REPORT TO CONGRESS

2023 Shark Finning Report

Developed pursuant to: Shark Finning Prohibition Act (Public Law 106-557)

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I. Executive Summary

This report describes the efforts of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) during calendar years 2018 to 2022 to implement the 2000 Shark Finning Prohibition Act and more recent shark conservation legislation. As one of the top ocean predators, sharks play an important role in the food web and help ensure balance in the ocean's ecosystem. With increased demand and exploitation rates for some shark species and shark products, concern has steadily grown regarding the status of many shark stocks and their exploitation in global fisheries. NMFS is committed to shark conservation and sustainable management of shark fisheries.

Domestically, U.S. fishermen landed more than 12.1 million pounds of sharks in 2021, valued at more than $3.9 million, the most recent year data has been made available.[1] Majority of the value is for shark meat. In 2022, only six out of 42 U.S. shark stocks or stock complexes (14 percent) were listed as subject to overfishing and only seven (17 percent) were listed as overfished.

Since 2019, the U.S. has not imported shark fins. However, some shark fins were still exported up until late 2022 when the Shark Fin Sales Elimination Act (SFSEA) was signed into law. The majority of shark fins exported in 2022 before the SFSEA was signed into law were sent from the U.S. to China, with smaller amounts going to the British Virgin Islands and Mexico. The mean value of shark fin exports increased slightly from $5,133 per metric ton in 2021 to $5,515 per metric ton in 2022. For more information, see Section 2 of the Appendix.

Internationally, NMFS has advanced shark-related projects in multiple venues and assisted with many international studies and stock assessments for sharks. For example, at the 19th Regular Session of the Western and Central Pacific Fisheries Commission in December 2022, the Commission adopted CMM-2022-04 (Conservation and Management Measure), which includes several conservation and management measures for sharks. This includes prohibiting longline vessels operating in the Convention Area between 20° North and 20° south from using wire trace as branch lines, and prohibiting them from using shark lines or branch lines running off of the longline floats or drop lines. It also requires longline vessels to follow certain guidelines when releasing sharks that are not retained. Both of these provisions become effective January 1, 2024, and NMFS is developing regulations to implement the measures domestically.

In 2022, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) listed Carcharhinidae species (requiem sharks) with a 12-month implementation delay. Of the requiem shark species listed, Atlantic sharpnose, blacknose, blacktip, blue, bull, lemon, sandbar, and spinner sharks are managed by the HMS Management Division and can be retained by commercial fishermen. Bignose, Caribbean reef, Caribbean sharpnose, dusky, Galapagos, night, and smalltail sharks are also listed on Appendix II of CITES, but retention of these shark species in the U.S. is prohibited. Bonnethead sharks were listed in Appendix II with the rest of the non-listed hammerhead shark species based on the similarity in appearance of specimens of these species to others in the CITES Appendices.

[1] Commercial Fishery Statistics Database, https://www.fisheries.noaa.gov/foss

II. Introduction

The 2000 Shark Finning Prohibition Act amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit the practice of shark finning by any person under U.S. jurisdiction. Additionally, the Shark Finning Prohibition Act required NMFS to promulgate regulations to implement its provisions, initiate discussion with other nations to develop international agreements on shark finning and data collection, provide Congress with annual reports describing efforts to carry out the Act, and establish research programs. This report describes NMFS' efforts during calendar years 2018 to 2022 to implement legislation on shark conservation.

III. Background and Context

Sharks are among the ocean's top predators and vital to the natural balance of marine ecosystems. They are also a valuable recreational fishing species and food source. The practice of shark finning and shark bycatch in some fisheries can affect the status of shark stocks and the sustainability of their exploitation in world fisheries. When the Shark Finning Prohibition Act became law in 2000, global annual shark catches reported to the Food and Agriculture Organization of the United Nations (FAO) had tripled since 1950, reaching an all-time high of 888,000 metric tons (mt). Since then, the U.S. has undertaken several new conservation actions maintains some of the strongest shark management measures in the world. The most recent FAO report reported global imports of shark fins at approximately 16,166 mt in 2021, the most recent year data has been made available. In 2021, the average value of global shark fin imports increased to $19,045/mt, and the average value of exports increased to $14,342/mt. China was the largest importer and Spain the largest exporter of shark fins in 2021. In response to continued concerns about shark populations internationally, many countries have banned shark fishing in their waters in favor of promoting tourism opportunities. In addition, many nations have adopted finning bans.

IV. Domestic

Great hammerhead shark (*Sphryna mokarran*). Photo: NOAA

The MSA, as amended by the 2000 Shark Finning Prohibition Act and the 2010 Shark Conservation Act,[2] is the federal law governing the conservation and management of federal fisheries in the U.S. The suite of conservation and management measures required of all federal fisheries under the MSA makes the U.S. a leader in the sustainable management of domestic shark fisheries. Shark fisheries are valuable contributors to the U.S. economy. In 2021, U.S. fishermen landed more than 12 million pounds of sharks, valued at more than $3.9 million, primarily for their meat, not for their fins.[3] This was a decrease

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[2] https://www.fisheries.noaa.gov/national/laws-and-policies/shark-conservation-act

[3] Commercial Fishery Statistics Database, https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index

of approximately 8.1 million pounds and $1.6 million from 2020. In 2022:

- Six out of 42 U.S. shark stocks or stock complexes (14 percent) were listed as subject to overfishing;
- Seven shark stocks or stock complexes (17 percent) were listed as overfished;
- Eighteen stocks or stock complexes (43 percent) were listed as not subject to overfishing;
- 14 (33 percent) were listed as not overfished;
- Eighteen stocks or stock complexes (43 percent) had an unknown overfishing status;
- 21 (50 percent) had an unknown overfished status;
- Thirteen stocks or stock complexes (31 percent) were neither subject to overfishing nor overfished (Table 1, Page 12).

It is important to clarify that an "unknown" status does not mean NMFS is unknowledgeable about the stock. In some cases, an "unknown" stock status means that NMFS does not have the type of information that can be used in data-intensive stock assessments[4] to determine a "stock status." NMFS and partners, such as the regional fishery management councils and states, collect other information such as life history, catch rates, and landings data. While such data do not always provide definitive information regarding a stock's status, they do provide important information about trends that help inform management decisions and ensure all sharks are sustainably and responsibly harvested.

In the U.S., shark finning has been prohibited since 2000. In 2008, NOAA implemented regulations to require that all Atlantic sharks are landed with all fins naturally attached, to facilitate species identification and reporting and to improve the enforceability of existing shark management measures, including the finning ban. In 2011, the Shark Conservation Act of 2010 was enacted into law to further improve domestic and international shark conservation measures, including additional measures against shark finning. Domestically, the Shark Conservation Act states that it is illegal:

> "… *to remove any of the fins of a shark (including the tail) at sea; to have custody, control, or possession of any such fin aboard a fishing vessel unless it is naturally attached to the corresponding carcass; to transfer any such fin from one vessel to another vessel at sea, or to receive any such fin in such transfer, without the fin naturally attached to the corresponding carcass; or to land any such fin that is not naturally attached to the corresponding carcass, or to land any shark carcass without such fins naturally attached*."

These provisions improved the U.S.' ability to enforce shark finning prohibitions in domestic shark fisheries. The Shark Conservation Act also created an exception for smooth dogfish (*Mutelis canis*) in the "Atlantic"… if the individual holds a valid State commercial fishing license, unless the total weight of smooth dogfish fins landed or found on board a vessel to which

[4] In some cases, stock assessments are not possible because the stock is rarely caught and there is not enough data to run an assessment. In other cases, the stock assessment may have produced conflicting results, which can mean additional information or changes to models are needed before a definitive assessment can be conducted.

this subsection applies exceeds 12 percent of the total weight of smooth dogfish carcasses landed or found on board."

In addition, as of 2022, prior to SFSEA, many U.S. states and territories have passed laws addressing the possession, sale, trade, or distribution of shark fins, including Hawai'i (2010), California (2011), Oregon (2011), Washington (2011), the Commonwealth of the Northern Mariana Islands (2011), Guam (2011), American Samoa (2012), Illinois (2012), Maryland (2013), Delaware (2013), New York (2013), Massachusetts (2014), Rhode Island (2016), and Texas (2016). Finally, the SFSEA was enacted in the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023 (Sec. 5946(b); P.L. 117-263, Dec. 23, 2022) (2023 NDAA). The SFSEA makes it unlawful to "possess, acquire, receive, transport, offer for sale, sell, or purchase a shark fin or a product containing a shark fin."

V. International

The U.S. participated in the development of and endorsed the FAO International Plan of Action (IPOA) for the Conservation and Management of Sharks (IPOA-Sharks), which is voluntary. The IPOA-Sharks encourages all FAO members to adopt a corresponding National Plan of Action if their vessels conduct directed fisheries for sharks or if their vessels regularly catch sharks in non-directed fisheries. Consistent with the IPOA-Sharks, the U.S. developed a National Plan of Action for the Conservation and Management of Sharks in February 2001 and updated it in 2014. In addition to meeting the statutory requirement of the Shark Finning Prohibition Act, this annual Report to Congress serves as a periodic update of information called for in both the International and National plans of action for sharks.

The Shark Conservation Act amended the Moratorium Protection Act in two important ways. First, it outlined certain fishing activities that target or incidentally catch sharks in waters beyond any national jurisdiction that could result in the Secretary of Commerce identifying and certifying a nation if it has not adopted a regulatory program for the conservation of sharks comparable to that of the U.S. The 2023 NDAA further amended the Moratorium Protection Act to add new considerations for identifying nations whose vessels are engaged in shark fishing without a regulatory program comparable to that of the U.S., authorize NMFS to make such an identification any time the agency has sufficient information, and modify other aspects of the certification and consultation processes. Identification is the first step in a three-step process that ultimately ends in the U.S. issuing either a positive or negative certification of each identified nation.

Second, the Shark Conservation Act directed the U.S. to encourage international fishery management organizations, of which the U.S. is a member, to adopt shark conservation measures, including measures to prohibit removal of any of the fins of a shark (including the tail) and discarding the carcass of the shark at sea. Specifically, it directed the U.S. to seek to enter into international agreements that require measures for the conservation of sharks that are comparable to those of the U.S., taking into account different conditions. These approaches, along with our strong domestic shark fishery management, have made the U.S. a leader in the conservation and sustainable management of sharks globally.

VI. Accomplishments in Response to Requirements of the Shark Finning Prohibition Act

Section 6 of the Shark Finning Prohibition Act requires the Secretary of Commerce, in consultation with the Secretary of State, to provide to Congress an annual report describing efforts to carry out the Act. Report requirements are:

1. Include a list that identifies nations whose vessels conduct shark finning and detail the extent of the international trade in shark fins, including estimates of value and information on harvesting, landings, or transshipment of shark fins through foreign ports.
2. Describe and evaluate the progress taken to carry out this Act.
3. Set forth a plan of action to adopt international measures for the conservation of sharks.
4. Include recommendations for measures to ensure that the actions of the U.S. are consistent with national, international, and regional obligations relating to shark populations, including those listed under the CITES.

NMFS' 2018-2022 accomplishments to carry out the Act are discussed below. An appendix including detailed information on U.S. shark management and enforcement (Section 1), imports and exports of shark fins (Section 2), international shark conservation and management efforts (Section 3), 2018-2022 NOAA research on sharks (Section 4), ongoing NOAA shark research (Section 5), and references (Section 6) has been posted online. A copy of this report and the appendix are available online at: https://www.fisheries.noaa.gov/national/laws-and-policies/shark-conservation-act

As discussed above, the SFSEA was enacted at the end of 2022, and therefore does not apply to the 2018-2022 activities summarized in this report. The SFSEA will likely impact shark-related activities in the future and such activities will be included in future reports.

A. International Participation in Shark Finning and Trade

Data on the international trade of shark fins are available from the FAO, and data on U.S. imports and exports of shark fins are available from the U.S. Census Bureau (as provided by U.S. Customs and Border Protection). It is important to note that, due to the complexity of the shark fin trade, fins are not necessarily harvested by the same country from which they are exported. During 2022, shark fins were not imported into the U.S. The majority of shark fins exported in 2022 were sent from the U.S. U.S. to China, with smaller amounts going to the British Virgin Islands and Mexico before the SFSEA was signed into law. The mean value of exports increased slightly from $5,133/mt in 2021 to $5,515/mt in 2022 (Appendix Table 2.2.1). Detailed information regarding imports and exports of shark fins can be found in Section 2 of the appendix associated with this report.

B. U.S. Progress Implementing the Shark Finning Prohibition Act

Sharks in federal waters are managed under 11 fishery management plans under the authority of the MSA. The New England, Mid-Atlantic, Pacific, North Pacific, and Western Pacific regional fishery management councils have developed 10 of those plans. The Secretary of Commerce has developed the fishery management plan for oceanic sharks and other highly migratory species of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, as required by the MSA. All recent shark-related management**,** enforcement, international trade, and research activities in support of the Shark Finning Prohibition Act are summarized in the appendix.

Satellite tags are attached to a bull shark by NOAA scientists. Photo: NOAA

During calendar years 2018 to 2022, shark-related research took place at all six NOAA regional fisheries science centers and included research on data collection, stock assessments, biological information, incidental catch reduction, and post-release survival.

Major management actions took place both domestically and internationally from 2018 through 2022. Actions with respect to sharks in the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, and Caribbean Sea include:

- In 2018, NMFS published a final rule that revised the closure regulations for the commercial shark fishery to allow it to remain open after the fishery's landings reach, or are projected to reach, 80 percent of the available overall, regional, and/or subregional quota, if the fishery's landings are not projected to reach 100 percent of the applicable quota before the end of the season (83 FR 31677, July 9, 2018).
- NMFS also published an emergency rule in response to Recommendation 17-08 of the International Commission for the Conservation of Atlantic Tunas (ICCAT) regarding the overfished status of shortfin mako sharks (83 FR 8946, March 2, 2018). The rule included a reduction in shortfin mako shark landings in commercial and recreational shark fisheries, with retention allowed only in certain limited circumstances.
- In 2019, NMFS published the final rule for Amendment 11 to the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP), which, among other things, allowed the retention of shortfin mako sharks only if the shark is dead at haulback, and established the recreational minimum size limit for shortfin mako sharks based on the sex of the shark (84 FR 5358, February 21, 2019).
- In 2021, NMFS published a final rule to modify the shark retention limit for HMS Commercial Caribbean Small Boat permit holders and add regulatory criteria for inseason adjustment of those shark retention limits (86 FR 22882, April 30, 2021).
- In May 2022, NMFS' Pacific Island Region published a final rule to ban the use of wire leaders by Hawai`i longline fishing vessels that target tuna. The new rule is expected to result in significantly higher survival rates for oceanic whitetip sharks that are incidentally captured, because wire leaders are more difficult for sharks to bite off and free themselves from, as compared to monofilament line. The Hawai'i Longline Association initiated the action following the listing of oceanic whitetip sharks as threatened under the Endangered Species Act (ESA) in 2018.
- In 2022, NMFS published a final rule in response to ICCAT Recommendation 21-09 and the updated stock assessment for shortfin mako sharks (87 FR 39373, July 1, 2022). The rule implemented a flexible shortfin mako shark retention limit with a default limit of zero in commercial and recreational HMS fisheries.

Four stock assessments on Atlantic shark species were completed from 2018 through 2022. In 2018, Southeast Data, Assessment, and Review (SEDAR) updated the stock assessment for the blacktip shark stock in the Gulf of Mexico region (SEDAR 29 Update) and concluded that the stock is not overfished and overfishing is not occurring. In 2019, ICCAT's Standing Committee on Research and Statistics (SCRS) completed a North Atlantic shortfin mako shark assessment update of the previous 2017 stock assessment and provided additional rebuilding information. In 2020, SEDAR finalized a stock assessment for the blacktip shark stock in the Atlantic region (SEDAR 65) and concluded that the stock is not overfished and overfishing is not occurring. Also in 2020, the SCRS conducted a stock assessment on the Northwest Atlantic porbeagle shark stock and concluded that the stock is overfished and overfishing is not occurring.

In 2022, NMFS received two petitions to list Atlantic sharks as endangered or threatened under the ESA. In response to a petition from Defenders of Wildlife to list the shortfin mako shark as endangered, NMFS completed a comprehensive status review based on the best scientific and commercial information available, and taking into account efforts being made to protect the species, and determined that listing shortfin mako shark as endangered or threatened under the ESA was not warranted (87 FR 68236, November 14, 2022). In response to a petition from the Center for Biological Diversity to list the great hammerhead shark (*Sphyrna mokarran*) as endangered and designate critical habitat concurrent with the listing, NMFS made a negative finding on the petition (87 FR 67451, November 8, 2022).

On January 30, 2018, NMFS published a final rule listing oceanic whitetip sharks as a threatened species under the ESA, based on the best scientific and commercial information available and taking into account efforts being made to protect the species (83 FR 4153). In January 2023, NMFS published a draft recovery plan for the oceanic whitetip shark and requested public input and comment. NMFS is reviewing that input and plans to finalize the recovery plan early 2024. Details on specific shark management, enforcement, and education activities can be found in Section 1 of the appendix, and information on 2018-2022 shark research activities can be found in Sections 4 and 5 of the appendix.

C. Plans to Adopt International Measures for Shark Conservation and U.S. Consistency with National, International, and Regional Obligations

NMFS continues to work with the United States Department of State to promote the global conservation and sustainable management of sharks by having ongoing consultations consistent with the Shark Finning Prohibition Act. The U.S. brings forward recommendations through bilateral, multilateral, and regional efforts. As measures are adopted by international organizations, of which the U.S. is a member, the U.S. implements those measures.

Illegal shark fins sorted for species identification. Photo: NOAA

Throughout 2018-2022, NMFS participated in meetings of international regional fishery management organizations and regional fisheries bodies. At many of these meetings, the U.S. delegations supported or introduced proposals to strengthen international shark management. NMFS also engaged in efforts with international regional fishery management organizations, regional fisheries bodies, and foreign nations to strengthen international shark management. Examples of these efforts include:

- NMFS continued support for a collaborative project intended to equip and train Ecuadorian officials in standard genetic techniques to identify shark products in trade.
- Southeast and Northeast Fisheries Science Center scientists continued collaborations with scientists from several nations as part of the ICCAT Shark Research and Data Collection Program.
- NMFS engaged in several projects on blue, shortfin mako, porbeagle, silky, oceanic whitetip, and hammerhead sharks with Japan, Uruguay, and Portugal dealing with population genetics and life history (age and growth and reproduction), as well as multiple projects using archival satellite tags to determine post-release mortality and stock boundaries, movement patterns, and habitat use.
- In 2019, ICCAT's Shark Species Group conducted an updated assessment of the North Atlantic shortfin mako stock that included projections of future stock status, which indicated that very significant reductions in catches were needed to allow stock rebuilding. An assessment on the northern and southern Atlantic stocks of porbeagle shark, using four "data-limited" modeling approaches, was conducted in 2020. Results of the models indicated a rebuilding trend since the last prior assessment in 2009, but the stock was still predicted to be overfished.

TABLES

Table 1. Overfishing and Overfished Status of Shark Stocks and Stock Complexes in U.S. Fisheries as of December 31, 2022

Status of Shark Stocks and Stock Complexes in U.S. Fisheries as of December 31, 2022				
Fishery Management Council (FMC)	Fishery Management Plan (FMP) or Fishery Ecosystem Plan (FEP)	Stock or Stock Complex	Overfishing	Overfished
New England FMC & Mid-Atlantic FMC	Spiny Dogfish FMP	Spiny dogfish – Atlantic coast	No	No
NMFS Highly Migratory Species Management Division	2006 Consolidated Atlantic Highly Migratory Species FMP	Atlantic sharpnose shark – Atlantic	No	No
		Atlantic sharpnose shark – Gulf of Mexico	No	No
		Blacknose shark – Atlantic	Yes	Yes
		Blacknose shark – Gulf of Mexico	Unknown	Unknown
		Blacktip shark – Gulf of Mexico	No	No
		Blacktip shark – Atlantic	No	No
		Blue shark – Atlantic and Gulf of Mexico	No	No
		Bonnethead – Atlantic	Unknown	Unknown
		Bonnethead – Gulf of Mexico	Unknown	Unknown
		Bull shark – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Dusky shark – Atlantic and Gulf of Mexico	Yes	Yes
		Finetooth shark – Atlantic and Gulf of Mexico	No	No
		Great hammerhead – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Lemon shark – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Nurse shark – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Oceanic whitetip shark – Atlantic and Gulf of Mexico**	Unknown	Unknown
		Porbeagle – Atlantic and Gulf of Mexico	No	Yes
		Prohibited Species***	Unknown	Unknown
		Sandbar shark – Atlantic and Gulf of Mexico	No	Yes

		Scalloped hammerhead shark – Atlantic and Gulf of Mexico**	Yes	Yes
		Shortfin mako – North Atlantic	Yes	Yes
		Silky shark – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Smoothhound shark complex – Gulf of Mexico	No	No
		Smooth dogfish – Atlantic	No	No
		Smooth hammerhead – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Spinner shark – Atlantic and Gulf of Mexico*	Unknown	Unknown
		Thresher shark – Atlantic and Gulf of Mexico**	Unknown	Unknown
		Tiger shark – Atlantic and Gulf of Mexico*	Unknown	Unknown
Pacific FMC	Pacific Coast Groundfish FMP	Other Fish Complex (Leopard shark – Pacific Coast)	No	Unknown
		Spiny dogfish – Pacific Coast	No	No
Pacific FMC & Western Pacific FMC	U.S. West Coast Fisheries for Highly Migratory Species & Pacific Pelagic FEP	Common Thresher shark**** – North Pacific Bigeye thresher**** – Pacific Pelagic thresher**** – North Pacific	No Unknown Unknown	No Unknown Unknown
		Shortfin mako shark – North Pacific	No	No
		Blue shark – North Pacific	No	No
Western Pacific FMC	FEP for Pelagic Fisheries of the Western Pacific Region (Pacific Pelagic FEP)	Longfin mako shark – North Pacific	Unknown	Unknown
		Oceanic whitetip shark – Western and Central Pacific	Yes	Yes
		Salmon shark – North Pacific	Unknown	Unknown
		Silky shark – Western and Central Pacific	Yes	No
North Pacific FMC	Gulf of Alaska Groundfish FMP	Gulf of Alaska Shark Complex*****	No	Unknown
North Pacific FMC	Bering Sea/Aleutian Islands Groundfish FMP	Bering Sea/Aleutian Islands Shark Complex*****	No	Unknown
Totals:			**6 “yes” 18 “no” 18 “unknown”**	**7 “yes” 14 “no” 21 “unknown”**

*In prior reports, these sharks were combined in one species complex (Large Coastal Shark Complex).
**In prior reports, these sharks were combined in one species complex (Pelagic Shark Complex).
***Prohibited species include Atlantic angel shark, basking shark, bigeye sand tiger shark, bigeye sixgill shark, bigeye thresher shark, bignose shark, Caribbean reef shark, Caribbean sharpnose shark, Galapagos shark, longfin mako shark, narrowtooth shark, night shark, sand tiger shark, sevengill shark, sixgill shark, smalltail shark, whale shark, and white shark.

**** In prior reports, the three thresher shark species were combined in one species complex. As they are now being individually assessed, we provide a separate status for each species.
*****The Shark Complex consists of Pacific sleeper shark, salmon shark, and spiny dogfish.

2023 Shark Finning Report to Congress
Appendix

Pursuant to the

Shark Finning Prohibition Act

(Public Law 106-557)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

Prepared by the
National Marine Fisheries Service

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Section 1: Management and Enforcement

1.1 Conservation and Management Actions in the Atlantic Ocean

Atlantic Highly Migratory Species Management

The HMS Management Division and NMFS manage Atlantic shark fisheries in federal waters of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea under the 2006 Consolidated HMS FMP. 43 shark species are managed through several species complexes and management groups. Currently, 21 shark species can be commercially harvested.

Table 1.1.1 lists the species in each species complex and management group. The 2018-2022 annual commercial shark landings are shown in Table 1.1.2, separated by species group. A more detailed breakdown of 2018-2022 commercial shark landings relative to their respective 2018-2022 quotas are shown in Tables 1.1.3, 1.1.4, and 1.1.5. Table 1.1.3 shows 2018-2022 commercial shark landings for species and species groups with a Gulf of Mexico–specific quota. Table 1.1.4 shows 2018-2022 commercial shark landings for species and species groups with an Atlantic-specific quota. Finally, Table 1.1.5 shows 2018-2022 commercial shark landings for species and species groups without region-specific quotas.

Table 1.1.1 U.S. Atlantic shark management units, shark species for which retention is prohibited, and data-collection-only species.

Sharks in the Consolidated Atlantic HMS FMP			
Large Coastal Sharks (LCS)		Small Coastal Sharks (SCS)	
Aggregated LCS Management Group		**Non-Blacknose SCS Management Group**	
Spinner	*Carcharhinus brevipinna*	Finetooth	*Carcharhinus isodon*
Silky*	*Carcharhinus falciformis*	Atlantic sharpnose	*Rhizoprionodon terraenovae*
Bull	*Carcharhinus leucas*	Bonnethead	*Sphyrna tiburo*
Blacktip***	*Carcharhinus limbatus*	**Blacknose Sharks**	
Sandbar**	*Carcharhinus plumbeus*	Blacknose	*Carcharhinus acronotus*
Tiger	*Galeocerdo cuvier*	Pelagic Sharks	
Nurse	*Ginglymostoma cirratum*	**Pelagic Sharks other than Porbeagle or Blue**	
Lemon	*Negaprion brevirostris*	Common thresher	*Alopias vulpinus*
Hammerhead Shark Management Group		Oceanic whitetip	*Carcharhinus longimanus*
Scalloped hammerhead	*Sphyrna lewini*	Shortfin mako*****	*Isurus oxyrinchus*
Great hammerhead	*Sphyrna mokarran*	**Porbeagle Sharks**	
Smooth hammerhead	*Sphyrna zygaena*	Porbeagle	*Lamna nasus*
		Blue Sharks	
		Blue	*Prionace glauca*
		Smoothhound Sharks	
		Smooth dogfish****	*Mustelus canis*
		Florida smoothhound	*Mustelus norrisi*
		Gulf smoothhound	*Mustelus sinusmexicanus*
Prohibited Species			
Bignose	*Carcharhinus altimus*	Bigeye thresher	*Alopias superciliosus*
Galapagos	*Carcharhinus galapagensis*	Narrowtooth	*Carcharhinus brachyurus*
Dusky	*Carcharhinus obscurus*	Caribbean reef	*Carcharhinus perezii*
Night	*Carcharhinus signatus*	Smalltail	*Carcharhinus porosus*
Sand tiger	*Carcharias taurus*	Sevengill	*Heptranchias perlo*
White	*Carcharodon carcharias*	Sixgill	*Hexanchus griseus*
Basking	*Cetorhinus maximus*	Bigeye sixgill	*Hexanchus nakamurai*
Bigeye sand tiger	*Odontaspis noronhai*	Longfin mako	*Isurus paucus*
Whale	*Rhincodon typus*	Caribbean sharpnose	*Rhizoprionodon porosus*
		Atlantic angel	*Squatina dumeril*

Deepwater and Other Species (Data Collection Only)			
Iceland catshark	*Apristurus laurussoni*	Green lanternshark	*Etmopterus virens*
Smallfin catshark	*Apristurus parvipinnis*	Marbled catshark	*Galeus arae*
Deepwater catshark	*Apristurus profundorum*	Cookiecutter shark	*Isistius brasiliensis*
Broadgill catshark	*Apristurus riveri*	Bigtooth cookiecutter	*Isistius plutodus*
Japanese gulper shark	*Centrophorus acus*	American sawshark	*Pristiophorus schroederi*
Gulper shark	*Centrophorus granulosus*	Blotched catshark	*Scyliorhinus meadi*
Little gulper shark	*Centrophorus uyato*	Chain dogfish	*Scyliorhinus retifer*
Portuguese shark	*Centroscymnus coelolepis*	Dwarf catshark	*Scyliorhinus torrei*
Kitefin shark	*Dalatias licha*	Smallmouth velvet	*Scymnodon obscures*
Flatnose gulper shark	*Deania profundorum*	dogfish	
Bramble shark	*Echinorhinus brucus*	Greenland shark	*Somniosus microcephalus*
Lined lanternshark	*Etmopterus bullisi*	Pygmy shark	*Squaliolus laticaudus*
Broadband dogfish	*Etmopterus gracilispinnis*	Roughskin spiny	*Squalus asper*
Caribbean lanternshark	*Etmopterus hillianus*	dogfish	
Great lanternshark	*Etmopterus princeps*	Blainville's dogfish	*Squalus blainvillei*
Smooth lanternshark	*Etmopterus pusillus*	Cuban dogfish	*Squalus cubensis*
Fringefin lanternshark	*Etmopterus schultzi*		

*Not allowed for recreational harvest.
**Can only be harvested within a shark research fishery, and not allowed for recreational harvest.
***Blacktip shark is part of its own management group in the Gulf of Mexico Region.
**** Smooth dogfish is the only smoothhound species in the Atlantic Region.
***** The shortfin mako shark retention limit in all commercial and recreational Atlantic HMS fisheries is zero (87 FR 39373, July 1, 2022).

Table 1.1.2 Commercial landings for Atlantic large coastal, small coastal, pelagic, and smoothhound sharks in metric tons dressed weight, 2018–2022.
Source: HMS eDealer database.

Species Group	2018	2019	2020	2021	2022
Large Coastal Sharks	680.9	<303.9	525.4	<489.7	<455.1
Small Coastal Sharks	202.7	222.7	170.1	135.4	100.8
Pelagic Sharks	>55.5	>47.5	44.7	>38.5	>26.2
Smoothhound Sharks	>411.9	>365.5	282.4	>374.4	>303.7
Total	**>1,351.0**	**>939.6**	**1,022.6**	**>1,055.3**	**>885.8**

Use of “>” or “<” is to preserve data confidentiality.

Table 1.1.3 Landings estimates from the Gulf of Mexico Region in metric tons dressed weight for the 2018-2022 Atlantic shark commercial fisheries (includes any landings South and West 25° 20.4’ N. long.) followed by the percentage of the quota harvested.
Source: HMS eDealer database.

Shark Management Group	2018	2019	2020	2021	2022
Blacktip	370.0 (96%)	87.5 (31%)	234.9 (61%)	252.4 (66%)	236.3 (61%)
Aggregated Large Coastal (quota linked to Hammerhead)	174.6 (111%)	<103.0 (<65%)	162.6 (103%)	127.0 (81%)	95.1 (50%)
Hammerhead (quota linked to Agg. LCS)	26.2 (103%)	<18.1 (<72%)	6.7 (26%)	9.1 (36%)	<5.3 (<28%)
Non-Blacknose Small Coastal	66.2 (59%)	66.5 (59%)	63.7 (57%)	23.4 (21%)	32.4 (29%)
Smoothhound	C (-%)	C (-%)	1.4 (0%)	C (-%)	C (-%)

Percent of quota landed is based on that year’s quota for the management group. Use of “>” or “<” is to preserve data confidentiality. C = landings not disclosed due to reasons of data confidentiality.

Table 1.1.4 Landings estimates from the Atlantic Region in metric tons dressed weight for the 2018-2022 Atlantic shark commercial fisheries (includes any landings north of 25° 20.4’ N. lat.) followed by the percentage of the quota harvested. Source: HMS eDealer database.

Shark Management Group	2018	2019	2020	2021	2022
Aggregated Large Coastal (quota linked to Hammerhead)	96.8 (57%)	<79.4 (<47%)	103.3 (61%)	<81.2 (<49%)	91.6 (54%)
Hammerhead (quota linked to Agg. LCS)	13.3 (49%)	<15.9 (<59%)	17.9 (66%)	<20.0 (<74%)	26.8 (99%)
Non-Blacknose Small Coastal (quota linked to Blacknose south of 34° N. lat. only)	131.4 (50%)	147.6 (56%)	101.6 (38%)	105.2 (40%)	64.2 (24%)
Blacknose (South of 34° N. lat. only)	5.1 (30%)	8.6 (50%)	4.8 (28%)	6.8 (40%)	4.2 (25%)
Smoothhound	411.9 (23%)	365.5 (20%)	281.0 (16%)	374.4 (21%)	303.7 (17%)

Percent of quota landed is based on that year’s quota for the management group. Use of “>” or “<” is to preserve data confidentiality.

Table 1.1.5 Landings estimates for quotas without a region in metric tons dressed weight for the 2018-2022 Atlantic shark commercial fisheries followed by the percentage of the quota harvested.
Source: HMS eDealer database.

Shark Management Group	2018	2019	2020	2021	2022
Shark Research Fishery (Sandbar only)	60.2 (66%)	68.0 (75%)	22.7 (25%)	49.1 (54%)	39.5 (44%)
Blue	C (-%)	0.0 (0%)	0.0 (0%)	C (-%)	C (-%)
Porbeagle	0.4 (22%)	C (-%)	0.0 (0%)	C (-%)	0.0 (0%)
Pelagic Sharks Other Than Porbeagle or Blue	55.1 (11%)	47.5 (10%)	44.7 (9%)	38.5 (8%)	26.2 (5%)

Percent of quota landed is based on that year's quota for the management group. C = landings not disclosed due to reasons of data confidentiality.

Shark Stock Assessments and Overfishing/Overfished Status

In 2019, the International Commission for the Conservation of Atlantic Tunas (ICCAT) – Shark Species Group conducted an updated assessment of the North Atlantic shortfin mako stock that included projections of future stock status indicating that very significant reductions in catches were needed to allow stock rebuilding. In 2020, ICCAT conducted an assessment on the northern and southern Atlantic stocks of porbeagle sharks using four "data-limited" modeling approaches. Results of the models indicate a rebuilding trend since the year of the last assessment in 2009 but the stock is still predicted to be overfished.

A stock assessment for Atlantic blacktip shark (Southeast Data Assessment and Review [SEDAR] 65) was conducted from 2019-2020. The assessment and post review concluded that the stock is not overfished (SSF2018 > MSST) and overfishing is not occurring (F2018 < FMSY) and this result appears to be robust across the sensitivity analyses. Beginning in 2020, a stock assessment was initiated for scalloped, great, and smooth hammerhead sharks (SEDAR 77). The data workshop was conducted in 2021 and the assessment portion of the research track assessment began in 2022. The next step is a peer-review assessment of the results, which is scheduled for the last week of 2023.

Observer Coverage

Since 2002, observer coverage has been mandatory for selected bottom longline and gillnet vessels to monitor catch and bycatch in the shark fishery and compliance with the 2000 Shark Finning Prohibition Act and requirements under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). The data collected through the observer program is critical for monitoring takes and estimating mortality of protected sea turtles, seabirds, marine mammals, Atlantic sturgeon, and smalltooth sawfish. Data obtained through the observer program are also vital for conducting stock assessments of sharks and for use in the development of fishery management measures for Atlantic sharks. Gillnet observer coverage is also necessary to comply with the requirements of the 2007 Atlantic Large Whale Take Reduction Plan (ALWTRP) (72 FR 34632, June 25, 2007; 72 FR 57104, Oct. 5, 2007).

Atlantic Shark Endangered Species Act Updates

On January 30, 2018, NMFS published a final rule listing oceanic whitetip sharks as a threatened species under the ESA, based on the best scientific and commercial information available and taking into account efforts being made to protect the species (83 FR 4153). In January 2023, NMFS published a draft recovery plan for the oceanic whitetip shark seeking public input and comment. NMFS is reviewing that input and will finalize the recovery plan later in 2023.

NMFS completed a comprehensive status review of the shortfin mako shark under the ESA in response to a petition from Defenders of Wildlife to list the species. After reviewing the best available scientific and commercial data available, we determined that listing the species as threatened or endangered under the ESA is not warranted (87 FR 68236, November 14, 2022).

Shark Management by the Regional Fishery Management Councils and States

The Mid-Atlantic and New England fishery management councils and NMFS manage spiny dogfish (*Squalus acanthias),* the only shark species managed by the regional fishery management councils in federal waters off the Atlantic Coast, and the largest volume shark fishery in the United States. These councils manage spiny dogfish fisheries under the 2000 Spiny Dogfish FMP. The Atlantic States Marine Fisheries Commission manages the fishery with complementary measures in state waters. Spiny dogfish products landed in the United States are almost entirely exported to Europe (meat) and Asia (fins). Most products are landed whole. In 2021, the commercial quota for spiny dogfish was 29.56 million pounds (2021 fishing year), landings totaled 10.1 million pounds, and were valued at more than $2.0 million ($0.20 per pound). Spiny dogfish were not overfished and were not subject to overfishing in 2021.

1.2 Conservation and Management in the Pacific Ocean

Pacific Fishery Management Council (PFMC)

The PFMC and NMFS manage sharks under the 2004 FMP for U.S. West Coast Fisheries for Highly Migratory Species, and the Pacific Coast Groundfish FMP, which was approved in 1982 and most recently amended in 2010. Species included under the West Coast HMS FMP are the common thresher and shortfin mako (sharks commercially valued but not primarily targeted in the West Coast–based fisheries), as well as blue sharks (Table 1.2.1). Amendment 2 to the West Coast HMS FMP and its supporting regulations (76 FR 56327; Sept. 13, 2011) reclassified bigeye thresher and pelagic thresher sharks as ecosystem component species that do not require management. The West Coast HMS FMP also designates three shark species as prohibited (Table 1.2.1). If intercepted during HMS fishing operations, these species—great white, megamouth, and basking sharks—must be released immediately, unless other provisions for their disposition are established consistent with state and federal regulations.

Table 1.2.1 Shark species in the West Coast Highly Migratory Species Fishery Management Plan.

West Coast Highly Migratory Species FMP

Group	Common name	Scientific name
Sharks Listed as Management Unit Species	Common thresher Shortfin mako Blue shark	*Alopias vulpinus* *Isurus oxyrinchus* *Prionace glauca*
Sharks Included in the FMP as Ecosystem Component Species	Pelagic thresher Bigeye thresher	*Alopias pelagicus* *Alopias superciliosus*
Prohibited Species	Great white Basking shark Megamouth	*Carcharodon carcharias* *Cetorhinus maximus Megachasma pelagios*

Sharks within the West Coast HMS FMP are managed to achieve optimum yield (OY) set at a precautionary level of 75 percent of maximum sustainable yield (MSY). The precautionary approach is meant to prevent localized depletion of these vulnerable species. Blue, thresher, and shortfin mako sharks are managed under the West Coast HMS FMP, and, while blue and common thresher sharks are not overfished, the status of the shortfin mako sharks was still uncertain as of 2017. The FMP proposed annual harvest guidelines for common thresher and shortfin mako sharks given the level of exploitation in HMS fisheries at the time the FMP was adopted (e.g., large mesh drift gillnet), and accounting for the uncertainty about catch in Mexico of these straddling stocks. High exploitation rates and their impact on HMS shark stocks, if not checked, could take decades to correct given the vulnerable life history characteristics of the species.

In 2017, the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) shark working group (SHARKWG) conducted a new benchmark assessment of blue sharks in the North Pacific. The objective was to update the time-series data from the 2014 assessment through 2015, review the latest biological research, and develop an age-structured model to provide conservation advice to managers at the Western and Central Pacific Fisheries Commission (WCPFC). Participants from Japan, Taiwan, Korea, Mexico, Canada, IATTC, and the U.S. contributed data and/or analytical work. The SHARKWG developed two assessment models for consideration at the March 2017 working group meeting in La Jolla, California. The first was an age-based statistical catch-at-length model developed with Stock Synthesis (SS) (Carvalho et al. 2017), and the second was a Bayesian state-space surplus production (BSP) model (Kai et al. 2017). Results of the SS reference case model showed that the spawning stock biomass was near a time-series high in the late 1970s, fell to its lowest level between 1990 and 1995, gradually increased to reach the time-series high again in 2005, and has since shown small fluctuations close to the time-series high. Both the SS and BSP models indicate that spawning stock biomass is higher than MSY and fisheries mortality is lower than that at MSY consistent with the blue shark stock in the North Pacific neither being overfished nor subject to overfishing.

In addition to conducting a stock assessment on blue sharks, in 2017 the ISC SHARKWG prepared data to conduct an assessment of shortfin mako sharks in the North Pacific to be finalized in 2018. The objective was to update the fishery data time-series from the 2015 indicator analysis (ISC 2015), review the latest biological research, and develop a fully integrated age-structured model. Participants from Japan, Taiwan, Mexico, Canada, and the United States contributed data and/or analytical work. SWFSC and PIFSC scientists provided full catch time-series of mako sharks caught, landed, and released in U.S. commercial and recreational fisheries (Kinney et al. 2017) as well as information on the size and sex composition of mako sharks taken in several observed fisheries. The SHARKWG developed two models for consideration at the April 2018 working group meeting in La Jolla. The first was a fully integrated assessment model developed with Stock Synthesis (SS) (Carvalho et al. in prep), and the second was a virtual population analysis (VPA) model (Kanaiwa et al. in prep). Comparison of results from both models showed similar estimates of biomass.

In 2015, the Southwest Fisheries Science Center, in collaboration with Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), initiated the first bilateral Northeast Pacific common thresher shark stock assessment. This assessment used reproductive parameters estimated by Smith et al. (2008) for the Northeast Pacific. However, given the dramatic differences in estimates of age at first reproduction for females for the Atlantic and Pacific oceans (216 cm FL versus 160 cm FL, respectively) SWFSC scientists reexamined the data and specimens used by Smith in her study and determined that additional analyses were needed to quantify age at first reproduction for the Pacific stock. This assessment was peer-reviewed by a panel from NOAA’s Center for Independent Experts (CIE) during June 26–28, 2017. The reproductive biology of the common thresher shark was the major axis of uncertainty in the assessment. Given these concerns, a modified assessment using biological parameters from Atlantic thresher sharks was planned for 2018.

The Pacific Coast Groundfish FMP includes two shark species: leopard shark and spiny dogfish, in the groundfish management unit (Table 1.2.2). These shark species are mainly caught incidentally in groundfish fisheries and discarded at sea. A third species, soupfin shark, used to be listed as a management unit species. However, as part of the PFMC’s biennial specifications process for 2015–2016, soupfin shark was reclassified as an ecosystem component species, as it is not targeted, is not subject to overfishing or being overfished in the absence of conservation measures, and is not generally retained for sale or personal use. A separate overfishing limit (OFL) and annual catch limit (ACL) were also established for spiny dogfish, beginning in 2015. From 2006 through 2010, NMFS managed spiny dogfish using 2-month cumulative trip limits for both open access and limited entry fisheries. Since 2011, most of the limited entry trawl fishery for groundfish has been managed under an individual quota program, in which vessels are held accountable for their total catch of all species managed with quota shares. However, landings of spiny dogfish by trawlers continue to be managed through a cumulative trip limit, now of 1-month duration. Landing limits for non-trawl vessels remain at 2 months.

Table 1.2.2 Shark species in the groundfish management unit of the Pacific Coast Groundfish Fishery Management Plan.

Pacific Coast Groundfish FMP	
Sharks Listed as Management Unit Species	
Common name	Scientific name
Spiny dogfish	*Squalus suckleyi*
Leopard shark	*Triakis semifasciata*

Shark catch data are obtained from commercial landings receipts, observer programs, and recreational fishery surveys. Landings data for the U.S. West Coast are submitted by the states to the Pacific Fisheries Information Network (PacFIN) and Recreational Fisheries Information Network (RecFIN) data repositories. Table 1.2.3 shows commercial shark landings for the West Coast from 2013 to 2022. Estimates of commercial discards, as well as catch in the at-sea hake fishery, are developed by the West Coast Groundfish Observer Program, at the NOAA Northwest Fisheries Science Center. Additional recreational data collection and estimation of recreational catch are also conducted by NMFS. Data from all of these sources are used for monitoring and management by the PFMC. Recreational shark fishing, primarily for common thresher and shortfin mako shark, is popular among anglers seasonally in Southern California waters. Data collected formerly through the Marine Recreational Fisheries Statistics Survey (MRFSS) and now through the California Recreational Fisheries Survey (CRFS) are used as the best available information regarding shark catch and effort in Southern California Waters.

Table 1.2.3 Commercial shark landings (round weight equivalent in metric tons) for California, Oregon, and Washington, 2013-2022. Source: PacFIN Database, data for the Pacific Fishery Management Council area extracted July 19, 2023. Values rounded to the nearest whole number.

	Commercial Shark Landings (mt) for California, Oregon, and Washington									
Species Name	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Bigeye thresher shark	<1	0	1	1	2	0	1	1	0	0
Blue shark	<1	0	1	<1	1	2	13	2	1	2
Brown catshark	1	1	8	5	1	3	1	1	1	6
Common thresher shark	71	40	54	47	62	45	56	48	30	42
Leopard shark	1	3	4	6	4	4	5	3	5	3
Pacific angel shark	11	8	14	19	19	33	31	40	24	20
Pelagic thresher shark	0	6	3	<1	0	<1	5	0	0	0
Shortfin mako	29	19	11	18	19	17	28	7	8	5
Soupfin shark	1	2	3	5	7	9	10	14	16	12
Spiny dogfish	160	156	292	205	114	469	437	206	9	74
Unspecified shark	1	4	4	3	2	1	4	1	<1	2.3
Total	**277**	**238**	**393**	**310**	**229**	**582**	**592**	**323**	**94**	**167**

[A]This extraction includes all commercial landings, in West Coast U.S. ports, of sharks caught in areas managed by the PFMC. This summary does not include estimates of commercial discards or any recreational catch. Nor does it include any landings where there were <3 vessels as per confidentiality requirements.
Data changes from previous year's table are due to updated information.

North Pacific Fishery Management Council (NPFMC)

The NPFMC and NMFS manage fisheries in federal waters off Alaska. Twelve shark species are found in Alaska waters (Table 1.2.4; Tribuzio et al. 2022 and Tribuzio unpublished data). NMFS monitors shark catch in season for Pacific sleeper, salmon, and spiny dogfish sharks and the remaining species of sharks are grouped into "other/unidentified sharks." Pacific sleeper, salmon, and spiny dogfish sharks are taken incidentally in federal groundfish fisheries, while the other eight species are very rarely taken in any sport or commercial fishery.

Table 1.2.4 North Pacific shark species.

North Pacific shark species	
Common name	Scientific name
Pacific sleeper shark	*Somniosus pacificus*
Salmon shark	*Lamna ditropis*
Spiny dogfish shark	*Squalus suckleyi*
Brown cat shark	*Apristurus brunneus*
Basking shark	*Cetorhinus maximus*
Sixgill shark	*Hexanchus griseus*
Blue shark	*Prionace glauca*
Pacific angel shark	*Squatina californica*
White shark	*Carcharodon carcharias*
Common thresher shark	*Alopias vulpinus*
Soupfin shark	*Galeorhinus glaeus*
Sevengill shark	*Notorynchus cepedianus*

In federal waters, sharks are currently in a "bycatch only" status, which prohibits directed fishing for the species. In the Bering Sea/Aleutian Islands (BSAI), most of the shark incidental catch occurs in the midwater trawl pollock fishery and in the hook-and-line fisheries for sablefish, Greenland turbot, and Pacific cod along the outer continental shelf and upper slope areas. In the Gulf of Alaska (GOA), most of the shark incidental catch occurs in the midwater trawl pollock fishery, non-pelagic trawl fisheries, and hook-and-line Pacific cod, sablefish, and Pacific halibut fisheries. The most recent estimates of the incidental catch of sharks in the BSAI and GOA are from 2022. These data are included in Chapter 19 in the 2022 BSAI and GOA Stock Assessment and Fishery Evaluation (SAFE) reports and the NMFS catch accounting system. Estimates of the incidental catch of sharks in the groundfish fisheries from 2013 through 2022 ranged from 1,524 to 3,591 mt in the GOA and from 103 to 221 mt in the BSAI (Table 1.2.5). Very few sharks incidentally taken in the groundfish fisheries in the GOA and BSAI are retained. There has been no effort targeting sharks in the BSAI or GOA since 2008.

In October 2010, NMFS issued a final rule to implement Amendments 95 and 96 to the BSAI FMP and Amendment 87 to the GOA FMP (75 FR 61639) to comply with statutory requirements for annual catch limits and accountability measures (under National Standard 1), and to rebuild overfished stocks. NMFS specified the NPFMC recommended overfishing levels (OFLs), acceptable biological catch (ABCs), and total allowable catch (TAC) amounts. Due to conservation concerns, the final rules to implement groundfish harvest specifications in the BSAI and GOA in 2016 and 2017 prohibited directed fishing for sharks in both management areas. In other groundfish fisheries open to directed fishing, the retention of sharks taken as incidental catch is limited to no more than 20 percent of the aggregated amount of sharks, skates, octopuses, and sculpins in the BSAI, and 20 percent of the aggregated amount of sharks, octopuses, squids, and sculpins in the GOA.

Table 1.2.5 Incidental catch and utilization (in metric tons) of sharks in the Gulf of Alaska and Bering Sea/Aleutian Islands commercial groundfish fisheries, 2018-2022. (Values are rounded to nearest metric ton)
Source: NMFS Catch Accounting System Data

Incidental Catch of Sharks (mt) - Gulf of Alaska					
Species	2018	2019	2020	2021	2022
Spiny dogfish	3,281	2,037	1,457	1,915	2,345
Pacific sleeper shark	278	113	108	131	97
Salmon shark	6	16	37	45	53
Unidentified shark	25	15	6	23	64
Total	**3,591**	**2,180**	**1,609**	**2,114**	**2,560**
% Retained	0.7	1.9	2.8	1.1	0.5
Incidental Catch of Sharks (mt) - Bering Sea/Aleutian Islands					
Spiny dogfish	10	4	4	2	2
Pacific sleeper shark	40	53	68	78	75
Salmon shark	51	92	106	141	48
Unidentified shark	2	1	2	1	2
Total	**103**	**151**	**180**	**221**	**127**
% Retained	12.3	5.3	8.3	3.3	5.7

Data changes from previous year's table are due to updated information.

At its December 2022 meeting, the NPFMC recommended OFLs, ABCs, and TACs for sharks in both the BSAI and GOA for the 2023 and 2024 fishing years. The GOA ABC and TAC were based in large part on the natural mortality and biomass estimates for spiny dogfish combined with an average historical catch (1997-2007) of other shark species, while the BSAI TAC was set at a value of 250 mt, 200 mt less than the recommended ABC, which was based on historical maximum catch (2003-2015) of all the shark species. The difference in years between the FMPs is due to an examination of historical bycatch data in the BSAI suggesting errors in the observer records (Tribuzio et al. 2016). Table 1.2.5 lists the recent historical catch of sharks in the BSAI and GOA. In 2022, the BSAI TAC was 425 mt, and catch was 127 mt. The 2022 GOA TAC was 3,755 mt, and catch was 2,560 mt. The most recent assessments for sharks are in Chapter 19 to the 2022 SAFE reports for the BSAI and GOA, which is currently available online.

The shark complexes in the BSAI and GOA are assessed biennially in even years, with the final assessments available in late autumn. Thus, the most recent BSAI and GOA SAFE reports were completed in 2022, as a combined document, and include complete data through 2021 (Tribuzio et al. 2022a, b). In the BSAI, NMFS conducts surveys annually in the Eastern Bering Sea shelf and biennially along the Aleutian Islands for all groundfish, including sharks. NMFS also surveys the Eastern Bering Sea slope; however, funding has limited the biennial schedule to semi-irregular surveys. NMFS surveys the Northern Bering Sea for groundfish, including sharks, with only a few years of data and no shark catch recorded to date. In the GOA, NMFS conducts surveys biennially for groundfish, including sharks. The most recent surveys were conducted in the Eastern Bering Sea slope in 2016, the Aleutian Islands in 2022, and the Eastern Bering Sea shelf in 2022. For the GOA, the most recent survey was in 2021. Results were incorporated into the SAFE reports for sharks.

The North Pacific Observer Program was restructured in 2013. As a result, observers are now deployed on smaller vessels and vessels fishing in the Pacific halibut Individual Fishing Quota fishery, which were previously unobserved. Details of the restructuring are provided in Faunce et al. (2014). The restructuring in essence created a new time-series of catch, which more accurately reflects catch of sharks in both the GOA and BSAI. Analyses are ongoing to determine the overall impact of the new catch time-series and how it affects the stock assessments.

Commercial shark fishing in State waters

State of Alaska regulation 5 AAC 28.084 prohibits directed commercial fishing of sharks statewide unless a Commissioner's Permit is issued (5 AAC 28.379). In 2006, one Commissioner's Permit was issued for a spiny dogfish permit fishery in the Cook Inlet area; this fishery was not successful. Sharks taken incidentally to commercial groundfish and salmon fisheries may be retained and sold provided that the fish are fully utilized as described in 5 AAC 28.084. In Southeast Alaska, the State limits the amount of incidentally taken sharks that may be retained (5AAC 28.174 (1) and (2)). In addition, in the East Yakutat Section and the Icy Bay Subdistrict salmon gillnetters may retain all spiny dogfish taken as bycatch during salmon gillnet operations (5AAC 28.174 (3)). Since 2014, in Prince William Sound and Cook Inlet an emergency order is issued annually that sets bycatch limits in the halibut, directed groundfish, and drift or set gillnet (herring or salmon) fisheries. Participants in these fisheries may retain 15 percent shark species in aggregate, which includes spiny dogfish, of the round weight of their target species. All sharks landed must be recorded on an ADF&G fish ticket; however, landings are rare.

Western Pacific Fishery Management Council (WPFMC)

The WPFMC's area of jurisdiction includes the EEZ around Hawai'i, American Samoa, Guam, the Northern Mariana Islands, and the Pacific Remote Islands Areas (PRIA). The Western Pacific Fishery Management Council and NMFS conserve and manage sharks through two fishery ecosystem plans. The WPFMC's Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region identifies nine sharks as management unit species (Table 1.3.6). Five species of coastal sharks are listed in the fishery ecosystem plan for the Pacific Remote Island Areas (Table 1.3.7) as currently harvested. However, the Pacific Remote Islands are now designated as a marine national monument where all commercial fishing is prohibited.

The longline fisheries in the western Pacific, mostly in Hawai'i and American Samoa, have historically landed the vast majority of the sharks. Shark landings (estimated whole weight) by the Hawai'i-based longline fisheries peaked at about 2,870 mt in 1999, largely due to the finning of blue sharks, which is now prohibited. A State of Hawai'i law prohibiting landing shark fins without an associated carcass was passed in mid-2000 (Hawai'i Revised Statutes 188.40-5). Shark landings decreased by almost 50 percent to 1,450 mt in 2000. With the subsequent enactment of the federal Shark Finning Prohibition Act, shark landings have declined precipitously with landings in 2022 being approximately 3 mt (Table 1.2.8). Today, mako and thresher sharks are the only species with market value. The few sharks landed in the fishery are marketed as fresh shark filets and primarily exported to the U.S. mainland.

Table 1.2.6 Sharks in the management unit of the Fishery Ecosystem Plan (FEP) for Western Pacific Pelagic Fisheries (as amended December 2009).

Western Pacific Pelagic Fisheries FEP	
Common name	Scientific name
Common thresher shark	*Alopias vulpinus*
Pelagic thresher shark	*Alopias pelagicus*
Bigeye thresher shark	*Alopias superciliosus*
Silky shark	*Carcharhinus falciformis*
Oceanic whitetip shark	*Carcharhinus longimanus*
Shortfin mako shark	*Isurus oxyrinchus*
Longfin mako shark	*Isurus paucus*
Salmon shark	*Lamna ditropis*
Blue shark	*Prionace glauca*

Table 1.2.7 Coastal sharks listed as management unit species and designated as currently harvested coral reef taxa in the Pacific Remote Island Areas Fishery Ecosystem Plan.
Other coastal sharks in the management unit of the FEP belonging to the families Carcharhinidae and Sphyrnidae are designated as potentially harvested coral reef taxa.

Pacific Remote Island Areas Fishery Ecosystem Plan		
Sharks Listed as Management Unit Species		
Common Name	Scientific Name	PRIA FEP
Silvertip shark	*Carcharhinus albimarginatus*	X
Grey reef shark	*Carcharhinus amblyrhynchos*	X
Galapagos shark	*Carcharhinus galapagensis*	X
Blacktip reef shark	*Carcharhinus melanopterus*	X
Whitetip reef shark	*Triaenodon obesus*	X

Table 1.2.8 Shark landings (in metric tons) from the Hawai'i-based and American Samoa-based pelagic longline fisheries, 2018-2022.
Source: Pacific Islands Fisheries Science Center, Fisheries Research and Monitoring Division. For 2018-2022 blank cells = no catch and “0” cells = catch <0.5 mt

	Species	2018	2019	2020	2021	2022
Hawai'i-based Longline Fisheries	Blue shark	0	0	0	0	0
	Mako shark	36	32	2	1	1
	Thresher shark	2	4	1	1	42
	Misc. shark	0	0	0	0	0
	Total shark landings	38	36	3	2	3
American Samoa	**Total shark landings**	4	1	0	0	0

Protected Species Workshop Trainings
Western Pacific longline fishing vessel owners and captains are required to complete annual training on protected species. These trainings include content on regulations regarding handling and release of oceanic whitetip, silky, and whale sharks. These regulations include prohibiting the retention of oceanic whitetip and silky sharks, and requirements to release these sharks, by longline vessels. For more information on these regulations, see Section 3.2 Regional Efforts.

1.3 NOAA Enforcement of the Shark Finning Prohibition Act

The NMFS Office of Law Enforcement (OLE) has responsibility for enforcing both the Shark Finning Prohibition Act of 2000 (SFPA) and implementing regulations. During calendar years 2018, 2019, 2020, 2021 and 2022, violations of the SFPA and noncompliance with regulations to protect sharks have been investigated in the Pacific Islands, Alaska, West Coast, Northeast, and Southeast Enforcement Divisions. Violations that were investigated included domestic vessels landing sharks in improper form, finning, and the illegal export and transport of shark fins.

- A USCG cutter boarded a federally permitted shark vessel in federal waters and recorded the following violations: 149 shark fins, 93 sharks over the limit, 101 sharks in improper form, and four prohibited sandbar sharks. The investigation was sent to general counsel for review and a $130,000 Notice of Violation and Assessment was issued.

- Florida Fish and Wildlife Conservation Commission officers observed a commercial gillnet vessel return to the dock with shark carcasses and fins detached, which they seized as evidence. The investigation was sent to general counsel for review and a $7,250 Notice of Violation and Assessment was issued.

- A fishery observer on a Hawai'ian longline fishing vessel reported possible shark finning activity. Compliance assistance was provided on proper landing requirements for sharks.

- Florida Fish and Wildlife Conservation Commission submitted a case package involving a vessel found in possession of a blacknose shark not in whole condition, among other violations. NOAA OLE investigated and a $2,100 summary settlement was issued to the captain.

- Rhode Island Department of Environmental Management officers boarded a vessel and found packaged remains of mako shark. Upon further investigation by NOAA OLE, it was determined the mako remains came from an undersized female mako. A $1,250 summary settlement was issued to the captain.

- Rhode Island Department of Environmental Management officers boarded a vessel and found mutilated mako. A $1,000 summary settlement was issued to the captain.

- At a Rhode Island public boat ramp, a NOAA OLE enforcement officer inspected a vessel and found one mako shark, which was finned at sea and landed in improper form. A $1,000 summary settlement was issued to the captain.

- In Louisiana, an individual was found in possession of 15 prohibited shark fins. The individual was issued a $1,000 summary settlement.

- An offshore boarding of a shrimp vessel in the Gulf of Mexico revealed a number of violations, including possession of four shark fins and no permit for highly migratory species. A $2,300 summary settlement was issued to the captain.

- In Florida, a fishing vessel was found in possession of one shark fin not naturally attached to a carcass. A $500 summary settlement was issued to the captain.

- NOAA OLE assisted CBP with a case where approximately 19kg of shark fins were detected at the San Ysidro Port of Entry in California. The driver of the vehicle transporting the shark fins was issued a $500 summary settlement.

- Four shark fins were found during a USCG dockside inspection in Louisiana. Crewmembers admitted to catching the shark while in federal waters. A written warning was issued.

- An at sea boarding in the Gulf of Mexico off the coast of Texas revealed 10 shark fins. The violations were referred to the Texas Parks and Wildlife Department.

- A USCG station in Texas found shark fins aboard a shrimp trawler. A general counsel attorney was assigned to the case, which is ongoing as of the writing of this report.

1.4 Education and Outreach

The U.S. National Plan of Action for the Conservation and Management of Sharks states that each U.S. management entity (i.e., NMFS, regional fishery management councils, interstate marine fisheries commissions, and states) should cooperate with regard to education and outreach activities associated with shark conservation and management. As part of the effort to implement the U.S. National Plan of Action, NMFS, OLE, and other U.S. shark management entities have completed the following actions:

- To facilitate identification of Atlantic sharks, the HMS Management Division requires that all federal Atlantic shark dealers attend a mandatory Atlantic Shark Identification

Workshop at least once every 3 years. These free workshops provide hands-on training to help identify both processed and whole sharks to the species level. State and federal fish and wildlife law enforcement officers also frequently attend these workshops, which are conducted throughout the entire Atlantic and Gulf of Mexico coasts. Dealers must attend their first Atlantic Shark Identification Workshop in person, but have the option between an online or in-person workshop to recertify. The number of in-person workshops held annually was: 12 in 2018, 12 in 2019, 12 in 2020, 14 in 2021, and 10 in 2022.

- To facilitate the proper safe handling and release of protected species, shark identification, and compliance with fishing regulations, the HMS Management Division requires that all HMS pelagic longline, bottom longline, and shark gillnet vessel owners and operators attend a free mandatory Safe Handling, Release, and Identification Workshop at least once every 3 years. Fishermen required to attend these workshops must attend their first workshop in person, but have the option between an online or in-person workshop to recertify. The number of in-person workshops held annually was: 23 in 2018, 22 in 2019, 24 in 2020, 17 in 2021, and 10 in 2022.

- In 2018, as part of the implementation plan for Amendment 5b to the 2006 Consolidated HMS FMP, all HMS permit holders were required to obtain a shark endorsement on their HMS permit to target and retain sharks. To obtain this endorsement, permit holders must watch an educational shark endorsement video and take a quiz that covers key identification characteristics of common prohibited shark species and proper catch-and-release practices. In 2022, 75 percent of HMS Charter/Headboat and 55 percent of HMS Angling permit holders received a shark endorsement on their permits. Additionally, 49 percent of Atlantic Tunas General and Swordfish General Commercial permit holders obtained a shark endorsement to retain sharks while participating in registered HMS tournaments.

- In 2019, the HMS Management Division first implemented a shark retention limit for the HMS Commercial Caribbean Small Boat permit to allow the capture and sale of a limited number of shark species in the U.S. Caribbean region, which includes Puerto Rico and the U.S. Virgin Islands. As part of the implementation for this rulemaking, NMFS conducted extensive outreach efforts and educational products for fishermen and government agencies in the U.S. Caribbean region to address species identification and compliance concerns. Outreach efforts included informational talks to territorial agencies and local fishermen organizations. Educational products included the development of shark identification placards and videos on permit requirements, shark species identification, safe catch-and-release protocols in English and Spanish, and the publication of Spanish-written articles on permit requirements in local publications.

- In 2021, the HMS Management Division led a year-long social media campaign focused on providing fact-based shark information to the public. The campaign addressed misperceptions about commercial and recreational shark fishing and the status of domestic shark populations via monthly web stories.

- In 2022, the HMS Management Division released the draft Atlantic Shark Fishery Review (SHARE) document. SHARE is a review of the current state of the Atlantic shark fishery and examined a variety of factors affecting the fishery, including all aspects of commercial and recreational shark fisheries conservation and management and shark depredation. SHARE identified areas of success, concerns, and potential modifications to regulations and management measures, and may be used to develop future management measures.

- The Greater Atlantic Regional Fisheries Office (GARFO) and the Northeast Fisheries Science Center (NEFSC) work together to provide the public with information about shark and skate species found in the Northwest Atlantic Ocean. This includes collaborating and coordinating media interviews with shark experts to highlight recent research as well as offering updated information about shark-related management actions.

- NEFSC staff work with NOAA Public Affairs, often in coordination with the NMFS HMS Division and GARFO, to address public and media requests for information about current shark research, biology and ecology, strandings, and interactions with humans, such as shark attacks and fishery interactions.

- NEFSC staff attended Northeast U.S. recreational shark fishing tournaments, captains meetings, and local sport fishing shows to inform participants on current shark management regulations and discuss and answer questions on current research. The NEFSC tagging booklet is updated, detailing tagging and recapture instructions, catch and release guidelines, research results, length and weight information, management regulations, and contact websites and telephone numbers. This booklet, along with tags and identification guides and placards, are made available to the fishing public and the booklet is also mailed to NMFS Cooperative Shark Tagging Program (CSTP) participants. Feedback is given to tournament officials on historic tournament landings to encourage further shark conservation measures and to facilitate better catch-and-release practices.

- In 2018, NEFSC staff provided lab tours and lectures on shark research for U.S. Congressional staffers and presented an Apex Predators Program overview to domestic and international journalists participating in a workshop sponsored by the Metcalf Institute responding to questions about shark biology and abundance and the potential effects of climate change on shark species. Staff worked with NEFSC Research Communications to provide information on shark dissection guides for a teacher request, reply to media inquiries for information on sharks, and participate in interviews on climate change and its influence on shark distributions and K-12 interviews on shark nurseries and how sharks use these areas, and helped create two NEFSC web feature articles—one about recent shark age and growth research titled "Researchers Demonstrate Shark Vertebral Band Pairs Are Related to Growth, Not Time" and another about the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program titled "Estuarine Waters Home to Shark Nursery Habitat along East Coast." NEFSC staff also provided information on COASTSPAN to the NEFSC Social Media Coordinator for use in the "Twelve Days of Fishmas" posting on the NEFSC website (COASTSPAN was highlighted on the seventh day), and provide APP and general shark information and photos to the NEFSC Social Media Coordinator for use in the NEFSC Oceans Month Quiz #5 – Fish and Sharks. NEFSC's shark biologist, Lisa Natanson, and the articles about the COASTSPAN program and NEFSC shark age and growth research were highlighted on the NMFS website during shark week this year (https://www.fisheries.noaa.gov/feature-story/shark-week-2018) in addition to one other featured article NEFSC staff contributed to: "12 Shark Facts that May Surprise You."

- In 2019, NEFSC staff provided lab tours and lectures on shark research for U.S. Congressional staffers, fisheries students from the University of Rhode Island, and Atlantic White Shark Conservancy staff and interns and Gills Club members during a visit to the Narragansett Lab to learn about shark anatomy. NEFSC staff also worked with NEFSC and HMS Communications to provide online content for shark week. Staff posted (Twitter/Facebook) real-time information during the DE COASTSPAN surveys during the summer and helped create articles featured on NEFSC and NMFS web pages and highlighted in FishNews."Highlighting the Cooperative Shark Tagging Program," "Shark Discovery May Help People with Bone Disease," "Eight Surprising Shark Facts," and "Atlantic Spiny Dogfish Benefits from Sustainable Shark Management" were all featured on the NMFS webpage during shark week in 2019. NEFSC staff also helped create a story map on COASTSPAN and GULFSPAN (: https://www.fisheries.noaa.gov/story-map/search-atlantic-shark-nurseries), a fact sheet for seals and sharks shared traits (https://www.fisheries.noaa.gov/feature-story/cape-cod-seals-and-sharks-shared-traits-and-top-10-facts), and an article on white sharks and gray seals off Cape Cod (https://www.fisheries.noaa.gov/feature-story/together-again-white-sharks-and-gray-seals-cape-cod).

- In 2020, NEFSC Research Communications worked to highlight APP research online ("Updated Shark Tagging Atlas Provides More Than 50 Years Of Tagging And Recapture Data") and revamp the APP web pages on research, surveys, and the CSTP, its online shark tag recapture form and shark identification pages. NEFSC staff also responded to media and public inquiries about shark strandings, shark reproduction, conventional and high-technology tags, white shark research, sharks in New York waters, and potential effects offshore wind energy development on sharks, and to highlight a CSTP volunteer (with his permission) from the United Kingdom for a story on his contribution to the CSTP and recognition for his promotion of catch-and-release sportfishing in Saltwater Boat Angling magazine. Additionally, Lisa Natanson, NEFSC shark life history biologist, conducted a live shark discussion on the University of Rhode Island Graduate School of Oceanography's Ocean Classroom, was interviewed by the Atlantic White Shark Conservancy for their "Shark Conservation Career Week," and was featured in an article in the Providence Journal highlighting her career as a shark biologist and mentor.

- In 2021, NEFSC staff worked with NEFSC Research Communications to create two NEFSC web feature articles: one on the NEFSC's Large Coastal Shark Bottom Longline Survey that was also featured on the NMFS website during shark week ("2021 Coastal Survey Catches Nearly 2,500 Atlantic Sharks") and another one later in the year on the increase in CSTP participation ("Citizen Science Participation in Shark Tagging Program Grows During Pandemic"). NEFSC staff loaned shark jaws to the Atlantic White Shark Conservancy for use during public exhibits at their Shark Center in Chatham, Massachusetts and responded to media and public inquiries about general shark information, shark in New York, shark strandings, shark identification, and how to distinguish shark fins from other marine life. Cami McCandless, NEFSC APP Lead, gave a public seminar through Rutgers University's Marine Extension Program on the CSTP and citizen science supporting research to inform management. Additionally, NEFSC staff worked with NEFSC Communications to enhance the CSTP shark tag recapture form to accept photos for identification and worked with the New York Department of Environmental Conservation and the New Jersey Department of Environmental Protection to provide CSTP volunteers with information on New York and New Jersey regulations regarding prohibited species.

- In 2022, NEFSC staff provided lab tours and lectures on shark research for U.S. Congressional staffers and University of Rhode Island students, continued to loan shark jaws to the Atlantic White Shark Conservancy for use during public exhibits, and provided information on the CSTP for two articles ("Tracking Sharks and Listening to Rays" and "How Citizen Science Helps NOAA Keep Tabs on Our Oceans") on the SciStarter Blog, which highlights citizen science projects, people, and perspectives. NEFSC staff worked with NEFSC Communications to produce a web story ("Climate Change Is Shifting Tiger Shark Populations Northward") to promote APP research on the use of CSTP data to help detect changes in tiger shark distribution due to climate change and provided information on the common thresher shark for the NMFS-inspired "Pumpkin Carving Stencils for Ocean Lovers." Additionally, NEFSC staff responded to inquiries from the media and public on general shark information, shark strandings, climate change effects on sharks, and the seasonal distribution of sharks along the U.S. East Coast. Additionally, Michelle Passerotti, NEFSC shark life history biologist, was interviewed by a local news channel about APP research and how it relates to fisheries management ("Sharks: Inside the Belly of the Beast") and was the featured shark scientist on the Atlantic White Shark Conservancy Gills Club podcast in October 2022.

- Dr. John Carlson continues to work with NOAA Public affairs providing information to the media and the public, as needed, regarding shark attacks and sharks and their interactions with people.

- SEFSC staff continue to support NOAA's Teacher at Sea program by hosting teachers aboard the annual shark survey. Two teachers participated in the survey in 2016, and 21 teachers have participated in the shark survey since 2000. Staff also attended the NOAA Heritage Day in Silver Spring, Maryland, to talk to the public in person as well as through an interview with the Washington Post about sharks and NOAA's work.

- The NMFS Office of Communications coordinates a national Shark Week campaign to which each regional office and science center can contribute.

- SWFSC staff organize and participate in annual events that include shark outreach including the Day at the Docks and the Fred Hall Fishing Show, Barrio Logan, Nature Center. The SWFSC also regularly fields calls from the media to address shark-related questions, often in response to a local shark sighting or the infrequent attacks.

Section 2: Imports and Exports of Shark Fins

The summaries of annual U.S. imports and exports of shark fins in Tables 2.1.1 and 2.2.1 are based on information submitted by importers and exporters to U.S. Customs and Border Protection and to the U.S. Census Bureau as reported in the NMFS Trade database.

2.1 U.S. Imports of Shark Fins

During 2022, shark fins were not imported into the United States. Shark fin imports into the United States decreased steadily in 2018 and ended in 2019. Since 2019 there have been no imports.

2.2 U.S. Exports of Shark Fins

The majority of shark fins exported in 2022 were sent from the United States to China, with smaller amounts going to the British Virgin Islands and Mexico. The mean value of exports increased from $3,869 per metric ton in 2021 to $7,268 per metric ton in 2022 (Table 2.2.1). However, this is still a decline from the 5-year average (2018 to 2022) of $10,894 per metric ton.

2.3 International Trade of Shark Fins

The Food and Agriculture Organization of the United Nations (FAO) compiles data on the international trade of fish. The summaries of imports, exports, and production of shark fins in tables 2.3.1, 2.3.2, and 2.3.3 are based on official FAO statistics contained in the FishStatJ database. The quantities and values in those tables are totals for all dried, dried and salted, fresh, or frozen shark fins. For the most recent FAO update, data were added for 2021, and global imports of shark fins were approximately 16,166 metric tons. In 2021, the average value of global imports decreased to $14,343 per metric ton. By volume Ukraine was the largest importer and Singapore was the largest exporter of shark fins in 2021.

Table 2.1.1 Weight and value of shark fins imported into the United States, by country of origin.
Note: Weight is rounded to the nearest metric ton and value is rounded to thousands of dollars.
Source: U.S. Census Bureau

Country	2018		2019		2020		2021		2022	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
Brazil	3	9	1	3	0	0	0	0	0	0
China	0	0	0	0	0	0	0	0	0	0
China, Hong Kong	2	145	0	0	0	0	0	0	0	0
India	0	0	0	0	0	0	0	0	0	0
Total	**5**	**154**	**1**	**3**	**0**	**0**	**0**	**0**	**0**	**0**
Mean value	**$30,800/mt**		**$3,000/mt**		**$0/mt**		**$0/mt**		**$0/mt**	

Table 2.2.1 Weight and value of dried shark fins exported from the United States, by country of destination.

Note: Data in table are "total exports," which is a combination of domestic exports (may include products of both domestic and foreign origin) and re-exports (commodities that have entered the United States as imports and not sold, which, at the time of re-export, are in substantially the same condition as when imported). (1) means that the weight was less than 500 kilograms.

Source: U.S. Census Bureau

Country	2018		2019		2020		2021		2022	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
British Virgin Islands	0	0	0	0	0	0	0	0	7	40
Canada	13	78	(1)	28	0	0	0	0	0	0
China	17	47	0	0	0	0	0	0	33	255
China, Hong Kong	22	1,032	38	593	3	145	38	112	0	0
Dominican Republic	0	0	0	0	2	25	6	57	0	0
Mexico	0	0	0	0	9	39	2	4	1	3
South Africa	0	0	0	0	8	21	0	0	0	0
South Korea	4	27	0	0	0	0	0	0	0	0
Total	**56**	**1,184**	**38**	**593**	**22**	**230**	**46**	**178**	**41**	**298**
Mean value	**$ 21,143/mt**		**$15,605/mt**		**$ 10,455/mt**		**$3,869/mt**		**$7,268/mt**	

Table 2.3.1 Weight and value of shark fins imported by countries other than the United States.

Note: Weight is rounded to the nearest metric ton and value is rounded to thousands of dollars. (1) means that the weight was less than 500 kilograms.

Source: Food and Agriculture Organization of the United Nations, FishStatJ database, www.fao.org

Country	2018		2019		2020		2021	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
Andorra	-	-	(1)	(1)	-	-	-	-
Australia	2	188	4	306	1	132	3	166
Austria	-	-	-	-	-	-	-	-
Bahamas	(1)	(1)	-	-	(1)	1	-	-
Bahrain	-	-	-	-	-	-	(1)	(1)
Bangladesh	-	-	(1)	(1)	-	-	-	-
Belgium	26	145	16	81	14	73	14	86
Botswana	-	5	0	1	1	1	(1)	(1)
Brunei Darussalam	-	-	-	-	(1)	1	-	-
Bulgaria	17	53	13	42	11	43	9	35
Cambodia	-	-	(1)	(1)	(1)	1	-	-
Cameroon	-	-	-	-	-	-	-	-
Canada	179	2,691	162	2,096	88	961	74	698
China	2,433	19,238	3,298	26,425	2,456	19,394	2,211	21,491
China, Hong Kong SAR	4,702	131,697	2,796	107,108	1,663	72,734	1,945	96,726
China, Macao SAR	62	5,284	81	6,732	18	1,095	27	2,348
Comoros	15	10	19	30	20	23	44	35

Croatia	19	56	13	41	10	38	8	31
Cuba	-	-	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-	12	140
Czechia	-	-	-	-	-	-	-	-
Denmark	-	-	(1)	(1)	-	-	-	-
El Salvador	-	-	-	-	-	-	(1)	(1)
Equatorial Guinea	-	-	-	-	-	-	-	-
Estonia	3	1	-	-	-	-	-	-
Faroe Islands	-	-	-	-	-	-	-	-
Finland	-	-	-	-	-	-	(1)	(1)
France	-	1	4	38	2	4	-	-
Germany	-	-	-	-	(1)	2	-	-
Ghana	-	1	-	-	-	-	(1)	(1)
Greece	2	5	-	-	-	-	(1)	(1)
Greenland	1	7	1	8	-	-	-	-
Guatemala	-	-	-	-	-	-	4	7

Table 2.3.1 Continued

Country	2018		2019		2020		2021	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
Hungary	1	7	3	45	2	30	1	25
Iceland	-	-	-	-	4	3	-	-
Indonesia	128	1,242	131	1,183	127	1,063	477	1,040
Iraq	-	-	(1)	(1)	-	-	(1)	(1)
Ireland	3	17	87	406	114	551	(1)	(1)
Italy	511	3,174	246	1,473	270	1,566	361	2,423
Jamaica	-	-	-	-	1	6	-	-
Japan	223	13,575	314	17,210	229	8,870	323	10,195
Kazakhstan	-	21	1	13	(1)	2	(1)	2
Kiribati	-	-	(1)	1	-	-	-	-
Korea, Republic of	22	2,048	26	2,363	24	2,250	24	2,176
Kuwait	-	-	-	-	-	-	-	-
Lao People's Dem. Rep.	1	8	-	-	-	-	-	-
Latvia	-	-	-	-	-	-	(1)	2
Libya	-	-	22	40	-	-	-	-
Luxembourg	4	32	3	28	3	36	3	36
Madagascar	-	-	-	-	-	-	-	-
Malaysia	1,756	6,671	1,735	7,469	1,848	7,315	2,464	9,505

Maldives	-	-	(1)	1	1	4	-	-
Mali	-	-	1	2	-	-	-	-
Marshall Islands	-	-	-	-	-	-	-	-
Mauritius	-	-	-	-	-	-	-	-
Mexico	-	-	-	-	1	13	-	-
Micronesia (Fed. States)	1	3	(1)	1	(1)	1	(1)	1
Morocco	-	-	3	156	-	-	-	-
Myanmar	-	-	-	-	-	-	4	1
Namibia	-	-	(1)	(1)	-	-	-	-
Netherlands (Kingdom of the)	16	116	7	50	9	92	1	8
New Caledonia	-	-	(1)	1	-	-	-	-
Total	**14,387**	**234,165**	**15,160**	**250,884**	**12,389**	**176,851**	**16,164**	**231,859**
Mean value	**$1,628/mt**		**$1,6554/mt**		**$1,427/mt**		**$1,434/mt**	

Table 2.3.2 Weight and value of shark fins exported by countries other than the United States.

Note: Data are for "total exports," which is a combination of domestic exports (may include products of both domestic and foreign origin) and re-exports (commodities that have entered into a country as imports and not sold, which, at the time of re-export, are in substantially the same conditions as when imported). Weight is rounded to the nearest metric ton and value is rounded to thousands of dollars. (1) indicates that the weight < 500 kilograms.

Source: Food and Agriculture Organization of the United Nations, FishStatJ database, www.fao.org

Country	2018		2019		2020		2021		2022	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
Angola	6	401	-	-	-	-	-	-	-	-
Argentina	-	-	4	41	-	-	-	-	-	-
Armenia	-	-	-	-	-	-	-	-	(1)	1
Australia	1	125	14	184	2	112	2	87	5	368
Bangladesh	45	510	(1)	7	7	563	0	35	1	97
Belgium	3	24	4	23	3	26	3	42	3	41
Belize	-	-	(1)	(1)	(1)	(1)	-	-	-	-
Bosnia and Herzegovina	(1)	3	-	-	-	-	-	-	-	-
Botswana	130	205	-	-	-	-	-	-	-	-
Brazil	31	1,037	33	1,294	22	830	23	847	20	1,092
Cameroon	-	-	-	-	(1)	6	(1)	2	(1)	2
Chile	1	36	8	67			(1)	(1)	-	-
China	283	11,179	245	9,125	212	10,506	166	9,846	112	5,643
China, Hong Kong SAR	1,434	24,942	1,644	33,008	983	23,898	81	4,521	50	4,351
China, Macao SAR	(1)	27	(1)	4	1	50	1	102	2	131
Colombia	1	109	-	-	-	-	-	-	-	-

Congo	4	35	(1)	3	-	-	-	-	-	-
Costa Rica	42	3,297	39	3,505	38	3,402	37	2,550	49	3,314
Cuba	3	143	3	132	-	-	-	-	-	-
Czechia	2	5	-	-	-	-	-	-	-	-
Denmark	(1)	1	1	7	1	7	3	7	(1)	3
Ecuador	79	944	161	2,963	116	3,662	91	3,148	321	9,757
El Salvador	14	803	16	374	21	680	9	271	8	216
Eritrea	-	-	-	-	5	18		-	-	-
France	12	62	2	123	2	11	(1)	1	(1)	(1)
Germany	(1)	7	1	1	(1)	(1)	(1)	(1)	2	29
Ghana	-	-	-	-	1	(1)	-	-	-	-
Greenland	-	-	-	-	-	-	40	275	14	116
Guatemala	33	74	3	7	4	19	6	62	2	56
Guinea	9	279	15	216	8	128	13	266	17	214
Guyana	-	-	-	-	-	-	4	80	17	359

Table 2.3.2 Continued

Country	2018		2019		2020		2021		2022	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
Iceland	-	-	(1)	1	-	-	-	-	-	-
India	4	189	(1)	(1)	(1)	(1)	4	208	-	-
Indonesia	674	7,892	640	8,144	865	12,469	633	11,395	810	15,355
Iran (Islamic Rep. of)	7	173	8	241	2	3	-	-	-	-
Italy	89	341	102	357	2	17	1	13	1	9
Japan	438	4,404	545	6,672	573	8,246	238	3,675	359	5,494
Kazakhstan	-	-	22	84	35	39	-	-	-	-
Kenya	-	-	-	-	-	-	2	14	(1)	1
Korea, Republic of	43	926	43	1,113	27	600	10	291	20	450
Liberia	2	174	-	-	-	-	-	-	-	-
Luxembourg	(1)	2	(1)	2	(1)	2	(1)	1	(1)	(1)
Madagascar	15	163	11	146	15	109	14	117	11	54
Malaysia	446	4,103	476	6,881	467	4,534	409	3,496	549	4,399
Mauritius	2	5	-	-	5	44	-	-	(1)	(1)
Mexico	170	7,187	119	6,423	119	5,121	105	3,891	153	4,050
Morocco	70	1,105	88	1,226	48	958	51	970	77	1,349
Mozambique	-	-	-	-	5	62	11	144	8	79

Myanmar	-	-	(1)	(1)	-	-	-	-	-	-
Namibia	424	4,052	458	5,002	377	4,385	357	3,356	167	2,097
Netherlands (Kingdom of the)	3	36	(1)	2	(1)	3	1	21	1	11
New Zealand	670	6,720	30	234	31	332	14	110	29	343
Nicaragua	-		(1)	1	7	190	4	67	10	183
Norway	-	-	-	-	2	27	2	25	5	45
Oman	25	81	51	23	32	98	61	206	75	104
Pakistan	-	-	-	-	-	-	1	5	-	-
Panama	1	23	6	89	(1)	1	-	-	-	-
Papua New Guinea	1	42	7	447	10	644	6	611	14	782
Peru	280	7,355	322	9,362	207	9,913	231	10,314	415	17,755
Philippines	52	242	1	10	-	-	-	-	6	32
Portugal	111	1,049	218	2,349	234	2,607	204	2,167	200	2,806
Russian Federation	(1)	1	-	-	2	23	-	-	-	-
Senegal	84	1,433	47	563	108	1,074	90	447	83	474

Table 2.3.2 Continued

Country	2018		2019		2020		2021		2022	
	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)	Metric ton	Value ($1,000)
Seychelles	1	59	3	68	3	51	3	73	2	63
Sierra Leone	4	68	4	50	4	50	5	64	2	30
Singapore	1,345	22,627	1,648	33,678	3,309	66,218	2,316	44,029	2,422	58,911
Slovakia	(1)	(1)	-	-	-	-	-	-	(1)	(1)
Solomon Islands	1	20	(1)	15	6	90	-	-	2	66
Somalia	17	980	9	467	39	1,505	15	1,217	21	1,187
South Africa	50	1,315	68	1,159	93	2,410	25	443	71	940
Spain	1,919	28,520	2,303	37,905	2,656	48,417	2,408	37,929	2,131	38,934
Sri Lanka	52	1,401	86	2,037	91	2,804	66	2,015	102	3,730
Sudan	-	-	-	-	(1)	1	-	-	-	-
Sweden	215	61	-	-	-	-	-	-	-	-
Taiwan Province of China	480	5,212	505	5,084	659	5,393	309	3,958	447	5,769
Thailand	437	2,661	123	453	27	297	186	671	53	454
Togo	23	1,448	16	1,429	21	908	15	331	5	421
Trinidad and Tobago	1	13	3	54	3	53	4	59	5	154
Uganda	-	-	-	-	-	-	-	-	1	8
Ukraine	-	-	-	-	-	-	98	240	166	511
United Arab Emirates	252	3,971	122	2,824	82	2,230	78	2,223	6	125

United Kingdom	46	164	30	288	20	213	5	54	-	-
Uruguay	(1)	1	-	-	-	-	-	-	-	-
Vanuatu	32	122	-	-	-	-	-	-	-	-
Venezuela (Boliv Rep of)	-	-	-	-	(1)	(1)	(1)	(1)	(1)	(1)
Viet Nam	3	113		-	12	307	10	250	92	3,405
Yemen	200	5,421	210	5,016	137	3,466	107	2,769	90	3,435
Total	**10,822**	**166,123**	**10,517**	**190,982**	**11,762**	**229,832**	**8,576**	**160,012**	**9,233**	**199,803**
Mean value	**$15,351/mt**		**$1,816/mt**		**$1,954/mt**		**$1,866/mt**		**$2,164/mt**	

Table 2.3.3 Production of shark fins in metric tons by country other than the United States.
Note: The production of shark fins represents the amount that a country processed at the fin level (not the whole animal level). NA = data not available. Note, 2020 is the most recent year for which the FAO has processed product data.
Source: Food and Agriculture Organization of the United Nations, FishStatJ database, www.fao.org

Country	2016	2017	2018	2019	2020
Bangladesh	7	5	1	0	0
Brazil	24	27	33	22	23
Ecuador	79	87	160	118	90
El Salvador	11	14	16	21	9
Guyana	51	56	46	20	16.4
India	100	66	72	74	105
Indonesia	280	300	365	344	344
Korea, Republic of	63	43	30	27	4
Madagascar	28	15	5	2.32	1.09
Pakistan	125	128	132	138	146
Peru	0	51	2	0	0
Senegal	43	3	24	26	30
Singapore	210	115	100	118	138
South Africa	72	43	25	76	23
Sri Lanka	40	50	90	90	60
Taiwan Province of China	257	3	4	404	262

Uruguay	2	0	0	0	0
Yemen	240	200	210	137	107
TOTAL (mt)	**2,006**	**1,663**	**1,730**	**2,960**	**1,693**

Section 3: International Efforts to Advance the Goals of the Shark Finning Prohibition Act

The key components of a comprehensive framework for international shark conservation and sustainable management have been established in global and regional agreements, as well as through resolutions and conservation and management measures adopted by international organizations. These relevant mechanisms and fora have identified, adopted, and/or published detailed language, provisions, or guidance to assist nations and regional fisheries management organizations and arrangements (RFMO/As) in the development of measures for the conservation and sustainable management of sharks. Some of these mechanisms have created international legal obligations with regard to shark conservation and management, while others are voluntary. To that end, the United States continues to promote the global conservation and sustainable management of sharks by having ongoing consultations consistent with the Shark Finning Prohibition Act. The Act calls for the United States to pursue an international ban on shark finning and to advocate for improved data collection, including biological data, stock abundance, bycatch levels, and information on the nature and extent of shark finning and trade. Determining the nature and extent of shark finning is the key step toward decreasing the incidence of finning worldwide. More information about the United States' international shark conservation activities can be found here.[1]

3.1 Bilateral Efforts

The United States continues to participate in bilateral discussions with a number of nations and entities to address issues relating to international shark conservation and management. In recent years, discussions with certain nations have focused on gathering information on directed shark fisheries, shark bycatch, and illegal shark fishing, pursuant to the international provisions of the High Seas Driftnet Moratorium Protection Act. In addition, the United States consults and cooperates with our international partners in this context to develop and build support for shark conservation and management measures in RFMO/As.

3.2 Regional Efforts

The U.S. Government continues to prioritize shark conservation and sustainable management globally and to work within RFMO/As and other regional entities to facilitate shark research,

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[1] https://www.fisheries.noaa.gov/national/international-affairs/shark-conservation

data collection, monitoring, and management initiatives, as appropriate. In recent years, the United States has successfully led efforts to implement measures within a number of such organizations. Table 3.2.1 lists RFMOs and regional/multilateral programs in which the United States has worked to address shark conservation and management. Of the list in Table 3.2.1, the United States is a party to ICCAT, NAFO, CCAMLR,[2] WCPFC, NPFC, SPRFMO, IATTC, and WECAFC. Six of the organizations or programs listed (ICCAT, NAFO, WCPFC, IATTC, IOTC, and NEAFC) have adopted binding finning prohibitions. In 2014, the North East Atlantic Fisheries Commission (NEAFC) was the first RFMO to require Contracting Parties to land sharks with their fins naturally attached, and NAFO followed suit in 2016. Relevant activities of the RFMOs and regional/multilateral programs to which the United States is a Party are discussed below.

Table 3.2.1 Regional Fishery Management Organizations and Programs.

Regional Fishery Management Organizations and Programs
• Northwest Atlantic Fisheries Organization (NAFO)
• Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)
• Inter-American Tropical Tuna Commission (IATTC)
• International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC)
• International Commission for the Conservation of Atlantic Tunas (ICCAT)
• Western and Central Pacific Fisheries Commission (WCPFC)
• Western Central Atlantic Fishery Commission (WECAFC)
• International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC)
• Indian Ocean Tuna Commission (IOTC)
• North East Atlantic Fisheries Commission (NEAFC)
• North Pacific Fisheries Commission (NPFC)
• South Pacific Regional Fisheries Management Organization (SPRFMO)
• Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

Northwest Atlantic Fisheries Organization (NAFO)

Greenland sharks are caught incidentally in the northwest Atlantic, and are subject to nationally legislated landing requirements by some NAFO Parties. In 2018, NAFO adopted measures co-sponsored by the United States and the EU to prohibit directed fishing of Greenland sharks, and to require NAFO Contracting Parties to "take reasonable efforts to minimize incidental catches and mortalities." In the intervening years, further analysis by the NAFO Scientific Council, the NAFO Working Group on Bycatch, Discards, and Selectivity, and elevation of the species to "Vulnerable" on the IUCN Red List, highlighted the need for further action. Thus, at its 2022 Annual Meeting, the United States and Canada proposed (and NAFO adopted) measures that expand the 2018 measures to also prohibit retention, transshipments, and/or landing part or

[2] CCAMLR is a conservation organization with an ability to manage fisheries within the area under its Convention and thus is included here as one of the regional fishery management programs.

whole of Greenland sharks in the Regulatory Area. These measures maintain a carve-out for Contracting Parties with applicable domestic law banning discards, allowing for retention and landing of dead Greenland sharks, provided that their fishermen are prohibited from drawing any commercial value from such fish.

Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)
In 2019, the United States again led a proposal to require that any sharks incidentally caught in the CCAMLR Convention Area be kept with all fins naturally attached to the point of first landing. This time co-sponsors included Argentina, Australia, the EU, Norway, and Uruguay. As in the past, the proposal received broad support but consensus could not be reached due to objections from a few members, who view the measure as unnecessary because of the low level of shark bycatch in the Convention area but also find a requirement for all fins to remain naturally attached to be unacceptable. The United States maintained that a fins-attached requirement is essential to ensuring an enforceable finning ban and enhancing species-specific reporting.

Inter-American Tropical Tuna Commission (IATTC)
Due to concerns with the 5 percent fin-to-carcass weight ratio requirement, the United States continues to strongly support a fins-attached proposal at the IATTC. However, the Commission has been unable to reach consensus.

The IATTC adopted a 2019 resolution on silky sharks, and extended this resolution in 2021. It includes a 3-month prohibition on the use of steel leaders in certain longline fisheries and also requires the IATTC staff to present an analysis of the available data, including the shark fishery sampling program in Central America.

The IATTC adopted a 2019 resolution that prohibits setting a purse seine net around a whale shark, and requires the captain do everything possible to safely release any whale shark that is caught incidentally. In 2022, the IATTC's scientific staff used a spatially explicit quantitative ecological risk assessment method (EASI-fish) to conduct the first comprehensive quantitative vulnerability assessment for 32 shark species caught in industrial and artisanal fisheries in the eastern Pacific Ocean.

Western and Central Pacific Fisheries Commission (WCPFC)
At its 16th Regular Session in December 2019, WCPFC adopted CMM 2019-04, which combined and replaced five management measures related to sharks that had previously been adopted by the Commission (CMM 2010-07, "Conservation and Management Measure for Sharks"; CMM 2011-04, "Conservation and Management Measure for Oceanic Whitetip Sharks"; CMM 2012-04, "Conservation and Management Measure on the Protection of Whale Sharks from Purse Seine Operations"; CMM 2013-08, "Conservation and Management Measure for Silky Sharks"; and CMM 2014-05, "Conservation and Management Measure for Sharks"). Most of the provisions of CMM 2019-04 have already been promulgated through existing U.S. regulations (50 CFR 300.226; 50 CFR 300.223(g) and (h)), which implemented prior WCPFC decisions. However, there are two new provisions in CMM 2019-04: (1) an exemption for purse seine vessels from the prohibition on the retention, transshipment, storage, or landing of the oceanic whitetip shark and the silky shark in cases where the shark is not seen during fishing operations and is delivered into the vessel hold; and (2) a requirement that sharks be hauled

alongside the vessel before being cut free in order to facilitate species identification when an observer or electronic monitoring camera is present.

Also at WCPFC16, WCPFC adopted CMM 2019-05 to enhance the conservation of mobulid rays (i.e., rays in the family Mobulidae, which includes manta rays and devil rays (Mobula spp.)) by reducing incidental take and mortalities in the Convention Area. The measure requires that members: (1) prohibit vessels from setting on a mobulid ray in the Convention Area; (2) prohibit vessels from targeting, retaining on board, transshipping, or landing any part or whole carcass of a mobulid ray caught in the Convention Area; (3) require vessels to promptly release mobulid rays, alive and unharmed, to the extent practical, as soon as possible and in a manner that will result in the least possible harm to the individuals captured; (4) provide for an exemption in cases where a mobulid ray not seen during purse seine fishing operations is delivered into the vessel hold; and (5) require that vessels allow for observers to collect biological samples of mobulid rays that are dead at haul-back.

On May 12, 2023, NMFS published a final rule implementing the new provisions of CMM 2019-04 and the provisions of CMM 2019-05 88 FR 30671.

At its 19th Regular Session in December 2022, WCPFC adopted CMM-2022-04, which prohibits longline vessels operating in the Convention Area between 20° North and 20° South from using wire trace as branch lines and from using shark lines or branch lines running off of the longline floats or drop lines, and a requirement for longline vessels to follow certain guidelines when releasing sharks that are not retained. Both of these provisions become effective January 1, 2024, and NMFS is developing regulations to implement the measures domestically.

International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC)

In 2022, the ISC Shark Working Group conducted a stock assessment for North Pacific blue sharks using a fully integrated, size-based, age- and sex- structured model. Target and limit reference points have not yet been established for pelagic sharks in the Pacific Ocean by either the WCPFC or the IATTC. However, the current stock assessment of North Pacific blue shark estimates that the stock is unlikely to be overfished and that overfishing is unlikely to be occurring, based on MSY-based reference points derived from the current modeling approach.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

Every year since 2009, the United States has introduced a proposal at ICCAT to require that all sharks be landed with their fins naturally attached. At the 2022 annual meeting, as in previous years, no consensus could be reached; however, support for the measure has continued to increase.

ICCAT has a Shark Research and Data Collection Program that is focused on Atlantic shortfin mako including: 1) age and growth of the South Atlantic stock; 2) post-release mortality; and, 3) analyses of genetic structure. In addition, ICCAT’s Standing Committee on Research and Statistics (SCRS) has supported electronic tagging of shortfin mako, silky shark, oceanic whitetip, porbeagle, smooth hammerhead, and scalloped hammerhead throughout the Atlantic Ocean. The SCRS also assessed three of the Atlantic porbeagle stocks (Northwest, Southwest, and Southeast) in 2020, and the Northeast stock was assessed in 2022 in a joint process with the International Council for the Exploration of the Sea. The results did not indicate any substantial change in status, and ICCAT has maintained its conservation and management measures for Atlantic porbeagle.

Following a stock assessment update for North Atlantic shortfin mako in 2019 and after several years of intense negotiations, ICCAT adopted a rebuilding program for this stock in 2021 to end overfishing immediately and rebuild the stock by 2070. It includes a 2-year retention ban as a first step in the process, with very limited exceptions for the retention of dead animals. Among other things, the measure also prohibits transshipment of North Atlantic shortfin mako and requires additional reporting. In 2022, a new ICCAT recommendation established a similar suite of measures for South Atlantic shortfin mako.

Also in 2019, ICCAT adopted the first-ever total allowable catch (TAC) levels for North Atlantic blue shark and South Atlantic blue shark, and updated these precautionary catch limits in 2021. SCRS is assessing both Atlantic blue shark stocks in 2023, and the Commission may revise its conservation and management measures based on the new scientific advice. The harvest of the South Atlantic stock has exceeded the TAC since 2020 and no allocation of the TAC has been agreed. Allocation negotiations are expected to take place for the southern stock of blue shark at the 2023 Annual Meeting.

Western Central Atlantic Fishery Commission (WECAFC)

In 2019, the Western Central Atlantic Fishery Commission (WECAFC) adopted a non-binding recommendation aimed at promoting the conservation and management of sharks and rays. This recommendation encourages members to develop National Plans of Action for the Conservation and Management of Sharks; to implement management measures consistent with those adopted by ICCAT and other relevant international bodies, as appropriate; to land sharks with fins naturally attached; and to improve data reporting. In 2022, WECAFC adopted a Regional Plan of Action for the Conservation and Management of Sharks, Rays and Chimaeras in the WECAFC Area that amplifies these objectives by fostering regional cooperation, improved governance, increased stakeholder awareness, and capacity building for the effective implementation of shark conservation and management measures.

3.3 Multilateral Efforts

The U.S. Government continues to work within other multilateral fora to facilitate shark research, data collection, monitoring, and management initiatives, as appropriate. Table 3.3.1 lists some of these multilateral fora.

Table 3.3.1 Other multilateral fora.

Other Multilateral Fora
• Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) • Convention on the Conservation of Migratory Species of Wild Animals (CMS) • CMS Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MoU)

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

At the meeting of the Conference of the Parties to CITES (CoP18)which took place May 23 to June 3, 2019, in Colombo, Sri Lanka—three proposals to include shark and ray species in Appendix II of CITES were adopted. These species include shortfin and longfin mako shark (*Isurus oxyrinchus* and *Isurus paucus*), all species of giant guitarfish (*Glaucostegus species*), and all species of wedgefishes (Rhinidae species).

Additional shark and ray proposals were adopted at the 19th meeting of the Conference of the Parties to CITES (CoP19), which occurred November 13 to 25, 2022. Proposals were adopted to include all requiem sharks (*Carcharhinidae* species), all non-listed species of hammerhead sharks (*Sphyrnidae* species), and all species of guitarfishes (*Rhinobatidae* species) in CITES Appendix II. CITES Parties agreed to delay the inclusion of requiem sharks in CITES Appendix II by 12 months; this listing will become effective on November 25, 2023.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

The 13th Session of the Conference of Parties to CMS occurred February 15 to 22, 2020, in Gandhinagar, India. The Parties agreed to list oceanic white-tip shark (*Carcharhinus longimanus*) in Appendix I; smooth hammerhead shark (*Sphyrna zygaena*) in Appendix II; and, tope shark (*Galeorhinus galeus*) in Appendix II. In addition, several pertinent resolutions/decisions were adopted, including a request for all Parties to strengthen measures to protect migratory chondrichthyan species and a resolution urging Parties to take steps to eliminate finning. The 14th Session of the Conference of the Parties will take place October 23 to 28, 2023, in Samarkand, Uzbekistan.

CMS Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MoU)

The 4th Meeting of the Signatories to the Sharks MoU (MOS4) was held February 28 to March 2, 2023, in Bonn, Germany. MOS4 agreed to list tope shark (*Galeorhinus galeus*) in Annex I. In addition, conservation measures were included in the 2023-2025 Program of Work. Kenya will host MOS5 in late 2025.

Section 4: 2018-2022 NOAA Research on Sharks

Large predators such as sharks are a valuable part of marine ecosystems. Many shark species are vulnerable to overfishing because they are long-lived, take many years to mature, and only have a few young at a time. To manage sharks sustainably, we need information about their biology and the numbers caught (either as target species, incidentally, or as bycatch) to make sure their populations are not depleted. NOAA's regional fisheries science centers are investigating shark catch, abundance, age, growth, diet, migration, fecundity, and requirements for habitat. Additional research aims to identify fishing methods that minimize the incidental catch of sharks and/or maximize the survival of captured sharks after release. A summary of the research completed in 2018-2022 is presented here, but more complete descriptions of ongoing research taking place in each region is found in Section 5.

4.1 Data Collection and Quality Control, Biological Research, and Stock Assessments

Pacific Islands Fisheries Science Center (PIFSC)

Between the years 2018 and 2022, the PIFSC has been involved in a number of research projects specific to shark biology and conservation. In a study of post-release survival of five species of sharks released from longline fishing gear in the central Pacific Ocean, researchers tagged 280 blue, bigeye thresher, shortfin mako, oceanic whitetip, and silky sharks using survival tags. PIFSC scientists trained NMFS observers to attach tags during commercial tuna deep-set trips in the Hawai'i and American Samoa-permitted fisheries. At vessel "condition" (alive, dead), handling and release methods, trailing gear, and release conditions were recorded by observers using newly developed codes for the study to describe the conditions of the interactions. Bayesian analyses concluded that after species and at vessel condition, the handling method used and amount of trailing gear had the largest impacts on post-release survival rates, where animals that were left in the water and gear was cut away from the shark leaving less than 1 meter had the best chances of survival.

PIFSC scientists are at the core of the Hawai'i Community Tagging Program (HCTP) in Kona, which is a community telemetry project to reduce the impacts of fishing on pelagic sharks and simultaneously reduce the impacts of depredation from sharks on local small-scale fisheries. The program has trained more than 150 fishermen in tagging methods and uses a combination of telemetry products to answer various conservation questions. The program has a targeted outreach strategy that reaches thousands of community members via social media platforms and a quarterly newsletter. Fishermen who deploy tags are also informed of their tags' fate and provided with all of the movement data from their animals. In addition to the telemetry and outreach, there is a photo identification program using the unique dorsal fin markings on oceanic whitetips to understand population demographics and fishery interaction rates around Hawai'i. The project includes studies of 1) population dynamics of oceanic whitetip sharks around

Hawai'i using photo-identification, 2) Fish Aggregating Device association and residency dynamics of oceanic whitetip and silky sharks around Hawai'i, and 3) habitat use and movement behavior of oceanic whitetip and silky sharks around Hawai'i. This work is a continuation of previous work studying the habitat use and movement behavior of oceanic sharks around west Hawai'i. Numerous species are all encountered seasonally in the waters surrounding west Hawai'i and are often incidentally captured in several local, small-scale fisheries. Several of these species also inflict high rates of depredation, drastically reducing the value of the catch for fishermen operating in the area. Due to the conflict arising from these interactions, many sharks are killed, which may have compounding effects if this region is being utilized for biological imperatives such as reproduction and feeding, or as a nursery area. This study is designed to engage local fishermen in a collaborative tagging effort, with both acoustic and satellite tags, to understand the movement behavior, habitat use, and residency patterns of these species in west Hawai'i. Additionally, fishermen have been tasked with devising testable methods to deter oceanic whitetip sharks from the catch and in the development of non-lethal bycatch mitigation strategies.

A collaborative study with the University of Hawai'i aims to investigate alternative and safe approaches to line weighting in longline fisheries. A team of engineers and fisheries scientists from the University of Hawai'i assembled to investigate methods to reduce the risk of weights flying back at vessels by either altering trajectories or developing new technologies. Prototypes and flight path models have been developed. Simulation chambers are currently being built and results will be ready by October 31, 2023.

Figure 4.1.1: An oceanic whitetip shark tagged with an acoustic tag cruises through a school of Opelu off the Kona coast in March 2023. Photo credit: Dylan Currier.

Research is underway with PIFSC FRMD scientists developing Ecosystem-Based Fisheries Models (EBFM) to build species distribution models for oceanic whitetip and blue sharks in the central Pacific Ocean, with the goal of minimizing incidental captures given predictive abilities of environmental factors associated with shark presence.

Southwest Fisheries Science Center (SWFSC)

The SWFSC's shark research program focuses on pelagic sharks that occur along the U.S. Pacific coast, including shortfin mako (*Isurus oxyrinchus*), blue sharks (*Prionace glauca*), basking sharks (*Cetorhinus maximus)*, and three species of thresher sharks: thresher (*Alopias vulpinus*), bigeye thresher (*Alopias superciliosus),* and pelagic thresher (*Alopias pelagicus).* Historically, SWFSC scientists have studied their basic biology including age and growth and diets, distributions and movements, stock structure, population status, and potential vulnerability to fishing pressure. Methods used include satellite telemetry, microchemistry of hard parts, stomach content analyses, and stable isotope analyses, among others. This information is provided to international, national, and regional fisheries conservation and management bodies having stewardship for sharks. A number of projects were completed between 2018 and2022 and results published in peer-reviewed journals.

Movements of Electronically Tagged Shortfin Mako (Isurus oxyrinchus) Sharks in the Eastern North Pacific Ocean

Most information on shortfin mako (*Isurus oxyrinchus*) in the eastern North Pacific (ENP) currently comes from fisheries data and short-term tracking studies. Although its range has been inferred from catch and conventional tag data, little is known about the migration patterns and behavior of this species in the ENP. This long-term electronic tagging study was designed to examine in detail the movement patterns and behavior of shortfin mako in the ENP (Nasby-Lucas et al. 2019).

In this study, a total of 105 shortfin makos (104-280 cm fork length) were successfully tagged in the California Current between 2002 and 2014 with Argos satellite tags, including 93 satellite-linked radio-transmitting (SLRT) tags and 71 pop-up satellite archival tags (PSATs). This included 29 males that were in the size range of maturity, but only one mature female. Mean track durations from SLRT data were 337 days (max 1,025), and PSAT tags were 136 days (max 272). The estimated minimum distance traveled ranged from 6,945 to 18,800 km/year. Habitats utilized included the entire California Current, the Gulf of California, and offshore in the areas of the North Pacific Subtropical Gyre, North Pacific Transition Zone, and North Equatorial Current. Seasonal movements within the California Current coincided with periods of higher primary productivity and chlorophyll a, and sea surface temperatures (SSTs) between 15 and 25°C. SST ranged from 11 to 31°C throughout the range, indicating a broad thermal tolerance.

Some of the key findings included the discovery of a high degree of variability between individuals in their vertical and horizontal movements, a strong influence of body size and season on shortfin mako movements, and the repetitive use of certain areas by individuals. Seasonal patterns north and south were tied to both SST and regional productivity (Figure 4.1.2). Large females presumed to be mature moved the farthest south into the north equatorial current. Although shortfin makos are thought to comprise a single stock throughout the North Pacific, the horizontal distribution of tagged shortfin makos in this study was limited to the ENP, demonstrating some spatial substructure. This study provided important data that can be used to identify fishery and gear vulnerabilities and inform management.

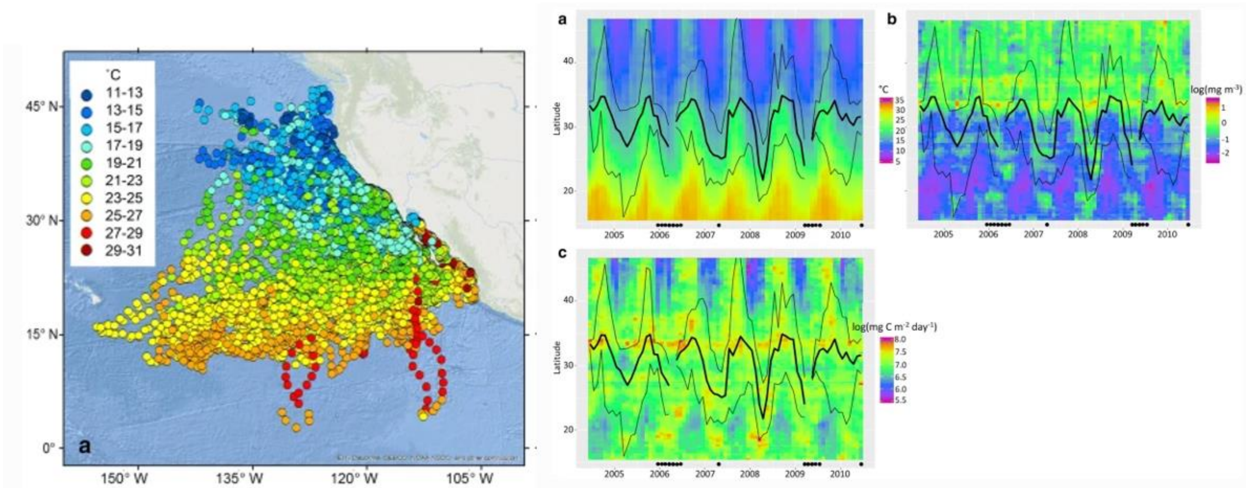

Figure 4.1.2: Left) Tracks from mako sharks and associated SST. Right) Hovmöller diagrams showing seasonal phenology in a SST, b Chl-a and c primary productivity in the California Current Region. Mean, min, and max latitude of shark location are indicated. Black dots indicate months where n is less than 4.

Oceanographic Drivers of Spatial Segregation in Blue Sharks (Prionace glauca) by Sex and Size Class

One important element for fishery management is determining whether there are differences in fish distributions by sex and size. Blue sharks (*Prionace glauca*) have clear habitat separation by sex and size in the open ocean. Using solely the fin-mounted satellite tags data, researchers compared mature males and immature females in coastal waters (Connors et al. 2022). The sample size for mature females and immature males was not large enough to include. Researchers found that immature females are found at higher latitudes in the summer months and undergo a seasonal southward migration along the U.S. West Coast (Figure 4.1.3), similar to patterns observed in the North Atlantic. This more northern distribution translates into small females experiencing cooler SST (12-15°C) than the larger males (>15°C). Researchers also found some overlap between adult males and immature females in the fall months, indicating the importance of the Southern California Bight for multiple size classes. Additional work is needed to characterize the full range of mature females and immature males. This work was accepted for publication in Diversity and Distributions (Maxwell et al. in press).

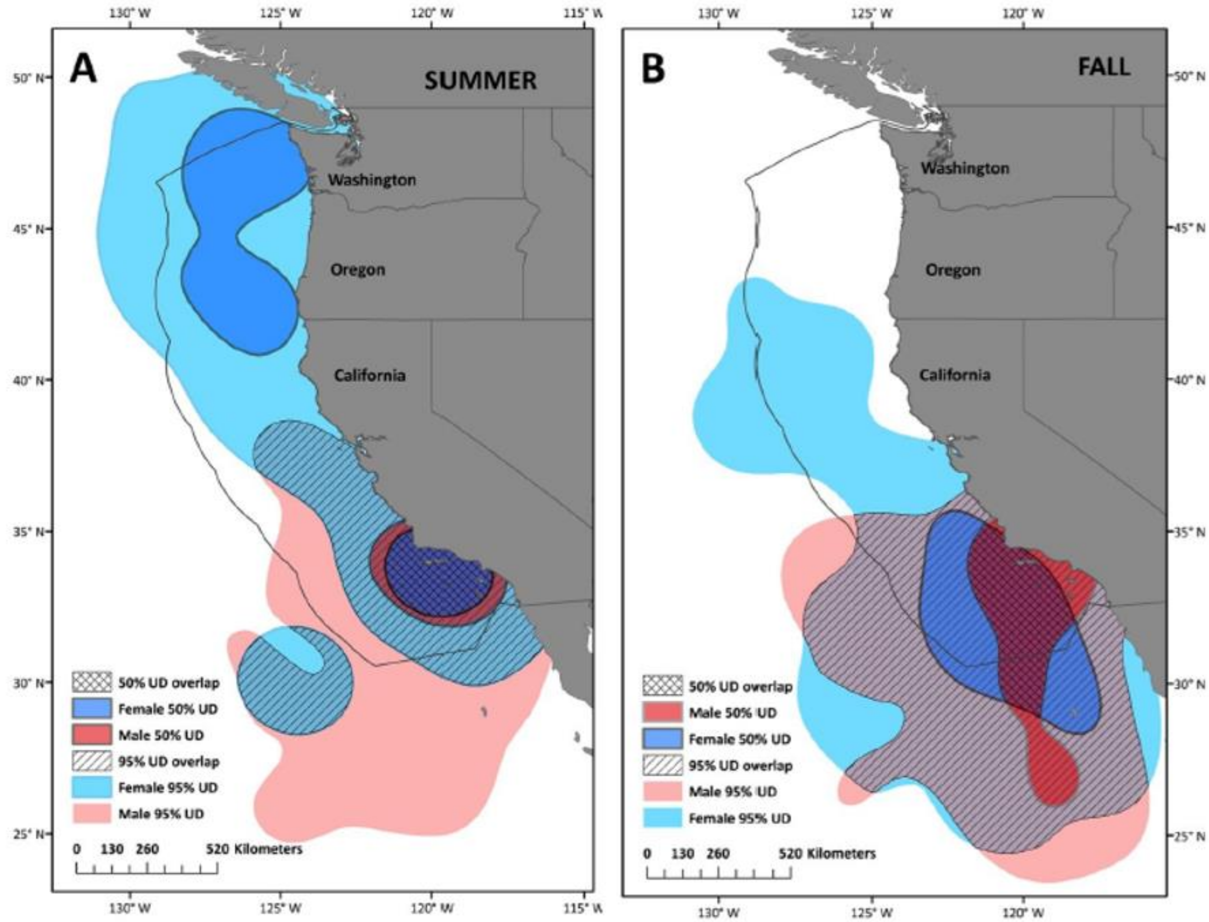

Figure 4.1.3: Home range (50 and 95 percent utilization distributions, UDs) for immature female (blue shades) and mature male (red shades) blue sharks (Prionace glauca) in the (A) summer and (B) fall. Overlap of 50 and 95 percent UDs indicated via hatching. The solid black line indicates the U.S. Exclusive Economic Zone.

Global-Scale Environmental Niche and Habitat of Blue Shark (Prionace glauca) by Size and Sex: a Pivotal Step to Improving Stock Management.

Blue shark (*Prionace glauca*) is amongst the most abundant shark species in international trade. Similar to other shark species, they are segregated by size and sex throughout their range. Since the impact of fisheries removals differs depending on both size and sex, it is important to better understand distributions and their overlap with fisheries both geographically and vertically. Given the relatively high landings and the recent electronic tagging programs, a large volume of data is available on the occurrence and movements of blue sharks globally, although these datasets had not been combined. We combined 265,595 blue shark observations (capture or satellite tag) with environmental data to present the first global-scale analysis of blue shark habitat preferences for five size and sex classes: small juveniles, large juvenile males, large juvenile females, adult males, and adult females (Druon et al. 2023). We leveraged the understanding of blue shark biotic environmental associations to develop two indicators of foraging location: productivity fronts in mesotrophic areas and mesopelagic micronekton in oligotrophic environments.

To capture the horizontal and vertical extent of thermal habitat for the blue shark, we defined the temperature niche relative to both sea surface temperature (SST) and the temperature 100 m below the mixed layer depth (Tmld+100). We show that the lifetime foraging niche incorporates highly diverse biotic and abiotic conditions: the blue shark tends to shift from mesotrophic and temperate surface waters during juvenile stages to more oligotrophic and warm surface waters for adults (Figure 4.1.4 shows the distribution for one age/sex class). However, low productivity limits all classes of blue shark habitat in the tropical western North Atlantic, and both low productivity and warm temperatures limit habitat in most of the equatorial Indian Ocean (except for the adult males) and tropical eastern Pacific. Large females tend to have greater habitat overlap with small juveniles than large males, which are more defined by temperature than productivity preferences. In particular, large juvenile females tend to extend their range into higher latitudes than large males, likely due to greater tolerance to relatively cold waters. Large juvenile and adult females also seem to avoid areas with intermediate SST (~21.7-24.0 °C), resulting in their separation from large males mostly in the tropical and temperate latitudes in the cold and warm seasons, respectively. A greater understanding of sex- and size-specific habitat preferences of blue sharks will contribute to management and projections of shifts in distributions associated with climate variability over long and short time scales.

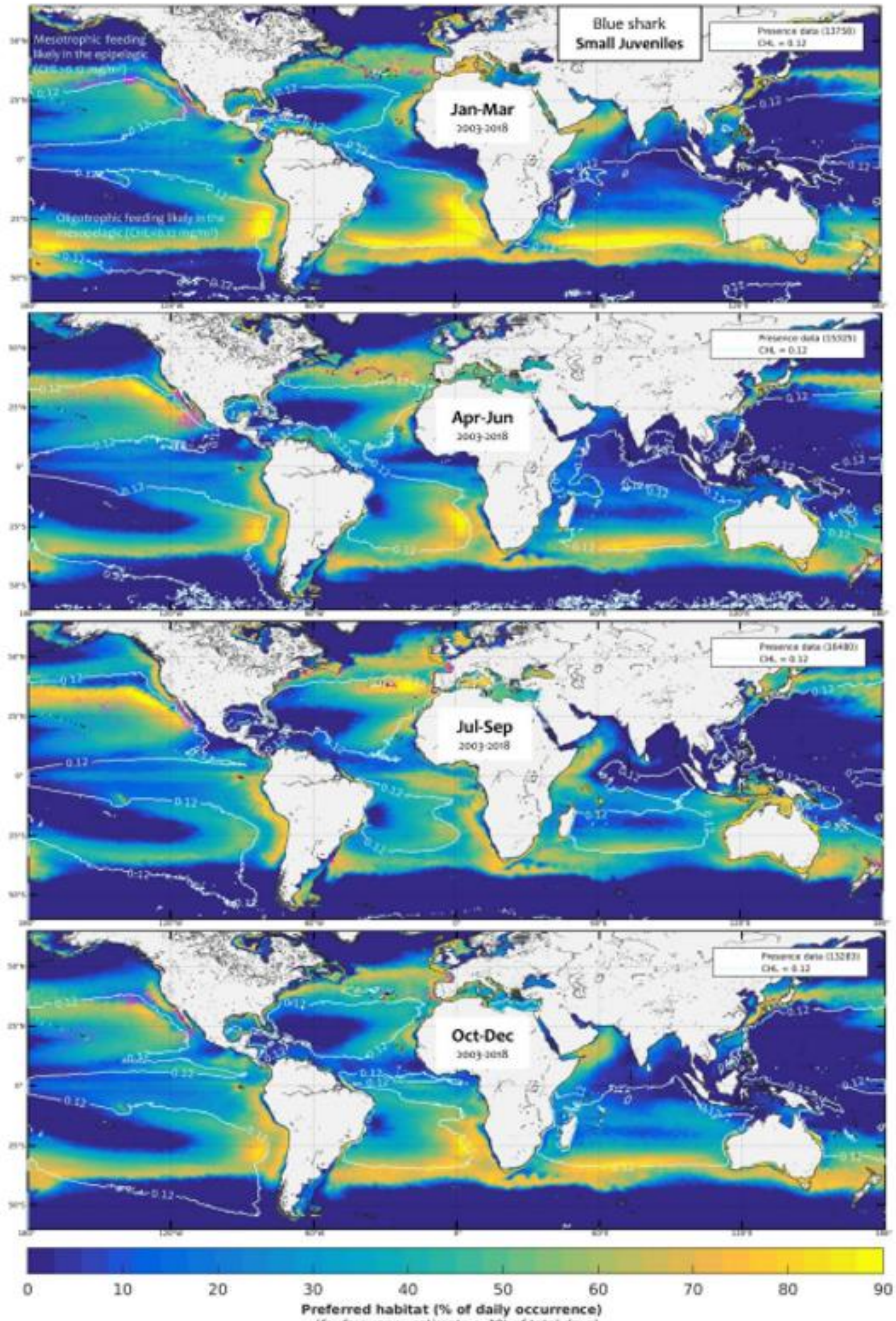

Figure. 4.1.4: Mean seasonal distribution of blue shark (Prionace glauca) foraging habitat for the small juveniles (2003-2018) in frequency of suitable habitat occurrence, percent. The chlorophyll-a isocontour of 0.12 mg.m-3 (CHLmin) separates the mean area of oligotrophic foraging (below this value using mesopelagic micronekton as foraging proxy) and mesotrophic

foraging (above this value using productivity fronts). Presence data are pink dots for observer data and colored line transects for electronic tagging data.

Diving into the Vertical Dimension of Elasmobranch Movement Ecology

Knowledge of the three-dimensional movement patterns of elasmobranchs is vital to understanding their ecological roles and exposure to anthropogenic pressures. To date, comparative studies among species at global scales have mostly focused on horizontal movements. This study (Andrzejaczek et al. 2023) addressed the knowledge gap of vertical movements by compiling the first global synthesis of vertical habitat use by elasmobranchs from data obtained by the deployment of 989 biotelemetry tags on 38 elasmobranch species from all ocean basins. Elasmobranchs displayed high intra- and inter-specific variability in vertical movement patterns (Figure 4.1.5). Substantial vertical overlap was observed for many epipelagic species, indicating an increased likelihood to display spatial overlap, biologically interact, and share similar risks to anthropogenic threats that vary on vertical gradients. We highlighted the critical next steps toward incorporating vertical movement into global management and monitoring strategies for elasmobranchs, emphasizing the need to address geographic and taxonomic biases in deployment and to concurrently consider both horizontal and vertical movements.

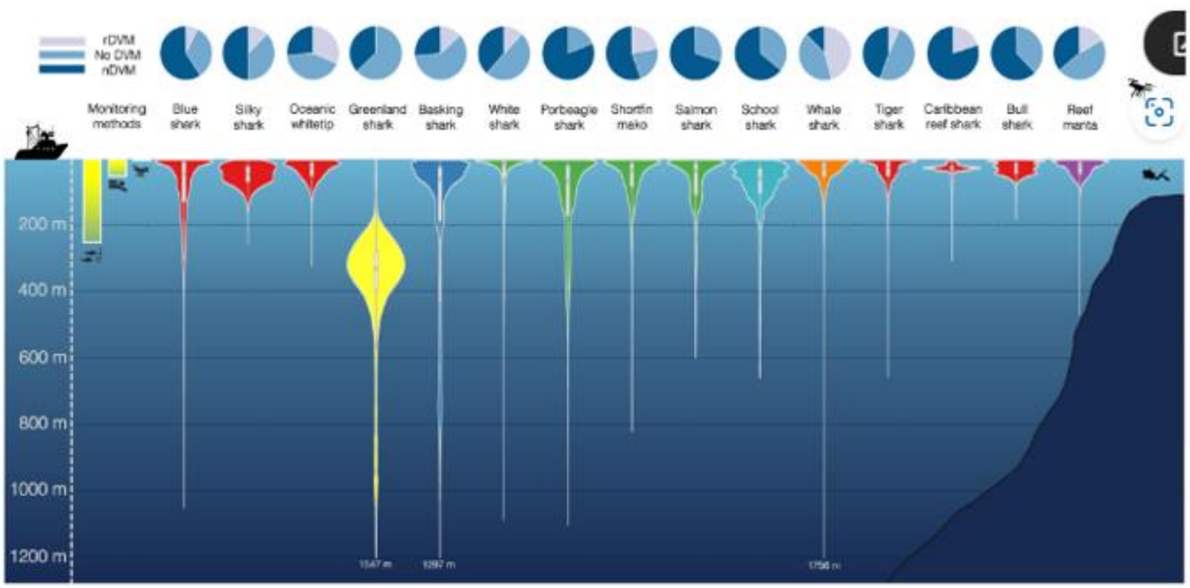

Figure 4.1.5: The hourly median depth distributions of 15 species of elasmobranchs with >1,000 days of depth time-series data. Violin plots represent the full depth distribution, with colors relating to family. Bars represent the estimated detection zones of aerial surveys (top 5 m), scuba-diving surveys (top 50 m), and longline fishing (top 250 m) used within this study. Pie charts represent the proportion of individuals within each species that primarily exhibited nDVM, rDVM, or no clear evidence of DVM (neutral) (DVM=diel vertical movements, n=shallow during the night and deep during the day, r=shallow during the day and deep at night). Species are ordered by habitat type, moving from oceanic to transient to coastal species from left to right.

Isotopic Tracers Suggest Limited Trans-Oceanic Movements and Regional Residency in North Pacific Blue Sharks (Prionace glauca)

Blue sharks (*Prionace glauca*) are globally distributed, large-bodied pelagic sharks that have been shown to migrate across entire ocean basins. In the North Pacific, mark-recapture studies have demonstrated trans-Pacific migrations, but knowledge gaps in migration frequency hinder understanding of regional connectivity and assessments of regional demography. Using stable isotope analyses from blue sharks matched to gradients of stable isotope ratios (i.e., regional isoscapes), migration and residency patterns were examined (Madigan et al. 2021).

Results, drawing upon published δ13C and δ15N data for blue sharks and prey sampled at multiple locations in the eastern Pacific Ocean (EPO) and western Pacific Ocean (WPO), provided a new and replicable means to assess blue shark residency and migration dynamics in the North Pacific. The analyzed data provided strong evidence for limited direct migrations between the WPO and EPO, and reiterated the utility of δ15N isoscapes for the reconstruction of migratory predator movements in the North Pacific Ocean. Regional structure in δ13C and δ15N revealed localized patterns (Figure 4.1.6) and regional patterns in movement. These results hold promise for further quantification of finer-scale blue shark movements, increasing the resolutions of movement patterns suggested, but consideration of isotopic parameters (e.g., accurate Trophic discrimination factors), appropriate sample preparation of shark tissues, and length/sex metadata of sampled sharks are necessary. With emerging research showing varying residency and trans-regional movements in migratory predators, isoscapes can employ high sample sizes across a breadth of animal life stages, regions, and timeframes to reconstruct habitat use of highly migratory animals. Further studies are required to assess size- and sex-specific movement patterns based on empirical isotopic values from regional studies with large sample sizes.

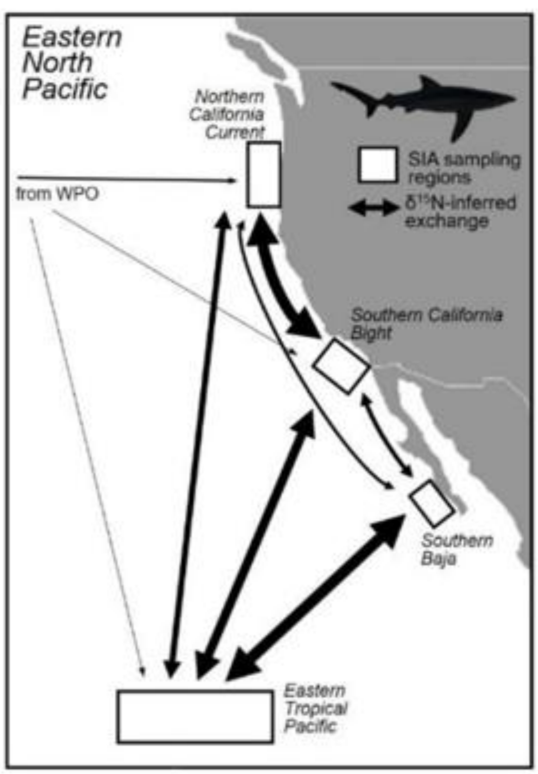

Figure 4.1.6: Summarized estimates of blue shark migratory exchange between eastern North Pacific Ocean regions, inferred from niche overlap of regional δ13C and δ15N values. Arrows are scaled to the degree of isotopic niche overlap between regions; note that exchange rates are relative and approximate.

Vertebral Chemistry Distinguishes Nursery Habitats of Juvenile Shortfin Mako (Isurus oxyrinchus) in the Eastern North Pacific Ocean

Shortfin mako (*Isurus oxyrinchus*) are ecologically and economically important predators throughout the global oceans. The eastern North Pacific Ocean contains several coastal nurseries for this species, where juveniles can forage and grow until venturing into offshore pelagic habitats. In this study, the vertebrae of juvenile shortfin mako were opportunistically collected (65.5-134.4 cm total length, neonate to age 2), from two distinct nurseries in the eastern North Pacific: the Southern California Bight (n=12), United States, and Bahía Sebastián Vizcaíno (n=11), Mexico (LaFreniere et al. 2023). Mineralized vertebral cartilage was analyzed to determine concentrations of selected elements (Li, Mg, Mn, Zn, Sr, Ba, standardized to Ca) using laser ablation inductively coupled plasma mass spectrometry, targeting growth bands at specific life stages, including postparturition at the birth band and the recent life history of the individual at the vertebral edge. Comparing the vertebral core revealed significant differences between the two nursery grounds in Zn:Ca, Sr:Ca, and Ba:Ca. These differences were likely associated with factors such as temperature and water chemistry. Comparing the core with the recent history edge revealed variability across ontogeny in Li:Ca, Mg:Ca, and Zn:Ca, which may reflect regional differences and/or developmental shifts in mineralization. Understanding what drives element variations in vertebrae is likely complicated but will further efforts to use elements as a tool in species management. The ability to determine the origin of highly migratory species allows fishery managers to better understand how nursery habitats contribute to adult populations.

Elements of Time and Place: Manganese and Barium in Shark Vertebrae Reflect Age and Upwelling Histories

As upper-level predators, sharks are important for maintaining marine food web structure, but populations are threatened by fishery exploitation. Sustainable management of shark populations requires improved understanding of migration patterns and population demographics, which has traditionally been sought through physical and/or electronic tagging studies. The application of natural tags such as elemental variations in mineralized band pairs of elasmobranch vertebrae cartilage could also reveal endogenous and exogenous processes experienced by sharks throughout their life histories. Here (Figure 4.1.7, Mohan et al. 2018), elemental profiles were characterized in vertebrae encompassing complete life histories (birth-to-death) of shortfin mako (*Isurus oxyrinchus*), thresher (*Alopias vulpinus*), and blue shark (*Prionace glauca*) of known tag and recapture locations in the eastern North Pacific Ocean. All sharks were injected with oxytetracycline at initial capture, released, and subsequently recaptured, with individual liberty times ranging from 215 days to 6 years. Vertebral band pairs forming over the at-liberty intervals were verified by counting the number of band pairs deposited since the oxytetracycline band. Regular oscillations in vertebrae manganese (Mn) content corresponded well with the number of validated band pairs, suggesting that Mn variation could be used to age sharks. Increases in vertebrae barium concentration were correlated with times when individuals occupied areas with high coastal upwelling indices, the timing and spatial intensity of which varied from year to year. Interspecific relationships were probably influenced by behavioral differences in horizontal and vertical habitat use, feeding habits, and thermoregulatory physiology. These results indicate that vertebral sclerochronology has the potential to advance our knowledge of elasmobranch life history including age and growth estimation and environmental reconstruction.

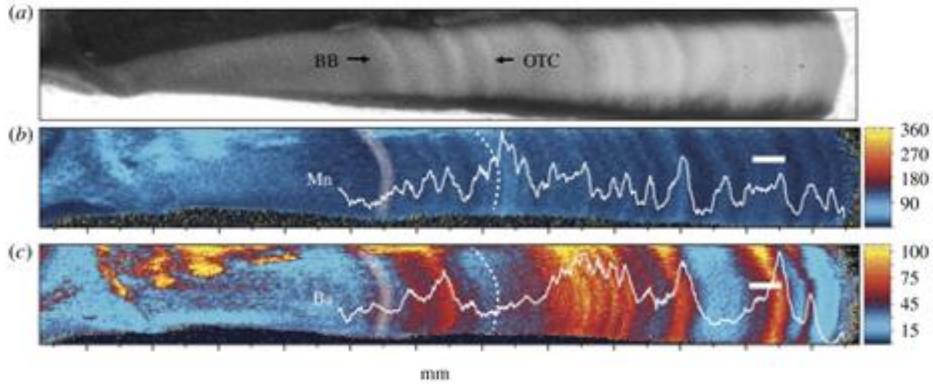

Figure 4.1.7: (a) Shortfin mako (Isurus oxyrinchus) vertebrae under transmitted light, and (b,c) two-dimensional elemental map of (b) manganese and (c) barium variation. Birth band (BB) denoted in (b) and (c) with white shading and oxytetracycline band (OTC) denoted with dashed lines. Translucent zones (hypermineralized, slow growth) in a), matches with Mn decreases; opaque hypomineralized high protein zones matches with Mn peaks. White scale bar, 500 µm.

Species-Specific Characteristics Influence Contaminant Accumulation Trajectories and Signatures Across Ontogeny in Three Pelagic Shark Species

Factors influencing organic contaminant accumulation in sharks, especially across ontogeny, are not well-known. Contaminant concentrations were measured in three species of sharks (blue shark, *Prionace glauca*; shortfin mako, *Isurus oxyrinchus*; and thresher shark, *Alopias vulpinus*) across a range of size classes (neonatal to adult) that vary in their ecological and physiological characteristics (Lyons et al. 2019a). Empirical data were compared to a theoretical framework that predicted the shape of lifetime accumulation curves.

We found that a one-size-fits-all accumulation model was not appropriate, as species-specific characteristics had a significant effect on contaminant accumulation trajectories (Figure 4.1.8). Maternal offloading likely has an important effect on determining neonatal shark contaminant starting points, and trophic ecology and physiology may interact to affect the shape of species' contaminant accumulation curves. Shortfin makos were found to have the highest accumulation potential and blue sharks the lowest, with thresher sharks being intermediate in accumulation potential.

Changes in species' ecology and/or physiology were also reflected in contaminant signature changes over ontogeny. If contaminant concentrations are to be used as a proxy for risk, species-specific characteristics need to be taken into account when estimating contaminant exposure and its potential negative effects on shark health and human consumption safety.

In a complementary analysis of the contaminant data (Lyons et al. 2019b), the chemical contaminant profiles were linked to an animal's niche, providing a potential tool to assess resource partitioning in pelagic species. As proof of concept, we examined contaminant signatures in three species of sharks (blue shark, shortfin mako, and thresher sharks) known to overlap in both space and time. Since these sharks comprise a predatory guild within the Southern California Bight (SCB), we predicted that species may partition spatial and dietary resources to limit the extent of competitive exclusion. Indeed, species were distinguishable by both total contaminant loads and their contaminant fingerprint, as random forest analysis found that species could be correctly classified 96 percent of the time. Our results demonstrated the utility of chemical analyses for ecological studies, and how contaminant tracers can be used in combination with traditional methods to elucidate how species may undergo niche partitioning to reduce competition for overlapping resources within predatory guilds.

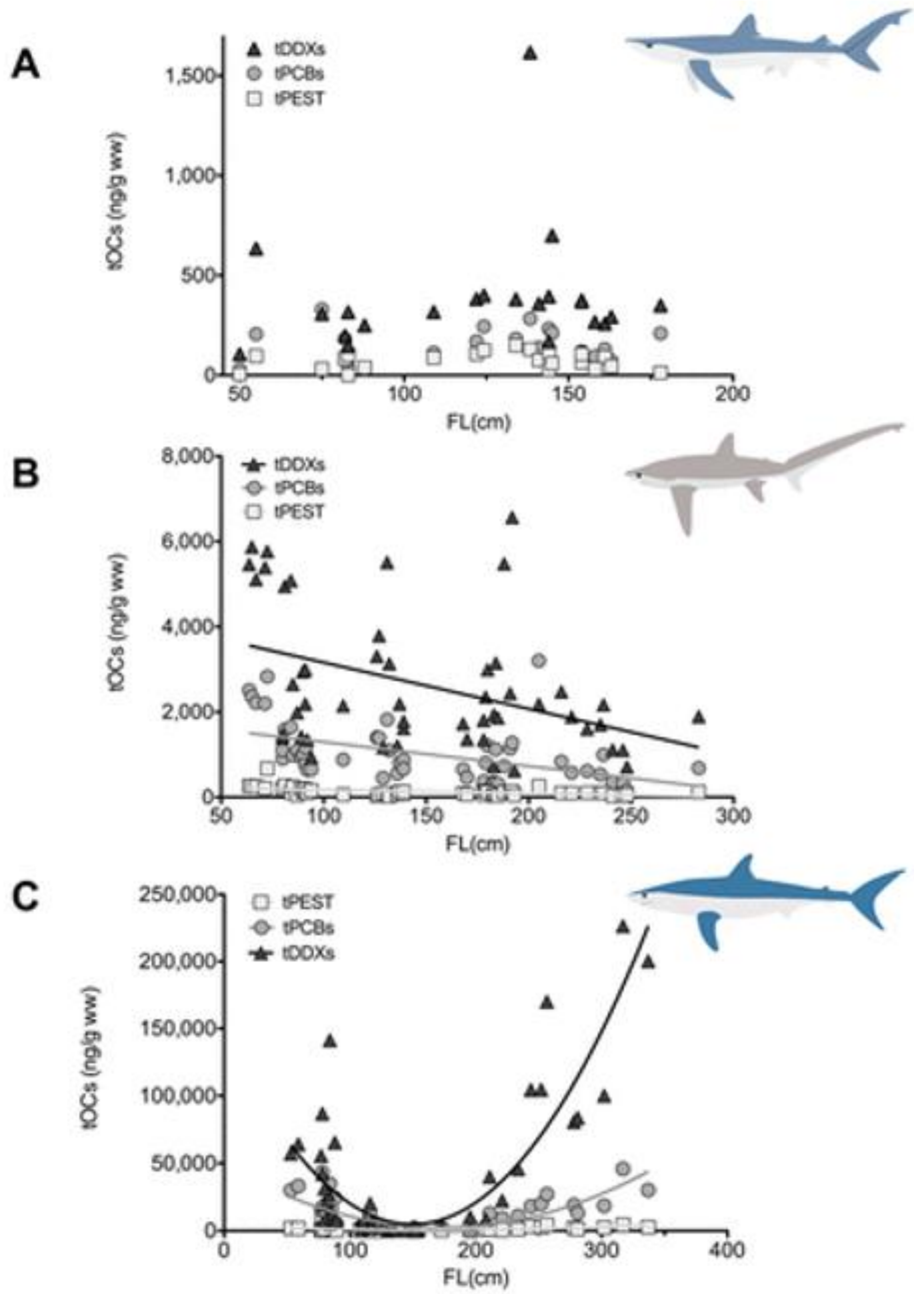

Figure 4.1.8: Concentrations for the three main contaminant groups (PCBs, gray circles; non-DDT pesticides, open squares; DDXs, black triangles) over fork length for (A) blue sharks, (B) thresher sharks, and (C) mako sharks. There was no significant change over size in blue sharks. Note differences in the scales of the x axis.

Spatial Distribution, Temporal Changes, and Knowledge Gaps in Basking Shark, Cetorhinus maximus, Sightings in the California Current Ecosystem

Among the largest fish species, the basking shark (*Cetorhinus maximus*) is found circumglobally in temperate and tropical waters. Though historical documents have recorded their presence in the California Current (CC), basking sharks are now only rarely observed in this part of their range. We compiled recent and historical data from systematic surveys (1962–1997) and other sources (1973–2018) to: (i) examine temporal patterns of basking shark sightings in the CCE; and (ii) determine the spatial, temporal, and environmental drivers that have affected basking shark presence and distribution in the CCE for the last 50 years (Figure 4.1.9, McInturf et al. 2022).

The sightings records indicated that the number of shark sightings was variable across years, but the number and probability of sightings declined in the mid-1980s. The systematic survey data showed that a maximum of 4,000 sharks were sighted per year until the 1990s, after which there were no sightings reported. In parallel, there was more than a 50 percent decline in school size from the 1960s to the 1980s (57.2 to 24.0 individuals per group). During the subsequent decades in the non-systematic data (>1990), less than 60 sharks were sighted per year. There were no schools larger than 10 reported, and the mean school size in the last decade (2010s) was 3.53 individuals per group. Low sea surface temperature and high chlorophyll a concentration increased sighting probability, and prevailing climatic oscillations (El Niño-Southern Oscillation, North Pacific Gyre Oscillation, Pacific Decadal Oscillation) were also correlated with basking shark presence. Lastly, researchers observed a significant shift in the seasonality of sightings, from the fall and spring during the systematic survey period to the summer months after the 2000s.

Suggestions for future research include a number of recommendations. Coordinating the documentation of fisheries mortalities and sightings throughout the Pacific basin would facilitate more robust population estimates and identify sources of mortality. Additionally, developing region-specific genetic markers would help with monitoring efforts.

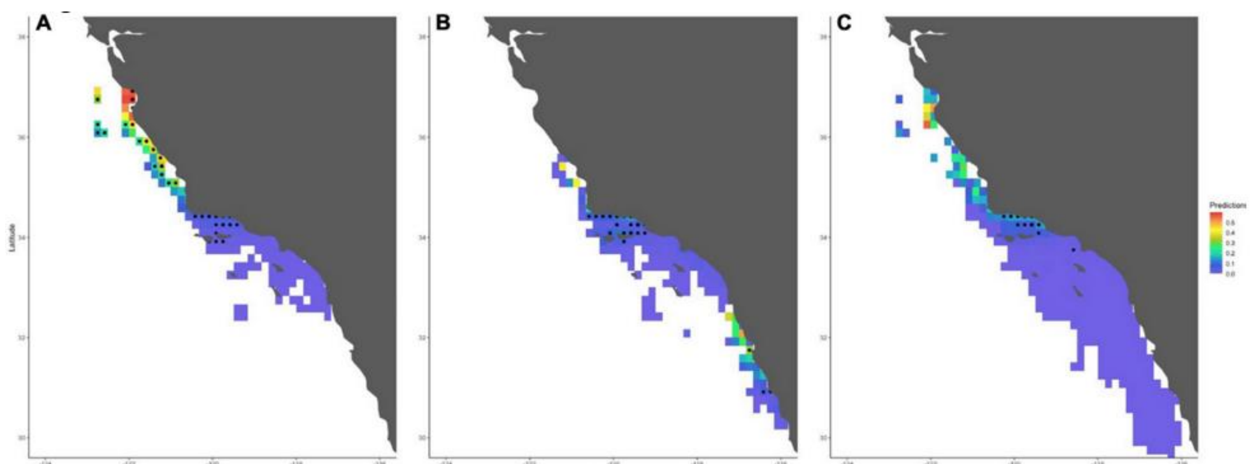

Figure 4.1.9: Maps showing the probability of basking shark (Cetorhinus maximus) sightings for each decade (A–C: 1960s, 1970s, 1980s). Black dots represent basking shark presences recorded during the systematic surveys. White represents areas for which there is no model prediction.

Vulnerability to Climate Change of Managed Stocks in the California Current Large Marine Ecosystem

Understanding how the abundance, productivity and distribution of individual species may respond to climate change is a critical first step toward anticipating alterations in marine ecosystem structure and function and developing strategies to adapt to the full range of potential changes. This study (McClure et al. 2023) applied the NOAA Fisheries Climate Vulnerability Assessment method to 64 species in the California Current (CC) to assess their vulnerability to climate change. Vulnerability is a function of two factors: 1) species' exposure to environmental change and 2) its biological sensitivity to a set of environmental conditions. "Exposure" includes factors such as changes in sea surface temperature, ocean acidification, and phenology. "Sensitivity" includes components of a species resiliency, population status, reproductive rate, and adaptive capacity to respond to these new conditions. Species classified as Highly or Very Highly vulnerable shared one or more characteristics including: 1) having complex life histories that utilize a wide range of freshwater and marine habitats; 2) having habitat specialization, particularly for areas that are likely to experience increased hypoxia; 3) having long lifespans and low population growth rates; and/or 4) being of high commercial value combined with impacts from non-climate stressors such as anthropogenic habitat degradation. Species with Low or Moderate vulnerability were typically habitat generalists, occupy deep-water habitats, or are highly mobile and likely to shift their ranges.

For this report we focused specifically on sharks considered to be highly migratory species (HMS): blue, shortfin mako, thresher, and white sharks. All HMS shark species had a high level of exposure, given the level of expected change in the CC. The two factors that had the highest ranking for negative impacts were sea surface temperature and ocean acidification. Sensitivity to this exposure varied across species. Only thresher sharks were estimated to have a moderate vulnerability. The other three species were found to have low vulnerability. For threshers sharks increased sensitivity resulted from the fact that they have a more specialized diet than other HMS considered and have relatively low reproductive rates. The ability of HMS to undertake large-scale movements was a key factor reducing their overall vulnerability as a group.

This approach compiled a large amount of diverse biological and environmental information into a relatively simple metric. This metric can inform near-term advice for prioritizing species-level data collection and research on climate impacts and help fishermen predict changes and shifts in available target and non-target species. In addition, the results can help managers to determine when and where a precautionary approach might be warranted, in harvest or other management decisions, and can help identify habitats or life history stages that might be especially effective to protect or restore.

Shark Foraging Ecology in the California Current

The California Current (CC) is a productive eastern boundary current that provides important habitat for highly migratory sharks species, including shortfin mako (*Isurus oxyrinchus*), thresher (*Alopias vulpinus*), bigeye thresher (*Alopias superciliosus*), and blue sharks (*Prionace glauca*). These species migrate to the CC to forage, taking advantage of the seasonally high productivity. For the blue, shortfin mako, and thresher sharks, the region, especially the Southern California Bight (SCB), is also an important nursery area. Studies of diets are key to understanding foraging ecology, essential habitat across life history stages, and movements to and within the CC. To this end, the SWFSC has been conducting long-term studies on the diets of these shark species (Preti 2020). The primary goals of this research were to better understand their foraging ecology in the CC and how and why diets vary in space and time and by size and sex. We also examined dietary diversity, richness, and niche overlap to provide insight into the level of specialization and potential competition among species.

Stomachs for the four shark species were collected by federal fishery observers aboard large-mesh drift gillnet vessels from 1990 to 2014. While historically the fishery spanned the U.S. West Coast, since 2001 the majority of the fishery has operated in the SCB. For each species, other than bigeye thresher, more than 150 individuals were examined. Prey were weighed, counted, and identified to the lowest possible taxonomic group. Data analyses included prey accumulation curves and relative indices of importance including the standard metrics for diet analyses.

A comparison across the species revealed some important differences and similarities. Shortfin makos fed primarily on teleosts, cephalopods, elasmobranchs, and marine mammals. Jumbo squid (*Dosidicus gigas*) and Pacific saury (*Cololabis saira*) were the most important species in their diet. Blue sharks consumed primarily cephalopods; Gonatus spp. and jumbo squid were their most important prey. They also fed on teleosts, elasmobranchs, and occasionally on marine mammals. Threshers fed heavily on coastal pelagic species such as northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), and market squid (*Doryteuthis opalescens*). Bigeye threshers ate primarily jumbo squid and barracudinas. All four shark species showed differences in diets by size, area, and years. Threshers presented the least diverse diet compared to other sharks. Shortfin makos and blues had the most similar diet while diets of blues and threshers sharks were least similar. Bigeye thresher shark presented a broader niche than shortfin mako or thresher sharks.

Diving behavior, horizontal movements, and body features of sharks, as well as oceanographic conditions and consequent prey availability, were some of the co-occurring factors likely to have influenced the observed differences in diets. Understanding the feeding ecology of these species is relevant for managing fisheries especially as we move towards ecosystem management. Future diet studies would benefit from information on prey distribution and abundance and size of prey.

Spiral Valve Parasites as Indicators of Shark Feeding Behavior and Ecology

Elasmobranchs are hosts to many metazoan parasites. The spiral valve or intestine is a suitable habitat for parasites and home to digeneans, nematodes, cestodes, and, infrequently, monogeneans. The spiral valve is the most heavily parasitized internal organ of elasmobranchs and is the primary site occupied by cestodes, the most diverse group of elasmobranch parasites. It is rare to find a wild-caught elasmobranch that does not host at least one species of cestode in its spiral valve. Despite the ubiquity of shark cestodes, including tapeworms, relatively little is known about the parasite fauna of pelagic sharks, in particular thresher sharks. This study is a preliminary attempt to analyze the gut parasite faunas of blue and thresher sharks caught in the CCLME north of the Mexican border, with the ultimate objective of investigating possible links between parasites, shark diet, and the environment.

The spiral valves of 18 blue and 19 thresher sharks caught in the CCLME from 2009 to 2013 were examined for parasites (Preti et al. 2020). Blue shark intestines were predominately infected with cestodes and a small number of nematodes, while thresher sharks presented a more diverse parasite fauna. Blue and thresher sharks shared one nematode species (*Hysterothylacium sp*.) and two cestode genera (*Paraorygmatobothrium* and *Molicola*). The difference in parasite species composition is an indication of the different feeding and migratory behaviors of these two predators. The occurrence of two parasites (*Rhadinorhynchus cololabis* and *Pennella sp.*) of Pacific saury in threshers indicates recent feeding on saury, while the high prevalence of *Anisakis sp*. in the same host may be a result of intensive feeding on Pacific sardine; both saury and sardine are important components of the diet of threshers in the study area. The *Piscicapillaria sp.* (Figure 4.1.10) found in threshers and the *Hysterothylacium sp.* found in both shark species are new host records and may represent new species. This study paves the way for a more comprehensive examination, including more samples and a wider variety of shark species, to provide a greater understanding of shark feeding behavior and possibly provide

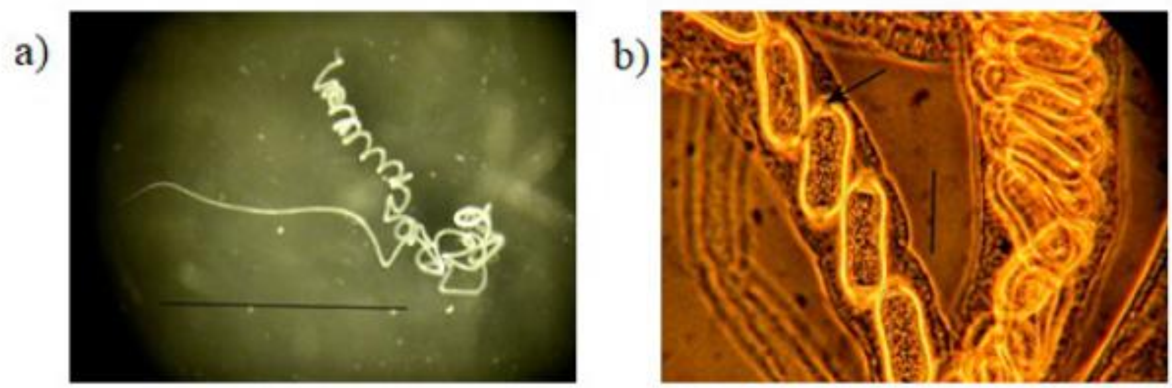

Figure 4.1.10: Legend. (a) Piscicapillaria sp.: a whole nematode; (b) eggs with the protruding polar pugs arrowed. Scale: a = 1 mm, b = 50µm.

<u>Northwest Fisheries Science Center (NWFSC)</u>

Monitoring and Assessment Activities

The NWFSC conducts and supports several activities addressing the monitoring and assessment of sharks along the West Coast of the United States and in Puget Sound. The Pacific Fishery Information Network (PacFIN) serves as a clearinghouse for commercial landings data, including sharks. In addition, the At-Sea Hake and West Coast Groundfish Observer Programs collect data on shark species caught on vessels selected for observer coverage.

The NWFSC conducts annual trawl surveys of the West Coast, designed primarily to acquire abundance data for West Coast groundfish stocks. The tonnages of all shark species collected during these surveys are documented. In recent years, the survey program conducted numerous special projects to help researchers acquire data and samples necessary for research on various shark species. Since 2002, the survey has collected biological data and tissue samples from spiny dogfish, including dorsal spines, which can be used to age the fish.

Stable Isotope Analysis

NWFSC ecologists have led the collection of samples for sixgill sharks in Puget Sound and analysis of stable isotope ratios. This research has improved understanding of the diet of these sharks, which can include spiny dogfish, through the application of Bayesian mixing models to estimate diet proportions. Some of this research is reported in a chapter of *Advances in Marine Biology, Vol. 77,* entitled "Stable Isotope Applications for Understanding Shark Ecology in the Northeast Pacific Ocean" (Reum et al. 2017). An additional research paper on related topics is undergoing final revisions.

Forensic Shark Species Identification

NWFSC Forensic Laboratory staff analyzed evidence in 24 cases submitted to the laboratory by NOAA Office of Law Enforcement personnel from the Northeast, Southeast, West Coast, and Pacific Islands divisions. Evidence items were subject to detailed forensic analysis to determine species identity. One of the analyzed cases resulted in the first conviction under an Oregon law prohibiting possession, sale, trade, or distribution of shark fins.

Alaska Fisheries Science Center (AFSC, Auke Bay Laboratory)

Stock Assessments of Shark Species Subject to Incidental Harvest in Alaskan Waters

Stock assessments are currently completed on the shark species most commonly encountered as incidental catch: Pacific sleeper sharks (*Somniosus pacificus*), spiny dogfish (*Squalus suckleyi*), and salmon sharks (*Lamna ditropis*). In both the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) fishery management plans, sharks are managed as a complex. Directed fishing for all sharks is prohibited. In the BSAI, the shark complex is managed with catch limits based on historical maximum catch. In the GOA, catch limits for the complex are the sum of individual species recommendations: spiny dogfish catch limits are based on survey biomass estimates and the remaining species are based on historical average catch. Stock assessments are summarized annually and are available online (see Tribuzio et al. 2022a and 2018b, or the most recent North Pacific Groundfish Stock Assessment and Fishery Evaluation Reports).

Age and Growth Methods of Deep Water Sharks

Scientists at Auke Bay Laboratory and AFSC's Resource Ecology and Fisheries Management Division age and growth lab are investigating the use of bomb radiocarbon in the eye lens as a potential method for ageing Pacific sleeper sharks, a previously unageable species. Pilot studies show the presence of the bomb radio-carbon in the eye lens and preliminary data indicate that Pacific sleeper sharks can attain long life spans, and may not mature until they are at least 50 years old. A detailed study, funded by the North Pacific Research Board, will begin in fall 2023. This study will examine factors that can influence the interpretation of the bomb radiocarbon levels and will produce the first age estimates for this species.

Figure 4.1.11: Eye of a 3.2m Pacific sleeper shark, with parasitic copepod attached (left). The same eye once dissected out (right). Photos: AFSC-NMFS.

Electronic Monitoring and Large Sharks

Electronic monitoring (EM) is a compliance and monitoring tool used to monitor catch and bycatch in Alaska’s longline and pot gear fisheries since 2018. Historically, at-sea monitoring for large sharks in these fisheries was limited because of the nature of the gear and size of the vessels. Data on the size of large sharks are scarce and the total catch estimates are based on an average weight derived from smaller sharks. Preliminary research suggests that, in the longline fisheries, most of the Pacific sleeper sharks are larger than the average recorded weights used for total catch estimates. Therefore, the catch estimates are likely biased low.

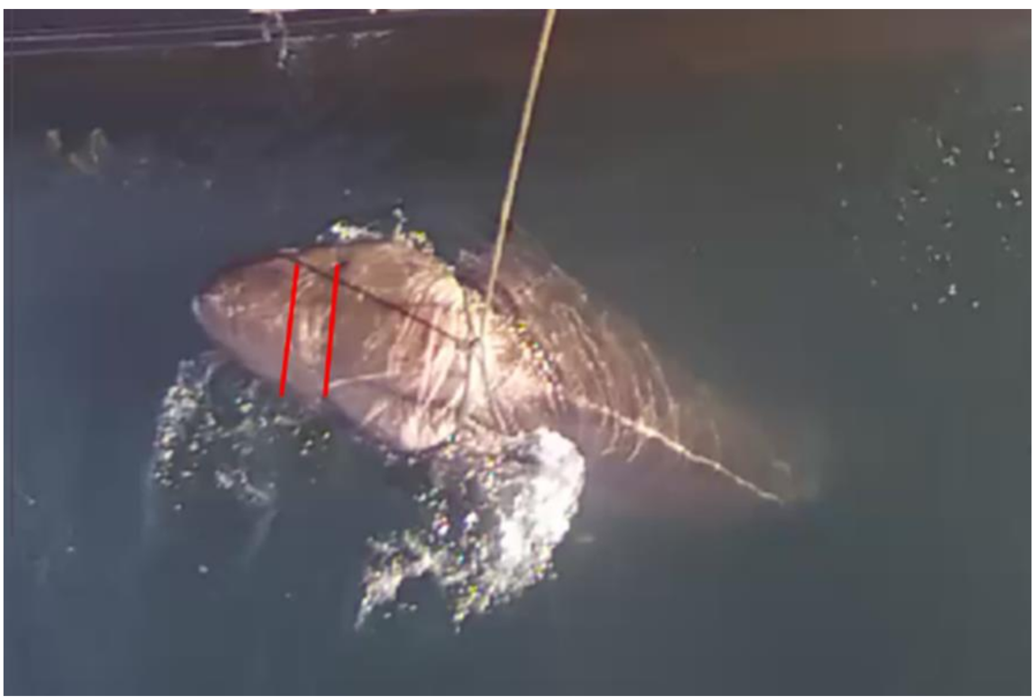

Figure 4.1.12: Pacific sleeper shark image taken by an EM camera onboard a commercial longliner. The red lines represent potential measurements (left: distance between the eyes; and right: distance between the spiracles) that can be extrapolated to total length.

Photo: AFSC-NMFS.

Improved Species Identification

With the advent of EM and changing climates, other species of sharks are now found in Alaskan waters. Generally, other species are recorded as "other/unidentified sharks." A project is underway to examine the extent to which other sharks are observed, to improve how observers identify them, and to evolve the data stream so that catch estimates for other shark species can be quantified.

Figure 4.1.13: Examples of some species that have historically been documented as "other/unidentified sharks," clockwise from the top left: six-gill shark caught commercial longlining, seven-gill shark caught commercial longlining, likely a soupfin shark as seen from an electronic monitoring camera, and brown cat sharks caught commercial trawling.
Photos: AFSC-NMFS.

Population Genetics of Pacific Sleeper Sharks

The purpose of this study is to investigate the population structure of Pacific sleeper sharks (*Somniosus pacificus*) in the eastern North Pacific Ocean. Tissue samples were collected from ~400 sharks from the West Coast, British Columbia, the Gulf of Alaska, and the Bering Sea. Samples of Greenland shark (*S. microcephalus*) and southern sleeper sharks (*S. antarcticus*) were also used in this study. The AFSC generated next-generation sequencing data using the reduced representation library method RADseq and conducted phylogenomic and population genomics analyzes to provide novel information for use in stock assessments. Our results strongly support the species status of *S. microcephalus* (n = 79), but recover *S. antarcticus* (N = 2) intermixed within the *S. pacificus* (N = 170) clade. Population genomic analyses reveal genetic homogeneity within *S. pacificus* and *S. microcephalus*, and estimates of effective population size suggest populations of hundreds of individuals. Kinship analysis identified two first-degree relative pairs within our dataset (one within each species). Overall, our research provides insight into the evolutionary relationships within the Somniosus Somniosus subgenus. Results were published in Timm et al. 2022.

Electronic Tagging of Alaska Sharks

A tagging program for spiny dogfish began in 2009, with 186 pop-off satellite archival tags (PSATs) deployed through 2018. Data were recovered from 157 of those tags (nine tags are still at liberty), with eight tags physically recovered, and the remainder unrecovered. The PSATs record depth, temperature, light levels, and sunrise/sunset for geolocation. Staff at AFSC, along with collaborators, developed a Hidden Markov Movement (HMM) model based on these tag data that incorporates environmental variables (e.g., temperature/depth profiles and sea-surface temperature) (see Nielsen and Tribuzio 2023). The HMM model provides daily locations in the form of probability surfaces as well as total residence probabilities for the duration of deployment for each tag. The results will be used to define habitat utilization distributions, and eventually inform Essential Fish Habitat (EFH). Ongoing analytics include habitat utilization and migration to inform EFH and to evaluate fisheries interactions, and simulation testing of the HMM from tags recovered from spiny dogfish double tagged with acoustic transceivers.

Staff at AFSC are collaborating with UAF, the Alaska Sea Life Center, Kingfisher Marine Research, and Wildlife Technology Frontiers on a collaborative tagging project on Pacific sleeper sharks. This NPRB funded project will apply modern modeling techniques to historical PSAT data, as well as deploy and analyze data from recent and future tags.

Staff at AFSC are collaborating with ADF&G, UAF, and Kingfisher Marine Research to deploy tags on salmon sharks in the GOA and Bering Sea. To date, four male salmon sharks have been tagged in the Northern Bering Sea, each with both a SPOT (i.e., GPS) and PSAT tag and one female in the Gulf of Alaska. The SPOT tags provide multiple years of position data when the shark is at the surface, while the PSAT provides detailed temperature and depth movement. The two datasets will be combined to validate the HMM model. This study is unique in that nearly all previous tagging on the species was on females captured in Prince William Sound. Early results suggest seasonal migration to/from the Northern Bering Sea, but not necessarily the same movement pattern between years. A manuscript has been published detailing first-year movement for the two Northern Bering Sea sharks (Garcia et al. 2021). Further tags are planned for 2023 and beyond as tags and opportunities are available.

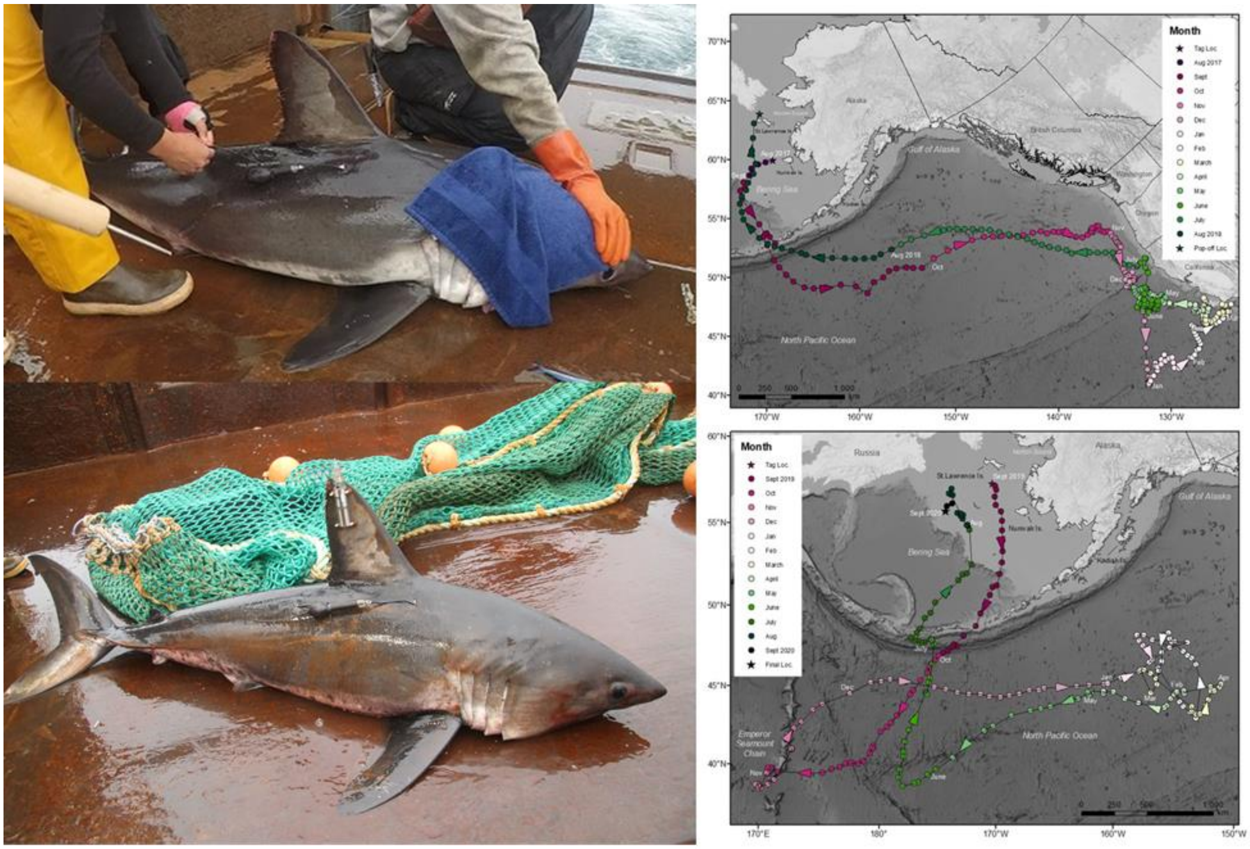

Figure 4.1.14: From Garcia et al. 2021 (Left) Shark A (top) tagged with a PSAT using two tethers on August 27, 2017. The harness of the second tether attachment is looped around the body of the tag. Shark B (bottom) with a SPOT-257 tag affixed to the dorsal fin and a PSAT attached with two tethers in the musculature beneath the dorsal fin. Data from Shark B's PSAT are not reported here. (Right) Monthly HMM-derived locations from August 27, 2017, through August 28, 2018, for Shark A (top) and best daily locations transmitted by a SPOT tag carried by Shark B (bottom) from September 7, 2019, through September 6, 2020. Arrows depict swim direction.

Northeast Fisheries Science Center (NEFSC)

NEFSC Coastal Shark Bottom Longline Survey

This fishery-independent survey of Atlantic large coastal sharks is conducted biennially in U.S. waters, depending on funding. Its primary objective is to conduct a standardized, systematic survey of the shark populations off the U.S. Atlantic coast to provide unbiased indices of relative abundance for species inhabiting the waters from Florida to the mid-Atlantic. The time series of abundance indices from this survey are critical to the evaluation of coastal Atlantic shark species. Results from recent surveys included 2,724 fish (2,713 sharks) representing 22 species, of which 2,052 (76 percent) were tagged and released in 2018, and 2,462 sharks representing 11 species, of which 2,132 (87 percent) were tagged and released in 2021. The survey was originally scheduled to be conducted in 2020, but was postponed due to the COVID-19 pandemic. Sharks represented 99 percent of the total catch in both 2018 and 2021, of which sandbar (*Carcharhinus plumbeus*) and dusky (*C. obscurus*) sharks were the most common. Other species commonly encountered during these surveys included blacktip (*C. limbatus*), Atlantic sharpnose (*Rhizoprionodon terraenovae*), tiger (*Galeocerdo cuvier*), scalloped hammerhead (*Sphryna* *lewini*), and spinner (*C. brevipinna*) sharks. Staff reviewed the catch time series and survey methods during the September 2018 Advisory Panel Meeting for the HMS Management Division and summarized survey depredation events during the September 2019 Advisory Panel Meeting. In 2019, blacktip shark reproductive data collected during this survey were analyzed with other data sources to determine reproductive parameters for use in the SEDAR 65 process for Atlantic blacktip sharks (Natanson et al. 2019a). In 2021, life history samples and morphometric data collected from great and scalloped hammerheads during this survey were used in the SEDAR 77 process to determine both age and growth (Frazier et al. 2021) and reproductive (Moncrief-Cox et al. 2021) parameters, and provide morphometric conversions used within the assessment process (Natanson et al. 2021). Additionally, blacktip shark and scalloped hammerhead catch-per-unit-effort data were analyzed with respect to environmental variables to develop standardized indices of relative abundance for use in the SEDAR 65 and 77 data workshop (McCandless 2019a, McCandless and Natanson 2021). In 2022, development of a spatiotemporal index of scalloped hammerhead abundance from this survey was explored during the SEDAR 77 Assessment process for use in sensitivity analyses.

Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program

The NEFSC manages and coordinates this program, which surveys Atlantic coastal waters from Florida to Massachusetts by conducting cooperative, comprehensive, and standardized investigations of coastal shark nursery habitat. COASTSPAN participants from the NEFSC, Virginia Institute of Marine Science, South Carolina Department of Natural Resources (SCDNR), University of North Florida (UNF), and Florida Atlantic University (FAU) tagged and released more than 15,000 sharks from 2018 to 2022. Data from these surveys were provided to NMFS' HMS Management Division for use in updating the Essential Fish Habitat (EFH) designations for all managed shark species and the annual Stock Assessment and Fisheries Evaluation (SAFE) report. Depredation events were summarized for the September 2019 Advisory Panel Meeting for the HMS Management Division. Mark-recapture data from the SCDNR COASTSPAN survey were analyzed for use in a publication on bonnethead growth rates (Frazier et al. 2020). COASTSPAN data also contributed to the length-length and length-weight conversion factors used during the SEDAR 77 Data Workshop process (Natanson et al. 2021). Data summaries and analyses were submitted for use in the SEDAR 65 and 77 Data Workshop process detailing the length data and standardized indices of abundance for blacktip and scalloped hammerhead sharks caught during the COASTSPAN surveys in South Carolina, Georgia, and northern Florida (Frazier and McCandless 2019, McCandless and Frazier 2019a, McCandless et al. 2019a, McCandless and Frazier 2021a, McCandless and Frazier 2021b, McCandless et al. 2021). Additionally, young-of-the-year standardized indices of abundance from COASTSPAN gillnet and longline surveys conducted by the SCDNR and UNF were used during the SEDAR 65 and 77 Assessment process to create hierarchical recruitment indices of abundance (McCandless 2020, McCandless and Carlson 2022).

Cooperative Shark Tagging Program (CSTP)

The CSTP provides information on distribution, movements, and essential fish habitat for shark species in U.S. Atlantic and Gulf of Mexico waters. This program has involved more than 6,000 volunteer recreational and commercial fishermen, scientists, and fisheries observers since 1962. In 2018 and 2019, information was received on more than 30,000 tagged and 1,200 recaptured fish, bringing the total number tagged to more than 330,000 (including more than 50 shark species) and more than 19,000 fish recaptured (including more than 30 shark species). These data were provided to the NMFS Atlantic HMS Management Division to facilitate updates to the EFH designations for all managed shark species. In 2019, a tagging atlas summarizing and displaying 52 years of mark and recapture data from the CSTP was published (Kohler and Turner 2019). In 2018 and 2019, mark-recapture data on blacktip sharks located in the Gulf of Mexico (SEDAR 29 Update) and Atlantic (SEDAR 65, McCandless 2019b) were reviewed. These data support the continued need for separate Atlantic and Gulf of Mexico assessments for the blacktip shark. Although NEFSC Apex Predators fieldwork ceased in 2020 due to the pandemic, CSTP summer tag distribution to commercial and recreational fishers was up 7 percent from last year and our recapture reporting rate thru October was up 25 percent from last year based on online and email reporting. In 2021, CSTP movement and distribution data from great, scalloped, and smooth hammerhead sharks were used to inform stock identification during the SEDAR 77 Stock ID process. Additionally, in 2022 CSTP movement and distribution data from spiny dogfish (*Squalus acanthias*) and shortfin mako (*Isurus oxyrinchus*) mark-recapture data were used to inform the 2022 Research Track Assessment (RTA) for northwest Atlantic spiny dogfish and a Species Review for the ESA, respectively.

Opportunistic Sampling from Recreational, Commercial, and Stranding Events
Historically, species-specific landings data from recreational fisheries are lacking for sharks. In an effort to augment these data, the NEFSC has attended recreational shark tournaments continuously from 1961 through 2019, collecting data on species, sex, and size composition from individual events—in some cases, for nearly 50 years. Tournaments have been a primary source of biological samples used in NEFSC shark food habits, reproduction, and age/growth studies that provide biological reference points used during the ICCAT pelagic shark and SEDAR assessments. The majority of recreational shark tournaments were canceled in 2020, with few returning in the following years, limiting biological sampling to stranding events and commercial incidental mortalities. Biological samples for life history studies and catch and morphometric data for 107 pelagic sharks were collected at six recreational fishing tournaments in the northeastern United States from 2018 through 2019. These numbers were reduced to 21 sharks at two tournaments in 2021 and nine sharks at the single tournament in 2022. An additional 10 sharks were sampled from commercial incidental mortality and stranding events. A great hammerhead (*S. mokarran*), sampled from a Florida stranding event in 2021, was a large female that contributed to life history analyses for the SEDAR 77 Assessment (Moncrief-Cox et al. 2021).

Southeast Data, Assessment, and Review (SEDAR) Contributions
NEFSC staff contributed to the Southeast Data Assessment and Review (SEDAR) process for Gulf of Mexico (GOM) blacktip sharks (SEDAR 29 Update), Atlantic blacktip sharks (SEDAR 65), and Carolina (S gilberti) great, scalloped, and smooth (S. zygaena) hammerhead sharks (SEDAR 77) from 2018 through 2022. In 2018, NEFSC staff analyzed mark-recapture data from the Cooperative Shark Tagging Program (CSTP) for the GOM blacktip shark assessment update (SEDAR 29 Update). Data from blacktip sharks tagged or recaptured in the GOM indicated no exchange between the GOM and the Atlantic.

During the SEDAR 65 Data Workshop in 2019, CSTP mark-recapture data for Atlantic blacktip sharks were presented and, as seen with the GOM population, evidence was provided for maintaining separate Atlantic and GOM stocks (McCandless 2019b). Reproductive data collected during the NEFSC Coastal Shark Bottom Longline Survey were analyzed with other data sources to determine reproductive parameters for use during this SEDAR process (Natanson et al. 2019a). Discard estimates from the northeast gillnet fishery using blacktip shark data collected by the Northeast Fisheries Observer Program (NEFOP) were presented during the Data Workshop (McCandless et al. 2019b) and multiple methods (3-year moving average of discard estimates, multi-year block averaging of discard estimates, and multi-year block averaging of discard ratios) were explored for improving available discard time series (the northeast sink gillnet fishery, southeast coastal gillnet fishery, and shark bottom longline fishery) in a presentation during the Assessment Workshop (McCandless et al. 2020). Data summaries and analyses detailing the blacktip shark length data and standardized indices of abundance for the NEFSC Coastal Shark Bottom Longline Survey (McCandless 2019a), COASTSPAN surveys in South Carolina, Georgia, and northern Florida (Frazier and McCandless 2019, McCandless and Frazier 2019a, McCandless et al. 2019a), and Southeast Area Monitoring and Assessment Program (SEAMAP) surveys in South Carolina, Georgia, and northern Florida (McCandless and Frazier 2019b, McCandless et al. 2019b) were submitted for use during the SEDAR 65 process in 2019. Additionally, staff presented on the development of a recruitment index of abundance using standardized, young-of-the-year, catch-per-unit-effort data from the COASTSPAN gillnet and longline surveys in a hierarchical analysis during the SEDAR 65 Assessment Workshop (McCandless 2020).

NEFSC staff participated in the SEDAR 77 Stock ID, Data, and Assessment processes from 2021 through 2022 toward the assessment of Atlantic hammerhead populations. During the Stock ID process, staff contributed samples, data, and analyses to the Life History and Spatial (Co-Lead) Working Groups. During the Data process, staff contributed to the Catches, Ecosystem (Lead), Indices (Co-Lead), and Life History Working Groups. Staff presented working papers on great and scalloped hammerhead age and growth (Frazier et al. 2021) and reproductive parameters (Moncrief-Cox et al. 2021). Staff also provided a working paper on length-length and length-weight conversions using data from APP surveys, recreational tournament sampling, and commercial opportunistic sampling, as well as contributions from other partners, both domestic (SEFSC; SCDNR; Georgia Department of Natural Resources, UNF; and University of Southern Mississippi) and international (Fisheries and Oceans Canada) (Natanson et al. 2022). During the SEDAR 77 Data Workshop, APP staff presented scalloped and smooth hammerhead discard estimates for the northeast sink gillnet fishery using data collected by the NEFOP (McCandless and Mello 2022). Staff presented six working papers detailing multiple indices of abundance and summarizing length data for scalloped hammerhead sharks using gillnet and longline survey data from the COASTSPAN surveys (McCandless and Frazier 2021a, McCandless and Frazier 2021b, McCandless et al. 2021) and longline survey data from the NEFSC Coastal Shark Bottom Longline Survey (McCandless and Natanson 2021) and SEAMAP longline surveys by the SCDNR and the University of North Carolina (McCandless and Frazier 2021c, McCandless and Fodrie 2021). In 2022, staff presented updated discard mortality estimates for scalloped and smooth hammerheads using data from the NEFOP and a spatiotemporal index of abundance for scalloped hammerheads from the NEFSC Coastal Shark Bottom Longline Survey. Additionally, staff presented a working paper on hierarchical recruitment indices of abundance for scalloped hammerheads in both the Atlantic and Gulf of Mexico (GOM) combined and separately for each area using data from the COASTSPAN surveys in the Atlantic and Gulf of Mexico Shark Pupping and Nursery (GULFSPAN) and the Texas Parks and Wildlife surveys in the GOM (McCandless and Carlson 2022).

Atlantic Spiny Dogfish Research Track Assessment

Data available for this assessment included multiple fishery-independent indices of abundance, commercial (U.S. and Canadian) and recreational (U.S.) landings, and estimated discards (U.S.). Concerns as to whether surveys that only sampled a portion of the stock unit adequately track temporal population changes led the Working Group to use only the NEFSC spring bottom trawl survey for modeling purposes. Of the available data, this survey best samples the entirety of the stock. A Vector Autoregressive Spatiotemporal (VAST) index was investigated to integrate the information from multiple surveys into one index; however, fitting proved challenging for the length composition data and the trend showed a similar pattern to the NEFSC spring bottom trawl survey. The assessment was developed using Stock Synthesis 3 to provide an alternative to the index-based approach (Stochastic Estimator) used in the last research track assessment in 2006 and the ability to produce a length-based model for both sexes separately. Assessment results indicated that the stock was not overfished, but overfishing was occuring in 2019.

NEFSC Apex Predators Program (APP) staff co-chaired the Spiny Dogfish Research Track Assessment Working Group, working with each member to ensure assessment tasks were completed and providing support where needed. APP staff presented spiny dogfish movement data at a stakeholder meeting for spiny dogfish and two working papers during the assessment process: one on spiny dogfish movements and growth estimates using CSTP data (McCandless 2022) and another on age and growth using the second dorsal fin spines (Passerotti and McCandless 2022).

Endangered Species Act

NEFSC staff participated on the Status Review and Extinction Risk Team for the shortfin mako (*Isurus oxyrinchus)* in 2022. Based on the best available scientific and commercial information, the team concluded that, while overutilization will continue to be a threat to the shortfin mako shark in certain parts of its range through the foreseeable future (25 years), the species is at a low risk of extinction based on available abundance projections, the species' high adaptability and wide spatial distribution, and the existence of genetically and ecologically diverse, sufficiently well-connected populations. The team also did not find that the species is at a high or moderate risk of extinction in any portions of its range, nor that any distinct population segments of the species exist (Lohe et al. 2022).

Synthesis of the Science: Fisheries and Offshore Wind Energy

Given the forecasted rapid pace and broad scope of offshore wind development (OSW) in the United States and globally, there is a need to synthesize current and past scientific research that has examined the interactions between OSW, fisheries, and the marine ecosystems. From 2020 to 2022, NMFS and the Bureau of Ocean Energy Management (BOEM) partnered with the Responsible Offshore Development Alliance (RODA) on the Synthesis of the Science: Fisheries and Offshore Wind Energy project, bringing together the agencies, states, fisheries representatives, and offshore wind developers to help gather this information and identify future research needs and priorities. NEFSC staff—with staff from NMFS' HMS Management Division, New England Aquarium, Inspire Environmental, Commercial Fisheries Foundation, and the Royal Belgian Institute of Natural Sciences—gave an overview of the existing information related to the biological effects of offshore wind development on pelagic species; moderated the "The Matter of Migration: HMS, Small Pelagics, Anadromous Fish, and Others

Who Roam" break-out session; and engaged with the commercial and recreational fishing industries about their concerns, knowledge gaps, and research recommendations during the Synthesis of the Science: Fisheries and Offshore Wind Energy Workshop in October 2020. At the annual American Fisheries Society Meeting in November 2021, NEFSC staff—with staff from NMFS' HMS Management Division, New England Aquarium, Inspire Environmental, and Washington University in St. Louis—presented their preliminary findings on the synthesis of information, knowledge gaps, and research recommendations for the effects of offshore wind development on pelagic highly migratory finfish during the Interactions Between Offshore Wind, Fisheries, and Fisheries Resources Symposium.

Comprehensive Manual for Estimating Age and Growth of Atlantic and Gulf of Mexico Marine Species

NMFS collaborated with both the Atlantic and Gulf States marine fisheries commissions to produce a manual on best practices for estimating the age and growth of marine bony fishes and elasmobranchs (VanderKooy et al. (eds) 2000). This collaboration involves NOAA scientists from the NEFSC and the SEFSC. NEFSC Apex Predators staff contributed expertise on the age and growth of elasmobranch species.

Elasmobranch Age and Growth Methods, Validation, and Emerging Technologies

In 2018, NEFSC staff with co-authors from the NMFS PIFSC, University of South Carolina, and KwaZulu-Natal Sharks Board contributed a book chapter on elasmobranch age and growth in *Shark Research: Emerging Technologies and Applications for the Field and Laboratory* (Natanson et al. 2018a). This chapter discusses common methods used for elasmobranch age and growth, validation, and new frontiers in age and growth studies. It is noted that, as age validation of elasmobranchs has progressed, it has become apparent that for some species vertebral band pairs either are not related to time or are related to time only for a specific period of life. In most cases, bomb carbon validation shows distinct underestimation of age for species studied. The basis for band pair formation needs to be determined due to the importance of age in determining stock status and management strategies. Equally important is the need for new methods of age determination that are not related to band pair counting.

Structure and Function of Vertebrae for Elasmobranch Species

NEFSC staff—in cooperation with staff from the Massachusetts Division of Marine Fisheries (MADMF), FAU, Alaska Department of Fish and Game, and Wood River Animal Hospital—published a study investigating the relationship between vertebral band pairs (used to estimate shark age) and vertebral shape and growth (Natanson et al. 2018b). Intracolumn differences in centrum morphology (size and structure) and band pair counts were quantified in seven shark species: *Squatina dumeril, Carcharodon carcharias, Lamna nasus, Isurus oxyrinchus, Alopias vulpinus, Prionace glauca* and *Carcharhinus obscurus*. In all species examined, band pair deposition was closely related to body girth and the structural properties of the cartilaginous skeleton, relative to maximum size, and body type. These findings indicate the need to critically examine past studies on vertebral aging. Future studies should assume that band pair deposition is not triggered by a time-related event, but rather to growth that may coincidentally correspond to time on some centra along the vertebral column for a portion of a species' lifespan. This study has far-reaching implications for the conservation and management of elasmobranch species and the data needed to calculate the productivity necessary for stock assessment modeling. The use of improper ages can seriously alter model output, thereby affecting management decisions.

A complementary study to the one described above was published in 2018 by NEFSC staff and co-authors from FAU on the mechanical behavior of shark vertebrae (Ingle et al. 2018). This study used six of the same shark species (*Carcharodon carcharias*, *Lamna nasus*, *Isurus oxyrinchus, Alopias vulpinus, Prionace glauca* and *Carcharhinus obscurus*) to examine the biomechanics of the vertebral centra related to vertebral structure and function. Results showed that the mechanical properties of the shark vertebral centra vary among ontogeny, species, and body type; further supporting the hypothesis that band pair structure is related to the function of the vertebral centra and not directly related to time.

Additionally, NEFSC staff contributed to a publication with a University of Rhode Island graduate on the positional and ontogenetic variation in vertebral centra morphology in five batoid species (James and Natanson 2021). Elasmobranch studies increasingly show that band-pair counts in vertebral centra do not accurately reflect age. Recent shark research indicates that the number of band pairs vary with body size and that centrum morphology is related to structural needs. This study examined the relationship between band-pair deposition and morphology of centra along the vertebral column, and ontogenetically, for five batoid species (little skate, *Leucoraja erinacea*, winter skate, *Leucoraja ocellata*, barndoor skate, *Dipturus laevis*, Atlantic stingray, *Dasyatis sabina*, and round ray, *Urobatis halleri*). Centrum morphology and band-pair count varied along the vertebral column in all individuals of all species, except in young of the year. Variation in band-pair counts among centra within individuals supports the hypothesis that band-pair formation is related to somatic growth and body shape rather than to an annual cycle.

The Structure and Mineralization of Shark Centra

In 2021 and 2022, APP staff contributed to five publications studying the structure and mineralization of shark centra with co-authors from the Feinberg School of Medicine, Argonne National Laboratory, SWFSC, Duke University, and Stonybrook University. The center of shark vertebrae consist of cartilage mineralized by a bioapatite similar to bone's carbonated hydroxyapatite, and, without a repair mechanism analogous to remodeling in bone, these structures still survive millions of cycles of high-strain loading. The main structures of the centrum are the corpus calcarea (an hourglass-shaped double cone) and the intermedialia, which supports the cones. Park et al. (2022a) studied bioapatite in shark centra using wide- and small-angle X-ray scattering, finding that crystallographic quantities from lamniform and carcharhiniform centra closely matched and were closely related to that in bone, but do possess differences, which probably affect mechanical property and warrant further study. Morse et al. (2022) studied centra microanatomy and mineral density variation using microcomputed tomography and found that all lamniform and carcharhiniform centra contained growth bands that were visible as small changes in linear attenuation coefficient and these coefficients were the same in the corpus calcarea and intermedialia of the lamniforms, but were smaller in the intermedialia than in the corpus calcarea of the carcharhiniforms. Stock et al. (2021, 2022) looked at the microstructure and energy dispersive diffraction reconstruction of 3D patterns of crystallographic texture in a blue shark centrum. This study determined that mineralized tissue samples can be mapped in 3D with energy dispersive x-ray diffraction and subsequently studied by destructive methods and that bioapatite in the cone walls and intermedialia wedges of a centrum is oriented to resist lateral and axial deflections, respectively. Park et al. (2022b) studied bioapatite structure in intact centra also using 3D mapping with energy dispersive diffraction. As in the previous study, the bioapatite structure is oriented laterally within the cone walls, but axially within the intermedialia wedges for the blue shark to resist lateral deformation and support axial loads, respectively. In the shortfin mako, there is some tendency for variation in orientation with position. Because bioapatite mineralized tissues vary significantly with both volume fraction of bioapatite and crystallographic texture, the present maps should inform future 3D numerical models of shark centra under applied load. The work from these four studies will help inform future age and growth studies as new methodologies are needed to improve age estimates.

Changes in Vertebral Band-Pair Deposition Rates with Ontogeny in Sandbar Sharks

NEFSC staff, in cooperation with staff from the SEFSC, published a study using oxytetracycline (OTC) validation for confirmation of changes in vertebral band-pair deposition rates with ontogeny in sandbar sharks (*Carcharhinus plumbeus*) in the western North Atlantic Ocean (Natanson and Deacy 2019). Age underestimation of many shark species, such as the sandbar shark, has been proven with age validation methods including bomb radiocarbon dating, OTC injection, and tag recapture data. Validation studies indicate that band-pair deposition in vertebral centra may not be directly related to time, especially in older individuals of a species. In this study, vertebrae from tagged, OTC injected, and recaptured sandbar sharks were examined to determine if band-pair deposition past the OTC mark matched time at liberty. In six of eight OTC-injected sharks at liberty for >1 year, band-pair count past the OTC mark underestimated time at liberty by 24 to 58 percent. Additionally, growth rates derived from tag-recapture data were slower than those described by previously published vertebral band-pair growth curves but were similar to those predicted by previous bomb radiocarbon dating and OTC results from this study. Together, the results from these studies indicate that modeling tag-recapture data may be more accurate for age determination in elasmobranchs given that band-pair counts on vertebral centra do not coincide with age throughout life. Analyses indicate that sandbar sharks may be less productive than previously understood.

Validation of Dorsal-Fin Spine Use over Vertebrae for Age Determination of Spiny Dogfish

In 2021, NEFSC staff worked in cooperation with staff from the Dauphin Island Sea Lab and the AFSC to publish a study on the validation of the use of vertebrae and dorsal-fin spines for age determination of spiny dogfish (*Squalus acanthias*) in the western North Atlantic Ocean (James et al. 2021). Spiny dogfish are traditionally aged by counting band pairs on dorsal-fin spines; however, wear and tear of the spines makes obtaining accurate age estimates of older spiny dogfish difficult. Vertebral centra are an alternate structure that can be used to estimate age, but success in their use has been varied. APP staff conducted a tag-recapture study using oxytetracycline injections to validate annual deposition in both dorsal-fin spines and vertebral centra of spiny dogfish. When band pairs in vertebral centra were used, time at liberty was significantly underestimated. Additionally, band-pair counts were found to change along the vertebral column of an individual, further refuting the use of vertebral centra to generate age estimates. Band-pair deposition in dorsal-fin spines was confirmed to be annual in spiny dogfish at liberty for up to 2.6 years. Dorsal-fin spines should continue to be used to age spiny dogfish, and vertebral centra are not a viable alternative.

Common Sawsharks Defy Age Determination using a Range of Traditional Methods

In 2020, NEFSC staff worked in cooperation with staff from Macquarie University, the University of New Castle, and the Sydney Institute of Marine Sciences to publish a study on the inability to age common sawsharks (*Pristiophorus cirratus*) using traditional aging methods

(Burke et al. 2020). The vertebral morphology of common sawsharks was first assessed to determine the best method for band pair elucidation. Vertebrae located in the post-brachial region were identified as the largest and least variable for band pair analysis. A total of eight different age-determination methods were then applied to the shark vertebrae to test the viability of traditional and nontraditional techniques in elucidating band pairs. Band pairs were indeterminable across all treatments. This research adds to the growing body of evidence that vertebral band pairs may not be appropriate for age determination in some groups of sharks and that novel techniques need to be developed to accurately age sawsharks.

Growth Rates of Bonnetheads Estimated from Tag-Recapture Data

In 2020, NEFSC staff with coauthors from the SCDNR, Mote Marine Laboratory's Center for Shark Research, NMFS' Southeast Regional Office, and SEFSC published a study on growth rates of bonnetheads (*Sphyrna tiburo*) estimated from tag-recapture data (Frazier et al. 2020). Results from published age and growth models for bonnetheads indicate significant differences in life history between populations in the eastern GOM and those in estuarine waters of the Atlantic coast of the southeastern United States. An age-independent model that uses maximum likelihood estimation of GROwth and growth variability from TAGging data (GROTAG) was used with region-specific tag-recapture data to generate estimates of von Bertalanffy growth parameters and growth rates for sharks in each of these regions. Results from the GROTAG model indicate that female bonnetheads in the GOM initially grew faster and attained a smaller maximum size than females in the Atlantic region. The final GROTAG model for females in the Atlantic region produced estimates of von Bertalanffy parameters and growth rates similar to those produced by the age-based growth model. For the population in the GOM, GROTAG model results indicate that growth rates were slower and average maximum size and longevity were greater than those from age-based models. Although models for males were generated with tag-recapture data, large 95 percent confidence intervals hindered comparisons. For both sexes and regions, calculated maximum longevity and age at 50 percent maturity are larger than published estimates, indicating that age underestimation may have occurred in both age and growth studies, with significant differences in life history estimates for bonnetheads in the GOM.

Inferring Life History Characteristics of Oceanic Whitetip from Vertebral Bomb Radiocarbon

NEFSC staff contributed to a study on inferring life history characteristics of the oceanic whitetip shark (*Carcharhinus longimanus*) from vertebral bomb radiocarbon that was published with coauthors from the University of South Carolina and the University of Hawai'i (Passerotti et al. 2020). This work revealed that high-precision vertebral bomb radiocarbon measurements likely track philopatric movements in oceanic whitetip sharks. The use of a novel replicate sampling design revealed remarkably precise Δ 14C patterns across vertebral centra within the same shark, giving the ability to infer migratory patterns based on dietary 14C shifts over the lifespans of individual sharks. Further work using vertebral d 13C patterns is needed to verify these findings. Age estimates were validated up to 13 years, but older specimens from sharks alive in the 1950s to 1960s are needed to validate longevity. The Δ 14C of pre-birth material formed in utero is also reported, which may provide future insights into maternal movements and diet during gestation.

Inferring Spatial and Trophic Ecology from Vertebrae Carbon and Nitrogen Isotopes Compositions

NEFSC staff contributed to a study using compound-specific stable isotope analysis of amino acids in pelagic shark vertebrae to reveal baseline, trophic, and physiological effects on bulk protein isotope records published with international participation (University of Southampton, Fano Marine Centre, Cefas Laboratory, Universidade do Porto, Consejo Superior de Investigaciones Científicas, Instituto Português do Mar e da Atmosfera, ICCAT) and domestic (WHOI) participation (Magozzi et al. 2021). Variations in stable carbon and nitrogen isotope compositions in incremental tissues of pelagic sharks can be used to infer aspects of their spatial and trophic ecology across life-histories. This may not be the case for bulk tissue isotopic compositions, because multiple processes influence these values, including variations in primary producer isotope ratios and consumer diets and physiological processing of metabolites. Stable isotope compositions of individual amino acids can partition the isotopic variance in bulk tissue into components associated with primary production or diet and physiology. The carbon framework of essential amino acids can be synthesized de novo only by plants, fungi, and bacteria and must be acquired by consumers through the diet. Consequently, the carbon isotopic composition of essential amino acids in consumers reflects that of primary producers in the location of feeding, whereas that of non-essential amino acids is additionally influenced by trophic fractionation and isotope dynamics of metabolic processing. This study determined isotope chronologies from vertebrae of individual blue sharks and porbeagles from the North Atlantic using carbon and nitrogen isotope compositions in bulk collagen and carbon isotope compositions of amino acids. Despite variability among individuals, common ontogenetic patterns in bulk isotope compositions were seen in both species. However, while life-history movement inferences from bulk analyses for blue sharks were supported by carbon isotope data from essential amino acids, inferences for porbeagles were not, implying that the observed trends in bulk protein isotope compositions in porbeagles have a trophic or physiological explanation, or are spurious effects. Variations in carbon isotope compositions of non-essential amino acids were explored in search for systematic variations that might imply ontogenetic changes in physiological processing, but patterns were highly variable and did not explain variance in bulk protein $\delta 13C$ values. Isotopic effects associated with metabolite processing may overwhelm spatial influences that are weak or inconsistently developed in bulk tissue isotope values, but interpreting mechanisms underpinning isotopic variation in patterns in non-essential amino acids remains challenging.

Common Thresher Seasonal Distribution and Habitat Use from Fishery-Dependent Data

NEFSC staff from the NEFOP and the APP with co-authors from the Anderson Cabot Center for Ocean Life, Bedford Institute of Oceanography, MADMF, and the University of Massachusetts Dartmouth published a study on the seasonal distribution and habitat use of the common thresher shark (*Alopias vulpinus*) in the western North Atlantic Ocean (WNA) inferred from fishery-dependent data (Kneebone et al. 2020). Data on 3,478 fishery-dependent capture records in the WNA between 1964 and 2019 were compiled and analyzed by sex and life stage (i.e., young of the year, juvenile, and adult). Capture locations occurred over a broad geographic range from the Gulf of Mexico to the Grand Banks, primarily in continental shelf waters shallower than 200 m. Seasonal north–south movements along the east coasts of the United States and Canada were observed for all life stages and both sexes, with occurrences at more northerly latitudes in the summer and more southerly latitudes in the winter. Distinct areas of frequent capture were identified for all life stages throughout their range. Common thresher sharks were most commonly observed in waters with sea-surface temperatures of 12–18°C (range: 4–31°C). These results will help to identify essential fish habitat for each life stage of common thresher sharks along the U.S. East Coast and to develop management measures for the WNA population.

Porbeagle Horizontal and Vertical Movement Patterns and Habitat Use

In 2021, NEFSC staff with co-authors from the MADMF, University of Massachusetts Dartmouth, State College of Florida, University of Washington, Woods Hole Oceanographic Institution (WHOI), and GARFO published a study on horizontal and vertical movement patterns and habitat use of juvenile porbeagles (*Lamna nasus*) in the western North Atlantic (Skomal et al. 2021). Although much is known of the life history of this species, there is little fishery-independent information about habitat preferences and ecology. To examine migratory routes, vertical behavior, and environmental associations, pop-up satellite archival transmitting tags were deployed on 20 porbeagles in November 2006 from a commercial longline fishing vessel on the northwestern edge of Georges Bank, about 150 km east of Cape Cod. Tags were programmed to release in March (n = 7), July (n = 7), and November (n = 6) of 2007, and 17 (85 percent) successfully reported. Based on known and derived geopositions, the porbeagles exhibited broad seasonally dependent horizontal and vertical movements ranging from minimum linear distances of 937 to 3,310 km and from the surface to 1,300 m, respectively. All of the sharks remained in the western North Atlantic from the Gulf of Maine, the Scotian Shelf, on George's Bank, and in the deep, oceanic waters off the continental shelf along the edge of, and within, the Gulf Stream. In general, the population appears to be shelf-oriented during the summer and early fall with more expansive offshore radiation in the winter and spring. Although sharks moved through temperatures ranging from 2 to 26°C, the bulk of their time (97 percent) was spent in 6–20°C. In the summer months, most of the sharks were associated with the continental shelf moving between the surface and the bottom and remaining < 200 m deep. In the late fall and winter months, the porbeagles moved into pelagic habitat and exhibited two behavioral patterns linked with the thermal features of the Gulf Stream: “non-divers” (n = 7) largely remained at epipelagic depths and “divers” (n = 10) made frequent dives into and remained at mesopelagic depths (200–1,000 m). These data demonstrate that juvenile porbeagles are physiologically capable of exploiting the cool temperate waters of the western North Atlantic as well as the mesopelagic depths of the Gulf Stream, possibly allowing exploitation of prey not available to other predators.

Shortfin Mako Movements, Diving Behavior, and Habitat Use

In 2021, NEFSC staff worked in cooperation with staff from the SEFSC and international partners from the Portuguese Institute for Sea and Atmosphere, University of Algarve, Dirección Nacional de Recursos Acuáticos, Universidade Federal Rural de Pernambuco, Instituto Español de Oceanografía, and the Centro de Investigación y Conservación Marina to publish a study on the movements, habitat use, and diving behavior of shortfin mako (*Isurus oxyrhincus*) in the Atlantic Ocean (Santos et al. 2021). Given increasing concerns for the stock status of the species, the present study was designed to fill in knowledge gaps on habitat use and movement patterns of shortfin mako in the Atlantic Ocean. From 2015 to 2019, 53 shortfin makos were tagged with pop-up satellite archival tags within the North, Central, and Southwest Atlantic Ocean, with successful transmissions received from 34 tags. Generally, sharks tagged in the Northwest and Central Atlantic moved away from tagging sites showing low to no apparent residency patterns, whereas sharks tagged in the Northeast and Southwest Atlantic spent large periods of time near the Canary Archipelago and Northwest Africa, and over shelf and oceanic waters off southern Brazil and Uruguay, respectively. These areas showed evidence of site fidelity and were identified as possible key areas for shortfin mako. Sharks spent most of their time in temperate waters (18–22°C) above 90 m; however, data indicated the depth range extended from the surface down to 979 m, in water temperatures ranging between 7.4 and 29.9°C. Vertical behavior of sharks seemed to be influenced by oceanographic features, and ranged from marked diel vertical movements, characterized by shallower mean depths during the night, to yo-yo diving behavior with no clear diel pattern observed. These results may aid in the development of more informed and efficient management measures for this species.

Tiger Sharks Migrate into Higher Latitudes Earlier and Expand Distribution Due to Ocean Warming

In 2022, NEFSC staff with co-authors from the University of Miami, Mississippi State University, SWFSC, and Rutgers University published a study on how ocean warming altered the distributional range, migratory timing, and spatial protections of tiger sharks (*Galeocerdo cuvier*, Hammerschlag et al. 2022). It is important to understand the responses of species to warming, especially in the case of apex predators that exhibit relatively high extinction risk and where changes to their distribution could impact predator–prey interactions that can initiate trophic cascades. A combined analysis of animal tracking, remotely sensed environmental data, habitat modeling, and capture data was used to evaluate the effects of climate variability and change on the distributional range and migratory phenology of this ectothermic apex predator. Tiger sharks satellite tracked in the western North Atlantic between 2010 and 2019 revealed significant annual variability in the geographic extent and timing of their migrations to northern latitudes from ocean warming. Specifically, migrations have extended farther poleward and arrival times to northern latitudes have occurred earlier in the year during periods with anomalously high sea-surface temperatures. A complementary analysis of nearly 40 years of tiger shark captures from the CSTP in the region revealed decadal-scale changes in the distribution and timing of shark captures in parallel with long-term ocean warming. Specifically, areas of highest catch densities have progressively increased poleward and catches have occurred earlier in the year off the North American shelf. During periods of anomalously high sea-surface temperatures, movements of tracked sharks shifted beyond spatial management zones that had been affording them protection from commercial fishing and bycatch. Taken together, these study results have implications for fisheries management, human–wildlife conflict, and ecosystem functioning.

Implications of a Porbeagle Resting Population in the Western North Atlantic Ocean

In 2019, APP staff with co-authors from the SEFSC, Bedford Institute of Oceanography, and the University of New England published a study identifying a resting population of female porbeagles (*Lamna nasus*) in the general vicinity of Stellwagen Bank in the western North Atlantic Ocean (Natanson et al. 2019b). Previous porbeagle research based on specimens collected from the western North Atlantic Ocean has indicated that this lamnid shark has an annual reproductive cycle. However, the results of a recent evaluation of reproductive tracts from a geographically segregated group of porbeagles within the western North Atlantic Ocean indicate the presence of females in a resting stage of maturity, indicating a biennial reproductive cycle. The observation of a resting stage has implications not only in the reproductive cycle)biennial versus annual) of this species but also in the lifetime productivity. This finding indicates that this shark follows the typical lamnid resting period between pregnancies, a period that would decrease the lifetime output of young sharks and their resilience to direct and indirect fishing pressure.

Updated Blue Shark Reproductive Characteristics

NEFSC staff worked in cooperation with staff from the Atlantic White Shark Conservancy and the University of Rhode Island to publish a study on the reproductive characteristics for the blue shark (*Prionace glauca*) in the North Atlantic Ocean, where the blue shark is caught in large numbers by commercial fisheries (Viducic et al. 2022). Reproductive parameters, such as size and age at maturity, are important descriptors of life history characteristics essential for stock assessment and effective management, but had not been updated in this region since 1979. To address this gap in knowledge, 369 female and 488 male reproductive samples from 1971 to 2016 were used to examine whether maturity parameters have changed over time. A comparison of sex-specific fork length (FL) (L50) and weight (W50) at median maturity between two time periods (1971–1977 and 2003–2016) showed no evidence of change in females, but males had a statistically significant increase in both parameters, which may be the result of differences in sample size range between the time periods. Thus, all data from 1971 through 2016 were combined to obtain new estimates of age and size at 50 percent maturity for both sexes. The L50 and W50 are 192.5 cm FL and 49.5 kg for male blue sharks and 190.9 cm FL and 50.1 kg for female blue sharks. These updated L50 and W50 values increase the reliability of data inputs for fisheries management.

Asymmetry in the External Reproductive Morphology of Female Spiny Dogfish

NEFSC staff with co-authors from the University of Oxford, Mount Holyoke College, and the University of Massachusetts Amherst published a study on the variability and asymmetry in the shape of the spiny dogfish vagina revealed by 2D and 3D geometric morphometrics (Hedrick et al. 2019). The vast majority of research on genital morphology has been done on male genitalia and this is one of few studies on the female genital shape and the first using 3D geometric morphometrics. In a sample of 21 adult females, no correlations between body size and reproductive and non-reproductive trait size were found indicating no general allometric patterns. There was limited evidence for different 2D and 3D vaginal shapes in visibly pregnant and not visibly pregnant sharks. Results using 3D geometric morphometrics showed clearer trends than seen using 2D. High directional asymmetry (>48 percent of total variation) was found in visibly pregnant sharks, likely as a result of an asymmetric distribution of pups in the shark’s paired oviducts. Since this asymmetry is functional rather than developmental, it presents an important consideration when studying vaginal shape. The lack of significant association of vaginal shape with pregnancy in a species with such a long gestation period suggests that differences in shape may be under selective forces such as sexual antagonism during copulation.

Feeding Habits of the Tiger Shark in the Northwest Atlantic Ocean and Gulf of Mexico

NEFSC staff contributed to a 2018 publication on food habits of tiger sharks in the northwest Atlantic with co-authors from Duke University Marine Laboratory and the SEFSC (Aines et al. 2018). Tiger sharks (*Galeocerdo cuvier*) are apex predators that may structure marine communities through predation. Despite a large number of studies in other areas, such as the Pacific Ocean, there are no quantitative data on the diet of tiger sharks in the northwest Atlantic Ocean and GOM. Diet was assessed from 169 tiger sharks by life stage, area, and environmental factors. Fifteen prey groups were identified, with teleosts, molluscs, birds, cephalopods, and reptiles being the predominant prey categories. There was an ontogenetic shift in diet, prey size, and diversity. Molluscs were the most common prey in smaller sharks, while teleosts and reptiles became more important in the diet of larger sharks. Dietary overlap was significant by area (GOM vs Atlantic Ocean) and among all life stages except for young-of-the-year and adult tiger sharks. Juvenile tiger sharks also demonstrated selective feeding by targeting gastropod feet over ingesting the entire animal. While results were similar to feeding studies conducted on tiger sharks in other ocean basins, an understanding of area-specific trophic interactions is necessary to inform decision support tools for ecosystem-based approaches to management.

Southeast Fisheries Science Center (SEFSC)

Observer Programs

The shark longline observer program was created to obtain better data on catch, bycatch, and discards in the shark bottom longline fishery. Amendments to the Consolidated Atlantic HMS FMP have significantly modified the major directed shark fishery and implemented a shark research fishery. NMFS selects a limited number of commercial shark vessels (3-5) on an annual basis to collect life history data and catch data for future stock assessments. Outside the research fishery, vessels targeting sharks and possessing valid directed shark fishing permits were randomly selected for coverage with a target coverage level of 4 to 6 percent. From 2019 to 2022, there were 80 hauls on 42 trips observed for bottom longline vessels targeting coastal sharks in the southern Atlantic and Gulf of Mexico. Trips averaged 1.5 days in length. Sharks comprised 99.19 percent of the catch, teleosts 0.51 percent, and batoids 0.17, and invertebrates, smalltooth sawfish, and unknown all 0.04 percent. Large coastal shark species (excluding sandbar shark) comprised 54.42 percent of the shark catch and small coastal shark species comprised 32.73 percent. Prohibited shark species were also caught, including sandbar shark (5.28 percent) and Caribbean reef shark (2.23 percent). There were 292 hauls on 153 trips observed in the Shark Research Fishery in the Gulf of Mexico and the southern Atlantic. Trips averaged 1.9 days in length. Sharks comprised 98.44 percent of the catch, followed by teleosts (1.24 percent), smalltooth sawfish (0.12 percent), batoids (0.11 percent), unknown (0.04 percent), invertebrates (0.03 percent), and sea turtles (0.02 percent). Sandbar shark comprised 68.87 percent of the shark catch, other large coastal shark species comprised 23.28 percent, and small coastal shark species comprised 5.73 percent. Prohibited shark species were also caught including dusky shark (1.22 percent), sand tiger shark (*Carcharhias taurus*) (0.39 percent), Caribbean reef shark (0.07 percent), and white shark (0.05 percent). Pelagic species comprised 0.01 percent of the shark catch. Fishing locations ranged from North Carolina to the Florida Keys in the Atlantic Ocean and the Gulf of Mexico. While an observer program exists for the southeast shark gillnet fishery, the trend of declining effort in the large coastal shark targeted gillnet fishery continued to be observed in 2019–2022. Strike gillnet gear was observed exclusively in teleost-targeted (king mackerel) sets. The majority of sink gillnet fishermen continued to target teleost species. Incidental take of protected species, such as sea turtles and marine mammals, remained a rare occurrence, with one sea turtle observed in 2019–2022. The general gillnet fishing effort continues to decrease.

Elasmobranch Feeding Ecology

Studies are currently underway describing the diet and foraging ecology, habitat use, and predator–prey interactions of elasmobranchs. The diets of multiple shark species caught by commercial longline gear, including sandbar (*C. plumbeus*) and dusky (*C. obscurus*) sharks, are currently being investigated. Along with basic diet analysis, stomach contents will be examined for evidence of line feeding, or depredation, on longline gear. This study will help to test the hypothesis that diet studies based on longline-caught animals could be biased due to longline depredation. Additional data are being collected during SEFSC bottom longline and trawl surveys to examine spatial variability in the diets and feeding behaviors of various shark species.

Cooperative Gulf of Mexico States Shark Pupping and Nursery Survey (GULFSPAN) and Tagging Database

The SEFSC Shark Population Assessment Group manages and coordinates a survey of coastal bays and estuaries from Florida to Louisiana. Surveys identify the presence or absence of neonate (newborn) and juvenile sharks and attempt to quantify the relative importance of each area as it pertains to essential fish habitat. A database currently includes more than 20,000 tagged animals from 1993 to the present for both the Gulf of Mexico and U.S. southeast Atlantic Ocean.

Monitoring the Recovery of Smalltooth Sawfish (Pristis pectinata)

The smalltooth sawfish was the first marine fish listed as endangered under the ESA. Smalltooth sawfish has been listed under the ESA since 2003, and the completion of the Smalltooth Sawfish Recovery Plan in early 2009 identified new research and monitoring priorities that are currently being implemented**.** Surveys identify the presence or absence of neonates, young-of-the-year, and juveniles in southwest Florida and research in the Florida Keys and Florida examines the distribution and abundance of adult animals.

Life History Studies of Elasmobranchs

To support stock assessments, age and growth and reproductive (maturity) models were completed for Atlantic blacktip sharks (SEDAR 65) and great and scalloped hammerheads (SEDAR 77). Studies on the life history of blue, tiger, and night sharks are being conducted with the Northeast Fisheries Science Center. Other species currently being studied to provide information for upcoming assessments include blue, spinner, and bull sharks.

Stock Assessment of Atlantic Blacktip Sharks

A standard stock assessment of Atlantic blacktip shark was conducted in 2019–2020 under the SEDAR process (SEDAR 65). The data available for this assessment were relatively complete for a shark population, including multiple fishery-independent indices of abundance, and at least some length frequency data from several components of the fishery. The assessment and projections were done using Stock Synthesis, following usual practices for developing statistical catch at age models. This was the first Stock Synthesis application to Atlantic blacktip shark, which was last assessed in 2006 using age structured production and surplus production models. The conclusion is that the stock is not overfished (SSF2018 > MSST) and overfishing is not occurring (F2018 < FMSY) and this result appears to be robust across the sensitivity analyses.

Stock Assessment of Porbeagle Sharks

The SCRS Shark Species Group conducted a stock assessment of porbeagle sharks for the Atlantic northern and southern stocks in 2020. A total of four modeling approaches were trialed to assess the status of porbeagle shark in the Atlantic. The Sustainability Assessment for Fishing Effects (SAFE) approach was used to evaluate whether the North and South Atlantic stocks were experiencing overfishing; the Incidental Catch Model (ICM) was used for the Northwest Atlantic stock (and only explored but not used for the Southwest Atlantic stock); length-based approaches were explored for the Northwest, Southwest, and Southeast stocks, and the performance of input control management options explored in a preliminary MSE approach for the Northwest stock.

Results of the SAFE approach indicated that neither the North Atlantic nor the South Atlantic stocks are undergoing overfishing. The ICM model estimated that biomass in 2018 was 57 percent of the biomass at MSY and a 98 percent probability of the stock being overfished in 2018. Projections predicted that removals of less than 7,000 sharks (214 mt) would allow rebuilding with a 60 percent probability by 2070 (a projection interval of 2.5 generations) and removals of less than 8,000 sharks (245 mt) would allow rebuilding with a 50 percent probability by 2060. The remaining two approaches initially attempted to estimate the reproductive potential for the species were not further considered because of a lack of representation of mature individuals in the available size-distribution data from all stocks and fleets.

Stock Assessment for Lemon Sharks

To date there has been no quantitative assessment of lemon shark stock status available despite being caught and harvested in commercial fisheries. A collaborative project outside of SEDAR with SEFSC, HMS, and university scientists synthesized available data to develop a stock assessment of the lemon shark in the western North Atlantic. All information on stock identity was considered to define a fishery management unit off the southeastern United States. Stock abundance and trends in fishing mortality were estimated from 1981 to 2017 using a Bayesian state–space surplus production model. The model incorporated prior knowledge of lemon shark demography, catches, and a combination of 11 indices of abundance. Seven model configurations that fit the data well and produced plausible estimates were used to evaluate the sensitivity of posterior estimates to assumed priors and data decisions. Results suggested that lemon shark stock abundance has been relatively stable since the mid-1990s, with some estimates of prior depletion. Estimates of relative fishing mortality indicate earlier periods of overfishing, with a decrease in fishing mortality since the early 2000s.

Shark Assessment Research Surveys

The SEFSC has conducted annual bottom longline surveys in the northern Gulf of Mexico and off the U.S. East Coast since 1995. The primary objective is to utilize standardized gear to assess the distribution and abundance of large and small coastal sharks across their known ranges to provide fishery-independent time series data for trend analysis. The survey is the largest of its kind and is considered essential for accurate stock assessments of sharks occurring off the U.S. East Coast and throughout the northern Gulf of Mexico. This survey also provides a platform for other shark research activities including identification of essential habitats, reproductive biology, feeding behavior, gear selectivity, and effects of deleterious anthropogenic impacts. Additionally, movement patterns and habitat utilization are being examined through the use of conventional, acoustic, and satellite tagging. To date, more than 50,000 fishes have been collected during the survey, of which approximately 85 percent were sharks. Current research is examining temporal trends in shark depredation of longline catch and identifying responsible species.

Population Structure of Atlantic Angel Sharks

The distributions of sharks inhabiting deepwater ecosystems (>200 m) remain largely speculative because of limited collection efforts for species of relatively low commercial value and because of difficulties associated with sampling in deepwater habitats. As a result, ranges of deepwater shark species are often considered continuous across broad expanses despite records of occurrence, in many cases, being spatially fragmented. Within U.S. waters of the western North

Atlantic Ocean, the range of angel sharks (of the Squatinidae family) in continental shelf and slope waters has been variously reported as both continuous and disjunct. The objective of this study was to use fishery-independent data to describe the range of angel sharks in U.S. waters of the western North Atlantic and identify potential spatial discontinuities that could be consistent with the idea of multiple species or populations in the region. Results indicate that angel sharks in U.S. waters of the western North Atlantic have a disjunct distribution and discontinuities occur from approximately Georgia through southern Florida and within a well-defined area off the coast of Louisiana. Evidence suggests spatial discontinuities could be related to thermal, salinity, or current velocity barriers, or to a combination of these factors.

Atlantic Highly Migratory Species (HMS) Management Division

New York Bight Shark Studies

Staff from the HMS Management Division collaborated on multidisciplinary electronic tagging and biological sampling research on sharks off Long Island, New York, including juvenile white sharks, dusky sharks, sandbar sharks, and smooth dogfish. In cooperation with OCEARCH, Harbor Branch Oceanographic Institute, and other collaborators, satellite and/or coded acoustic tags were attached to juvenile white, sandbar, and dusky sharks to study their movements, migration, and habitat use patterns. Numerous biological samples (fin clips, blood, muscle tissue, parasites) were collected for collaborating institutions studying stress physiology, stable isotopes, population genetics, contaminants, and parasitology.

Spiny Dogfish Ecology

In collaboration with the NEFSC and the University of Aberdeen, Scotland, an analysis of seasonal distribution and sexual segregation of spiny dogfish was completed (Haugen et al. 2017). The study evaluated NEFSC bottom trawl research survey data on the distributions of male and female spiny dogfish along the U.S. East Coast and identified significant spatial and temporal segregation between the sexes. The results may help improve the management and long-term sustainability of the spiny dogfish fishery.

4.2 Incidental Catch Reduction

Pacific Islands Fisheries Science Center (PIFSC)

Developing Bycatch Mitigation Strategies for Oceanic Sharks Captured in Purse Seine Gear

In tropical tuna purse seine fisheries an increasing amount of fishing effort is based on setting gear around drifting Fish Aggregating Devices (FADs). In the western central Pacific Ocean, 21 percent of the effort is conducted on FADs and results in 40 percent of the total tuna catch (Williams and Terawasi 2016). FAD-associated sets have increased rates of shark bycatch in comparison to non-FAD sets. PIFSC scientists in collaboration with researchers from several institutions around the world are working with the International Seafood Sustainability Foundation (ISSF) to develop and test shark bycatch mitigation strategies in tropical tuna purse seines (Restrepo et al. 2016) in every ocean. Between 2011 and 2015, 11 research cruises were conducted. During 2015, ISSF and PIFSC project scientists worked on both commercial purse seine vessels and chartered research vessels in collaboration with industry to test a shark release panel in strategic positions in purse seine nets. They also worked to tag silky and oceanic whitetip sharks captured at drifting FADs to better understand their FAD associative behavior, residence times, and habitat use. These data are advancing knowledge of the movement behavior of silky and oceanic whitetip sharks, and providing insight into potential catch mitigation techniques and safe release mechanisms. There have been no updates since 2015.

Understanding FAD Residency and Behavior of Oceanic Whitetip Sharks
Oceanic whitetip sharks (*Carcharhinus longimanus*) are a large component of the shark bycatch in tuna purse seine and longline fisheries worldwide (Rice and Harley 2012). Oceanic whitetip shark (OCS) populations, historically one of the most numerically abundant species in tropical waters (Bonfil et al. 2008), have undergone significant declines in all oceans. OCS were listed in appendix II of CITES in 2014. NMFS received a petition in September 2015 to list the oceanic whitetip shark as threatened or endangered under the ESA, and to designate critical habitat concurrent with any final listing. In 2016, NMFS proposed to list the oceanic whitetip shark as a threatened species under the ESA (81 FR 96304; December 29, 2016). A stock assessment conducted by the Secretariat to the Pacific Community found oceanic whitetip shark populations in the Pacific Ocean to be in decline as a result of overfishing and concluded overfishing was still occurring (Rice and Harley 2012). OCS have also shown significant declines in relative abundance in the Hawai'i longline fishery since 1995 (Walsh and Clarke 2011). They are currently the subject of an investigation on ways to reduce OCS mortality in the FAD-associated purse seine fishery. Conservation and management measures have been implemented by several of the tuna RFMOs that ban the retention of this species (Clarke et al. 2015). No-retention policies can reduce targeted fishing effort but may have little effect on reducing total mortality in OCS bycatch. In an effort to build the stock, fisheries scientists have called for additional research on the reproductive biology of this species and for tagging studies to gain a better understanding of the basic ecology and stock structure (Rice and Harley 2012). OCS are a highly migratory species, but few studies have focused on OCS movements to identify any migratory patterns. However, a recent paper documented evidence of residency and philopatry on OCS tagged in the Atlantic Ocean (Howey-Jordan et al. 2013). OCS are temporally resident at anchored FADs and found in association with tuna schools and pilot whales around Hawai'i. As such, FADs are subject to interactions with local troll fishermen and are known to cause high rates of depredation in troll-captured fish. These interactions are often fatal for the sharks because local fishermen are known to kill sharks. Therefore, the primary objective of this study is to inform conservation engineering efforts to reduce OCS mortality in the FAD-associated purse seine fishery. By identifying potential spatial mitigation factors present in their behavior at anchored FADs in Hawai'i, and by working with local fishermen to elucidate movement behavior times and areas of high depredation rates in the Kona-based troll fishery, the researchers hope to come up with practical solutions to reduce OCS-fishery interactions.

4.3 Post-Release Survival

Alaska Fisheries Science Center (AFSC)
Survival of Pacific Sleeper Sharks Post-Release in the Trawl Fisheries of the Bering Sea
This project aimed to explore the survival of Pacific sleeper sharks released during commercial fishing operations. Previous tagging research on Pacific sleeper sharks suggested high survival, post-release. The AFSC stock assessments assume a 100 percent discard mortality rate and this project was developed to determine if a more detailed examination of discard mortality was warranted. Ten survivorship tags (i.e., wildlife computers) were deployed during the fall, B season pollock trawl fishing in the Bering Sea. All tags suggested that the released fish were

either dead upon release or died shortly after (Trubizio in prep.). All of the tagged Pacific sleeper sharks were less than 1.5 meters long and were subject to up to 8 hours in holding tanks and released via discard chutes. Larger sharks were prevented from entering the holding tanks and are not available to observers. However, reports from industry suggest they are left on the deck for long periods before being discarded, suggesting high mortality.

Discard Mortality of Spiny Dogfish

AFS is collaborating with a graduate student at the University of Florida to examine the discard mortality of longline-caught spiny dogfish (Figure 4.3.1). Samples for stress physiology have been collected since 2016. PSATs were deployed on 13 of the sampled spiny dogfish in 2017 and 2018. Sampled fish were handled similarly to commercial fishing operations to simulate typical stress during capture. This often resulted in broken jaws. Early results suggested that the fish are highly stressed based on blood physiology but tag returns suggest that many survived a year or more. Analyses for this study are ongoing.

Figure 4.3.1. University of Florida graduate student, Rachael Cashman, and an AFSC scientist performing a blood draw on spiny dogfish during the AFSC groundfish longline survey. Right: spiny dogfish tagged and ready for release. Photos: AFSC-NMFS.

__**Northeast Fisheries Science Center (NEFSC)**__

Post-Release Recovery and Survivorship Studies in Sharks—Physiological Effects of Capture Stress

This ongoing cooperative research is directed toward coastal and pelagic shark species caught on recreational and commercial fishing gear. This work is collaborative with researchers from MADMF and many other state and academic institutions. These studies use blood and muscle sampling methods, including hematocrit, plasma ion levels, and red blood cell counts, coupled with acoustic tracking and pop-up satellite archival tag (PSAT) data to quantify the magnitude and impacts of capture stress. The primary objectives of the new technology tag studies are to examine shark migratory routes, potential nursery areas, swimming behavior, and environmental associations. Secondarily, these studies can assess the physiological effects of capture stress and post-release recovery in commercially and recreationally captured sharks. These electronic tagging studies include: 1) acoustic tagging and bottom monitoring studies for coastal shark species in Delaware Bay and the USVI as part of COASTSPAN; 2) tracking of porbeagle sharks with acoustic and PSATs in conjunction with the MADMF; 3) placing real-time satellite (SPOT) and PSAT tags on shortfin makos and blue sharks in the Northeast United States and on their pelagic nursery grounds; 4) placing PSAT tags on sand tigers in Delaware Bay and Plymouth Bay (Massachusetts) as part of a fishery-independent survey and habitat study; and 5) placing PSAT and SPOT tags on dusky and tiger sharks in conjunction with Monterey Bay Aquarium, University of California Long Beach, and MADMF. Integration of data from new-technology tags and conventional tags from the CSTP is necessary to provide a comprehensive picture of the movements and migrations of sharks along with possible reasons for the use of particular migratory routes, swimming behavior, and environmental associations. In addition, the results of this research will be critical to evaluate the extensive current catch-and-release management strategies for sharks. From 2018 and 2019, electronic tags were placed on common threshers, shortfin makos, and porbeagles as part of ongoing post-release recovery and migration studies.

Post-Release Mortality of Dusky Sharks Captured in the U.S. Pelagic Longline Fishery

In 2020, NEFSC staff worked in cooperation with staff from the University of New England, the University of Maine, and the SEFSC to publish a paper on dusky shark post-release mortality from interactions with the U.S. pelagic longline fishery (Sulikowski et al. 2022). The latest stock assessment for the dusky shark (*Carcharhinus obscurus*) in the western North Atlantic indicates the population is overfished and experiencing overfishing. Dusky shark retention in U.S. fisheries is prohibited, but they are still caught as bycatch in multiple fisheries, including the pelagic longline fishery. Post-release mortality rates were estimated for dusky sharks captured by the U.S. pelagic longline fleet in the western North Atlantic Ocean utilizing pop-up satellite archival transmitting tags. One hundred twenty-three dusky sharks were captured on commercial pelagic longline gear and time on the hook, based on hook timer data, ranged from 0.8 to 8.1 h (4.3 ± 0.28 h). No at-vessel mortality was observed for any dusky sharks in this study. Prior to release, 50 tags were attached to dusky sharks (females n = 12, 209 ± 8 cm FL; males n = 4, 198 ± 7 cm FL; unknown sex n = 34, 214 ± 7 cm FL) to assess post-release mortality rates during a 30-day attachment period. Forty-three of the 50 deployed tags reported data with deployment times ranging from 1 to 28 days (11.2 ± 9.8 days). Four dusky sharks were in poor condition at release and two individuals suffered post-release mortality, which occurred within 2 hours after release. Total mortality rate (at-vessel and post-release mortalities combined) in the current study was 5.1 percent, far below estimates reported for bottom longline gear (~97%), and reinforces the need to evaluate post-release mortality by species, season, and gear type.

Southeast Fisheries Science Center (SEFSC)

Connecting Post-Release Mortality to the Physiological Stress Response of Large Coastal Sharks in a Commercial Longline Fishery

SEFSC and scientists from a host of institutions used paired blood-stress physiology with animal-borne accelerometers to quantify post-release mortality (PRM) rates of sharks caught in a commercial bottom longline fishery. Blood was sampled from the same individuals that were tagged, providing direct correlation between stress physiology and animal fate for sandbar (*Carcharhinus plumbeus*, N = 130), blacktip (*C. limbatus*, N = 105), tiger (*Galeocerdo cuvier*, N = 52), spinner (*C. brevipinna*, N = 14), and bull sharks (*C. leucas*, N = 14). PRM rates ranged from 2 percent and 3 percent PRM in tiger and sandbar sharks to 42 percent and 71 percent PRM in blacktip and spinner sharks, respectively. Decision trees based on blood values predicted mortality with >67 percent accuracy in blacktip and spinner sharks, and >99 percent accuracy in sandbar sharks. Ninety percent of PRM occurred within 5 hours after release and 59 percent within 2 hours. Blood physiology indicated that PRM was primarily associated with acidosis and increases in plasma potassium levels. Total fishing mortality reached 62 percent for blacktip and 89 percent for spinner sharks, which may be under-estimates given that some soak times were shortened to focus on PRM. Findings suggest that no-take regulations may be beneficial for sandbar, tiger, and bull sharks, but less effective for more susceptible species such as blacktip and spinner sharks (Whitney et al. 2021).

Capture Times and Hooking Mortality of Sharks Caught on Bottom Longlines

NMFS is mandated by the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to implement effective annual catch limits and accountability measures to prevent overfishing. These requirements compel further research into alternative fishing practices that could reduce mortality of sharks (class Chondrichthyes) and allow fishermen to release unwanted sharks to the water alive, while still effectively catching targeted species. We used hook timers and temperature–depth recorders aboard contracted vessels and participants in the NMFS Shark Research Fishery to collect hooking time and time-on-the-line data for 10 species of sharks that were commonly encountered in the fishery. A subset of standardized fishing sets compared the most popular circle hook and J-hook models. Over 60 percent of sharks were hooked within 4 hours of hook soak time. The fastest to bite the hook was the Atlantic sharpnose shark and the slowest was the dusky shark. Shark resilience to time on the longline varied among species, with sandbar sharks exhibiting the most resilience and Atlantic sharpnose sharks the least. Shorter set soak times, approximately 2 hours, would still maximize catch, while minimizing at-vessel mortality. The most frequently used circle hook model did not significantly reduce at-vessel mortality over large J-style hooks. The recent circle hook requirement will have little effect for fishermen who previously used 12/0 J-hooks, but it may be beneficial by preventing the use of smaller J-hooks that are more likely to cause at-vessel mortality (Gulak and Carlson 2021).

Determination of Alternate Fishing Practices to Reduce Mortality of Prohibited Dusky Shark in Commercial Longline Fisheries

SEFSC continues to conduct a series of fishing experiments using commercial longline fishing vessels to investigate methods to reduce at-vessel mortality of dusky sharks, a prohibited species. A study was published (Kroetz et al. 2021) that used archival satellite telemetry to provide preliminary information on vertical and horizontal movements of immature dusky sharks in the western North Atlantic Ocean. Dusky sharks may be more vulnerable to incidental capture in the pelagic longline fishery due to the high fishing effort, larger areas of horizontal overlap, and greater percentage of vertical overlap. This information will inform mitigation measures of commercial longline fisheries, which can work toward population rebuilding of the species.

Shortfin Mako Shark Post-Release Mortality in the Atlantic Ocean

A study on quantifying and reducing post-release mortality for shortfin mako sharks discarded in the commercial pelagic longline fishery was funded by the Bycatch Reduction Engineering Program. This study is being conducted by researchers from the University of Missouri, Arizona

State University, and the SEFSC. To date, pop-up satellite archival tags were attached to 44 shortfin mako sharks prior to release from pelagic longline gear to evaluate extended (~28 days) post-release mortality. Biological, physical, and capture variables—including soak time, size, sex, hook location, water temperature, tissue damage, and gangion length—were recorded at the time of release. After accounting for an initial batch of defective tags that were deployed in 2021 (n = 19) of which half were never reported and none of which could be used to study post-release mortality because there was no depth release, we have deployed an additional 25 tags, 22 of which have reported data. Three sharks died before the end of the 28-day period, and three tags detached prematurely. From these data, we derived a known-fate model-based estimate of post-release survival probability to 28 days of 0.85 (95 percent confidence interval: 0.62-0.95).

<u>Pacific Islands Fisheries Science Center (PIFSC)</u>

The Effects of Handling on Post-Release Mortality Rates of Shark Bycatch in Longline Fisheries: Identifying "Best Practices" and Improving Stock Assessments

Banning or retention measures are in effect in the Western and Central Pacific Ocean (WCPO) for some shark species. However, these measures may not have the intended consequence of reducing mortality since many sharks at haulback and/or during the handling procedures may incur physiological and/or physical damage that results in mortality. It is well understood that there is an urgent need to estimate levels of unobservable mortality and to account for these losses in population assessments. Additionally, there is an urgent need to adopt measures to mitigate sources of unobservable mortality, such as through identifying best handling and release practices. It is well established that three main factors affect shark bycatch mortality rates in longline fisheries: 1) physiological sensitivity to stress, where impacts are species-specific, 2) the amount of time an animal spends struggling on the line, and 3) shark handling methods used to release/remove sharks from fishing gear. Many studies have identified which species are most sensitive to capture stress through physiological investigations and by quantifying at-vessel mortality rates (e.g., Beerkircher et al. 2002; Marshall et al. 2012). However, the effects that shark handling and at-vessel condition have on post-release mortality and/or survival rates have never been quantified for commercial tuna longline vessels.

This study is an investigation into the effects of standard shark bycatch handling practices utilized in the Hawai'i and American Samoa tuna longline fisheries on the post-release survival of discarded blue, bigeye thresher, oceanic whitetip, and silky sharks that are in good condition at haulback and to assess the post-release fate of sharks that are alive but in compromised conditions at haulback and to understand the effects of trailing gear on sharks released by cutting the line. These additional data points will help generate a more accurate picture of the fate of sharks that are released “alive” but may have incurred injuries or exhausted themselves while fighting on the line. These data will also identify which handling practices have the largest effect on post-release fate and we will use these data to generate quantitative estimates of delayed or post-release mortality rates for discarded sharks. In addition, by identifying appropriate shark handling practices that maximize post-release survival probabilities, we can then produce guidelines that can be easily implemented into current practices.

To quantify post-release mortality rates of sharks discarded in Hawai'i and American Samoa longline fisheries and to identify handling and release methods that enhance survivorship, PIFSC scientists initiated research by improving the quality and quantity of data that were collected by fisheries observers from the Pacific Islands Regional Observer Program (PIROP). Observers were trained on assessments of an animal's condition and handling, and further trained in the attachment of satellite telemetry devices. Research, including codes and satellite tagging, began during summer 2015 and final definitions were adopted and implemented into the program in December 2016. To quantify post-release mortality rates of incidental blue, bigeye thresher, oceanic whitetip, and silky sharks captured in the Hawai'i and American Samoa tuna longline fisheries, PIROP observers were trained to tag sharks captured during normal fishing operations.

The Shark Focus Study component resulted in information on at-vessel and release conditions and handling or release methods of 18,636 elasmobranchs. This research showed that condition had declined significantly for sharks from capture to release. Additionally, some handling methods may negatively affect condition at release, and thus post-release survivorship, more than other handling methods. The handling and damage data recorded by trained observers shows that most sharks (72.65 percent) are released by cutting the line. In the Hawai'i tuna fishery this means that most sharks are released with an average of 8.51 meters of trailing gear (0.0–17.2 m). This includes a stainless-steel hook, a braided wire leader, a 45-gram weighted swivel, and then monofilament to the tuna clip.

Observers based in American Samoa and Hawai'i have deployed 144 pop-up archival satellite tags (PATs) and 12 mini-PATs. Results showed that survivorship to 30 days is relatively high for sharks captured in good condition. Post-release survival rates are higher for injured animals than expected and tagging of oceanic whitetips is still ongoing, as encountering oceanic whitetips that are alive but injured is extremely rare. The results of the long-term tag deployments (mini-PATs) showed that delayed mortality rates are quite high and it appears that mortality, potentially due to the trailing gear, may occur outside the 30-day window of the deployment period of the survivorship PATs used in the rest of this study. This detail may have broad implications for the determinations regarding post-release mortality rates derived from the survivorship tags used in earlier components of this study. PIFSC is beginning to collect information on shark bycatch following implementation of a rule prohibiting the use of wire leaders in 2022. However, no analysis has been conducted yet.

Section 5: Additional Information About Ongoing NOAA Shark Research

Alaska Fisheries Science Center (AFSC, Auke Bay Laboratory)

Stock Assessments of Shark Species Subject to Incidental Harvest in Alaskan Waters

Species currently assessed in Alaskan waters include Pacific sleeper sharks (*Somniosus pacificus*), spiny dogfish (*Squalus suckley*i, note that this was formerly referred to as *S. acanthias*; see Ebert et al. 2010 for details of the species description), and salmon sharks (*Lamna ditropis*). These are the shark species most commonly encountered as incidental catch in Alaskan waters. In both the GOA and BSAI fishery management plans, sharks are managed as a complex. There are no directed fisheries for sharks in either area and directed fishing for all sharks is prohibited. Most shark species are considered Tier 6, where annual catch limits are based on estimated historical incidental catch in the groundfish fisheries. In the GOA, spiny dogfish is currently Tier 5, with annual catch limits based on biomass and natural mortality. Biomass is currently estimated from the NMFS fishery-independent bottom trawl survey; however, it is thought that other surveys may better reflect the populations. Efforts are underway to develop a model to estimate biomass for spiny dogfish that would include data such as the NMFS and International Pacific Halibut Commission annual longline surveys. Stock assessments are summarized biennially in even years in the NPFMCs Stock Assessment and Fishery Evaluation Report (see Tribuzio et al. 2022).

The AFSC conducts a variety of surveys that provide data for the stock assessments. In the GOA there is a biennial trawl and annual longline survey. The trawl survey provides an estimate of biomass for spiny dogfish and the longline survey provides a relative index of abundance for spiny dogfish and Pacific sleeper sharks. The trawl surveys in the BSAI do not sample sharks well and are not used in the stock assessment. The International Pacific Halibut Commission (IPHC) also conducts an annual longline survey in the GOA and BSAI, which samples a large number of stations each year and provides a relative index of abundance for both spiny dogfish and Pacific sleeper shark. The IPHC survey likely provides the most informative index because it samples both species of sharks across the full range of the survey and regularly at most of the stations.

Stock assessment and research efforts at the Alaska Fisheries Science Center’s Auke Bay Laboratory (not described above) are focused on:

- Improving stock assessments and collection of data to support stock assessments of shark species subject to incidental harvest in waters off Alaska.
- Migration and habitat use of Pacific sleeper sharks.
- Migration and habitat use of spiny dogfish.
- Development and validation of improved ageing methods for Pacific sleeper sharks.

- Investigations into life history characteristics and population demography.
- Examining the accuracy of catch estimates in weight for large, hard-to-weigh sharks, and exploring managing large sharks by numbers instead of weight.

<u>Northwest Fisheries Science Center (NWFSC)</u>

Monitoring and Assessment Activities

The NWFSC conducts and supports several activities addressing the monitoring and assessment of sharks along the U.S. West Coast and in Puget Sound. The PacFIN serves as a clearinghouse for commercial landings data, including sharks. In addition, the At-Sea Hake and West Coast Groundfish observer programs collect data on shark species caught on vessels selected for observer coverage.

The NWFSC conducts annual trawl surveys of the West Coast, designed primarily to acquire abundance data for West Coast groundfish stocks. The tonnages of all shark species collected during these surveys are documented. In addition, the survey program has conducted numerous special projects in recent years to help researchers acquire data and samples necessary for research on various shark species.

In addition to these monitoring activities, the NWFSC conducted the first assessment for longnose skate in 2007. This assessment was reviewed during the 2007 stock assessment review (STAR) process, and was adopted by the Pacific Fishery Management Council for use in management. The NWFSC last conducted an assessment of spiny dogfish along the Pacific coast of the United States in 2011 (see section 2.3 of the 2014 Shark Finning Report to Congress).

<u>Southwest Fisheries Science Center (SWFSC)</u>

Electronic Tagging Data Analyses

As mentioned in section 4, SWFSC scientists continue to analyze the electronic tagging data from a range of species. These analyses are detailed below and most will result in peer-reviewed publications.

Electronic Tagging: Blue Shark

The SWFSC has been deploying satellite tags on blue sharks since 2002 to examine movements and habitat use in the eastern North Pacific. To date, a total of 100 sharks (51 males and 49 females) have been tagged with some combination of SPOT (n=95) and/or PSAT tags (n=60), with 55 sharks carrying both tag types. The majority of sharks were tagged in the SCB, with a few additional deployments off Baja California Sur, Mexico, or southwest Canada. Satellite tag deployment durations for both tag types are substantially shorter than for mako sharks. For the 37 PSAT tags that provided data, only eight remained attached until the programmed pop-up date and the average deployment duration was 115 days. The mean SPOT tag track duration was 88 days; however, six tags transmitted for 337 days or more, allowing for an examination of seasonal patterns. Analyses of size and sex specific patterns reveal that mature males (based on size) returned to the California Current in subsequent years. Mature females, in contrast, swam to the North Equatorial Current where they remained until their tags stopped transmitting. Results have been presented at a number of meetings and analyses are ongoing.

<u>Pacific Islands Fisheries Science Center (PIFSC)</u>

Fishery Data Collection

Market data from the PIFSC shoreside sampling program contain detailed biological and economic information on sharks in the Hawai'i longline fishery dating from 1987. These data are primarily collected from fish dealers who are required to submit sales/transaction data to the State of Hawai'i. The Western Pacific Fishery Information Network (WPacFIN) is a federal–state partnership collecting, processing, analyzing, and sharing fisheries data on sharks and other species from U.S. island territories and states in the Central and Western Pacific (Hamm et al. 2011). The WPacFIN program has assisted other U.S. islands' fisheries agencies in American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands in modifying their data collection procedures to include bycatch information. These modifications have improved the documentation of shark interactions with fishing gear. Shark catches in the Hawai'i longline fishery have been monitored by a logbook program since 1990 and by an observer program since 1994. American Samoa has had a federal logbook program since 1996 and an observer program since 2006. Longline landings of sharks are reported by the PIFSC Fisheries Research and Monitoring Division's (FRMD) International Fisheries Program (IFP).

Insular Shark Surveys

Densities of insular sharks have been estimated at most of the U.S. island possessions within the Tropical Central, Northern, and Equatorial Pacific on annual, biennial, or triennial surveys conducted by the PIFSC Ecosystem Science Division (ESD) since 2000.
These estimates include surveys of:

- 12 major shallow reefs in the Northwestern Hawai'ian Islands (2000, 2001, 2002, 2003, 2004, 2006, 2008, 2010, 2013, 2016, 2017).
- The Main Hawai'ian Islands (2005, 2006, 2008, 2010, 2013, 2015, 2016, 2019).
- The Pacific Remote Island Areas of Howland and Baker in the U.S. Phoenix Islands and Jarvis Island, and Palmyra and Kingman Atolls in the U.S. Line Islands (2000, 2001, 2002, 2004, 2006, 2008, 2010, 2012, 2015, 2018).
- American Samoa, including Rose Atoll and Swains Island (2002, 2004, 2006, 2008, 2010, 2012, 2015, 2016, 2018).
- Guam and the Commonwealth of the Northern Mariana Islands (2003, 2005, 2007, 2009, 2011, 2014, 2017, 2022), Johnston Atoll (2004, 2006, 2008, 2010, 2012, 2015), and Wake Atoll (2005, 2007, 2009, 2011, 2012, 2015, 2017).

Table 5.1.1 Shark species observed in PIFSC-ESD Reef Assessment and Monitoring Program (RAMP) surveys around U.S. Pacific Islands.

Shark species observed	
Common Name	Species
Grey reef shark	*Carcharhinus amblyrhynchos*
Galapagos shark	*Carcharhinus galapagensis*
Whitetip reef shark	*Triaenodon obesus*
Blacktip reef shark	*Carcharhinus melanopterus*
Silvertip shark	*Carcharhinus albimarginatus*
Sicklefin lemon shark	*Negaprion acutidens*
Tiger shark	*Galeocerdo cuvier*
Tawny nurse shark	*Nebrius ferrugineus*

Whale shark	*Rhincodon typus*
Scalloped hammerhead shark	*Sphyrna lewini*
Great hammerhead shark	*Sphyrna mokarran*
Zebra shark	*Stegostoma varium*

Although 12 species of shark have been observed during RAMP surveys (see Table 5.1.1), only four species are typically recorded in sufficient frequency by towed divers to allow meaningful statistical analyses: grey reef shark (*Carcharhinus amblyrhynchos*), Galapagos shark (*Carcharhinus galapagensis*), whitetip reef shark (*Triaenodon obesus*), and blacktip reef shark (*Carcharhinus melanopterus*). Analyses show a highly significant negative relationship between grey reef and Galapagos shark densities and proximity to human population centers (e.g., proxy for potential fishing pressure and other human impacts). Average combined numerical density for these two species near population centers is less than 10 percent of densities recorded at the most isolated islands (e.g., no human population, very low present or historical fishing pressure or other human activity). Even around islands with no human habitation, but within reach of populated areas, grey reef and Galapagos shark densities are only between 15 and 40 percent of the population densities around the most isolated near-pristine reefs. Patterns in whitetip and blacktip reef shark numbers are similar, but less dramatic.

Because all RAMP shark data were gathered by SCUBA divers, surveys were limited by safe diving practices to reef areas of 30 meters or shallower, which is the upper end of reef sharks' potential depth distribution. In addition, surveys by SCUBA divers are potentially biased by acquired behavioral differences of sharks in the presence of divers between isolated and fished locations. For those reasons, diver-independent assessments of shark populations over wider depth ranges—as are possible by deploying remote video systems—would likely yield stronger information on the relative abundance of reef sharks. As of 2016, NOAA ESD have conducted a small number of baited remote video (BRUV) surveys at locations in Hawai'i, Tutuila, and Guam, at depths down to 100 m. Only data from Hawai'i have been fully analyzed to date, but results from those surveys confirm a general pattern for substantial depletion of reef sharks in the populated MHI compared to the isolated NWMI—shark densities in MHWI BRUV surveys being approximately five times higher in the NWHI (Asher et al. 2017).

Insular Shark Population Model

PIFSC scientists study the status of reef shark populations in the central-western Pacific Ocean. During PIFSC coral reef assessment and monitoring surveys conducted between 2004 and 2010, shark observations were recorded around 46 individual U.S. islands, atolls, and banks. PIFSC scientists analyzed shark count data from 1,607 towed-diver surveys conducted on fore reefs (seaward slope of a reef) using techniques developed specifically to survey large-bodied species of reef fishes.

The shark count data were used to build a computer model capable of explaining observed reef shark abundances at various reefs by examining the effects of variables related to human impacts, oceanic productivity, sea surface temperature, and reef habitat physical complexity. This model was used to predict reef shark densities in the absence of humans (i.e., baseline or pristine abundance) and found that current reef shark numbers around populated islands in Hawai'i, the Mariana Archipelago, and American Samoa are down to about 3 to 10 percent of their baseline values (Figure 5.1.5). These results show the extent of the detrimental effect of human activities on reef shark populations. However, the exact cause of the decline is not known. The likely causes are probably related to prey population depletion (i.e., reef fish biomass around populated islands is about 50 to 80 percent lower than on pristine reefs) and direct removal through fishing (bycatch, recreational, or targeted) (Nadon et al. 2012).

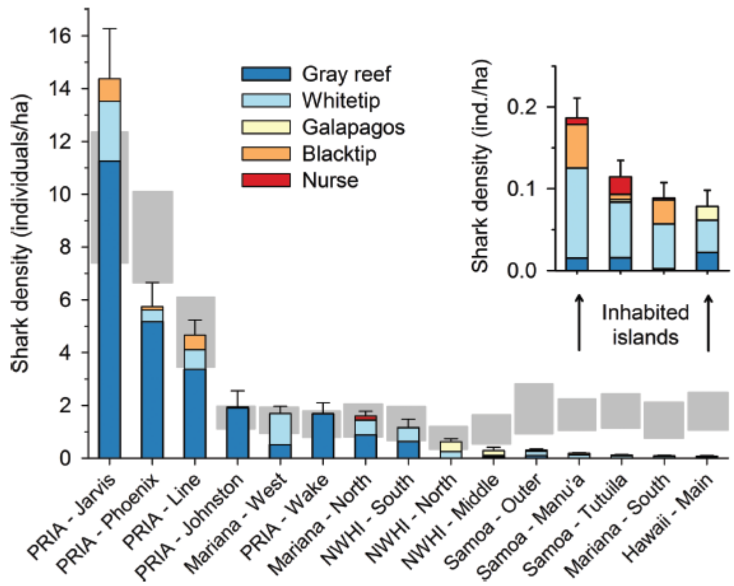

Figure 5.1.1: Mean (SE) observed densities of reef sharks in the U.S. Pacific. Colors represent actual densities; gray rectangles represent model predictions in the absence of humans.

Mitigation of Shark Predation on Hawaiian Monk Seal Pups at French Frigate Shoals

Shark predation on Hawaiian monk seal pups (*Monachus schauinslandi*) has become unusually common at one breeding site, French Frigate Shoals (FFS) in the Northwestern Hawaiian Islands (NWHI). Since 1997, NMFS has frequently observed Galapagos sharks (*Carcharhinus galapagensis*) patrolling and attacking monk seal pups. Tiger sharks (*Galeorcerdo cuvier*) also prey on monk seals and are abundant at FFS; however, tiger sharks have not been observed to attack pups (Gobush 2010, unpublished data). For these reasons, monitoring and mitigation efforts at FFS continue to be focused on Galapagos sharks. Shark tagging studies at FFS indicate that, although Galapagos sharks are the most abundant shark species, they generally prefer deeper water and only a small fraction of the population, equating to a few tens of individuals, likely frequents the shallow areas around monk seal pupping islets (Dale et al. 2011).

Reducing shark predation on pups at FFS is one of several key activities identified in the Hawaiian Monk Seal Recovery Plan (NMFS 2007). Since 2000, NMFS has attempted to mitigate shark predation through harassment and culling of sharks, shark deterrents, and translocation of weaned pups to islets in the atoll with low incidence of shark attacks (Baker et al. 2011; Gobush 2010). NMFS has implemented an ongoing highly selective shark removal project to mitigate predation on monk seal pups beginning in 2000, with the exception of 2008–2009 when deterrents were tested. Nineteen Galapagos sharks frequenting the nearshore areas of pupping islets have been lethally removed through 2022. In 2009, the number of shark sightings and predation incidents at two pupping islets did not differ significantly between the control and two experimental treatments: (1) acoustic playback and a moored boat, and (2) continuous human presence, versus a control (Gobush and Farry 2012). No sharks were removed at FFS during the 2016 season (after 72.75 fishing hours).

Electronic Tagging Studies and Movement Patterns

PIFSC scientists are using acoustic, archival, and pop-up satellite archival tags (PSATs) to study vertical and horizontal movement patterns in commercially and ecologically important tuna, billfish, and shark species, as well as sea turtles. The work is part of a larger effort to determine the relationship of oceanographic conditions to fish and sea turtle behavior patterns. This information is intended for incorporation into population assessments, addressing fisheries interactions and allocation issues, as well as improving the overall management and conservation of commercially and recreationally important tuna and billfish species, sharks, and sea turtles. PIFSC is finishing manuscripts detailing the movements of pelagic sharks in relation to oceanographic conditions.

Physiological Investigations of Sharks Captured in Tropical Tuna Purse Seine Fisheries

The tropical tuna purse seine fishery and other commercial fisheries have high rates of incidental shark capture. In the western central Pacific Ocean (WCPO) purse seine fishery, juvenile silky sharks comprise greater than 90 percent of the shark bycatch. These sharks are of low market value and are discarded at sea. While discarded sharks are often released alive, several studies have shown that they may have sustained injuries (both physical trauma from capture and handling and physiological disturbances) that can have immediate or delayed effects that result in mortality. Blood-borne biochemical indicators of stress are increasingly being used to elucidate the post-release condition of elasmobranchs released after being captured in commercial fisheries. To identify the physiological perturbations that occur in silky shark bycatch in a purse seine, PIFSC, ISSF, and University of Hawai'i scientists quantified several blood-borne indices of stress including pH, lactate, glucose, adrenaline, blood gasses, electrolytes and osmolality from animals sampled during every stage of the fishing operation, including sharks that were sampled with a minimal amount of handling prior to interaction with purse seine fishing gear. The results show increasing lactate concentrations and decreases in pH as the fishing procedure progressed. This suggests that metabolic acidosis takes place following prolonged exposure to netting procedures. The levels of the potassium and calcium were higher in moribund sharks landed later in the fishing operations, suggesting intracellular leakage. Overall, irreparable physiological damage (and ultimately mortality) occurred once the sharks had been confined in the sack portion of the net. Thus, sharks discarded after purse seine capture have a low probability of post-release survival.

Barbless Hooks and De-hookers

Hawai'i longline fisheries are required to carry and use dehookers for removing hooks from sea turtles. These dehookers can also be used to remove external hooks and ingested hooks from the mouth and upper digestive tract of fish, and could improve post-release survival and condition of released sharks. Sharks are generally released from the gear by one of the following methods: (1) severing the branch line, (2) hauling the shark to the vessel to slice the hook free, or (3) dragging the shark from the stern until the hook pulls free. Fishermen are encouraged to use dehooking devices to minimize trauma and stress of bycatch by reducing handling time and to mitigate post-hooking mortality.

Testing of the dehookers on sharks during research cruises has indicated that removal of circle hooks from shark jaws with the dehookers can be quite difficult. PIFSC is looking into the feasibility of barbless circle hooks for use on longlines, which would make it easier to dehook unwanted catch with less harm. Preliminary research in the Hawai'i shore fishery has indicated that barbless circle hooks catch as much as barbed hooks, but the situation could be different with more passive gear such as longlines, where bait must soak unattended for much of the day and fish have an extended period in which to try to throw the hook. Initial results from very limited longline testing of barbless hooks on research cruises in American Samoa, and in collaboration with NEFSC, indicated a substantial increase in bait loss using barbless hooks. Subsequent testing used rubber retainers to prevent bait loss. Summary information from before and after the use of bait retainers showed no difference between barbed and barbless hooks in the catch and catch rates of targeted species and sharks, although catches have so far been too few to provide much statistical power. Also in this study, the efficacy of the pigtail dehooker (the device required by U.S. regulations for releasing sea turtles) showed a 67 percent success rate in dehooking and releasing live sharks on barbless hooks, compared to a 0 percent success rate when used with sharks caught on barbed hooks.

Post-Release Survival and Biochemical Profiling

Successful management strategies in both sport and commercial fisheries require information about long-term survival of released fish. Catch-and-release sport fishing and non-retention of commercially caught fish are justifiable management options only if there is a reasonable likelihood that released fish will survive for long periods. All recreational anglers and commercial fisherman who practice catch-and-release fishing hope the released fish will survive, but it is often not known what proportion of released fish will survive. Many factors, like fish size, water temperature, fight time, and fishing gear could influence survival.

Post-release survival is typically estimated using tagging programs. Historically, large-scale conventional tagging programs were used. These programs yielded low return rates, consistent with a high post-release mortality. For example, in a 30-year study of Atlantic blue sharks, only 5 percent of tags were recovered. Short-duration studies using ultrasonic telemetry have shown that large pelagic fish usually survive for at least 24 to 48 hours following release from sport fishing or longline gear. PIFSC researchers and collaborators from other agencies, academia, and industry have been developing alternative tools to study longer-term post-release mortality. Whereas tagging studies assess how many fish survive, new approaches are being used to understand why fish die. A set of diagnostic tools is being developed to assess the biochemical and physiological status of fish captured on various gear. These diagnostics are being examined in relation to survival data obtained from a comprehensive PSAT program. Once established as an indicator of survival probability, such biochemical and physiological profiling could provide an alternative means of assessing consequences of fishery release practices.

Post-Release Survival of Juvenile Silky Sharks Captured in a Tropical Tuna Purse Seine Fishery

Juvenile silky sharks (*Carcharhinus falciformis*) comprise the largest component of the incidental elasmobranch catch taken in tropical tuna purse seine fisheries. During a 2015 chartered cruise on board a tuna purse seine vessel conducting typical fishing operations, we investigated the post-release survival and rates of interaction with fishing gear of incidentally captured silky sharks using a combination of satellite linked pop-up tags and blood chemistry analysis. To identify trends in survival probability and the point in the fishing interaction when sharks sustain the injuries that lead to mortality, sharks were sampled during every stage of the fishing procedure. The total mortality rates of silky sharks captured in purse seine gear was found to exceed 84 percent. We found survival to precipitously decline once the silky sharks had been confined in the sack portion of the net just prior to loading. Additionally, shark interactions recorded by the scientists were markedly higher than those recorded by vessel officers and the fishery observer. Future efforts to reduce the impact of purse seine fishing on silky shark populations should be focused on avoidance or releasing sharks while they are still free swimming.

Assessing Shark Bycatch Condition and the Effects of Discard Practices on Post-Release Survival Rates in the Hawai'i and American Samoa–Permitted Tuna Longline Fisheries

Sharks captured in commercial longline fisheries are typically discarded at sea, due to finning and no-retention management measures or low market values. The post-release fate of these sharks is unobserved and may be a large source of cryptic mortality for some populations. The three main factors that have the largest effect on post-release survivorship have been identified as 1) the underlying physiology of some species make them more vulnerable to effects of capture related stress; 2) the amount of time a shark spends struggling on the line; and 3) the handling and dispatch procedures that the fishermen use to remove an animal from the fishing gear. In this study initiated in 2016, PIFSC scientists are working with pelagic longline fishermen and observers in Hawai'i and American Samoa to tag blue, bigeye thresher, oceanic whitetip, and silky sharks that are captured and subsequently released from longline gear targeting tropical tunas with pop-off archival satellite tags. These tags validate post-release fate whereby quantitative estimates of post-release mortality rates can be generated. These data will also assist in the identification of best handling practices for discarding sharks from pelagic longline fishing gear to improve survivorship.

Southeast Fisheries Science Center (SEFSC)

Risk Assessment and Behavioral Ecology of Whale Sharks in the U.S. Gulf of Mexico

Scientists from the SEFSC in a collaborative effort with scientists from the University of Southern Mississippi, Blue Water Research Institute, and the Bureau of Ocean and Energy Management are conducting a risk assessment of whale sharks in and around energy operations in the northern Gulf of Mexico. This work will provide whale shark spatial and ecological behavioral data to understand and assess how their behavior and habitat use near energy operations affects their mortality risk. Fieldwork will be conducted primarily at Ewing Bank, a known whale shark aggregation site in the north-central Gulf of Mexico during the summer months of 2023–2024. Whale sharks will be fitted with satellite, acoustic, and accelerometry transmitters to examine both short- and long-term movements and behaviors. Vessel strike and gear entanglement risk models will be developed based on tag and automatic identification system (AIS) data. This effort will provide stakeholders with detailed information on the ship strike and gear entanglement risks to whale sharks in this region of the northern Gulf of Mexico.

Elasmobranch Feeding Ecology

The current Consolidated Atlantic HMS FMP gives little consideration to ecosystem function because there is little quantitative species-specific data on diet, competition, predator-prey interactions, and habitat requirements of sharks. Therefore, several studies are currently underway describing the diet and foraging ecology, habitat use, and predator-prey interactions of elasmobranchs in various communities.

Cooperative Gulf of Mexico States Shark Pupping and Nursery Survey (GULFSPAN) and Tagging Database

The SEFSC Shark Population Assessment Group manages and coordinates a survey of coastal bays and estuaries from Cedar Key, Florida, to Terrebonne Bay, Louisiana. Surveys identify the presence or absence of neonate (newborn) and juvenile sharks and attempt to quantify the relative importance of each area as it pertains to EFH. The group initiated a juvenile shark abundance index survey in 1996. The index is based on random, depth-stratified gillnet sets conducted throughout coastal bays and estuaries in coastal areas of the Gulf of Mexico from April to October. The species targeted in the index of abundance survey are juvenile sharks in the large and small coastal management groups. This index has been used as an input to various stock assessment models. A database containing tag and recapture information on elasmobranchs tagged by GULFSPAN participants currently includes more than 20,000 tagged animals from 1993 to present for both the Gulf of Mexico and U.S. southeast Atlantic Ocean.

Monitoring the Recovery of Smalltooth Sawfish (Pristis pectinata)

The smalltooth sawfish was listed as endangered under the ESA in 2003 and is the first marine fish and first elasmobranch to be listed under the ESA. Smalltooth sawfish were once common in the Gulf of Mexico and off the southeast coast of the United States. Decades of fishing pressure, both commercial and recreational, and habitat loss caused significant declines in the population during the second half of the 20th century. It is estimated that the species may be found in less than 20 percent of its former range worldwide. Currently, they exist primarily in southern Florida.

The completion of the Smalltooth Sawfish Recovery Plan in early 2009 (NMFS 2009) brought about a new phase of research and management for the U.S. population of smalltooth sawfish. Research and monitoring priorities identified in the Recovery Plan are now being implemented. Field work is underway to gather information on determining critical habitat and monitoring the population. This information will evaluate the effectiveness of protective and recovery measures and help determine if the population is rebounding or, at the very least, stabilizing.

One of the high-priority research areas is monitoring the number of juvenile sawfish in various regions throughout Florida to provide a baseline and time series of abundance. Successful recovery of sawfish populations requires juvenile recruitment success, and initiatives now strive to include the protection of areas used by juveniles in order to promote survivorship. Initial studies have identified sheltered, shallow, mangrove areas as nursery habitat with subsequent studies finding warmer water temperatures and variable salinity associated with the capture of juvenile sawfish. However, further refinement is required to fully predict the essential features smalltooth sawfish require as juveniles. Since 2009, a fishery-independent gillnet survey of smalltooth sawfish abundance has occurred along the section of coast from Marco Island to Florida Bay, Florida. Previous research has identified this region to be important for juvenile sawfish and encompasses the coast of the Ten Thousand Islands National Wildlife Refuge and Everglades National Park. Scientists from the SEFSC conduct quarterly surveys in this region (the TTI/EU of Critical Habitat) to capture, collect biological information from, tag, and then release smalltooth sawfish. Preliminary results over the course of the past 14 years indicate that juvenile sawfish exhibit a high degree of site fidelity (Kroetz et al. 2018, 2020). Genetic identification of recaptured individuals indicates that juvenile sawfish caught on the same mudflat, for example, are siblings or half-siblings and a single adult female sawfish may give birth on that same mudflat year after year (Smith et al. 2021).

Highly productive, protected habitats have been shown to serve as nurseries for many marine fishes. However, few studies quantitatively measure the biotic characteristics that often drive a habitat's function as a nursery. We used a combination of passive acoustic monitoring and quantification of biotic attributes to assess nursery habitat use of juvenile smalltooth sawfish. Acoustic receivers were deployed within Everglades National Park to quantify residency, identify the timing of emigration, and detect migration of juvenile smalltooth sawfish. Habitat features such as mangrove prop root density and limb overhang were quantified throughout the array to test for relationships between habitat attributes and smalltooth sawfish presence. Results indicated that sawfish moved quickly through deep water, narrow creeks, and rivers between shallow tidally influenced bays (Hollensead et al. 2018). A stepwise regression analysis of detections per hour indicated that sawfish had an increased probability of being encountered in areas with high prop root density. Observed residency within the nursery ranged from days to several months with some overwintering, which has never previously been documented (Hollensead et al. 2018). Given the large amount of individual variability of movement within the study area, we are continuing to acoustically tag and monitor all life-stages of smalltooth sawfish. Thirty acoustic receivers are deployed and actively maintained throughout the Ten Thousand Islands National Wildlife Refuge and Everglades National Park. Collaborative acoustic telemetry networks (e.g., iTAG and FACT) have established receiver arrays throughout the Gulf of Mexico and up the Atlantic coast of the United States, further expanding the area by which sawfish could be detected. Currently, 125 juvenile and adult smalltooth sawfish have been internally acoustically tagged with long-term (i.e., 4-5yr and 10yr) transmitters in southern Florida (Kroetz et al. 2023). We have a 79 percent success of detection and these sawfish have been detected on more than 400 receivers (e.g., iTAG and FACT arrays). The first set of analyses of this data revealed that larger male and female sawfish (>200 cm total length) seasonally migrate with individuals typically migrating north in the summer and south in the winter (Graham et al. 2021). Migrations occurred up both the east coast of Florida in the Gulf of Mexico as well as up the east coast of Florida in the Atlantic. A network analysis was used to identify significant areas based on how large sawfish moved through the study area, and the Florida Keys and Everglades National park had a high frequency of movements to and from these areas. Boca Grande, the Florida Keys, and Cape Canaveral were identified as the three most important regions for larger sawfish based on network metrics as a whole (Graham et al. 2021). The regions that were identified to have the least importance (i.e., time spent in these areas was very short) for large sawfish are Biscayne Bay and West Palm Beach. Identification of these high-use areas can lead to these regions being further evaluated as potential Critical Habitat for large juvenile and adult smalltooth sawfish, which has yet to be identified, as at the time of Critical Habitat designation in 2009, these areas were largely unknown. Additionally, these areas may be good starting points for establishing permanent receiver arrays that could be used to assess habitat use by this endangered species over predicted decadal scale recovery timelines. Monitoring habitat use of juvenile sawfish and analyses are ongoing, though preliminary analyses indicate that juvenile sawfish (<150 cm total length) move greater distances within their nursery habitat than previously documented (Kroetz et al. 2020).

Identifying habitat features and environmental requirements of threatened and endangered species is crucial to conservation and recovery efforts. Many species at risk of extinction have habitat ranges that have been significantly depressed, thus identifying specific habitat features that a species requires is necessary for the protection and preservation of critical habitats. Predictive spatial modeling is a powerful tool that can be used to identify important habitats for species that are at risk of extinction. We analyzed 10 years of data derived from a scientific gillnet survey to identify the most important environmental factors that influenced juvenile smalltooth sawfish occurrence. Combining habitat preferences with the environmental characteristics within a boosted regression tree model, we predicted occurrence throughout areas of known nursery use. The model output indicated that the presence and abundance of sawfish is predictable by mangrove density (i.e., red and black mangroves). Juvenile smalltooth sawfish were more likely to be found in locations with mangroves and in shallow (< 1 m) waters with temperatures >25°C and salinities >20 ppt. Limitations of data availability throughout southern Florida precluded the reliable spatial prediction of sawfish occurrence and abundance, bringing to light the need for high-resolution, nearshore (i.e., 1-3 m) abiotic data as well as vegetation/mangrove data. This study emphasizes the importance of identifying specific environmental features that can affect distribution and potential population recovery of a critically endangered species and the need to collect high-resolution data to achieve this goal. Spatial predictions can be used to formulate policy and should be taken into consideration when developing conservation and population recovery strategies.

Life History Studies of Elasmobranchs
Biological samples are obtained through research surveys and cruises, recreational and commercial fishermen, and collection by onboard observers on commercial fishing vessels. Age and growth rates and other life-history aspects of selected species are processed and analyzed following standard methodology. This information is vital as input to population models used to predict the productivity of the stocks and to ensure they are harvested at sustainable levels.

Long-Term Relative Abundance of Tiger Sharks
Scientists from SEFSC and Bimini Biological Laboratory investigated the relative abundance and demographics of tiger sharks Galeocerdo cuvier caught in a fishery-independent survey near Bimini, The Bahamas, from 1984 to 2019 to assess relative abundance trends following the banning of longline fishing in 1993 and the subsequent establishment of the shark sanctuary. To contextualize the relative abundance trends near Bimini, the authors compared this to the relative abundance of tiger sharks in a fishery-dependent survey from the southeastern United States, conducted from 1994 to 2019. The data of this study suggest that local abundance of tiger sharks has been stable near Bimini since the 1980s, including after the ban of longline fishing and the implementation of the shark sanctuary. In comparison, the abundance near the U.S. southeast has slowly increased in the past decade, following potential declines in the decade preceding the U.S. Shark Management Plan. The results of this study provide some optimism that current conservation efforts in The Bahamas have been effective to maintain local tiger shark abundance

within the protected area. In addition, current fisheries management in the southeastern United States is
allowing this species to recover within those waters.

Genetic Analysis of Shortfin Mako in the Atlantic Ocean
The main goal of this study, led by a Japanese colleague, was to investigate the genetic stock structure of the Atlantic shortfin mako using mitochondrial and microsatellite DNA of specimens collected across the entire Atlantic Ocean. The mitochondrial analyses conducted under this project indicated the differentiation of populations in the northern, southwestern, and south central and southeastern areas, which supports current stock structure hypotheses of Atlantic shortfin makos, and also suggested the possibility of multiple stocks within the South Atlantic; however, no significant genetic structuring was found based on the microsatellite analyses. Additional analyses to investigate the fine-scale genetic structure, especially in the North Atlantic, were conducted in 2017 based on tissues collected through collaboration with members of the SSG from the entire Atlantic. Tissues from 54 individuals were collected from the Caribbean Sea, Mediterranean, tropical Atlantic Ocean, and Uruguay and were processed. Results of the new analyses confirmed previous findings and were reported more in detail at the SSG's meeting in September 2017 and in document SCRS/2017/214 (Nohara et al. 2017).

Post-Release Mortality of Shortfin Mako in the Atlantic Ocean
The main purpose of this project, led by a colleague from Uruguay, is to quantify the post-release mortality of Atlantic shortfin makos on pelagic longlines, which is currently non-existent, to potentially contribute to their assessment and management. To that end Survivorship Popup Satellite Archival Transmitting Tags (sPATs) were acquired and distributed to the participating laboratories for deployment in three main areas of the Atlantic: the Northwest Atlantic, the tropical Northeast Atlantic and equatorial region, and the Southwest Atlantic. Fourteen sPATs have been deployed thus far by scientific observers from IPMA (EU-Portugal), DINARA (Uruguay), and NOAA with 13 transmitting tags, and additional information from eight miniPATs is also available to estimate post-release mortality. Of the 21 specimens with available information, six died (28.6 percent) whereas the remaining 15 (71.4 percent) survived, at least the first 30 days after tagging. The updated results from this project were reported and published in document SCRS/2017/050 (Coelho et al. 2017).

Movements, Stock Boundaries and Habitat Use of Shortfin Mako in the Atlantic Ocean
The purpose of this project, led by a colleague from EU-Portugal, is to use satellite telemetry to gather and provide information on stock boundaries, movement patterns, and habitat use of shortfin mako in the Atlantic Ocean, to potentially contribute to their assessment and management. All phase 1 (2015-2016) tags (23 tags: 9 miniPATs and 14 sPATs) have been deployed by scientific observers on Portuguese, Uruguayan, and U.S. vessels in the temperate Northeast, temperate Northwest, and Southwest Atlantic. Additionally, in late 2016, 12 additional miniPATs were acquired with the funds from 2016 for deployment in 2017, during the second phase of the project. As one of the original miniPATs (2015) failed due to a depth sensor problem, the tag manufacturer provided one additional replacement tag. As such, for the second phase of the project 13 miniPATs were available for deployment in 2017. Additional tags from other projects (n=15) involving the same partners may also be deployed in these same areas, which cover both hemispheres and both sides of the Atlantic. 747 tracking days have been

recorded so far with ICCAT tags. The preliminary movement analysis shows that specimens tagged in the temperate Northeast moved to southern areas, while specimens tagged in the tropical Northeast region close to the Cabo Verde Archipelago moved easterly to the African continent shelf. One specimen was tagged in equatorial waters and moved south to Namibia. The specimens tagged in the Southwest Atlantic off Uruguay stayed in the same general area, and the specimens tagged in the temperate Northwest Atlantic showed some general southward movements. The updated results from this project were reported and published in document SCRS/2017/050 (Coelho et al. 2017).

Shark Assessment Research Surveys

The SEFSC has conducted bottom longline surveys in the Gulf of Mexico (see Figure 5.9), Caribbean, and southern North Atlantic since 1995. The primary objective is assessment of the distribution and abundance of large and small coastal sharks across their known ranges in order to develop a time series for trend analysis. The surveys, which are conducted at depths between 9 and 366 meters, were designed specifically for stock assessment purposes. The bottom longline surveys are the only long-term, nearly stock-wide, fishery-independent surveys of western North Atlantic Ocean sharks conducted in U.S. waters and neighboring waters. Recently, survey effort has been extended into depths shallower than 5 fathoms (9.1 meters) to examine seasonality and abundance of sharks in inshore waters of the northern Gulf of Mexico and to determine what species and size classes are outside of the range of the sampling regime of the long-term survey. This work is being done in cooperation with SEAMAP partner institutions. For all surveys, ancillary objectives are to collect biological and environmental data, and to tag and release sharks. The surveys continue to address expanding fisheries management requirements for both elasmobranchs and teleosts.

Northeast Fisheries Science Center (NEFSC)

Fishery-Independent Coastal Shark Bottom Longline Survey

This fishery-independent survey of Atlantic large coastal sharks is conducted biennially in U.S. waters, depending on funding. Its primary objective is to conduct a standardized, systematic survey of the shark populations off the U.S. Atlantic coast to provide unbiased indices of relative abundance for species inhabiting the waters from Florida to the mid-Atlantic. This survey also provides an opportunity to tag sharks with conventional and electronic tags as part of the NEFSC Cooperative Shark Tagging Program (CSTP), to inject with oxytetracycline for age validation studies, to collect biological samples and determine life history characteristics (age, growth, reproductive biology, trophic ecology, etc.), and to collect morphometric information to calculate length-length and length-weight conversions. Additionally, this is the only fishery-independent survey that monitors use of the Mid-Atlantic Shark Closed Area off North Carolina implemented to protect juvenile sandbar and dusky shark populations. The time series of abundance indices from this survey are critical to the evaluation of coastal Atlantic shark species.

Figure 5.1.2: White shark tagged with a satellite tag before release during the NEFSC Coastal Shark Bottom Longline Survey. Source: Lisa Natanson / NMFS photo.

Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program

The NEFSC manages and coordinates this program, which surveys shark nursery habitat annually in estuarine and nearshore waters along the U.S. Atlantic coast using federal, state, university, and commercial platforms. COASTSPAN surveys are used to describe species composition and habitat preferences, and to determine the relative abundance, distribution, and migration of shark species through longline and gillnet sampling and mark-recapture data. Data from the COASTSPAN program help to identify and refine essential fish habitat for coastal shark species. Our survey data are reported annually in the essential fish habitat section of the Highly Migratory Species Stock Assessment and Fisheries Evaluation Report and have been incorporated into the stock assessment models for all Atlantic coastal shark assessments conducted through the SEDAR process.

Fishery-Independent Surveys for Monitoring and Assessing Delaware Bay Sharks

Delaware Bay is surveyed annually by NEFSC staff as part of the COASTSPAN program. A random stratified longline sampling plan, based on depth and geographic location, was developed in 2001 to assess and monitor the juvenile sandbar shark population during the nursery season. In 2006 another longline survey using larger hooks and fixed stations based on NEFSC historical data and environmental niche predictors was initiated to target sand tigers for identifying Essential Fish Habitat (EFH) and for stock assessment purposes. Data from these surveys are used to update and refine EFH designations for multiple life stages of managed shark species, monitor habitat use within this Habitat Area of Particular Concern for both sandbar sharks and sand tigers, contribute to status updates for the sand tiger shark, and maintain the time series to update the recruitment index of abundance for sandbar sharks used during the SEDAR assessment process.

Figure 5.1.3: Tagging a sand tiger caught during the Delaware Bay COASTSPAN survey. Source: NMFS photo.

Cooperative Shark Tagging Program (CSTP)

The CSTP provides information on distribution, movements, and essential fish habitat for shark species in U.S. Atlantic and Gulf of Mexico waters. This program has involved more than 6,000 volunteer recreational and commercial fishermen, scientists, and fisheries observers since 1962. It is the longest running shark tagging program in the world and one of the NOAA's oldest citizen science programs. The objective of this program is to investigate spatial and temporal variation in the distribution and migratory patterns of Atlantic sharks while promoting conservation through catch and release. The CSTP has been instrumental in shaping what we know about shark migration and distribution. The data from this program provided the basis for defining essential fish habitat for managed shark species in the Atlantic and are used to update these designations regularly. CSTP data have also been used to define stock structure, document longevity, and validate age and growth in several species, all information essential for stock assessment and effective management. To improve the quality of data collected through the CSTP, the *Guide to Sharks, Tunas, & Billfishes of the U.S. Atlantic and Gulf of Mexico* has been reprinted and made available to recreational and commercial fishermen through the Rhode Island Sea Grant. In addition, identification placards for coastal and pelagic shark species were distributed. A toll-free number has been established as well as a dedicated email address, sharkrecap@noaa.gov, and online reporting to collect information on recaptures for all species. Annually, all mark/recapture data are processed and scanned tag card images from the CSTP are linked to the existing I-MARK (Integrated Mark-Recapture Database Management) system that tracks fish and tags independently. This is done through a web application with extensive quality control measures and annual verification that the validation parameters used are up to date.

Collection of Recreational Shark Fishing Data and Samples

Historically, species-specific landings data from recreational fisheries are lacking for sharks. In an effort to augment these data, the NEFSC has been attending recreational shark tournaments continuously since 1961, with the exception of 2020 due to the COVID-19 pandemic, collecting data on species, sex, and size composition from individual events; in some cases, for nearly 50 years. In addition, these tournaments provide a source of biological samples for pelagic and some coastal sharks to be used in NEFSC shark food habits, reproduction, and age/growth studies that provide biological reference points for ICCAT pelagic shark assessments and the SEDAR process. Analysis of these tournament landings data was initiated by creating a database of historic information and producing preliminary summaries of some long-term tournaments. These data have been used to provide advice on minimum size catch requirements at tournaments, and time series analyses from long-term tournaments have been used in species status reviews. The collection and analysis of these data are critical for input into species- and age-specific population and demographic models for shark management. Participation at recreational shark tournaments and the resultant information provides a valuable monitoring tool that can detect trends in species and size composition. These sampling events also provide specimens and tissue essential for life history and genetic studies, outreach opportunities for recreational fishermen and the public, and additional information on movements that complement the NMFS CSTP.

NEFSC Historical Longline Survey Database

The NEFSC recovered the shark species catch per set data from the exploratory shark longline surveys conducted by the Sandy Hook and Narragansett Laboratories from 1961 to 1991. In addition to the fishery-independent surveys conducted by the NEFSC, scientific staff has been working with the University of North Carolina (UNC) to electronically recover the data from an ongoing coastal shark survey in Onslow Bay that began in 1972. These surveys provide a valuable historical perspective for evaluating the stock status of Atlantic sharks. This data recovery process is part of a larger, systematic effort to electronically recover and archive historical longline surveys and biological observations of large marine predators (swordfish, sharks, tunas, and billfishes) in the North Atlantic. When completed, these efforts will include reconstructing the historic catch, size composition, and biological sampling data into a standardized format for time series analysis of CPUE and size. Standardized indices of abundance developed for sharks caught during these longline surveys have been and will continue to be used in stock assessments as part of the SEDAR process. Analyzing catch rates according to differences in time, space, or methods provides an opportunity to better understand seasonal distribution patterns and relative vulnerability of various species to different fishing practices. Current recovery efforts are focused on species-specific data (i.e., sex, size) for the catches.

Figure 5.1.4: Juvenile shortfin mako brought aboard for tagging before release during the NEFSC Pelagic Nursery Grounds cruise. Source: Lisa Natanson / NMFS photo.

Pelagic Nursery Grounds

NEFSC staff work in collaboration with the high seas commercial longline fleet to study pelagic shark biology, movements, and abundance on the Grand Banks. This fishery-dependent collaboration offers a unique opportunity to sample and tag blue sharks (*Prionace glauca*) and shortfin makos (*Isurus oxyrinchus*) in a potential nursery area on the Grand Banks, to collect length-frequency data and biological samples, and to conduct conventional and electronic tagging of these species. A total of 500 blue sharks have been double tagged using two different tag types to help evaluate tag-shedding rates used in sensitivity analyses for population estimates and to calculate fishing mortality and movement rates for this pelagic shark species. In 2007–2008, two real-time satellite (SPOT) tags and five pop-up satellite archival tags (PSAT) tags were deployed on shortfin makos and one PSAT tag was deployed on a blue shark. In 2016, five shortfin makos and four porbeagles were also tagged with satellite tags. More than 3,700 sharks have been tagged to date with conventional tags and more than 300 recaptured; the recaptures are primarily blue sharks recovered by commercial fishermen working in the mid-Atlantic Ocean.

Essential Fish Habitat (EFH) Designations

NEFSC staff participates on a working group with others from the NMFS HMS Management Division and SEFSC to update and refine the EFH designations for managed shark species. This process was ongoing from 2018 to 2022 and entailed providing information on recent research that could contribute to the EFH updates and reviewing proposed methods for updating the EFH designations for managed shark species. APP staff also provided annual summaries from COASTSPAN surveys for use in the EFH section of the annual Stock Assessment and Fisheries Evaluation Report. Additionally, NEFSC staff provided to the NMFS HMS Management Division expert advice pertaining to EFH consultations for HMS species with respect to dredging activities and offshore wind energy development, updates to previously supplied data, and results from ongoing research.

Elasmobranch Life History Studies

NEFSC life history studies are conducted on Atlantic species of elasmobranchs to address priority knowledge gaps and focus on species with declines and management issues. NEFSC staff have already developed growth models, completed reproductive studies, characterized the diet, and finished movement and migration studies for many shark species. In recent years, studies have concentrated on a complete life history for a species to obtain a total picture for management. This comprehensive life history approach encompasses studies on age and growth rates and validation, diet and trophic ecology, movement and migration patterns, and reproductive biology essential to estimate parameters for demographic, fisheries, and ecosystem models. Biological samples for these studies are obtained on research surveys and cruises, on commercial vessels, at recreational fishing tournaments, and opportunistically from strandings. Non-lethal techniques are also being used, such as using stomach eversion techniques for obtaining food habits samples and collaborative work using hormone levels for determining stages of maturity. Tagging data, both conventional and electronic, are also obtained through research surveys, as well as chartered vessel trips and through the CSTP. Collaborative projects to examine the biology and population dynamics of pelagic and coastal shark species in the North Atlantic are ongoing.

Research Intercalibrations
NEFSC staff hosted and worked at a shark tournament with staff from the NMFS Panama City, Florida, laboratory and the SWFSC in La Jolla, California, to ensure the comparability of reproductive measurements between the laboratories for porbeagle and common thresher sharks, respectively. Additionally, NEFSC staff have been working with MADMF and the Atlantic White Shark Conservancy to properly sample stranded sharks to ensure consistency in measurements between programs. In 2020, NEFSC staff presented on reproductive sampling methods at the ICCAT Workshop on Pelagic Shark Reproduction. Additionally, NEFSC staff hosted an intercalibration workshop with staff from the SEFSC and MADMF on blue shark ageing in 2022, ahead of the ICCAT Data Preparatory Meeting for the blue shark assessment in 2023.

Multi-Species Feeding Ecology Studies
Using the food habits data collected by the NEFSC Apex Predators Program over the past 40 years, temporal changes in prey species, taxonomic and ecological prey groups, and overall trophic levels for the blue shark and the shortfin mako NEFSC analyzed the feeding ecology. Indices of standardized diet composition were analyzed to identify changes in the prey species consumed, and then related to temporal changes in the distribution and abundance of these prey items. The two shark species have dissimilar feeding strategies and respond differently to environmental changes and fluctuations in prey availability. The blue shark has a generalized diet and easily switches between prey types. Over the four-decade period, some prey categories showed dramatic increases in the diet (spiny dogfish, marine mammals), others declined (cephalopods, flatfishes, hakes), and others fluctuated (bluefish, herrings, mackerels). The shortfin mako is more specialized, consuming mainly bluefish, and appears resistant to dietary change when its preferred prey becomes less abundant. Databases were updated from 2018 to 2022 to include blue shark and shortfin mako samples collected at recreational shark fishing tournaments and opportunistically throughout the year.

Migrations of the Spiny Dogfish (Squalus acanthias)

The NEFSC Cooperative Research and Apex Predators Program began tagging spiny dogfish in the Gulf of Maine, Southern New England, and Georges Bank regions in 2011. This project aims to answer long-standing questions about stock structure, movement patterns, and life history to update and improve spiny dogfish stock assessments. Over a 2-year period, dogfish were tagged during the winter, summer, and fall using three commercial vessels. During the tagging phase of this project, more than 34,000 spiny dogfish were tagged and released and 3 percent have been recaptured to date. This information was presented during a stakeholder session and working group meetings for the Spiny Dogfish Research Track Assessment (RTA) in 2022. Additionally, growth estimates were produced from the mark-recapture data and presented during working group meetings for the Spiny Dogfish RTA, which provided supporting evidence for a decrease in large females. A summary of the movement and growth data were reported in a working paper that contributed to the final assessment report (McCandless 2022).

Common Thresher Shark (Alopias vulpinus) Movement Patterns and Stock Structure
A multi-faceted investigation of the horizontal and vertical movement patterns, spatial and temporal habitat use, and stock structure of the common thresher shark in the western North Atlantic Ocean was funded in 2016 through a Saltonstall-Kennedy Grant. In 2017, NEFSC staff in collaboration with researchers from the New England Aquarium, University of Massachusetts, and MDMF began field work on this project. This project is ongoing, with electronic and conventional tags deployed on common thresher sharks annually, primarily using sportfishing vessels.

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2000 Shark Finning Prohibition Act
http://www.gpo.gov/fdsys/pkg/BILLS-106hr5461enr/pdf/BILLS-106hr5461enr.pdf

The 2010 Shark Conservation Act
http://www.gpo.gov/fdsys/pkg/BILLS-111hr81enr/pdf/BILLS-111hr81enr.pdf

National Marine Fisheries Service
https://www.fisheries.noaa.gov/welcome

Atlantic Ocean Shark Management
Copies of the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP) and its Amendments and Atlantic commercial and recreational shark fishing regulations and brochures can be found on the NMFS HMS website at https://www.fisheries.noaa.gov/topic/atlantic-highly-migratory-species. Information on Atlantic shark fisheries is updated annually in the Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic HMS, which is also available on the website. The website includes links to current fishery regulations (50 FR 635), shark landings updates, and the U.S. National Plan of Action for Sharks.

Domestic stock assessments under the SouthEast Data, Assessment, and Review (SEDAR) process are available online: http://sedarweb.org/

Pacific Ocean Shark Management
The U.S. West Coast Highly Migratory Species FMP and the Pacific Coast Groundfish FMP and annual SAFE Reports are currently available on the Pacific Fishery Management Council website: https://www.pcouncil.org/.

Data reported in Appendix 1, Table 1.3.3 (Shark landings (round weight equivalent in metric tons) for California, Oregon, and Washington, 2001–2016) was obtained from the Pacific States Marine Fisheries Commission's PacFIN database, which may be found on their website at: http://pacfin.psmfc.org/pacfin_pub/data.php.

Information about pelagic fisheries of the Western Pacific Region FMP is available on the Western Pacific Fishery Management Council's website: http://www.wpcouncil.org/fishery-plans-policies-reports/.

Data reported in Table 1.3.8 (Shark landings (mt) from the Hawai'i-based longline fishery and the American Samoa longline fishery, 2003-2013) was partially obtained from the Western Pacific Fisheries Information Network (WPacFIN). http://www.pifsc.noaa.gov/wpacfin/.

The Bering Sea/Aleutian Islands Groundfish FMP and the Groundfish of the Gulf of Alaska FMP are available on the North Pacific Fishery Management Council's (NPFMC) website:

https://www.npfmc.org/bering-seaaleutian-islands-groundfish/.

Stock assessments and other scientific information for sharks are summarized annually in the NPFMC SAFE Reports that are available online: https://www.afsc.noaa.gov/REFM/stocks/assessments.htm.

International Efforts to Advance the Goals of the Shark Finning Prohibition Act

NMFS Office of International Affairs
https://www.fisheries.noaa.gov/topic/international-affairs

FAO International Plan of Action for the Conservation and Management of Sharks
http://www.fao.org/ipoa-sharks

U.S. NPOA for the Conservation and Management of Sharks
https://www.fisheries.noaa.gov/webdam/download/64444114

NAFO Conservation and Enforcement Measures
https://www.nafo.int/Fisheries/Conservation

IATTC: https://www.iattc.org/

ICCAT: https://www.iccat.int/en/

International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC): http://isc.fra.go.jp/

WCPFC: https://www.wcpfc.int/

UNGA: http://www.un.org/en/sections/what-we-do/uphold-international-law/index.html

Memorandum of Understanding on the Conservation of Migratory Sharks
http://sharksmou.org/

U.S. Imports and Exports of Shark Fins

Summaries of U.S. imports and exports of shark fins are based on information submitted by importers and exporters to U.S. Customs and Border Protection. This information is compiled by the U.S. Census Bureau and is reported in the NMFS Trade database: http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index