme for Transshipment by Large-scale Fishing Vessels*, Res. 14/04 (Oct. 8, 2014), http://www.iotc.org/sites/default/files/documents/compliance/cmm/iotc_cmm_14-06.pdf.

146. *Id.*

147. IOTC, Res. 15/01, *On the Recording of Catch and Effort Data by Fishing Vessels in the IOTC Area of Competence* (2015), http://www.iotc.org/cmm/resolution-1501-recording-catch-and-effort-data-fishing-vessels-iotc-area-competence.

148. IOTC, Res. 15/08, *Procedures on a Fish Aggregating Devices (FADs) Management Plan, Including a Limitation on the Number of FADS, More Detailed Specifications of Catch Reporting from FAD Sets, and the Development of Improved FAD Designs to Reduce the Incidence of Entanglement of Non-Target Species* (2015), http://www.iotc.org/cmm/resolution-1508-procedures-fads-management-plan-including-limitation-number-fads-more-detailed.

149. *See, e.g.*, THE PEW ENVTL. GROUP, *Fish Aggregating Devices (FADs) and Tuna: Impacts and Management Options*, 6, tbl. 1 (2011), http://www.pewtrusts.org/~/media/legacy/uploadedfiles/peg/publications/report/pegosdfadsenglishfinalpdf.pdf (reporting that sharks are the second most common incidentally caught group of animals in FADs). In the Western and Central Pacific Ocean, while sharks represented just 5 percent of bycatch in fishing sets not associated with FADs, they represented 20 percent of bycatch in FAD-associated fishing sets. *Id.*

150. IOTC, Res. 15/08, *supra* note 148.

151. IOTC, Res. 16/06, *On Measures Applicable in case of Non Fulfilment of Reporting Obligations in the IOTC* (2016), http://www.iotc.org/cmm/resolution-1606-measures-applicable-case-non-fulfilment-reporting-obligations-iotc.

152. IOTC, Res. 16/07, *On the use of Artificial Lights to Attract Fish* (2016), http://www.iotc.org/cmm/resolution-1607-use-artificial-lights-attract-fish.

v. Northwest Atlantic Fisheries Organization (NAFO)

The Northwest Atlantic Fisheries Organization (NAFO) has less participants than other RFMOs, with only eleven contracting parties.[153] NAFO governs only a small area of the Atlantic Ocean between Canada and Greenland, yet it covers important commercial fisheries such as Atlantic cod, haddock, lobsters, and shrimp.[154] NAFO convention area includes portions of the U.S., Canada, and Greenland exclusive economic zones (EEZs), and as a result NAFO management only applies to the waters outside, or straddling, those EEZs.[155] NAFO aims at ensuring optimal utilization of fish stocks, rational management, and conservation of fishery resources within its convention area.[156]

NAFO has had shark conservation measures in place since 2006, but they are not very extensive. In 2006, NAFO followed the RFMO trend of passing shark conservation measures similar to IAATC Rec. 04-10.[157] This measure established a reporting requirement for all shark catches, required the full utilization of sharks by fishers, mandated a five percent fin-to-carcass ratio, and utilized a retention ban for all fisheries not directly targeting sharks, which required them to release all sharks caught incidentally. These measures were maintained without change from their passage in 2006 through 2011. Then, in 2012 NAFO added the requirement that vessels report shark catches to the species level when possible.[158] Finally, in 2016 during the NAFO General Council and Subsidiary Body meeting, a measure was recommended and rules were put in place to establish a fins-attached measure, which would prohibit fishers from removing shark fins from their carcass while at sea.[159]

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153. Contracting Parties include Canada, Cuba, Denmark (Faroe Islands and Greenland), the EU, Iceland, Japan, Norway, Korea, Russian Federation, Ukraine, and the United States.

154. NAFO, *NAFO Convention Area*, https://www.nafo.int/about-us. (last visited Nov. 10, 2016).

155. *Id.*

156. *Id.*

157. *Compare* NAFO, *Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures*, at Ch. I, Art. 13, Doc. 06/1, (2006), https://archive.nafo.int/open/fc/2006/fcdoc06-01.pdf, *with* ICCAT, Rec. 04-10, *supra* note 73.

158. NAFO, *Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures*, at Ch. I, Art. 12; Ch. IV, Art. 25, Doc. 12/1 (2012),https://archive.nafo.int/open/fc/2016/fcdoc16-01.pdf.

159. NAFO, *Northwest Atlantic Fisheries Organization Report of the General Council and its Subsidiary Body* (STACFAD), at Art.7, Art.10, Art.12, Doc. 16/03 (2016), https://archive.nafo.int/open/gc/2011/gcdoc11-03.pdf.; *but see* NAFO, *Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures*, at Ch. I, Art. 12, et seq., Doc. 16/01 (2016),

vi. Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

In terms of membership, the smallest of all the RFMOs is the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). The CCSBT consists of eight members and one cooperating non-member.[160] While other RFMOs have their jurisdictions geographically bounded, the CCSBT governs the conservation of Southern Bluefin tuna throughout its entire range. Southern Bluefin tuna are commonly found in the southern hemisphere, mainly between 30° and 50°S.[161]

The CCSBT has been by far the least proactive of the RFMOs as far as shark conservation is concerned. In 2011, the CCSBT passed its one and only recommendation relating to shark conservation.[162] This recommendation simply requests that CCSBT members follow, to the extent possible, all current measures aimed at protecting ecologically related species to tuna, such as sharks, that are adopted by the IOTC, WCPFC, or ICCAT.

IV. SCIENTIFIC KNOWLEDGE AND STOCK ASSESSMENTS FOR KEY SHARK SPECIES

Largely, management decisions about how to best protect shark species are guided by best guesses and indirect indications of shark populations rather than by concrete scientific information. Efforts to quantify shark population dynamics, catch per unit effort, and other matrices indicative of population health have not been established between the various RFMOs.[163] As a result, shark population statuses

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https://archive.nafo.int/open/fc/2016/fcdoc16-01.pdf (describing NAFO's current conservation and management measures for sharks, but not including any information on a fins-attached rule).

160. Members include Australia, the EU, the Fishing Entity of Taiwan, Indonesia, Japan, Republic of Korea, New Zealand, South Africa; and Cooperating. Non-members include the Philippines.

161. COMMISSION FOR THE CONSERVATION OF SOUTHERN BLUEFIN TUNA [CCSBT], *About Southern Bluefin Tuna*, https://www.ccsbt.org/en/content/about-southern-bluefin-tuna (last visited Nov. 11, 2016).

162. COMMISSION FOR THE CONSERVATION OF SOUTHERN BLUEFIN TUNA [CCSBT], *Recommendation to Mitigate the Impact of Ecologically Related Species of Fishing for Southern Bluefin Tuna*, Rec 2011 ERS (2011), https://www.ccsbt.org/sites/default/files/userfiles/file/docs_english/operational_resolutions/Recommendation_ERS.pdf.

163. For example, since 2015 the IOTC has conducted at least nine different scientific studies attempting to classify shark conservation statuses or determine how certain shark species interact with Indian Ocean fisheries, while the IATTC has conducted only two in its entire history and NAFO has conducted none. *See, e.g.*, IOTC, RES. 13/05, *supra* note 8; IOTC, *Shortfin Mako Shark Supporting Information* (2016); IOTC, *Executive Summary: Oceanic Whitetip Shark* (2015); IOTC, *Silky Shark Supporting Information* (2016). *But see* IATTC, *Fishery Status Report No. 14* (2016).

across the globe are largely unknown.[164] Recently, some RFMO scientific committees have made an effort to better determine the conservation status of key shark species.[165] This effort has also included determining the life-history and behavioral characteristics of shark species. In general, however, uncertainties and a lack of reliable data have forced RFMO scientific committees to make few confident predictions about the current status of shark stocks.[166] Current conservation determinations are largely based on uncertain data,[167] geographically bounded based on the respective RFMO conducting the study,[168] and without concrete conclusions.[169] The continuation of scientific forays into these topics is crucial in order to better inform conservation measures and to ensure the long-term survival of key shark species in our global oceans. Simply put, the more we know, the better we are able to identify species' vulnerabilities in order to protect sharks long into the future.

While scientific data on global shark populations may be limited, some patterns are able to be identified from the information that is known.[170] It is these overall patterns that, if incorporated into future

164. *See, e.g.*, THE IUCN RED LIST OF THREATENED SPECIES, http://www.iucnredlist.org/search (search "shark" in search term box, then click on "assessment" on the left hand side to see the available data) (stating that currently 61 out of 245, or nearly 25 percent, of shark species have not been analyzed to determine their conservation status because of a deficiency in data).

165. *See,* IOTC, Res. 13/05 *supra* note 8.

166. *See infra* note 291, 292 and accompanying text describing how, despite being listed as vulnerable by the IUCN, ICCAT was the only RFMO to attempt to classify the conservation status of Porbeagle sharks.

167. *See*, Western & Central Pacific Fisheries Commission Scientific Committee [WCPFCSC], *Stock Assessment of Blue Shark in the North Pacific Ocean using Stock Synthesis*, at ¶4 (Aug. 2014), https://www.wcpfc.int/system/files/SC10-SA-WP-08%20NP%20BSH%20 assessment%20SSynthesis.pdf (failing to determine a conservation status on blue sharks in the Pacific Ocean based on unreliable data).

168. *See, e.g.*, ICCAT, *2012 Shortfin Mako Stock Assessment and Ecological Risk Assessment Meeting*, at ¶ 6.2 (2012), https://www.iccat.int/Documents/Meetings/Docs/2012_SHK_ ASS_ENG.pdf (determining that the shortfin mako shark was neither overfished nor experiencing overfishing in the Atlantic Ocean); *c.f.* IOTC, *Shortfin Mako Shark Supporting Information*, *supra* note 163, at 2 (determining that it was not possible to come to a concrete determination on the conservation of shortfin mako sharks in the Indian Ocean).

169. *See, e.g.*, WCPFCSC, *Stock Assessment of Blue Sharks*, *supra* note 167; IOTC, *Shortfin Mako Supporting Information*, *supra* note 163; *but see* ICCAT, *2012 Shortfin Mako Stock Assessment and Ecological Risk Assessment Meeting*, *supra* note 168.

170. To be clear, the scientific information presented below is all the product of the various RFMO scientific committees and not necessarily adopted by the RFMOs themselves. In general, RFMO scientific committees conduct research, analyze data, and prepare reports to be presented to the RFMO. It is then up to the RFMO's discretion whether or not they wish to adopt those findings as their own. *See, e.g.*, WCPFC, *Guidelines outlining the process for formulating the work*

conservation measures, will help to ensure that measures are as effective as possible. Further, the more an individual species is studied, the more scientists are able to predict key behavioral and life-history traits. These traits can also be incorporated into species-specific conservation measures in order to protect those species from extinction.

A. The Blue Shark (Prionace glauca)

The International Union on the Conservation of Nature (IUCN) lists the blue shark as near threatened globally, largely due to its vulnerability to fishing pressures.[171] The blue shark is regularly caught as bycatch in the longline fishery.[172] High haul-back mortality rates (~24 percent),[173] especially among smaller individuals, cause a large proportion of incidentally caught sharks to perish before fishers are able to release them back into the ocean.

Blue sharks are also subjected to some targeted fishing pressures. The IOTC reported the targeting of blue sharks by some small-scale artisanal fisheries and semi-industrial fisheries. Due to the rising commercial value of shark fins on the global market, there has been an increase in fully industrial fisheries also targeting blue shark, most notably in the Indian Ocean.[174] The blue shark's tendency to congregate in large schools of similarly sized individuals makes them easily targeted by fishers.[175]

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programme and budget of the Scientific Committee, at SC-05, Attachment P (2009) (describing the process through which the Commission for the Conservation and Management of Highly Migratory Fish Stocks sets the work of their scientific committee, including the requirement that the commission review and endorse the scientific committee's recommendations in order to adopt those recommendations as the commission's). The below information was limited to RFMO scientific committee reports and data because that is the information that each RFMO would have at its disposal when considering new conservation measures, regardless of whether it was formally adopted by the RFMO or not.

171. THE IUCN RED LIST OF THREATENED SPECIES, *Blue Shark*, http://www.iucnredlist.org/details/39381/0 (last visited Nov. 10, 2016).

172. WCPFCSC, *An Indicator-Based Analysis of Key Shark Species Based on Data Held by SPC-OFP*, at ¶ 3.1 (2011), https://www.wcpfc.int/system/files/EB-WP-01%20%5BIndicator-based%20Analysis%20of%20SPC%20Shark%20Data%5D_0.pdf.

173. IOTC, *Blue shark supporting information*, *supra* note 8, at 3. A Haul-back mortality rate is the number of sharks that are dead when fishers pull them out of the water, preventing the shark from being safely returned to the sea if incidentally caught. *Id.*

174. *Id.* at 3, fig. 2 (depicting the exponential increase in total reported blue shark catches, according to the IOTC database, from 1970, when landings were below 5000 metric tons, through 2014, when landings were above 30,000 metric tons).

175. *Id.* at tbl. 1.

Blue sharks have a pan-Pacific distribution, which is influenced by seasonal water temperature variations.[176] Researchers have reported large migrations of blue sharks throughout the Pacific Ocean, but have not observed any evidence of blue sharks crossing the equator.[177] This led researchers to conclude that there are two stocks of blue shark in the Pacific Ocean: a North Pacific stock and a South Pacific stock.[178] A similar pattern was found in the Atlantic Ocean, causing researchers to conclude that there are two analogous separate stocks of blue sharks in the Atlantic Ocean as well.[179]

The blue shark life-history characteristics often leave it vulnerable to overfishing. Blue shark individuals are relatively long-lived, with males living to an estimated 25 years and females to 21 years.[180] They also exhibit variable fecundity based on the size of the female. On average, females will birth between 25 and 50 pups per year, but litter sizes can be as low as four or as high as 135 pups.[181] Litter sizes are largely dependent on the size of the female, with larger females pupping larger litters.[182] This indicates that fishing pressures on moderate or large-sized individuals could cause indirect negative effects on blue shark populations. Fishing efforts focused on large sized individuals would prevent those individuals with the highest pupping-potential from being able to continue reproducing. Blue sharks also have a nine- to 12-month gestation period, and an annual reproductive cycle.[183] This means that females will typically only have one litter per year.[184]

Blue sharks mature relatively late, with males maturing between four and seven years and females between five and seven.[185] This indicates that fisheries that impact juveniles, especially because juveniles are more likely to have higher haul-back mortality,[186] may also be negatively affecting stock status by preventing blue sharks from surviving to maturity.

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176. *Id.* Blue sharks are reported to have a thermal preference of 12-25° C. *Id.*

177. WCPFCSC, *Stock Assessment of Blue Sharks*, *supra* note 167, at ¶3.

178. *Id.* It remains unclear whether the Indian Ocean holds its own stock of blue sharks, or whether the Indian Ocean stock is mixed with the south Atlantic stock.

179. ICCAT, *Report of the 2015 ICCAT Blue Shark Stock Assessment Session*, at ¶4 (2015).

180. IOTC, *Blue shark supporting information*, *supra* note 8, at 2.

181. *Id.*

182. *Id.*; *see also* "BOFFFF Theory", *infra* note 315 and accompanying text.

183. IOTC, *Blue shark supporting information*, *supra* note 8, at 2.

184. *Id.*

185. *Id.*

186. *See id.* at 3.

Due to uncertainties in the data, and a lack of reliable reporting, confident stock statuses for blue sharks are not found. Only three RFMOs, the WCPFC, ICCAT, and IOTC, conducted surveys into the status of blue shark populations. The WCPFC was unable to provide any estimate of the conservation status of blue sharks in the Pacific Ocean.[187] It did note, however, that blue shark catch rates were falling exponentially in each region of the Pacific Ocean, even when accounting for variable catch-per-unit-effort (CPUE).[188] This indicates a decrease in blue shark population. ICCAT estimated that the North Atlantic stock of blue sharks was neither overfished nor subjected to overfishing, but conceded that there were high levels of uncertainty in the data and did not further justify its conclusions.[189] Further, ICCAT concluded that the South Atlantic stock could be subjected to overfishing and could be overfished, but was similarly unable to conclude this with any certainty.[190] The IOTC appeared to have the most reliable stock assessment on blue sharks. In the Indian Ocean, the IOTC concluded that blue sharks were not yet subjected to overfishing, nor were they overfished.[191] However, the IOTC also concluded that blue sharks were vulnerable to overfishing and that the stock levels were close to their maximum sustainable yield (MSY).[192] Further, the IOTC noted that due to piracy concerns in the western Indian Ocean, the fishing fleet has concentrated its efforts in the eastern Indian Ocean; consequently, localized depletion could be occurring.[193]

B. *Shortfin Mako (Isurus oxyrinchus)*

Globally, the IUCN lists the shortfin Mako shark as vulnerable,[194] largely due to its susceptibility to the fishing gear that it commonly encounters, its life-history characteristics, and its largely unknown

187. WCPFCSC, *Stock Assessment of Blue Sharks*, *supra* note 167, at ¶7.

188. In other words, despite fishing efforts remaining the same, blue shark catch rates were dropping; *see, e.g.*, WCPFCSC, *Indicator-Based Analysis of Key Shark Species*, *supra* note 172, at fig. 10 (depicting Blue Shark CPUE in the western and central Pacific Ocean rapidly declining from 1995 to 2010).

189. ICCAT, *Blue Shark Stock Assessment Session*, *supra* note 179, at ¶6.2.

190. *Id.*

191. IOTC, *Executive Summary Blue Shark*, *supra* note 5, at 1.

192. *Id.*

193. *Id.* The IOTC noted that because the risk of encountering pirates was high in the western Indian Ocean, as a response the fishing fleet was concentrating effort in the eastern Indian Ocean, and therefore shark stocks in the eastern Indian Ocean were being subjected to artificially high fishing pressures, which potentially subjected them to localized depletion. *Id.*

194. THE IUCN RED LIST OF THREATENED SPECIES, *Shortfin Mako Shark*, http://www.iucnredlist.org/details/39341/0 (last visited Feb. 19, 2018).

population status. The shortfin Mako is commonly encountered by longline fishers in both the Pacific and Indian Oceans.[195] Shortfin Mako sharks are highly susceptible to both longline and purse seine gear types, due to an estimated 56 percent haul-back mortality rate,[196] and to both deep and shallow water sets,[197] causing them to appear as bycatch in most fisheries.

Shortfin Mako sharks are widely distributed in both tropical and temperate waters, with an observed thermal preference for waters greater than 16°C.[198] They are not known to school, but their highly migratory tendencies suggest a single well-mixed population, at least, in the Indian and Pacific oceans.[199] Shortfin Mako sharks are often found in both epipelagic[200] and littoral[201] waters, commonly occurring at depths ranging from the surface to 500 meters.[202]

The life-history characteristics of shortfin Mako sharks make them vulnerable to fishing pressures. Shortfin Mako sharks are a long-lived species, with males typically living up to 29 years, and females to 32 years.[203] Shortfin Mako sharks, especially females, are a late maturing species. While male shortfin Mako sharks are estimated to mature between seven and nine years old, females do not mature until 15 to 21 years of age.[204] This indicates that any fishing pressure on juveniles, or even young adults, could have negative impacts on the overall populations because smaller females would not yet have reached sexual maturity. Making them even more vulnerable, shortfin Mako sharks have a low fecundity rate. Their gestation period is 15 to 18

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195. IOTC, *Executive Summary: Mako Shark* (2015), http://www.iotc.org/sites/default/files/documents/science/species_summaries/english/Shortfin%20mako%20shark%20Executive%20Summary.pdf; WCPFCSC, *A Status Snapshot of Key Shark Species in the Western and Central Pacific and Potential Management Options*, at 4, (2011), http://www.wcpfc.int/system/files/EB-WP-04%20%5BA%20Status%20Snapshot%20of%20key%20shark%20species%5D_0.pdf.

196. IOTC, *Shortfin Mako Shark Supporting Information*, *supra* note 163, at 2.

197. WCPFCSC, *Status Snapshot of Key Shark Species*, *supra* note 195, at 4.

198. IOTC, *Shortfin Mako Shark Supporting Information*, *supra* note 163, at 2.

199. *Id.*

200. The epipelagic zone is defined as the upper zone of the ocean or the zone into which enough light is able to penetrate so that photosynthesis may occur. *See epipelagic zone*, MERRIAM-WEBSTER DICTIONARY, https://www.merriam-webster.com/.

201. The littoral zone is defined as those parts of the ocean associated with the shore, "of, relating to, or situated . . . on or near a shore especially of the sea." *See littoral*, MERRIAM-WEBSTER DICTIONARY, https://www.merriam-webster.com/.

202. IOTC, *Shortfin Mako Shark Supporting Information* (2016), *supra* note 163, at 2.

203. *Id.*

204. *Id.*

months, and their reproductive cycle is biennial or even triennial, causing mature females to produce less than 25 pups every two to three years.[205]

Highly accurate stock assessments on shortfin Mako sharks have not yet been produced by RFMOs, largely because of uncertainty in the data collected and too few data sources. The WCPFC concluded that the status of shortfin Mako sharks in the western and central Pacific Ocean is unknown, but that the downward trend in spawning potentially indicates that the stock may have been subjected to overfishing and overexploitation.[206] ICCAT concluded that the Southern Atlantic stock was neither overfished, nor was overfishing occurring.[207] It also concluded that the Northern Atlantic stock had a biomass level above MSY, and a fishing level below MSY, indicating that the stock was neither overfished nor experiencing overfishing.[208] The IOTC was unable to determine with any certainty the stock status of shortfin Mako sharks in the Indian Ocean. The IOTC did, however, determine that shortfin Mako sharks warranted the highest possible vulnerability rating in the Indian Ocean.[209] Further, the IOTC noted the similar concerns of localized depletion indirectly resulting from piracy as it noted in other shark species.[210]

C. Oceanic Whitetip (Carcharhinus longimanus)

The oceanic whitetip shark is listed as globally vulnerable by the IUCN,[211] based on its frequent encounter with fishing gear, life-history characteristics, and observed declining populations. Oceanic whitetips are often encountered in both the purse seine and longline fisheries, predominately as bycatch, in both the western and central Pacific Ocean, and the Indian Ocean.[212] The tuna longline fishery likely has the greatest overall impact on oceanic whitetip sharks, especially juveniles, due to the overall effort of the fleet.[213] Some direct targeting

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205. *Id.*

206. WCPFCSC, *Status Snapshot of Key Shark Species*, *supra* note 195, at 4.

207. ICCAT, *Shortfin Mako Stock and Ecological Risk Assessment*, *supra* note 168, at 9.

208. *Id.*

209. IOTC, *Executive Summary: Mako Shark*, *supra* note 195, at 1.

210. *Id.*

211. THE IUCN RED LIST OF THREATENED SPECIES, *Oceanic Whitetip Shark*, http://www.iucnredlist.org/details/39374/0 (last visited Feb. 19, 2018).

212. IOTC, *Executive Summary: Oceanic Whitetip Shark*, *supra* note 163; WCPFCSC, *Stock Assessment of Oceanic Whitetip Sharks in the Western and Central Pacific Ocean*, at 5 (2012), http://www.wcpfc.int/system/files/Rice%20OWT%20Assessment%202012.pdf.

213. WCPFCSC, *Stock Assessment of Oceanic Whitetip Sharks*, *supra* note 212, at 5.

of oceanic whitetip sharks has been observed, especially in the waters near Papua New Guinea.[214] Given the high value of oceanic whitetip fins and the low level of observer coverage, finning is thought to be regularly occurring in other areas also.[215] Despite direct targeting, the longline fishery's bycatch of oceanic whitetip sharks is thought to have the greatest impact on populations,[216] likely because of the high effort and 50 percent haul-back mortality rate.[217] Further, oceanic whitetip sharks' pan-tropical global distribution regularly puts them in the same waters as, and therefore subjected to frequent encounters with, the tropical tuna fleets.[218]

The oceanic whitetip shark life-history characteristics make this species vulnerable to fishing pressures, as this is thought to be one of the least productive shark species.[219] Oceanic whitetip sharks are relatively long-lived, with the oldest recorded individual living to 17 years old.[220] Oceanic whitetip sharks also mature relatively late, between six and seven years old in the Indian Ocean,[221] and four to five years old in the South Atlantic Ocean. Further, they have a low fecundity level. Females will typically have litters consisting of between one and 15 pups, with a 12-month gestation, and a biennial reproductive cycle.[222] The oceanic whitetip shark's long lifespan, relatively late age at maturity, and low fecundity leaves this species vulnerable to overfishing, due to the species' low ability to repopulate itself at the same rate as harvest is occurring.

Oceanic whitetip shark populations are in a constant decline, indicating that the stocks are overfished and experiencing overfishing. Only two RMFOs conducted stock assessments on oceanic whitetip sharks. The IOTC determined that oceanic whitetips were highly vulnerable in the Indian Ocean, but were unable to determine their

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214. *Id.*

215. *Id.*; IOTC, *Executive Summary: Oceanic Whitetip Shark*, *supra* note 163, at 1.

216. IOTC, OCEANIC WHITETIP SHARK SUPPORTING INFORMATION, *supra* note 70, at 2; WCPFCSC, *Stock Assessment of Oceanic Whitetip Sharks*, *supra* note 212, at 5.

217. IOTC, *Executive Summary: Oceanic Whitetip Shark*, *supra* note 163, at 2.

218. *See* THE IUCN RED LIST OF THREATENED SPECIES, *Carcharhinus longimanus*, http://www.iucnredlist.org/details/39374/0 (last visited 21 May, 2017) (describing the major threats to oceanic whitetip sharks as including the fact that they are caught "in large numbers virtually everywhere they occur" because their global distribution overlaps with areas on which the tuna fishery focuses).

219. IOTC, *Executive Summary: Oceanic Whitetip Shark*, *supra* note 163, at 1–2.

220. IOTC, OCEANIC WHITETIP SHARK SUPPORTING INFORMATION, *supra* note 70, at 2.

221. *Id.*

222. *Id.*

conservation status.[223] Again, the IOTC was concerned about piracy indirectly resulting in localized depletion.[224] The WCPFC, however, was able to determine that the Western and Central Pacific stocks were overfished and overfishing was continuing to occur.[225] Further, the WCPFC observed a continual decline in population, total biomass, spawning stock biomass, and recruitment levels from 1995 to 2009.[226] Finally, the WCPFC observed that fishing mortality levels have increased to levels far in excess of MSY.[227]

D. Silky Shark (Carcharhinus falciformis)

The silky shark is listed by the IUCN as globally near-threatened, with additional near threatened listings specifically for the eastern and western Indian Ocean.[228] Silky sharks near-threatened status is likely due, at least in part, to the fact that they are the most commonly caught shark species in tropical tuna fisheries.[229] Silky sharks often encounter tuna longline and purse seine fisheries, as well as small- and medium-scale multi-species fisheries.[230] Some targeting of silky sharks does occur, especially by semi-industrial and recreational fisheries, and finning is thought to be both occurring regularly and increasing in frequency.[231] While both the WCPFC and the IOTC report high levels of silky shark bycatch, and a high vulnerability to both longline and purse seine gear,[232] the IATTC reports only low levels of bycatch from the purse seine fishery in eastern Pacific Ocean.[233]

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223. IOTC, *Executive Summary: Oceanic Whitetip Shark*, *supra* note 163, at 1.

224. *Id.* at 2.

225. WCPFC, *Stock Assessment of Oceanic Whitetip Sharks*, *supra* note 212, at ¶4.1.7, ¶6.

226. *Id.* at ¶6, fig. 13 (depicting population dynamic trends in Oceanic White Tip shark biomass, spawning biomass, and annual recruitment, with each metric declining rapidly from 1996 to 2008).

227. *Id.*

228. THE IUCN RED LIST OF THREATENED SPECIES, *Silky Shark*, http://www.iucnredlist.org/details/39370/0 (last visited Feb. 19, 2018); IOTC, *Executive Summary: Silky Shark* (2015), http://www.iotc.org/sites/default/files/documents/compliance/cmm/iotc_cmm_13-05_en.pdf.

229. WCPFCSC, *Updated Stock Assessment of Silky Sharks in the Western and Central Pacific Ocean*, at ¶1.1 (2013), http://www.wcpfc.int/system/files/Rice%20FAL%20Assessment%202013.pdf.

230. *Id.* at ¶1.2; IOTC, *Silky Shark Supporting Information*, *supra* note 163, at 2.

231. IOTC, *Silky Shark Supporting Information*, *supra* note 163, at 2; WCPFC, *Updated Stock Assessment of Silky Sharks*, *supra* note 229, at ¶1.2.

232. IOTC, *Executive Summary: Silky Shark*, *supra* note 228, at 1.

233. IATTC, *Fishery Status Report No. 14*, *supra* note 163, at ¶K (2016), https://www.iattc.org/PDFFiles2/FisheryStatusReports/FisheryStatusReport14.pdf.

Silky sharks are a circumtropical species, with an observed preference for warm, tropical waters.[234] They are thought to be an essentially pelagic fish, occupying depths up to 500 meters, but they are also commonly found at the edge of the continental shelf, over deep water reefs, and in close association with seamounts.[235] Silky sharks form mixed-sex schools, typically of similarly sized individuals, and often associate with schools of tuna, especially in close proximity to flotsam.[236] These behavior characteristics make silky shark particularly vulnerable to purse seine and FAD gear.

Silky shark life-history characteristics also leave them vulnerable to fishing pressures. Silky sharks are a long-lived species. In the Indian Ocean males are estimated to live up to 20 years and females up to 22 years, and in the Pacific Ocean both sexes live to an estimated twenty years.[237] These sharks mature rather late, with Indian Ocean females maturing around 15 years of age, and males between ten and 13 years of age.[238] Silky sharks also have a low to moderate fecundity level. Females commonly have between eight and ten pups per litter,[239] with a nine- to 12-month gestation[240] and a biennial reproductive cycle.[241]

Silky shark populations are in decline worldwide.[242] Of all the shark species that the various RFMOs have conducted scientific assessments on, the silky shark assessments appear to be the most confident. Silky shark stocks in the Pacific Ocean are overfished and experiencing overfishing.[243] In the western and central Pacific Ocean, the WCPFC has reported seeing an increase in fishing mortality, a

234. IOTC, *Silky Shark Supporting Information*, *supra* note 163, at tbl. 1; WCPFC, *Updated Stock Assessment of Silky Sharks*, *supra* note 229, at ¶1.1.

235. IOTC, *Executive Summary: Silky Shark*, *supra* note 228, at tbl. 1.

236. *Id.*

237. *Id.*

238. *Id.* In the Atlantic Ocean both sexes are estimated to have a ten- to twelve-year age at maturity. In the Pacific Ocean, females are estimated to have a six- to seven-year age at maturity, and males five- to six years. *Id.*

239. IOTC, *Silky Shark Supporting Information*, *supra* note 163, at tbl. 1; WCPFC, *Updated Stock Assessment of Silky Sharks*, *supra* note 229, at ¶1.1.

240. WCPFC, *Updated Stock Assessment of Silky Sharks*, *supra* note 229, at ¶1.1; IOTC, *Silky Shark Supporting Information*, *supra* note 163, at tbl. 1.

241. IOTC, *Silky Shark Supporting Information*, *supra* note 163, at tbl. 1.

242. *Id.* (revealing that no quantitative assessment has been conducted on the stock status of Silky Sharks in the Indian Ocean).

243. WCPFC, *Updated Stock Assessment of Silky Sharks*, *supra* note 229, at ¶4.1.7, ¶6; IATTC, *Fishery Status Report No. 14*, *supra* note 163, at ¶K.

decrease in CPUE[244], and a decrease in recruitment,[245] indicating that the stock is overfished and experiencing overfishing.

In the eastern Pacific Ocean, silky sharks exist in two separate stocks: a Northern stock and a Southern stock.[246] The Northern stock experienced sharp declines up until 1998, then stabilized at a relatively low level until 2009.[247] Since 2009, the stock has experienced both sharp increases and sharp decreases.[248] The Southern stock experienced a similar trend. Sharp declines were noted in population abundances up until 2004, followed by a period of stability at a relatively low population level.[249] There was a small increase in abundance noted in 2014, but not much change observed since.[250] The population trends of both stocks suggest that they have been overfished.

E. Thresher Sharks (Pelagic Thresher – Alopias pelagicus; Bigeye Thresher – Alopias supercilious)

The IUCN lists both the pelagic and bigeye thresher shark as vulnerable worldwide.[251] In the western and central Pacific Ocean thresher sharks are most often encountered in deep water longline fisheries, with the WCPFC reporting a stable fishing rate over the past decade.[252] In the Indian Ocean, pelagic threshers are commonly targeted by recreational, semi-industrial, and artisanal fisheries, and caught as bycatch in the fully industrial fisheries.[253] Bigeye threshers in

244. This indicates that population levels are decreasing because with the same level of fishing effort catch rates are dropping. WCPFC, *Updated Stock Assessment of Silky Sharks*, *supra* note 229, at ¶6.

245. This is further indicative of a decreasing population because of the assumed close relationship between recruitment and spawning stock biomass. *Id.* at 40, fig. 13 (depicting Silky Shark total biomass, spawning stock biomass, and annual recruitment, with each metric declining rapidly from 1996 to 2008).

246. IATTC, *Fishery Status Report No. 14*, *supra* note 163, at ¶K.

247. *Id*. at fig. K-1 (depicting CPUE for silky sharks in flotsam-related sets, with an overall decrease in CPUE from 1995 to 2015 for both the Northern and Southern Pacific Ocean stocks, despite sharp increases in the Northern stock between 2008 and 2010, and again between 2012 and 2015).

248. *Id.*

249. *Id.*

250. *Id.*

251. THE IUCN RED LIST OF THREATENED SPECIES, *Alopias superciliosus*, http://www.iucnredlist.org/details/161696/0 (last visited Feb. 13, 2018); THE IUCN RED LIST OF THREATENED SPECIES, *Alopias vulpinus,* http://www.iucnredlist.org/details/39339/0 (last visited Feb. 13, 2018).

252. WCPFC, *Status Snapshot of Key Shark Species*, *supra* note 195, at ¶2.5.

253. IOTC, *Executive Summary: Pelagic Thresher Shark*, at 2, (2016), http://www.iotc.org/sites/default/files/documents/science/species_summaries/english/Pelagic%20thresher%20shark%20Executive%20Summary.pdf.

the Indian Ocean are also commonly caught as bycatch in the fully industrial fisheries, especially in the tuna longline fishery.[254] An estimated high haul-back mortality rate has led the IOTC to conclude that thresher shark retention bans are ineffective.[255]

Both reported species of thresher shark are known to be pelagic-coastal and oceanic species.[256] When in coastal waters, thresher sharks frequently persist over the continental shelf or over inshore shallow waters.[257] When on the high seas, however, they are most commonly associated near the bottom of the ocean[258] or in the epipelagic zone.[259] While bigeye threshers occur in both tropical and temperate oceans, pelagic threshers are more commonly found in tropical oceans.[260] Pelagic thresher sharks are also commonly misidentified as the common thresher shark (*Alopias vulpinus*), which is a temperate water species.[261]

Thresher sharks are a solitary, highly migratory species with a prominent diurnal migration.[262] They are typically found between 200 and 700 meters in depth during the day but at the upper layers of the ocean at night.[263] Thresher shark do not often school and are not often found in shallow waters during the day, and their behavior makes them less vulnerable to purse seine fishing gear.[264] Threshers do, however, aggregate around seamounts and other structure-based ecosystems, making them more vulnerable to longline fishing gear.[265]

While thresher sharks are one of the least vulnerable shark species to fishing gear, their life-history characteristics make them vulnerable

254. IOTC, *Bigeye Thresher Shark Supporting Information*, at 3, (2016), www.iotc.org/.../Bigeye%20thresher%20shark%20Supporting%20Information.pdf.

255. IOTC, *Executive Summary: Pelagic Thresher Shark*, *supra* note 253 (estimating that the thresher shark has a high haul-back mortality rate, but not concluding an exact estimate of how high).

256. IOTC, *Bigeye Thresher Shark Supporting Information*, *supra* note 254, at 2; IOTC, *Pelagic Thresher Shark Supporting Information*, at 2, (2016), http://www.iotc.org/sites/default/files/documents/science/species_summaries/english/Pelagic%20thresher%20shark%20Supporting%20Information.pdf.

257. *IOTC, Bigeye Thresher Shark Supporting Information, supra note 254.*

258. The deepest recorded depth for a bigeye thresher shark in the Indian Ocean is 723 meters deep. *Id.*

259. *Id.*

260. *Id.*; IOTC, *Pelagic Thresher Shark Supporting Information*, *supra* note 256, at 2.

261. IOTC, *Pelagic Thresher Shark Supporting Information*, *supra* note 256, at 2.

262. *Id.*; IOTC, *Bigeye Thresher Shark Supporting Information*, *supra* note 254, at 2.

263. IOTC, *Bigeye Thresher Shark Supporting Information*, *supra* note 254.

264. IOTC, *Executive Summary: Pelagic Thresher Shark*, *supra* note 253.

265. IOTC, *Bigeye Thresher Shark Supporting Information*, *supra* note 254, at 2; IOTC, *Pelagic Thresher Shark Supporting Information*, *supra* note 256.

to fishing pressure. Pelagic thresher sharks are a long-lived species. In the Pacific Ocean, males have been found to live up to 20 years and females up to 28 years.[266] They also mature relatively late, with males between seven to eight years of age and females between eight and nine years of age.[267] Pelagic thresher sharks also have one of the lowest known fecundity rates of the key shark species. Pelagic threshers have litters typically consisting of just two pups with a 12-months gestation period.[268] Their reproductive cycle is unknown, making it unclear whether females pup each year or every two to three years.[269]

Bigeye thresher sharks have similar life-history characteristics as their sister taxa. Bigeye thresher sharks are a long-lived species, with males known to live to at least 19 years of age and females to 20 years.[270] Estimates indicate, however, that the bigeye thresher can live between 25 and 30 years old.[271] Bigeye threshers are also a late maturing species, with males maturing between nine and ten years and females maturing between 12 and 13 years. Further, they also have a very low fecundity. Females typically have litters of between two and four pups, with a 12-month gestation period and an unknown reproductive cycle.[272]

Little is known about either the population or stock status of thresher sharks. In the western and central Pacific Ocean, the WCPFC estimated that the stock was either slightly overexploited or overexploited[273] based on decreasing size trends,[274] but it could not make any firm conclusions. The WCPFC scientific committee also recommended the closure of thresher shark nursery grounds and size limit management in order to better protect against the unknown status of the stocks.[275] In the Indian Ocean, stock assessments for both the pelagic and bigeye thresher sharks were inconclusive, with unknown status for either species.[276]

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266. IOTC, *Pelagic Thresher Shark Supporting Information*, *supra* note 256, at tbl. 1.

267. *Id.*

268. *Id*.

269. *Id.*

270. IOTC, *Bigeye Thresher Shark Supporting Information*, *supra* note 254, at tbl. 1.

271. *Id.*

272. *Id.*

273. WCPFC*, Status Snapshot of Key Shark Species, supra* note 195, at ¶2.5; *see also* WCPFC, *An Indicator-Based Analysis of Key Shark Species*, *supra* note 172, at fig. 11 (depicting Thresher Shark CPUE in the western and central Pacific Ocean, with a generally declining trend from 1995 through 2010, despite some variability in the data).

274. WCPFC, *An Indicator-Based Analysis of Key Shark Species*, *supra* note 172, at ¶ 7.

275. WCPFC, *Status Snapshot of Key Shark Species*, *supra* note 195, at ¶2.5.

276. IOTC, *Executive Summary: Pelagic Thresher Shark*, *supra* note 253, at 2; IOTC, *Executive Summary: Bigeye Thresher Shark*, at 2, (2016), http://www.iotc.org/sites/default/files/

F. Hammerhead Shark (Scalloped hammerhead – Sphyrna lewini)

The IUCN reported that scalloped hammerheads are globally endangered.[277] Scalloped hammerhead sharks are commonly caught as bycatch in the purse seine fishery or are targeted by semi-industrial, artisanal, and recreational fisheries, but are considered to be of low vulnerability to longline fisheries.[278] Scalloped hammerhead sharks are, however, considered to be extremely vulnerable to gillnet fisheries.[279]

Scalloped hammerhead sharks are widely distributed throughout warm temperate and tropical waters,[280] with juveniles more commonly found in estuarine and inshore waters.[281] Scalloped hammerhead sharks typically form either large aggregations or resident populations.[282] Smaller sized individuals also form large seasonal schools for poleward migrations.[283] It is these large aggregations that make scalloped hammerhead sharks highly vulnerable to fishing pressures.[284] Because of scalloped hammerhead sharks behavioral characteristics, artificially high CPUEs are possible even with severely depleted stocks.[285]

Scalloped hammerhead sharks' life-history characteristics also leave them vulnerable to fishing pressures. Scalloped hammerhead sharks are a rather long-lived species, estimated to live over thirty years of age.[286] They are also a late maturing species, with males maturing between nine and ten years old, and females around 15 years old.[287] Finally, scalloped hammerhead sharks have a medium level of fecundity. Females will typically have litters of 12 to 41 pups, with the size of litter varying by area, rather than by female size or age.[288]

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documents/science/species_summaries/english/Bigeye%20thresher%20shark%20Executive%20 Summary.pdf.

277. THE IUCN RED LIST OF THREATENED SPECIES, *Scalloped Hammerhead Shark*, http://www.iucnredlist.org/details/39385/0 (last visited Feb. 14, 2018).

278. IOTC, *Executive Summary: Scalloped Hammerhead Shark*, at 1, (2016).

279. *Id.*

280. *Id.* at 2.

281. *Id.*

282. *Id.*

283. *Id.*

284. *Id.* at 1.

285. *Id.*

286. *Id.*

287. *Id.*

288. *Id.*

Gestation periods are between nine and ten months for scalloped hammerhead sharks, allowing them to have an annual reproductive cycle.[289]

The IOTC was the only RFMO to attempt a stock status assessment for the scalloped hammerhead, but was unable to make any firm conclusions, and therefore the status of hammerhead stocks is currently unknown. As with all IOTC fisheries, piracy has led to the IOTC being concerned about localized depletion.[290]

G. *Porbeagle (Lamna nasus)*

While the IUCN lists the porbeagle as vulnerable,[291] the porbeagle has the fewest studies of all of the key shark species. Only ICCAT reported any scientific information on porbeagle stock statuses.[292] There was no reported information from ICCAT on how the porbeagle interacts with fisheries, porbeagle behavioral or life-history.

In the Atlantic Ocean, there are four known stocks of porbeagle, all of which are in decline. The Northeast Atlantic stock has a biomass below that required for a finding of MSY, and a reported fishing mortality rate either near or above MSY.[293] The Northwest Atlantic stock has been depleted well below a biomass level able to sustain MSY.[294] However, ICCAT has reported that fishing mortality rates are well below MSY, and therefore porbeagle biomass may be increasing.[295]

There is much less certainty or data available for the Southern Atlantic Ocean porbeagle stocks. ICCAT reported that the Southwestern Atlantic stock is potentially in decline.[296] Further, ICCAT reported that in the Southeastern Atlantic Ocean, the CPUE for porbeagle suggests a stable population.[297]

289. *Id.*

290. *Id.*

291. THE IUCN RED LIST OF THREATENED SPECIES, *Porbeagle*, http://discover.iucnredlist.org/species/11200 (last visited Nov. 10, 2016).

292. *See* ICCAT, *Report of the 2009 Porbeagle Stock Assessment Meeting* (June 22, 2009), https://iccat.int/Documents/SCRS/DetRep/DET-POR.pdf.

293. *Id.* at ¶3.1.2, ¶6.

294. *Id.*

295. *Id.*

296. *Id.* at ¶6.

297. *Id.*

V. Integrating Scientific Knowledge into Future Conservation Measures

Conservation measures aimed at protecting sharks must take into account shark species' life-history and behavioral characteristics in order to be most effective. Key behavioral characteristics of shark species can indicate where and how various fishing fleets interact with sharks. By revealing shark species' notable vulnerabilities in their interactions with fishing fleets, scientific knowledge can be used to ensure that any measures aimed at protecting those species are successful. For example, shark species that school or aggregate in large groups are more vulnerable to fishing pressures than solitary species because fishers are more easily able to catch large numbers of schooling-sharks with less overall effort. Similarly, shark species with global distributions that overlap those of the fishing fleets are more vulnerable than relatively isolated populations because those species are more likely to encounter the fishing fleets in the first place.[298] Conservation measures specifically drafted with these vulnerabilities in mind would be more effective in addressing such issues than those which fail to account for such characteristics.

A. Issues with the Current Approach to CMMs

While RFMOs over the past decade have utilized a wide variety of strategies aimed at the conservation of shark stocks, the available data indicates that these measures have not had a positive impact on populations.[299] In general, available scientific data indicates that shark populations continue to decrease globally.[300]

In general, RFMO strategies to protect shark species have been aimed largely at reducing catch rates and fishing efforts and not at addressing shark life-history or behavioral characteristics. By reducing the amount of effort that fishers are able to exert towards fishing, such as by requiring landing catches in port instead of allowing transshipments to occur at sea,[301] RFMOs aim to reduce the total

298. For example, shark species with a tropical distribution are more likely to be vulnerable to fishing pressures than shark species with a temperate distribution because the tropical tuna fishery, especially the longline fishery, commonly exerts significantly more annual fishing effort than other fisheries. *See, e.g.*, WCPFC, *Stock Assessment of Oceanic Whitetip Sharks*, *supra* note 212, at ¶ 1.2.

299. *See supra* Section III.B.

300. *See generally* Musick & Musick, *supra* note 12; Dulvy, *supra* note 2.

301. *See, e.g.*, IOTC, Res 14/04, *supra* note 145 (mandating that fishers offload all catches within ports and not out at sea in order to allow managers the ability to better track and monitor the fishery).

amount of catch. By reducing the total fishery catch, RFMOs are able to afford sharks a tangential level of protection because if there are fewer boats fishing at any given time then there is less of a chance that any given shark will encounter a boat fishing.[302] By further establishing measures directly aimed at reducing shark catch rates, such as by banning certain gear types or establishing retention bans,[303] RFMOs aim to afford sharks additional protections from fishing pressures.

While in theory this makes perfect sense — reduce shark catch rates in order to reduce the negative impact the fishing fleet has on shark populations — in practice these strategies fall far short of the mark. This is mainly because any interaction a given shark has with a fishery is very likely to end in that shark's mortality.[304] Therefore, while RFMOs currently approach shark conservation through the attempted reduction in catch rates they should be addressing key life-history and behavioral aspects of shark populations in order to avoid fisheries encountering sharks altogether.

The most common strategy RFMOs have used in order to protect sharks is retention bans, followed by gear restrictions or requirements, and multi-tactic measures combining fin-to-carcass ratios with full utilization requirements. In total, from 1995 through 2016, the various RFMOs have passed 39 conservation measures aimed at, or at least significantly addressing, shark conservation, of which 36 are still currently in force.[305] Twenty-seven of these measures are "active measures," meaning that they are actively establishing a change in the behavior of the fishery.[306] In total, five of these use a multi-strategy approach including both a fin-to-carcass ratio and a full utilization

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302. I call this a tangential level of protection because the RFMOs are not directly protecting the shark species through these types of measures but are affecting a fishery behavior that has the secondary effect of offering some protection to shark species.

303. *See, e.g.*, IATTC, Res. C-16-05, *supra* note 125 (prohibiting fishers from using 'shark lines' or lines specifically set up to target sharks); ICCAT, Supp. Rec. 07-06, *supra* note 108 (establishing a retention ban for porbeagle and North Atlantic shortfin mako sharks).

304. This is because many of the key shark species have high haul-back mortality rates. *See supra* Section IV. The Blue Shark, for example, has an estimated haul-back mortality rate of 24%. IOTC, *Blue Shark Supporting Information*, *supra* note 8, at 3. Nearly one out of every four blue sharks that become caught in fishing gear do not survive that encounter.

305. The three measures included in this paper that are not currently in force were all superseded by nearly identical measures. *See* WCPFC, CMM 2006-05; CMM 2008-06; CMM 2009-04; CMM 2010-07; *supra* notes 85, 87, and accompanying text.

306. For example, I considered a gear restriction that actively bans the use of a certain type of gear an active measure because it forces a change in the fishery's behavior. A reporting requirement on the other hand upholds the status quo, but merely requires extra data to be divulged about the status quo. The label "active measure" was created by the author and to the best of his knowledge is not a customary term in international fisheries management.

requirement. One is a full utilization requirement alone. Eleven are retention bans, and eight are gear restrictions or requirements. Therefore, multi-strategy approaches (fin-to-carcass ratios, and full utilization requirements) account for 13.8 percent of the measures currently in effect, and 18.5 percent of active measures; full utilization requirements account for 2.7 percent of the measures currently in effect, and 3.7 percent of active measures; retention bans account for 30.5 percent of the measures currently in effect, and 40.7 percent of active measures; and gear restrictions or requirements account for 22.2 percent of the measures currently in force, and 29.6 percent of the active measures. Combining the multi-strategy measures and retention bans account for 44.4 percent of the measures currently in effect, and 59.2 percent of active measures.[307]

Although RFMO attention towards the conservation of global shark species makes them more likely to be protected, their approach has some inherent flaws. And as a result shark populations are still in decline. The most common strategy RFMOs have used to protect sharks is retention bans, despite the fact that retention bans fail to address the full scope of shark mortality caused by fisheries. While retention bans may limit the directed targeting of certain species, they do not prevent those species from being severely impacted by the fishery if the fisheries still interact with those sharks. This is especially true of those species that have high haul-back mortality rates. The oceanic whitetip shark, for example, has an estimated haul-back mortality rate of 30 percent. This indicates that slightly less than one out of every three oceanic whitetips that become caught in fishing gear do not survive that encounter.[308] The fact that fishers are unable to legally retain oceanic whitetip sharks does not matter for the overall health of the population if one out of every three interactions with the fishery leads to death.

The second most common strategy that RFMOs have used to protect sharks is gear restrictions and requirements. Gear restrictions and requirements can help shark populations if enacted in order to specifically target certain vulnerabilities. For example, some RFMOs have enacted a gear restriction that prohibits purse seine vessels from

307. Combining these two categories makes sense since all of the multi-tactic measures also included a retention ban for any sharks not caught in accordance with the RFMO regulations. *See supra* Sections III.B.1–5.

308. The actual number is likely slightly higher because haul-back mortality only counts those sharks that are dead when fully brought back on board the ship. However, at least some sharks are probably able to escape the nets, bite through the lines, or otherwise escape prior to being brought on board.

setting their nets around whale sharks.[309] This is a positive example of a gear restriction because RFMOs were specifically addressing a known vulnerability in whale shark populations. Due to the extremely large size of whale sharks, fishers were often unable to free them from nets causing intentionally encircled sharks to perish.[310] By preventing fishers from deliberately encircling whale sharks, RFMOs used a gear restriction to target a known shark vulnerability, resulting in an effective protection for the shark species involved.

Gear restrictions do, however, have the potential to be a very damaging strategy on the fishermen themselves. Fishing gear can be very expensive and if fishermen are constantly being told that they are required or prohibited from using certain gear types, the expense of compliance and uncertainty surrounding it can be seriously detrimental to industry participants. Therefore, gear restrictions or requirements, while having the potential to be very beneficial to sharks, must be carefully tailored to ensure that they are both necessary and as effective as possible to avoid placing an excessive burden on fishers. An excessive burden may reduce their interest in complying with management schemes at all.

The third most common strategy RFMOs have used is a combination fin-to-carcass ratio and full utilization requirement. The theory behind this strategy is that if fishers are required to retain the entire body or a minimum ratio of shark bodies to fins, then there is less storage space on board which equates to fewer sharks killed each trip. While, in theory, this practice makes sense – limiting the space fishers have to store shark fins means less shark mortality – in reality, this strategy has been highly criticized.[311] Because shark fins are able to

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309. *See, e.g.,* WCPFC, CMM 2012-04, *supra* note 92.

310. PIERCE & NORMAN, *supra* note 93.

311. *See, e.g.*, Julia Santana-Garcon, Sonja Fordham & Sarah Fowler, *Blue shark* Prionace glauca *fin-to-carcass-mass ratios in Spain and implications for finning ban enforcement*, 80 J. FISH BIOLOGY 1895, 1901 (2012) (arguing that because "problems with using fin-to-carcass-mass ratios to enforce shark finning prohibitions [exist] . . . fishermen [instead should be] required to land all sharks with the fins still naturally attached to their bodies . . ."); Leah Biery & Daniel Pauly, *A global review of species-specific shark-fin-to-body-mass ratios and relevant legislation*, 80 J. FISH BIOLOGY 1643, 1657 (2012) (determining that "the 5 percent fin-to-body-mass ratio used for the majority of current regulations is inadequate and inappropriate for most [shark] species[, and] [c]ountries that currently enforce a 5 percent ratio should switch to a fins-attached policy."); *but see* Musick & Musick, *supra* note 12, at 250 (arguing that "[a]lthough not perfect, [a fin-to-carcass ratio] discourages the wasteful practice of finning and, in some instances, it may encourage fishers to release sharks of low value to reserve hold space for more valuable species such as tuna"); Dulvy, *supra* note 2, at 13 (suggesting that fin-to-carcass ratios and other bans on finning "can enhance monitoring and compliance, [but] have not significantly reduced shark mortality or risk to threatened species.").

garner such a high price on the global market,[312] instead of reducing the overall amount of shark death, fin-to-carcass ratios and full utilization requirements have instead led to an increase in overall fishing effort.[313] When faced with the opportunity to make significant amounts of money, fishers are willing to exert extra effort through additional fishing trips. Therefore, while the theory behind these strategies seemed sound, the reality indicates that they are ineffective and do not reduce the overall amount of fishing mortality shark populations endure.

B. Maximizing the Effectiveness of Future Conservation Measures

In order for RFMOs to best account for the vulnerable life-history and behavioral characteristics of key shark species when drafting future conservation measures, important aspects of the sharks' lifecycles should be taken into account. Conservation measures aimed at protecting global shark populations should utilize the following procedure in order to fully incorporate scientific information into the drafting of either general, or species-specific, conservation measures. Largely, this can be done by focusing on the characteristics that key shark species share. Alternatively, shark species with unique characteristics will also benefit from this analysis because those distinctions can be specifically targeted in order to better protect such species.

First, managers should analyze the available scientific data in order to identify larger behavioral or life-history traits common to multiple shark species. Once those key characteristics are identified, managers should utilize that information in order to predict the broader patterns in behavior and life histories that shark species share. It is these broader patterns that should be analyzed, and then

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312. Dent & Clarke, *supra* note 23.

313. *See* David S. Shiffman & Neil Hammerschlag, *Shark conservation and management policy: a review and primer for non-specialists*, 19 ANIMAL CONSERVATION 401, 405 (2016) (explaining that "[f]in ratios do not restrict fishing pressure or total catch . . . fishers can potentially capture prohibited species and retain their fins through 'high grading,' switching the fins of prohibited but more valuable species for those of the species they [are allowed to] legally land . . ."); Shelley Clarke, E.J. Milner-Gulland & Trond Bjørndal, *Social, Economic, and Regulatory Drivers of the Shark Fin Trade*, 22 MARINE RESOURCE ECON. 305, 316–18 (2007) (stating that "even where finning regulations apply, they do not prevent fishermen from killing or grievously injuring hooked sharks . . . nor do they in any way prevent utilization of fins if the carcass can be stored and landed." Further suggesting that the recent rise in demand for shark meat may be a byproduct of shark fin regulation, and "even if finning regulations . . . are acting to reduce shark mortality, trends in utilization of shark meat are operating in the opposite direction.").

specifically addressed by conservation measures, in order to target vulnerabilities, minimize negative impacts, and maximize the effectiveness of future measures.

Shark species with distinctive behavioral traits would likely benefit more from specifically-targeted conservation measures than from the broader, more general measures described above. Managers should identify those unique or particularly distinct characteristics of individual shark species. While managers are analyzing the scientific information in order to identify the general characteristics that shark species share, notable distinct characteristics of individual species should be easily recognized. Once managers have identified these distinct characteristics, they will be able to understand the unique vulnerabilities of individual shark species. These vulnerabilities can be specifically addressed in order to better protect individual shark species.

i. Generally Applicable Case Study

As identified above,[314] many of the key shark species share common behavioral and life-history characteristics. It is these characteristics that managers should target in order to prepare scientifically-grounded conservation measures. For example, each of the key shark species identified is relatively long-lived, late-maturing, and has low fecundity rates. Further, most of the shark species have a documented high haul-back mortality rate. These shared characteristics are associated with certain identifiable vulnerabilities.

Longer-lived species are more vulnerable to fishing pressures than shorter-lived species because the odds are greater that over the course of a long life-time an individual shark will encounter more fishing gear. Further, long-lived species are often associated with later ages of maturity. This further leaves such a species vulnerable to fishing pressures, because a late-maturing species is more likely to encounter fishing gear before reaching sexual maturity, and therefore if killed would not yet have had the opportunity to contribute recruitment stock to the population. This is especially so when haul-back mortality rates are higher among smaller-sized individuals, because smaller sized individuals, in a late maturing species, are unlikely to have reached sexual maturity. If this is coupled with low fecundity, the vulnerability potential is even more severe because even if an individual shark has reached sexual maturity it may have only contributed a small number

314. *Supra* Sections IV.A–G.

of offspring to the population. Further, at least some key shark species increase fecundity with increased female size, indicating that larger, older females produce more offspring than younger, smaller females.[315] This suggests that the removal of moderate to large sized individuals may have a disproportionately negative effect on shark populations, because fishers are removing the most valuable spawning stock of that population.

These shared characteristics and associated vulnerabilities indicate that, among other things, these shark populations are especially vulnerable to fishing pressures that disproportionately affect juveniles. If conservation measures were specifically tailored towards the protection of juvenile sharks, they could account for the long-lived and late-maturing characteristics which leave these populations particularly vulnerable. Therefore, future management measures should use such strategies as gear and area restrictions in order to avoid catching juveniles, and to avoid areas with higher proportions of juveniles. These measures could include mandating larger hook sizes to physically prevent juveniles from becoming caught, or prohibiting fishing effort in known pupping areas or juvenile ranges.[316] Finally, while management measures could be drafted including strategies such as catch quotas with strict size limits, based on the known or estimated higher haul-back mortality rates of juvenile sharks, the best possible tactic to prevent the overharvest of juveniles would be the complete avoidance, rather than the mandatory release, of such individuals.

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315. This is a theory known as the "BOFFFF," or Big, Old, Fat, Fertile, Female Fish theory, which says that the most valuable spawning stock in a population are the oldest, biggest females because they spawn the highest number of and best offspring. *See*, *e.g.*, Hixon, et al., *BOFFFS: on the importance of conserving old-growth age structure in fishery populations*, 71 ICES J. MARINE SCI. 2171 (2014), http://icesjms.oxfordjournals.org/content/71/8/2171.full.pdf+html.

316. Further, there is some indication in the scientific literature that utilizing circle-, rather than J-, hooks would also have a positive effect on sharks by lowering haul-back mortality rates. Circle hooks, while minimally reducing the overall catch rate of fish, are designed to embed in the fish's mouth rather than being entirely swallowed by the fish as is common with J-hooks, which leads to higher mortality rates. *See, e.g.*, Joseph E. Serafy et al., *Can Circle Hook Use Benefit Billfishes?*, 10 FISH & FISHERIES 132 (2008); Paul J. Rudershausen et al., *A comparison between circle hook and J hook performance in the dolphinfish, yellowfin tuna, and wahoo troll fishery off the coast of North Carolina*, 110 FISHERY BULL. 156 (2012); *cf.* Douglas H. Adams, et al., *Mortality due to a Retained Circle Hook in a Longfin Mako Shark* Isurus paucus *(Guitart-Manday)*, 38 J. FISH DISEASE 621 (2015) (finding a female longfin mako shark's cause of death was a circle hook which was found within her pericardial mass).

ii. Species-Specific Case Study

As previously identified,[317] the scalloped hammerhead shark has a tendency to form either large resident populations or large seasonal aggregations of similarly sized individuals.[318] The tendency to form large resident populations indicates that a single gill net, or large purse seine, set in an area occupied by such a population, could have a disproportionately negative effect on that population due to the potential for a mass casualty event. Therefore, identifying and prohibiting fishing strategies with the potential to inflict mass casualty with minimal effort would be particularly beneficial to hammerhead shark populations. Some examples of management measures that could achieve these objectives are area restrictions for certain gear types, seasonal closures, or specifically tailored gear requirements.

Similarly, the thresher shark's diurnal migrations would be another potential behavior trait that can be the target of effective conservation measures.[319] These diurnal migrations leave thresher sharks more vulnerable to fishing mortality during the night, when they are closer to the surface and therefore more likely to encounter fishing gear. If RFMOs were to establish time-of-the-day limits for those fisheries that encounter thresher sharks, so that fisheries were allowed to fish only during the day, when the sharks are deeper, but not at night, when the sharks are shallower, it could have a high success rate. It is these distinct characteristics of individual shark species that lend themselves to being easily targeted by both fishermen, to sharks' exploitation, and therefore fishery managers, to sharks' protection. Taking advantage of the best available scientific information will allow fishery managers to draft, and RFMOs to pass, more effective conservation measures.

iii. Socioeconomics: Why Effective, Narrowly Tailored Conservation is Necessary

The above proposals are designed to maximize the effectiveness of future conservation measures by taking into account shark species' key behavioral and life-history characteristics. The proposals can also help ensure that conservation measures are narrowly tailored to addressing just those key vulnerabilities that sharks exhibit. Effective,

317. *See supra* Section IV.F.

318. These unique behavioral traits would have been easily identifiable while analyzing the more general information, above.

319. *See supra* Section IV.E; IOTC, *Bigeye Thresher Shark Supporting Information*, *supra* note 254; IOTC, *Pelagic Thresher Shark Supporting Information*, *supra* note 256.

narrowly tailored conservation measures will help ensure that RFMOs do not have to continually pass measure upon measure addressing the exact same thing.[320] This, in turn, will help ensure that those measures that are passed are actually followed.

As is quite often the case when managing fisheries, many of these proposed management strategies would likely face opposition. Fishers very likely do not want to be restricted from areas, forced to use certain gear types, or to fish only during certain times of the day. These are very real concerns for fishers because new gear is expensive and any restrictions that potentially reduce the amount of fish a fisher can catch is seen as an attack against their ability to feed and care for family members. Socioeconomic concerns are always at the forefront of the debate about how to best manage fisheries.

Many of the restrictions recommended to protect sharks would also act to reduce over-all catches of targeted species. Ensuring that conservation measures are as effective and narrowly tailored as possible allows RFMOs to pass a smaller total number of restrictions, which helps to keep fishers appeased, while still assuring the same amount of protection towards sharks. The strategy for shark conservation should not be a shotgun-style approach, where managers throw measure upon measure at the fishery hoping one will work. Instead, managers should strive for a carefully-constructed, narrowly-focused, and efficiency-maximized approach to shark conservation, more analogous to a scalpel than a sledgehammer.

VI. CONCLUSION

Despite over twenty years of RFMO attempts to protect global shark species, shark populations are still in decline worldwide. As leading researchers have said, "[f]or many [shark] species, the question is no longer about fishery sustainability, but rather extinction risk."[321] The fact that nearly one-quarter of all shark and shark-related species are at risk of extinction,[322] combined with the fact that the number of data deficient shark species is likely the highest of any vertebrate,[323] signifies that if action is not taken the world will soon begin to see shark extinction events taking place.

320. *See, e.g.*, WCPFC, CMM 2006-05, CMM 2008-06, CMM 2009-04, *supra* notes 84, 305.

321. Musick & Musick, *supra* note 12, at 250.

322. Dulvy, *supra* note 2, at 3.

323. *Id.* at 9.

Shark populations are not declining because of management organizations inaction but instead because of miss-action. The fact that current conservation measures largely fail to account for shark species' life-history and behavioral characteristics indicate that these measures are not and cannot be as effective as possible. With RFMO scientific committees continually conducting vital research on shark species and classifying the statuses of global shark stocks, RFMOs should utilize that information in order to ensure the long-term protection of shark species. In order to do so, fishery managers should identify and recognize broad trends in shark characteristics and those unique characteristics that stand out in individual species. It is these characteristics (when, where, and how shark species interact with fisheries) that indicate notable vulnerabilities and can be specifically targeted by conservation measures in order to ensure the long-term survival of sharks in our global oceans.