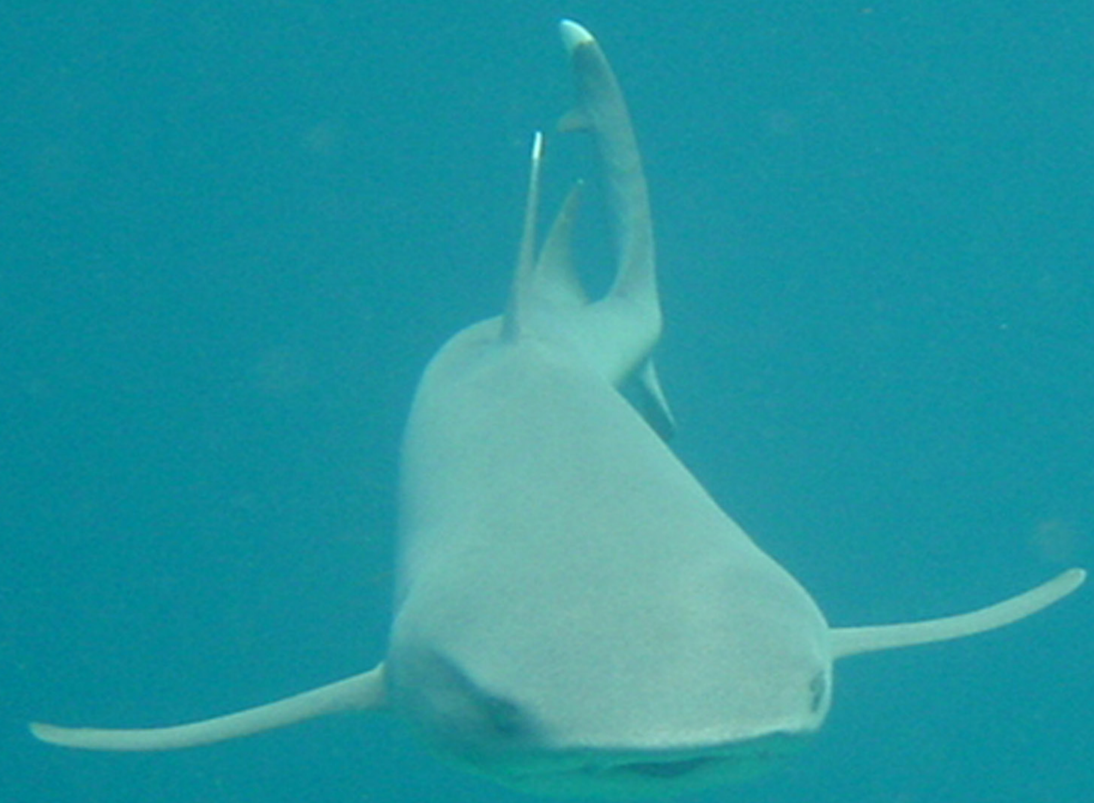
2011 Shark Finning Report to Congress



Issued Pursuant to the Shark Finning Prohibition Act
(Public Law 106-557)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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Prepared by the
National Marine Fisheries Service

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Abbreviations and Acronyms

ABC	allowable biological catch
ABL	Auke Bay Laboratory
ADF&G	Alaska Department of Fish and Game
AFSC	Alaska Fisheries Science Center
ALWTRP	Atlantic Large Whale Take Reduction Plan
BLL	bottom longline
BREP	Bycatch Reduction Engineering Program
BSAI	Bering Sea/Aleutian Islands
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CDNG	California drift gillnet fishery
CI	confidence interval
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COASTSPAN	Cooperative Atlantic States Shark Pupping and Nursery
COFI	Food and Agriculture Organization's Committee on Fisheries
CPUE	catch per unit effort
CRED	Coral Reef Ecosystem Division
CSTP	Cooperative Shark Tagging Program
dw	dressed weight
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EPO	Eastern Pacific Ocean
FAO	Food and Agriculture Organization of the United Nations
FEP	fishery ecosystem plan
FEP	fishery ecosystem plan
FMP	fishery management plan
FR	*Federal Register*
GCEL	General Counsel for Enforcement and Litigation
GOA	Gulf of Alaska
GULFSPAN	Gulf of Mexico States shark pupping and nursery
HIMB	Hawaii Institute of Marine Biology
HMS	highly migratory species
IATTC	Inter-American Tropical Tuna Commission
ICES	International Council for the Exploration of the Sea
ICCAT	International Commission for the Conservation of Atlantic Tunas
IPOA	International Plan of Action
IUCN	International Union for Conservation of Nature
kg	kilogram
LCS	large coastal sharks

MAFMC...Mid-Atlantic Fishery Management Council
MDMF ....Massachusetts Division of Marine Fisheries
MSA...Magnuson-Stevens Fishery Conservation and Management Act
MSY...maximum sustainable yield
mt ....metric tons
n ....sample size
NEFSC ....Northeast Fisheries Science Center
NEFMC...New England Fishery Management Council
NMFS...National Marine Fisheries Service
NOAA ....National Oceanic and Atmospheric Administration
NAFO...Northwest Atlantic Fisheries Organization
NOVA ....Notice of Violation and Assessment
NPFMC ....North Pacific Fishery Management Council
NPOA...National Plan of Action
NWFSC..Northwest Fishery Science Center
NWHI...Northwestern Hawaiian Islands
OFL ....overfishing levels
OLE..Office of Law Enforcement
OTC ....oxytetracycline
PacFIN ....Pacific Fisheries Information Network
PIFSC...Pacific Island Fishery Science Center
PSAT..pop-up satellite archival tags
PFMC...Pacific Fishery Management Council
PRIA ....Pacific remote island areas
RFMO ....regional fishery management organization
SAFE..Stock Assessment and Fishery Evaluation
SCRS..Standing Committee on Research and Statistics
SCS ....small coastal sharks
SEDAR ....Southeast Data, Assessment, and Review
SEFSC..Southeast Fisheries Science Center
SFPA..Shark Finning Prohibition Act
SPOT..smart position and temperature transmitting tags
SSL...sound scattering layer
SWFSC ....Southwest Fisheries Science Center
SWRO..Southwest Regional Office
TAC ....total allowable catch
TL...total length
UNGA ....United Nations General Assembly
USCG...United States Coast Guard
USVI ....United States Virgin Islands
VMS...vessel monitoring system
WCPFC ....Western and Central Pacific Fisheries Commission
WPacFin...Western Pacific Fishery Information Network
WPFMC ....Western Pacific Fishery Management Council

Executive Summary

Because of their biological and ecological characteristics, sharks present an array of issues and challenges for fisheries management and conservation. Many shark species are characterized by relatively late maturity, slow growth, and low reproductive rates, which can make them particularly vulnerable to overexploitation. Concern has grown about the status of shark stocks and the sustainability of their exploitation in world fisheries, as demand for some shark species and shark products has increased.

Shark finning is the practice of taking a shark, removing a fin or fins (whether or not including the tail), and returning the remainder of the shark to the sea. The Shark Finning Prohibition Act prohibited the practice of shark finning by any person under U.S. jurisdiction. The Act required the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) to promulgate regulations to implement the prohibitions of the Act, initiate discussion with other nations to develop international agreements on shark finning and data collection, and establish research programs. Regulations to implement the Act were completed in 2002; since then, NMFS has continued to carry out the objectives of the Act. This report describes NMFS' efforts to carry out the Act during calendar year 2010.

Sharks in Federal waters are currently managed under 10 different fishery management plans under authority of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). In the U.S. Atlantic Ocean, oceanic sharks and other highly migratory species (HMS) are managed directly by NMFS. One species of shark is managed jointly by the New England and Mid-Atlantic Fishery Management Councils. In the U.S. Pacific Ocean, three regional fishery management councils—Pacific, North Pacific, and Western Pacific—are responsible for developing fishery management plans. In 2010, domestic management of sharks included the following major actions:

- NMFS published a final rule for Amendment 3 to the 2006 Consolidated HMS Fishery Management Plan (FMP) (75 FR 30484), which implemented measures to rebuild blacknose sharks, prevent overfishing of shortfin mako and blacknose sharks, and create the smoothhound shark management complex.
- A final rule was published on December 8, 2010 (75 FR 76302), which established the 2011 fishing season for commercial quotas for sandbar sharks, non-sandbar large coastal sharks, small coastal sharks, and pelagic sharks based on over- or under-harvests from the 2009 and 2010 fishing years, and implemented adaptive management measures.
- In October 2010, NMFS issued a final rule (75 FR 193) to implement three amendments to the Gulf of Alaska and Bering Sea Aleutian Islands Fishery Management Plans that move all of the major taxonomic groups from the "other species" category to the "target species" category. Beginning in 2011 separate total allowable catch (TAC) levels will be set annually for sharks and skates.
- In 2010, Atlantic spiny dogfish quota was increased from 12 to 15 million pounds in response to an updated stock assessment showing that the stock is fully rebuilt (75 FR 121).

Additional information on shark management in the United States can be found in sections 2.1 through 2.3 of this report.

The Department of Commerce and the Department of State have been active in promoting development of international agreements consistent with the Shark Finning Prohibition Act. In 2010, the United States was successful in the following international efforts:

- In February 2010, the United States, along with 10 other States, signed a global Memorandum of Understanding (MOU) for Migratory Sharks under the auspices of the Convention on Migratory Species (CMS). The MOU aims to coordinate international action on the threats faced by sharks and works to improve their species conservation status. The MOU initially covers great white, basking, whale, porbeagle, shortfin mako, longfin mako, and the Northern Hemisphere population of spiny dogfish.
- In August 2010, the Inter-American Tropical Tuna Commission (IATTC) convened the first technical meeting on sharks to discuss the role of the IATTC in the conservation and management of sharks, stock assessment methods for sharks, life-history studies, the availability of data from national and regional programs, bycatch mitigation methods, and data collection needs and standardization.
- ICCAT adopted a measure that prohibits retention of oceanic whitetip sharks and all species of hammerhead sharks (with the exception of bonnethead sharks) caught in association with ICCAT fisheries. A statement was included in the record noting that several ICCAT members, including the United States, consider that this measure does not apply to directed fisheries in coastal waters.
- At the Western and Central Pacific Fisheries Commission's (WCPFC) annual meeting in December 2010, the Commission added porbeagle and hammerhead sharks to the list of key species, requiring annual reports on catch, effort, retention, and discards for these species as well as the five other shark species listed previously.
- In June 2010, the five global Tuna Regional Fisheries Management Organizations collaborated on a workshop addressing bycatch issues (Kobe II Bycatch). The workshop recommendations, all of which applied to sharks, were made in the areas of improving: (1) assessment of bycatch, (2) mitigation/reduction of bycatch, (3) cooperation and coordination across Regional Fishery Management Organizations, and (4) capacity-building for developing countries.

Further information on international efforts to advance the goals of the Shark Finning Prohibition Act can be found in Section 4 of this report.

Research conducted by the NMFS Regional Fisheries Science Centers has produced valuable information on shark status, survivorship, mobility, migration, habitat, ecology, and age and growth characteristics; all of which will be incorporated into effective shark fishery management decisions. A summary of NMFS' 2010 research efforts regarding sharks can be found in Section 5 of this report, with details offered in Appendix 1.

The Shark Conservation Act of 2010 was passed by the U.S. House of Representatives on March 2, 2009, and by the Senate on December 20, 2010. It was signed into law by President Obama on January 4, 2011. In summary, the Shark Conservation Act of 2010 amended two previous acts—the High Seas Driftnet Fishing Moratorium Protection Act and the MSA—to improve the existing local and international shark conservation measures.

1. Introduction

Sharks, skates, and rays are cartilaginous fishes, i.e., they have skeletons made of cartilage instead of bone. Shark species have been around for more than 400 million years. They hold a unique position as one of the top predators of the sea, and their abundance is often low compared to organisms lower on the food chain. Their life history strategies focus on long lives, late maturation, and low fecundity (Frisk et al. 2005). In addition, long-distance migrations often mean that individuals cross international boundaries. While these characteristics were successful for millions of years, they also make sharks particularly vulnerable to overexploitation by humans.

Shark finning is the practice of taking a shark, removing a fin or fins (whether or not including the tail), and returning the remainder of the shark to the sea.[1] Because the meat of the shark is usually of low value, the finless sharks are thrown back into the sea and subsequently die. Shark fins are very valuable and are among the most expensive fish products in the world. Shark fins are considered a delicacy in East Asia and are used to make shark fin soup. The growth in demand for some shark products, such as fins, continues to drive increased exploitation of sharks (Bonfil 1994, Rose 1996, Walker 1998, Clarke et al. 2007). In addition to being directly targeted in a few fisheries, sharks are also a common bycatch species in the tuna and marlin fisheries. The high value associated with shark fins has led to finning, where in the past these species were released overboard alive.

Over the past few decades, as evidence of overfishing has increased, concern has grown about the status of shark stocks and the sustainability of their exploitation in world fisheries. This situation has resulted in several international initiatives to promote greater understanding of sharks in the ecosystem and in greater efforts to conserve the many shark species in world fisheries. Internationally, 67 species of sharks are listed as critically endangered or endangered on the International Union for Conservation of Nature (IUCN) red list (Simpfendorfer et al. 2011). Lack of knowledge about catch and biology limits our ability to manage these species effectively. We have no real international estimates of how many sharks and what species of shark are killed each year by fishermen in other countries. Countries report catch to the Food and Agriculture Organization of the United Nations (FAO) on a voluntary basis, but research suggests this number underestimates the actual number of sharks landed annually (Clarke et al. 2006). Because shark life histories are more similar to whales than to other fish species, a group of scientists have suggested forming an organization like the International Whaling Commission that is dedicated to international cooperation for the sustainable use of sharks (Herndon et al. 2010).

As international awareness of the plight of sharks has increased, a few countries (Palau, Maldives, and Honduras) have determined the animals are worth more alive (for tourism) than dead (for fisheries) and have thus banned shark fishing in their waters. In the United States,

[1] As defined in Section 9 of the Shark Finning Prohibition Act.

Hawaii has made it unlawful for any person to possess, sell, offer for sale, trade, or distribute shark fins, and California is considering similar legislation.

For 2010, in United States fisheries, four shark stocks were subject to overfishing[2] and four shark stocks were overfished[3] (Table 1). Twenty shark stocks or stock complexes (59%) had an unknown or undefined status in terms of their overfishing status. Similarly, 21 (62%) had an unknown or undefined status in terms of their overfished status (Table 1).

The Shark Conservation Act of 2010 was passed by the U.S. House of Representatives on March 2, 2009, and by the Senate on December 20, 2010. It was signed into law by President Obama on January 4, 2011. In summary, the Shark Conservation Act of 2010 amended two previous acts—the High Seas Driftnet Fishing Moratorium Protection Act and the Magnuson-Stevens Fishery Conservation and Management Act (MSA)—to improve the existing Federal and international shark conservation measures.

The High Seas Driftnet Fishing Moratorium Protection Act was amended to include shark conservation measures (including measures to prohibit removal of shark fins at sea) in the international agreements the United States negotiates. In addition, the definition of illegal, unreported or unregulated fishing was amended to include "fishing activities that violate … shark conservation measures." Nations whose vessels are engaging in shark fishing in international waters and who have not adopted a regulatory program for shark conservation that includes measures to prohibit shark finning, will be listed in the biannual report to Congress as engaging in illegal, unreported or unregulated fishing.

The Shark Conservation Act of 2010 amended the Shark Finning Prohibition Act provisions in the MSA. The latter allowed fishing vessels to have on board or to land shark fins if the total weight of fins was less than 5 percent of the total weight of the shark carcasses on board or landed. In cases where the weight of the fins was less than 5 percent the weight of the carcass, multiple fins could be collected for each carcass kept, allowing for finning (including the discarding of carcasses at sea) to occur but still be within the limits of the law. In addition, the 2000 Act did not prohibit non-fishing vessels from having shark fins onboard or transferring or landing them in the United States. The new law clearly states it is illegal for all vessels (not just fishing vessels) to have custody of, transfer, or land a fin unless it is naturally attached to the corresponding shark carcass. The act retains the 5-percent rule implemented by the Shark Finning Prohibition Act, but this only applies to fins cut after the sharks have been landed. The 2010 Shark Conservation Act does include a savings clause, where the amendments "do not apply to an individual engaged in commercial fishing for smooth dogfish (Mustelus canis) in that area of the waters of the United States located shoreward of a line drawn in such a manner that each point on it is 50 nautical miles from the baseline of a State from which the territorial sea is measured, 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 this subsection applies exceeds 12 percent of the total weight of smooth dogfish carcasses landed or found on board."

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[2] A stock that is subject to overfishing has a fishing mortality (harvest) rate above the level that provides for the maximum sustainable yield.
[3] A stock that is overfished has a biomass level below a biological threshold specified in its fishery management plan.

NMFS will address the requirements of the 2010 Shark Conservation Act by publishing three regulations to be implemented in 2012: (1) the Office of International Affairs Office is redefining the definition of illegal, unreported or unregulated fishing, (2) the Office of Sustainable Fisheries' Domestic Fisheries Division is redefining shark finning regulations to prohibit the removal of the fins of a shark at sea, and (3) the Office of Sustainable Fisheries' Highly Migratory Species Division is modifying the smooth dogfish regulations.

Congressional Mandate for the Annual Shark Finning Report to Congress:

On December 21, 2000, the Shark Finning Prohibition Act was signed into law. The Act requires NMFS to promulgate regulations to implement its provisions (Section 4), initiate discussion with other nations to develop international agreements on shark finning and data collection (Section 5), provide Congress with annual reports describing efforts to carry out the Shark Finning Prohibition Act (Section 6), and establish research programs (Sections 7 and 8). Section 9 of the Act defines shark finning.

As directed by Section 4 of the Shark Finning Prohibition Act, NMFS published a rule (67 FR 6194; February 11, 2002) to implement the provisions of the Act. On June 24, 2008, NMFS published a final rule (73 FR 35778, corrected on July 15, 2008 (73 FR 40658), that amended the 2006 Consolidated Atlantic HMS Fishery Management Plan (FMP) that, among other things, requires that all sharks in the Atlantic HMS fishery be offloaded with the fins naturally attached.

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

(1) include a list that identifies nations whose vessels conduct shark finning and details the extent of the international trade in shark fins, including estimates of value and information on harvesting, landings, or transshipment of shark fins;
(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; and
(4) include recommendations for measures to ensure that United States actions are consistent with national, international, and regional obligations relating to shark populations, including those listed under the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES).

These four topics are described in this Report to Congress. Regarding item 1 above, no reliable information exists to determine those nations whose vessels conduct shark finning. However, data on the international trade of shark fins is available from the FAO and data on United States import and export of shark fins is available from the U.S. Census Bureau. This information is provided in Section 3 of this report. However, it is important to note that, due to the complexity of the shark fin trade, fins are not necessarily produced in the same country from which they are exported.

Consistent with item 2 above, this Report to Congress summarizes all recent shark-related management (Sections 2.1 to 2.3), enforcement (Section 2.4), international (Section 4), and research activities (Section 5) that are in support of the Shark Finning Prohibition Act. This report, prepared in consultation with the Department of State, also provides an update to last year's report and includes complete information for 2010 activities.

Regarding item 3 above, the United States participated in the development of and endorsed the FAO's International Plan of Action (IPOA) for the Conservation and Management of Sharks. Consistent with the IPOA, the United States developed a National Plan of Action (NPOA) for the Conservation and Management of Sharks in February 2001. In addition to meeting the statutory requirement of the Shark Finning Prohibition Act, the annual Report to Congress serves as a periodic update of information called for in the IPOA and NPOA.

Regarding item 4 above, NMFS has no specific recommendations for shark conservation and management at this time. Consistent with the provisions of Section 5 of the Shark Finning Prohibition Act, the Department of Commerce and the Department of State have been active in promoting development of international agreements consistent with the Act. Recommendations are brought forward through bilateral, multilateral, and regional efforts. As agreements are developed, the United States implements those agreements and reports on them in this annual Report to Congress. Information on recent international efforts, including CITES, is provided in Section 4 of this report.

Table 1. Status of shark stocks and stock complexes in U.S. fisheries in 2010.
Source: NMFS 2011.

Status of Shark Stocks and Stock Complexes in U.S. Fisheries in 2010				
Jurisdiction	**FMP**	**Stock or Stock Complex**	**Overfishing**	**Overfished**
NEFC & MAFMC	Spiny Dogfish FMP	Spiny dogfish – Atlantic coast	No	No
NMFS Highly Migratory Species Division	Consolidated Atlantic Highly Migratory Species FMP	Atlantic large coastal shark complex[2]	Unknown	Unknown
		Atlantic pelagic shark complex[6]	Unknown	Unknown
		Atlantic sharpnose shark[3]	No	No
		Atlantic small coastal shark complex[4]	No	No
		Blacknose shark – Atlantic[3]	Yes	Yes
		Blacktip shark – Gulf of Mexico[1]	No	No
		Blacktip shark – South Atlantic[1]	Unknown	Unknown
		Blue shark – Atlantic[5]	No	No
		Bonnethead – Atlantic[3]	No	No
		Dusky shark – Atlantic	Yes	Yes
		Finetooth shark – Atlantic[3]	No	No
		Porbeagle – Atlantic[5]	No	Yes
		Sandbar shark – Atlantic[1]	Yes	Yes
		Shortfin mako – Atlantic[5]	Yes	No
PFMC	Pacific Coast Groundfish FMP	Leopard shark – Pacific Coast	Unknown	Unknown
		Spiny dogfish – Pacific Coast	Unknown	Unknown
		Soupfin (Tope)- Pacific Coast	Unknown	Unknown
PFMC & WPFMC	U.S. West Coast Fisheries for Highly Migratory Species & Pacific Pelagic Fisheries of the Western Pacific Region Ecosystem	Thresher shark – North Pacific	Unknown	Unknown
		Shortfin mako shark – North Pacific	Unknown	Unknown
		Blue shark – North Pacific	No	No
		Bigeye thresher shark – North Pacific	Unknown	Unknown
		Pelagic thresher shark – North Pacific	Unknown	Unknown
WPFMC	Pacific Pelagic Fisheries Of the Western Pacific Region Ecosystem	Longfin mako shark – North Pacific	Unknown	Unknown
		Oceanic whitetip shark – Tropical Pacific	Unknown	Unknown
		Salmon shark – North Pacific	Unknown	Unknown
		Silky shark – Tropical Pacific	Unknown	Unknown
WPFMC	Hawaiian Archipelago FEP	Hawaiian Archipelago Coral Reef Ecosystem Multi-Species Complex[7]	Unknown	Unknown
WPFMC	American Samoa FEP	American Samoa Coral Reef Ecosystem Multi-Species Complex[7]	Unknown	Unknown
WPFMC	Mariana Archipelago FEP	Guam Coral Reef Ecosystem Multi-Species Complex[7]	Unknown	Unknown
		Northern Mariana Islands Coral Reef Ecosystem Multi-Species Complex[7]	Unknown	Unknown

WPFMC	Pacific Remote Islands Areas FEP	Pacific Island Remote Areas Coral Reef Ecosystem Multi-Species Complex[8]	Unknown	Unknown
NPFMC	Gulf of Alaska Groundfish FMP	Other species complex[9]	Undefined	Undefined
NPFMC	Bering Sea/Aleutian Island Groundfish FMP	Other species complex[10]	No	Undefined
Totals:			4 "yes" 10 "no" 19 "Unknown" 1 "Undefined"	4 "yes" 9 "no" 19 "Unknown" 2 "Undefined"

[1]This stock is part of the Large Coastal Shark Complex, but it is assessed separately.
[2]In addition to Sandbar Shark, Gulf of Mexico Blacktip Shark, and Atlantic Blacktip Shark (which are assessed individually), the Large Coastal Shark Complex also consists of additional stocks including Spinner Shark, Silky Shark, Bull Shark, Tiger Shark, Lemon Shark, Nurse Shark, Scalloped Hammerhead Shark, Great Hammerhead Shark, and Smooth Hammerhead Shark. In addition, several LCS species cannot be retained in commercial or recreational fisheries, including Dusky Shark, Bignose Shark, Galapagos Shark, Night Shark, Caribbean Reef Shark, Narrowtooth Shark, Sand Tiger Shark, Bigeye Sand Tiger Shark, Whale Shark, Basking Shark, White Shark.
[3]This stock is part of the Small Coastal Shark Complex, but is assessed separately.
[4]In addition to Finetooth Shark, Atlantic Sharpnose Shark, Blacknose Shark, and Bonnethead Shark (which are assessed individually), the Small Coastal Shark Complex also consists of: Atlantic Angel Shark, Caribbean Sharpnose Shark, and Smalltail Shark; these 3 species cannot be retained in recreational or commercial fisheries.
[5]This stock is part of the Pelagic Shark Complex, but is assessed separately.
[6]In addition to Shortfin Mako Shark, Blue Shark, and Porbeagle Shark (which are assessed individually), the Pelagic Shark Complex also consists of Oceanic Whitetip Shark and Thresher Shark. This complex also consists of stocks that cannot be retained in recreational or commercial fisheries, which include Bigeye Thresher Shark, Bigeye Sixgill Shark, Longfin Mako Shark, Sevengill Shark, and Sixgill Shark.
[7] In 2009, the Western Pacific Crustaceans, Bottomfish & Seamount Groundfish, Precious Corals, and Coral Reef Ecosystem FMPs were replaced by fishery ecosystem plans (FEP) for American Samoa, Hawaii, the Mariana Archipelago (Guam and the Northern Mariana Islands, and the Pacific Remote Island Areas). The western Pacific Pelagics FMP was converted to the Pelagics FEP. This complex contains up to 146 "currently harvested coral reef taxa" and innumerable "potentially harvested coral reef taxa." All commercial fishing is prohibited in the Marianas Trench (Mariana Islands) and Rose Atoll (American Samoa) Marine National Monuments.
[8] In 2009, the Western Pacific Crustaceans, Bottomfish & Seamount Groundfish, Precious Corals, and Coral Reef Ecosystem FMPs were replaced by fishery ecosystem plans (FEP) for American Samoa, Hawaii, the Mariana Archipelago (Guam and the Northern Mariana Islands, and the Pacific Remote Island Areas. The western Pacific Pelagics FMP was converted to the Pelagics FEP. This complex contains up to 146 "currently harvested coral reef taxa" and innumerable "potentially harvested coral reef taxa." The Pacific remote island areas (PRIA) are U.S. island possessions in the Pacific Ocean that include Palmyra Atoll, Kingman Reef, Jarvis Island, Baker Island, Howland Island, Johnston Atoll, Wake Island, and Midway Atoll. All reefs of the PRIA except Wake Island, which is under the jurisdiction of the Department of Defense, are National Wildlife Refuges. Fishing for coral reef-associated species is prohibited in all these areas except Palmyra Atoll, Johnston Atoll, Wake Island, and Midway Atoll. All commercial fishing is prohibited in the Pacific Remote Islands Marine National Monument.
[9]The Other Species Complex consists of the following stocks: Pacific Sleeper Shark, Salmon Shark, Spiny Dogfish, unidentified sharks, and numerous species of octopi, squid, and sculpins. An OFL and ABC is determined for sharks, which when added to the OFLs and ABCs for octopi, squid, and sculpins becomes the overall OFL and ABC for the other species category. For sharks the overfishing determination is based on the OFL, which is based on the average historical catch.
[10]The Other Species Complex consists of the following stocks: Pacific Sleeper Shark, Salmon Shark, Spiny Dogfish, unidentified sharks, and numerous species of skates, octopi, and sculpins. An OFL and ABC is determined for sharks, which when added to the OFLs and ABCs for octopi, skates, and sculpins becomes the overall OFL and ABC for the other species category. For sharks the overfishing determination is based on the OFL, which is based on the average historical catch.

2. Management and Enforcement

2.1 Management Authority in the United States

The MSA forms the basis for fisheries management in Federal waters and requires NMFS and the eight regional fishery management councils to take specified actions. State agencies and interstate fishery management commissions are bound by State regulations and, in the Atlantic region, by the Atlantic Coast Fisheries Cooperative Management Act.

2.2 Current Management Authority in the Atlantic Ocean

Atlantic Highly Migratory Species Management

Development of Fishery Management Plans (FMPs) is the responsibility of one or more of the eight regional fishery management councils, with one exception: Atlantic highly migratory species (HMS)—including tunas, swordfish, billfish, and oceanic sharks—and are managed directly by the Secretary of Commerce under the MSA. Since 1990, shark fishery management in Federal waters of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (excluding spiny dogfish, skates, and rays) has been the responsibility of the Secretary of Commerce, delegated to NMFS' HMS Division.

In 1993, NMFS implemented the FMP for Sharks of the Atlantic Ocean. Under the FMP, three management units were established for shark species: large coastal sharks (LCS), small coastal sharks (SCS), and pelagic sharks (Table 2.2.1). NMFS identified LCS as overfished, and therefore, among other things, implemented commercial quotas for LCS and established recreational harvest limits for all sharks. At that time, NMFS also banned finning of all sharks in the Atlantic Ocean.

In April 1999, NMFS published the FMP for Atlantic Tunas, Swordfish, and Sharks, which included numerous measures to rebuild or prevent overfishing of Atlantic sharks in commercial and recreational fisheries. The 1999 FMP replaced the 1993 FMP and addressed numerous shark management measures, including: reducing commercial LCS and SCS quotas, establishing a commercial quota for blue sharks and a species-specific quota for porbeagle sharks, expanding the list of prohibited shark species, implementing a limited access permitting system in commercial fisheries, and establishing season-specific over- and under-harvest adjustment procedures.

Table 2.2.1 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)**	
Spinner	*Carcharhinus brevipinna*	Finetooth	*Carcharhinus isodon*
Silky*	*Carcharhinus falciformis*	Blacknose	*Carcharhinus acronotus*
Bull	*Carcharhinus leucas*	Atlantic sharpnose	*Rhizoprionodon terraenovae*
Blacktip	*Carcharhinus limbatus*	Bonnethead	*Sphyrna tiburo*
Sandbar**	*Carcharhinus plumbeus*	**Pelagic Sharks**	
Tiger	*Galeocerdo cuvier*	Common thresher	*Alopias vulpinus*
Nurse	*Ginglymostoma cirratum*	Oceanic whitetip	*Carcharhinus longimanus*
Lemon	*Negaprion brevirostris*	Shortfin mako	*Isurus oxyrinchus*
Scalloped hammerhead	*Sphyrna lewini*	Porbeagle	*Lamna nasus*
Great hammerhead	*Sphyrna mokarran*	Blue	*Prionace glauca*
Smooth hammerhead	*Sphyrna zygaena*	**Smoothhound Sharks**	
		Smooth dogfish	*Mustelus canis*
		Florida smoothhound	*Mustelus norrisi*
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 dogfish	*Scymnodon obscures*
Flatnose gulper shark	*Deania profundorum*		
Bramble shark	*Echinorhinus brucus*	Greenland shark	*Somniosus microcephalus*
Lined lanternshark	*Etmopterus bullisi*	Pygmy shark	*Squaliolus laticaudus*
Broadband dogfish	*Etmopterus gracilispinnis*	Roughskin spiny dogfish	*Squalus asper*
Caribbean lanternshark	*Etmopterus hillianus*		
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.**

On December 24, 2003, the final rule implementing Amendment 1 to the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks was published in the *Federal Register* (68 FR 74746). This final rule revised the shark regulations based on the results of the 2002 stock assessments for SCS and LCS. In Amendment 1, NMFS revised the rebuilding timeframe for LCS to 26 years from 2004, and implemented several new regulatory changes, including: using maximum sustainable yield as a basis for setting commercial quotas; eliminating the commercial minimum size restrictions; implementing trimester commercial fishing seasons effective January 1, 2005; implementing a time/area closure off the coast of North Carolina effective January 1, 2005; and establishing three regional commercial quotas (Gulf of Mexico, South Atlantic, and North Atlantic) for LCS and SCS management units. In addition, as of November 15, 2004, directed shark vessels with gillnet gear on board, regardless of location, are required to have a Vessel Monitoring System (VMS) installed and operating during right whale calving season (November 15–March 31); and, as of January 1, 2005, directed shark vessels with bottom longline fishing gear on board, located between 33° and 36° 30′ N latitude, are required to have a VMS installed and operating during the mid-Atlantic shark closure period (January 1–July 31).

On October 2, 2006, the 1999 FMP was replaced with the final Consolidated Atlantic HMS FMP, which consolidated management of all Atlantic HMS under one plan, reviewed current information on shark essential fish habitat, required the second dorsal and anal fin to remain on shark carcasses through landing, required shark dealers to attend shark identification workshops, and included measures to address overfishing of finetooth sharks (71 FR 58058). This FMP manages several species of sharks (Table 2.2.1). The 2006–2010 commercial shark landings and the 2010 preliminary commercial shark landings are shown in tables 2.2.2 and 2.2.3, respectively.

On February 7, 2007, NMFS published a final rule (72 FR 5633) to implement additional handling, release, and disentanglement requirements for sea turtles and other non-target species caught in the commercial shark bottom longline fishery. These additional handling requirements require this fishery to use equipment and protocols consistent with the requirements for the pelagic longline fishery (July 6, 2004, 69 FR 40734). On September 23, 2008 (73 FR 54721), NMFS published a final rule that also requires U.S. HMS pelagic longline and bottom longline vessels to possess an additional sea turtle control device as of January 1, 2009. In addition, the February 7, 2007, final rule established measures to complement those implemented by the Caribbean Fishery Management Council on October 29, 2005 (70 FR 62073), to prohibit all vessels issued HMS permits with bottom longline gear onboard from fishing with, or deploying, any fishing gear in six distinct areas off the U.S. Virgin Islands and Puerto Rico, year-round. The intent of these restrictions is to minimize adverse impacts to Essential Fish Habitat (EFH) and reduce fishing mortality on other fish species.

On June 24, 2008, NMFS published a final rule (73 FR 35778, corrected on July 15, 2008, 73 FR 40658) that amended the 2006 Consolidated Atlantic HMS FMP based on recent stock assessments for LCS, dusky sharks, and porbeagle sharks. The rule included measures to adjust quotas and retention limits, modify authorized species for the commercial shark fishery, establish a shark research fishery, require that all sharks be offloaded with all fins naturally attached, and modify the species that can be landed by recreational fishermen. Final measures were effective on July 24, 2008.

Table 2.2.2 Commercial landings for Atlantic large coastal, small coastal, and pelagic sharks in metric tons dressed weight,[4] 2006–2010.
Source: Cortés pers. comm. (2011).

Commercial Shark Landings					
Species Group	2006	2007	2008	2009	2010
Large Coastal Sharks	1,724	1,056	618	686	689
Small Coastal Sharks	346	280	283	303	162
Pelagic Sharks	86	118	106	91	141
Total	**2,156**	**1,454**	**1,007**	**1,080**	**992**

Table 2.2.3 Preliminary landings estimates in metric tons (mt) and pounds (lb) dressed weight (dw) for the 2010 Atlantic shark commercial fisheries. Landings are based on the quota monitoring system.

2010 Landings Estimates			
Species Group	2010 Quota	Estimated Total Landings	% of Quota
Non-Sandbar LCS[5] (Region = Gulf of Mexico)	390.5 mt dw (860,896 lb dw)	426.8 mt dw (940,885 lb dw)	109%
Non-Sandbar LCS[5] (Region = Atlantic)	169.7 mt dw (374,121 lb dw)	174.3 mt dw (384,256 lb dw)	103%
Shark Research Fishery (Non-Sandbar LCS)	37.5 mt dw (82,673 lb dw)	34.1 mt dw (75,276 lb dw)	91%
Shark Research Fishery (SRF) (Sandbar Only)	87.9 mt dw (193,784 lb dw)	64.6 mt dw[6] (142,434 lb dw) 0.4 mt dw[7] (793 lb dw)	80%
Non-Blacknose Small Coastal Sharks (SCS)	221.6 mt dw (488,539 lb dw)	150.6 mt dw (331,943 lb dw)	68%
Blacknose Sharks	19.9 mt dw (43,872 lb dw)	14.9 mt dw (32,825 lb dw)	75%
Blue Sharks	273 mt dw (601,856 lb dw)	4.1 mt dw (9,121 lb dw)	2%
Porbeagle Sharks	1.5 mt dw (3,307 lb dw)	1.7 mt dw (3,788 lb dw)	114%
Pelagic Sharks Other Than Porbeagle or Blue	488 mt dw (1,075,856 lb dw)	130 mt dw (286,457 lb dw)	27%

[4] Dressed weight is the weight of fish after the gills, guts, head, and fins have been removed and discarded (usually at sea). Prohibited species are excluded from these totals.
[5] Non-sandbar Large Coastal Sharks (LCS) includes the following: silky, tiger, blacktip, spinner, bull, lemon, nurse, and hammerheads.
[6] Inside the shark research fishery.
[7] Outside the shark research fishery; these are from State landings.

On June 1, 2010, NMFS published a final rule for Amendment 3 to the 2006 Consolidated HMS FMP (75 FR 30484) for small coastal sharks (SCS), pelagic sharks, and smooth dogfish. The final rule and amendment implemented measures to rebuild blacknose sharks and prevent overfishing of shortfin mako and blacknose sharks. The amendment also created the smoothhound shark management unit, which consists of smooth dogfish (*Mustelus canis*) and Florida smoothhound (*Mustelus norrisi*) sharks (Table 2.2.1). Conservation and management measures implemented by the amendment for smoothhounds include a requirement to offload smoothhounds with their fins naturally attached, Federal dealers must report landings of smoothhounds, and a Federal permit is required for the commercial and recreational retention of smoothhound sharks. These smoothhound requirements have been delayed to allow time for the agency to complete a Biological Opinion (BiOp) under Section 7 of the Endangered Species Act and other rules regarding smoothhound sharks. Other measures in the final rule for Amendment 3 were effective in June and July 2010.

NMFS publishes rules each year to adjust Atlantic shark fishery quotas based on over- or under-harvests from the previous fishing year (the fishing year is from January to December of each year; each shark fishery closes when the respective shark species/management unit's quota reaches 80 percent with a 5-day notice upon filing in the *Federal Register*). A final rule was published on December 8, 2010 (75 FR 76302), which established the 2011 fishing season for commercial quotas for sandbar sharks, non-sandbar LCS, small coastal sharks, and pelagic sharks based on over- or under-harvests from the 2009 and 2010 fishing years. In addition to establishing opening dates and adjusting annual quotas, this final rule implements adaptive management measures, including flexible opening dates for the fishing season, as well as in-season adjustments to shark trip limits. These measures promote, to the extent practicable, equitable fishing opportunities for commercial shark fishermen in all regions and areas.

Shark Stock Assessments

A joint ICCAT (International Commission for the Conservation of Atlantic Tunas) / ICES (International Commission for the Exploration of the Seas) stock assessment was conducted for Atlantic porbeagle sharks in 2009. Four Atlantic stocks were considered for assessment: northwest, northeast, southwest, and southeast. For the northwest Atlantic stock, a surplus production model yielded a similar view of stock status to that found in an updated assessment undertaken by the Canadian Department of Fisheries and Oceans. Both assessments found that porbeagle sharks in the northwest Atlantic are overfished (biomass depleted to levels below MSY[8]), but that overfishing is not occurring (recent fishing mortality is below F_{MSY}). Despite the improving status of the stock, the Canadian assessment still projected that stock rebuilding will take decades due to the low productivity of this stock. NMFS had already implemented a rebuilding plan for porbeagle sharks in 2008 that included a total allowable catch (TAC) of 11.3 metric tons dressed weight (mt dw) and a reduction of the U.S. Atlantic commercial quota to 1.7 mt dw per year. More information on porbeagle management is described in Section 4.2 of this report.

[8]MSY refers to maximum sustainable yield. MSY is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological, environmental conditions and fishery technological characteristics (e.g., gear selectivity), and the distribution of catch among fleets.

The first individual stock assessment for dusky sharks was completed in May 2006. Due to potential identification problems and catch data originating from a variety of sources, the magnitude of dusky shark catch has previously been difficult to ascertain. Three models were used to ascertain the current status of a single dusky shark stock, the most optimistic of which indicated that the dusky shark population has been depleted by 62 to 80 percent of the unfished virgin biomass. The assessment also summarized the relevant biological data, discussed the fisheries affecting dusky sharks, and detailed the data and methods used to assess shark status. Some recommendations were also made regarding future avenues of research and issues to consider in future stock assessments. In 2010, NMFS began conducting a formal assessment for dusky sharks under the Southeast Data Assessment and Review (SEDAR) process described below.

The latest stock assessment on LCS, which followed the SEDAR process, was completed in June 2006. During the Review Workshop, an official recommendation was made to alter the current regime for conducting LCS management unit-based assessments to species-specific assessments. During the 2006 LCS assessment, the Atlantic stock of sandbar sharks was individually assessed and found to be overfished with overfishing occurring. Regulatory actions were put into place in 2008 to adjust the commercial quota of sandbar sharks as necessary to achieve rebuilding by 2070. Blacktip sharks were divided into two stocks, a Gulf of Mexico stock and an Atlantic stock. Due to an absence of reliable estimates of abundance, biomass, and exploitation rates, the current status of blacktips in the Atlantic is unknown. The Gulf of Mexico blacktip shark stock is not overfished and overfishing is not occurring; however, it was recommended that current catch rates of this stock be maintained. In 2010, a new SEDAR assessment began which focused on the sandbar shark stocks.

The latest stock assessments for the SCS management unit (and for Atlantic sharpnose, bonnethead, blacknose, and finetooth sharks individually) were conducted in 2007. The Review Panel for the 2007 SCS SEDAR concluded that, although the assessment of the status of the management unit was adequate based on the available data, given that species-specific assessments were also conducted, any conclusions should be based on the results of the individual species assessments. Results of the 2007 finetooth shark assessment indicated the stock was not overfished and overfishing was not occurring (in contrast to the 2002 SCS assessment, which found that overfishing was occurring). However, because of the general level of uncertainty in the data, the Review Panel suggested cautious management of this resource. For blacknose sharks, the assessment indicated the stock was overfished and overfishing was occurring not only in 2005 but also in the preceding 2001–2004 period. However, due to uncertainty in life history parameters, catches, and indices of relative abundance, the Review Panel cautioned that stock status could change substantially in an unpredictable direction in future assessments. In contrast, the assessments for Atlantic sharpnose and bonnethead sharks determined the stocks were not overfished and that overfishing was not occurring. The blacknose shark stock had another assessment in 2010.

In 2008, an updated stock assessment for blue and shortfin mako sharks was conducted by the ICCAT Standing Committee on Research and Statistics (SCRS). The results of these stock assessments are described in Section 4.2 of this report.

Observer Coverage

Observer coverage in the shark bottom longline fishery began in 1994 on a voluntary basis. Since 2002, observer coverage has been mandatory for selected bottom longline and gillnet vessels. NMFS aims to obtain 4 to 6 percent observer coverage of the commercial effort and deploys approximately five to seven observers to monitor 300 to 400 commercial fishing trips per year. The data collected through the observer program are critical for monitoring takes and estimating mortality of protected sea turtles, sea birds, marine mammals, 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 contingent upon requirements implemented by the Atlantic Large Whale Take Reduction Plan (ALWTRP). The most recent regulations amending the ALWTRP were published in the *Federal Register* on June 25, 2007 (72 FR 34632), and on October 5, 2007 (72 FR 57104). The ALWTRP, as amended, implements specific regulations for the shark gillnet component of the HMS fisheries.

Shark Management by the Regional Fishery Management Councils and States

The only shark species managed by the Regional Fishery Management Councils in the Atlantic is spiny dogfish. The Mid-Atlantic Fishery Management Council has the lead in consultations with the New England Fishery Management Council for the management of spiny dogfish in Federal waters of the Atlantic Coast pursuant to the Spiny Dogfish FMP, which became effective in February 2000. The FMP incorporates the MSA regulations governing the harvest, possession, landing, purchase, and sale of shark fins from 50 CFR Part 600, Subpart N. Due to its overfished status, from 2000 through 2008, the management program established a restrictive spiny dogfish possession limit of 600 pounds per trip and a 4 million pound coastwide commercial quota further split into two seasonal quotas (Period I and Period II). Upon attainment of the coastwide quota, the fishery is closed to further landings by Federally permitted vessels. Based on updated stock assessment results indicating that the stock was not overfished and overfishing was not occurring, the quota and possession limit increased to 12 million pounds and 3,000 pounds per trip, respectively, in the 2009 fishing year. In 2010, the quota was increased to 15 million pounds, and the trip limit maintained at 3,000 pounds. Stock assessment updates conducted in 2010 concluded that spiny dogfish spawning stock biomass was above the biomass target in 2008 and 2009, and is therefore considered rebuilt.

Coordinated State management of sharks is vital to ensuring healthy populations of Atlantic coastal sharks. The Atlantic States Marine Fisheries Commission developed and individual states implemented an Interstate Coastal Shark FMP in 2008. One goal of this FMP was to improve consistency between Federal and State management of sharks in the Atlantic Ocean. Complementary quotas were set in both State and Federal waters in the 2010 fishing year. However, for spiny dogfish, the Interstate Coastal Shark FMP allocates quota regionally in state waters, rather than seasonally, as in Federal waters. This misalignment may be addressed in future management actions for spiny dogfish.

2.3 Current Management of Sharks in the Pacific Ocean

Pacific Fishery Management Council (PFMC)

The PFMC's area of jurisdiction is the Exclusive Economic Zone (EEZ) off the coasts of California, Oregon, and Washington. In late October 2002, the PFMC adopted the U.S. West Coast Highly Migratory Species (HMS) Fisheries FMP. This FMP's management area also covers adjacent high-seas waters for fishing activity under the jurisdiction of the HMS FMP. The HMS FMP is implemented by the NMFS Southwest Regional Office in Long Beach, California. The final rule implementing the HMS FMP was published in the *Federal Register* on April 7, 2004 (69 FR 18443). This FMP manages several sharks as part of the management unit (Table 2.3.1), including the common thresher and shortfin mako (sharks commercially valued but not primarily targeted in the West Coast-based fisheries), as well as blue sharks (a frequent bycatch species), bigeye thresher, and pelagic thresher (incidental catch) sharks. The HMS FMP also includes some shark species which have been identified for monitoring purposes (Table 2.3.1). These species, which often comprise a fishery's bycatch, are monitored on a consistent and routine basis to the extent practicable. Lastly, the HMS FMP also designated some shark species as prohibited because of their special status (Table 2.3.1). If intercepted during HMS fishing operations, these species—including great white, megamouth, and basking sharks—must be released immediately, unless other provisions for their disposition are established consistent with State and Federal regulations.

Sharks within the HMS FMP are managed to achieve Optimum Yield (OY) set at a precautionary level of 75% of MSY. The precautionary approach is meant to prevent localized depletion of these vulnerable species. In addition, the FMP proposed annual harvest guidelines for common thresher and shortfin mako sharks given the level of exploitation in some HMS fisheries at the time the FMP was adopted (e.g., large mesh drift gill net), and 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. While comprehensive stock assessments of common thresher and shortfin mako sharks have not been conducted since the development of the FMP, recent analyses of the large mesh drift gill net fishery data demonstrate that the nominal CPUE of common thresher sharks was lowest in the early 1990s and has been increasing since. A blue shark assessment conducted by scientists at the PIFSC in collaboration with Japanese colleagues and published in 2009 concluded that the North Pacific population was above MSY and the fishing mortality rate below that associated with MSY (Kleiber et al. 2009). In June 2010, the Council took final action to adopt Amendment 2 to the HMS FMP, and the final rule is expected to publish by the end of August, 2011. Amendment 2 addresses annual catch limits and accountability measures which are required by the 2006 amendment to the Magnuson-Stevens Fishery Conservation and Management Act (MSA).

The Pacific Coast Groundfish FMP includes three shark species (leopard, soupfin, and spiny dogfish) in the groundfish management unit (Table 2.3.2). The FMP is implemented by the NMFS Northwest Regional Office in Seattle, Washington. Beginning in 2003, NMFS established a "rockfish conservation area" closing large areas to fishing for groundfish, including sharks, by most gear types that catch groundfish. In addition, the Pacific Coast Groundfish FMP manages its shark species with a combined annual optimal yield for all "other fish," which includes sharks, skates, ratfish, morids, grenadiers, kelp greenling, and some other groundfish species. This optimal yield is reduced by a precautionary adjustment of 50 percent from the acceptable biological catch. Beginning in 2006, NMFS implemented 2-month cumulative trip limits for spiny dogfish for both open access and limited entry fisheries to control the harvest of dogfish and associated overfished groundfish species. The PFMC has designated spiny dogfish as one of the species for which benchmark assessments will be conducted and reviewed in 2011. This assessment would inform management of the species in 2013-14. Table 2.3.3 lists landings (round weight[9] equivalent in metric tons) for various sharks from fisheries off California, Oregon, and Washington from 2001-2010.

Table 2.3.1 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	Pelagic thresher Bigeye thresher Common thresher Shortfin mako Blue shark	*Alopias pelagicus* *Alopias superciliosus* *Alopias vulpinus* *Isurus oxyrinchus* *Prionace glauca*
Sharks Included in the FMP for Monitoring Purposes	Silky shark Blacktip shark Oceanic whitetip shark Dusky shark Prickly shark Soupfin shark Sixgill shark Salmon shark Whale shark Hammerhead sharks Spiny dogfish Leopard shark	*Carcharhinus falciformis* *Carcharhinus limbatus* *Carcharhinus longimanus* *Carcharhinus obscurus* *Echinorhinus cookei* *Galeorhinus galeus* *Hexanchus griseus* *Lamma ditropis* *Rincodon typus* Sphyrnidae *Squalus acanthias* *Triakis semifasciata*
Prohibited Species	Great white Basking shark Megamouth	*Carcharodon carcharias* *Cetorhinus maximus* *Megachasma pelagios*

[9] Round weight is the weight of the whole fish before processing or removal of any part.

Table 2.3.2 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
Soupfin shark (Tope)	*Galeorhinus galeus*
Spiny dogfish	*Squalus acanthias*
Leopard shark	*Triakis semifasciata*

Table 2.3.3 Commercial Shark landings (round weight equivalent in metric tons) for California, Oregon, and Washington, 2001–2010[10].
Source: PacFIN Database, the Washington, Oregon, and California All Species Reports (Report # 307), as of September 2011, http://pacfin.psmfc.org/pacfin_pub/data.php

Commercial Shark Landings (mt) for California, Oregon, and Washington										
Species Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010[11]
Bigeye thresher shark	2	--	5	5	10	4	5	7	7	--
Blue shark	2	42	1	< 1	1	< 1	10	<1	2	<1
Brown catshark	--	--	--	--	--	--	--	--	--	11
Common thresher shark	373	301	294	115	179	160	204	148	105	95
Leopard shark	12	13	10	11	13	11	11	3	2	3
Pacific angel shark	28	22	17	13	12	15	8	12	12	9
Pelagic thresher shark	2	2	4	2	< 1	< 1	2	--	--	--
Shortfin mako	46	82	69	54	33	46	45	35	29	21
Soupfin shark	45	32	35	27	26	30	17	8	5	3
Spiny dogfish	565	876	450	412	495	431	472	723	257	230
Other shark	38	4	20	3	5	4	2	2	3	14
Unspecified shark	3	4	3	6	5	5	5	2	2	20
Total	**1,116**	**1,378**	**908**	**648**	**779**	**706**	**781**	**940**	**424**	**406**

Shark catch data are obtained from commercial landings receipts, observer programs and recreational fishery surveys. Data for the U.S. West Coast are submitted by the States to the PacFIN and RecFIN data repositories and used for monitoring and management by the PFMC.

[10] This report includes all annual landings into the States of Washington, Oregon, and California for all marine species. This report was generated using the fish-ticket-line table and includes all catch areas including Puget Sound, Alaska, and possibly Canadian catch areas.
[11] For the most up-to-date report of shark landings, check the PacFIN website: http://pacfin.psmfc.org/pacfin_pub/data.php, as the data may continue to be updated.

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 the California Recreational Fisheries Survey (CRFS) are scant for sharks, and may not adequately represent shark catch and effort. A Marine Recreational Information Program (MRIP) funded project was initiated in 2009 to develop an adaptive sampling protocol that would more completely sample the recreational shark catch and effort. A second MRIP proposal was submitted to field test the adaptive sampling protocol referenced above but the proposal was not funded.

North Pacific Fishery Management Council (NPFMC)

The NPFMC manages the groundfish fisheries in federal waters off Alaska. In 2010 sharks were managed under the "other species" category in the Bering Sea/Aleutian Islands (BSAI) Groundfish FMP and the Gulf of Alaska (GOA) Groundfish FMP. "Other species" comprises taxonomic groups of slight economic value and are not generally targeted. The category includes sharks, skates, octopi, and sculpins in the BSAI and sharks, octopi, squid, and sculpins in the GOA. These species have limited economic potential and are important components of the ecosystem, but sufficient data are lacking to manage each separately; therefore, an aggregate annual quota limits their catch. Catch of "other species" must be recorded and reported at the individual species level, such as spiny dogfish, or at a broader taxonomic level, such as sculpins. In 2010 sharks were closed to directed fishing in the BSAI and open to directed fishing in the GOA. There was no effort to target sharks in either area and all of the 2010 catch taken was incidentally while targeting other groundfish targets.

In October 2010 NMFS issued a final rule to implement Amendment 95 and 96 to the BSAI FMP and Amendment 87 to the GOA FMP to meet Magnuson-Stevens Fishery Conservation and Management Act National Standard 1 to end and prevent overfishing, rebuild overfished stocks, achieve optimum yield, and to comply with statutory requirements for annual catch limits (ACLs) and accountability measures (AMs). These amendments move all of the major taxonomic groups from the "other species" category to the "target species" category, removes the "other species" category and "non-specified species" category from the FMPs, establishes an "ecosystem component" category, and describes the current practices for groundfish fisheries management in the FMPs, as required by the National Standards guidelines. Beginning in 2011 separate overfishing levels (OFLs), allowable biological catch (ABC) amounts, and total allowable catch (TAC) levels will be set annually for sharks (BSAI and GOA), skates (BSAI), squid (GOA), sculpins (BSAI and GOA), and octopi (BSAI and GOA). The final rule also revised the definition for "other species" to allow the continued management of BSAI and GOA sharks, sculpins, and octopi, and GOA squids as a group for purposes of prohibited species catch management and maximum retainable amounts of incidental catch when closed to directed fishing.

In the BSAI NMFS conducts surveys annually in the Eastern Bering Sea and triennially along the deeper slope area in the BSAI for all groundfish, including sharks. In the GOA NMFS conducts surveys biannually for groundfish, including sharks. The most recent surveys were conducted in 2010 in the BSAI and in 2009 in the GOA. These survey results were incorporated into the Stock Assessment and Fishery Evaluation (SAFE) reports for sharks in the BSAI and

GOA available from the NPFMC. A NMFS survey of groundfish, including sharks, is scheduled for 2011 in the Eastern Bering Sea and GOA. The results will be incorporated in the 2011 SAFE reports.

Beginning in 2010, the BSAI and GOA Plan Teams and the Science and Statistical Committee recommend to the NPFMC an OFL and an ABC amount for the shark species group based on the best available and most recent scientific information. The Advisory Panel and Council then recommend a TAC level for sharks in the BSAI and GOA as part of the annual groundfish harvest specifications. The most recent assessments for sharks are in Chapter 18b to the 2010 SAFE reports for the BSAI and GOA (available online at http://www.afsc.noaa.gov/refm/stocks/assessments.htm). At its December 2010 meeting, the NPFMC recommended OFLs, ABCs, and TACs for each of these target species groups, including sharks, in both the BSAI and GOA for the 2011 and 2012 fishing years. The NPFMC recommended an OFL of 1,360 mt, an ABC of 1,020 mt, and a TAC of 50 mt for sharks in the BSAI based on recent average historical catch. In the GOA the NPFMC recommended an OFL of 8,263 mt, an ABC of 6,197 mt, and a TAC of 6,197 mt based in large part on the natural mortality and biomass estimates for spiny dogfish and the recent average historical catch of other shark species. The NPFMC also recommended that NMFS close directed fishing for sharks in both the BSAI and GOA for the 2011 and 2012 fishing years.

Seven shark species have been identified during fishery surveys or observed during groundfish fishing in the Alaskan waters (Table 2.3.4). The brown cat, basking, sixgill, and blue sharks are very rarely taken in any sport or commercial fishery and are not targeted for harvest. Pacific sleeper, salmon, and spiny dogfish sharks are taken incidentally in groundfish fisheries and are monitored in season by NMFS. Sharks are the only group in the "other species" category consistently identified to species in catches by fishery observers. 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 BSAI and in the midwater trawl pollock fishery, non-pelagic trawl fisheries and hook-and-line Pacific cod, sablefish, and halibut fisheries in the GOA. Estimates of the incidental catch of sharks in the BSAI and GOA and BSAI groundfish fisheries from 2001 through 2010 have ranged from 52-1,362 mt in the BSAI and from 418-1,603 mt in the BSAI (Table 2.3.5). Due to limited catch reports on individual species and larger taxonomic groups in the "other species" category estimates of the incidental catch of sharks in the BSAI and GOA in the earlier years (2001 to 2002) are largely based on NMFS survey results, observer data, and the NMFS Catch Accounting System data in the later years (2003 and onward).

Very few of the sharks incidentally taken in the groundfish fisheries in the BSAI and GOA are retained. Table 2.3.5 lists the amounts of sharks retained between 2003 and 2010 in the BSAI and GOA. The amount of sharks retained during the period range from 1.8 to 9.9 percent of the total incidental catch in the BSAI, and 1.4 to 6.8 percent in the GOA. In 2006 two vessels targeted sharks using hook-and-line gear in the GOA; one vessel using a Federal Fishing Permit and another vessel using a permit issued by the Commissioner of ADF&G for use in State waters. The catches of these vessels is confidential but catches of sharks were very low in amount, effort was very short-lived, and deemed unsuccessful by the participants. Since 2006 there has been no effort targeting sharks in the BSAI or GOA.

Table 2.3.4 North Pacific shark species.

North Pacific shark species	
Common name	Scientific name
Brown catshark	*Apristurus brunneus*
Basking shark	*Cetorhinus maximus*
Sixgill shark	*Hexanus griseus*
Salmon shark	*Lamna ditropis*
Blue shark	*Prionace glauca*
Pacific sleeper shark	*Somniosus pacificus*
Spiny dogfish shark	*Squalus acanthias*

Table 2.3.5 Incidental catch and utilization (in metric tons) of sharks in the Gulf of Alaska and Bering Sea/Aleutian Islands commercial groundfish fisheries, 2001–2010.
Source: NMFS Survey, Observer Data, and NMFS Catch Accounting System Data

Incidental Catch of Sharks (mt)											
Fishery	Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GOA Groundfish	Spiny dogfish	494	117	362	204	485	1,232	849	534	859	401
	Pacific sleeper shark	249	226	298	286	486	254	297	66	48	167
	Salmon shark	33	58	37	41	60	34	135	7	10	107
	Unidentified shark	77	16.8	54	40	70	83	107	12	24	9
	Total	**853**	**418**	**751**	**571**	**1,101**	**1,603**	**1,388**	**619**	**941**	**685**
	% Retained	**UNK**	**UNK**	**1.4**	**1.7**	**3.2**	**3.9**	**3.3**	**6.8**	**6.2**	**5.7**
BSAI Groundfish	Spiny dogfish	17	9	11	9	11	7	3	17	19	15
	Pacific sleeper shark	687	838	280	420	333	313	256	120	44	21
	Salmon shark	24	47	196	26	47	63	44	42	70	12
	Unidentified shark	35	468	33	60	26	305	28	7	6	5
	Total	**764**	**1,362**	**520**	**515**	**418**	**689**	**331**	**186**	**140**	**52**
	% Retained	**UNK**	**UNK**	**1.8**	**2.6**	**4.9**	**3.9**	**9.9**	**7.0**	**4.4**	**7.3**

Recreational shark fisheries

The ADF&G manages the recreational shark fishery in State and Federal waters under the statewide Sport Shark Fishery Management Plan (5 AAC 75.012), in effect since 1998. Until 2010, the plan stipulated a daily bag limit of one shark of any species per person per day, and an annual limit of two sharks of any species per person. In March 2010 the Alaska Board of Fisheries amended the plan to increase daily bag and possession limit for spiny dogfish only to five fish, with no annual limit. Demand for spiny dogfish is low and liberalization of the bag limit is not expected to result in a significant increase in harvest. Estimates of sport harvest are not yet available for 2010. There have been no reported incidents of sport-caught sharks being finned and discarded, and state regulations prohibit the intentional waste or destruction of any sport-caught species.

Recreational harvest of all shark species combined is estimated through a mail survey of sport fishing license holders. About 396 sharks of all species were harvested by the sport fishery in state and federal waters of Southeast and Southcentral Alaska in 2009 (most recent mail survey estimate). The Southcentral Region accounted for 60% of the harvest. The catch typically consists almost entirely of spiny dogfish and salmon shark. Although most spiny dogfish are released, they are believed to be the primary species harvested. There is a directed recreational fishery for salmon sharks in Prince William Sound involving a small number of charter boats. Salmon sharks are also taken incidentally by halibut anglers.

Harvest of salmon sharks by guided anglers is required to be reported in mandatory charter fishing logbooks. Charter boats reported salmon shark harvests of 94 fish in 2008, 63 fish in 2009, and 22 fish in 2010. Although estimates of salmon shark harvest are not available for unguided anglers, the charter fleet is believed to account for the majority of salmon shark harvest. In addition to the mail survey and logbook, shark fisheries are monitored in Southcentral Alaska through biological sampling for species, size, age, and sex composition, as well as spatial distribution of the harvest.

Commercial shark fishing in State waters

State of Alaska regulations prohibit directed commercial fishing of sharks statewide except for a spiny dogfish permit fishery (5 AAC 28.379) adopted by the Alaska Board of Fisheries for the Cook Inlet area in 2005. 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. The state limits the amount of incidentally taken sharks that may be retained to 20% of the round weight of the target species on board a vessel except in the Southeast District where a vessel using longline or troll gear may retain up to 35% round weight of sharks to round weight of the target species on board (5AAC 28.174 (1) and (2)). Also 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)). All sharks landed must be recorded on an ADF&G fish ticket. To date, a single permit was issued in 2006 for the Cook Inlet spiny dogfish fishery and there was a single landing of incidentally taken sharks from southcentral Alaska waters. Harvest data are confidential if less than three landings occur. Since 2006 no permits have been issued.

Western Pacific Fishery Management Council (WPFMC)

The WPFMC's area of jurisdiction is the EEZ around Hawaii, American Samoa, Guam, the Northern Mariana Islands, and the Pacific Remote Islands Areas (PRIA). The NMFS Pacific Islands Regional Office in Honolulu, Hawaii, implements the fishing regulations and other management measures and policies. In the western Pacific, the conservation of sharks is governed under the provisions of the five fishery ecosystem plans, the Shark Finning Prohibition Act and the MSA. The MSA (Section 317) makes it unlawful for any person to chum for sharks, except for harvesting purposes. The WPFMC's Fishery Ecosystem Plan for Western Pacific Pelagic Fisheries identifies nine sharks as management unit species (Table 2.3.6). Five species of coastal sharks are listed in the fishery ecosystem plans for American Samoa, Hawaii, the Marianas Archipelago, and the Pacific Remote Islands Areas (Table 2.3.7) as currently harvested.[12]

Table 2.3.6 Sharks in the management unit of the Fishery Ecosystem Plan for Western Pacific Pelagic Fisheries (December 2009, as amended).

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*

The longline fisheries in the western Pacific, mostly in Hawaii and American Samoa, were responsible for the vast majority of the sharks landed. Shark landings (estimated whole weight) by the Hawaii-based longline fisheries peaked at about 2,870 mt in 1999, due largely to the finning of blue sharks. A State of Hawaii law prohibiting landing shark fins without an associated carcass passed in mid-2000 (Hawaii Revised Statutes 188.40-5). This law apparently

[12] In 2009, the WPFMC's Crustaceans, Bottomfish & Seamount Groundfish, Precious Corals, and Coral Reef Ecosystem FMPs were replaced by fishery ecosystem plans (FEP) for American Samoa, Hawaii, the Mariana Archipelago (Guam and the Northern Mariana Islands, and the Pacific Remote Island Areas). The western Pacific Pelagics FMP was converted to the Pelagics FEP.

decreased shark landings by almost 50 percent in 2000. With the subsequent enactment of the Federal Shark Finning Prohibition Act, shark landings from 2001 to 2010 were down by more than 93 percent from their peak (Table 2.3.8). Landings in 2010 (preliminary data) were 87 mt; the lowest landings in recent history. Today, sharks are marketed as fresh shark fillets and steaks in Hawaii supermarkets and restaurants and are also exported to the U.S. mainland.

The American Samoa longline fishery lands a small amount of sharks compared to Hawaii's longline fishery (Table 2.3.8). The pattern of shark landings by the American Samoa longline fishery was similar to shark landings by the Hawaii-based longline fishery. Landings increased to 13 mt in 1999, followed by a decline. The decline in shark landings by the American Samoa longline fishery is attributed to the Shark Finning Prohibition Act.

Table 2.3.7 Coastal sharks listed as management unit species and designated as currently harvested coral reef taxa in the four western Pacific Archipelagic Fishery Ecosystem Plans (FEP) for Western Pacific Fisheries. 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.

Coral Reef Ecosystems of the Western Pacific Fishery Management Plan					
Sharks Listed as Management Unit Species and Designated as Currently Harvested Coral Reef Taxa					
Common Name	Scientific Name	American Samoa FEP	Hawaii FEP	Marianas FEP	PRIA FEP
Silvertip shark	*Carcharhinus albimarginatus*	*X*	-	*X*	*X*
Grey reef shark	*Carcharhinus amblyrhynchos*	*X*	*X*	*X*	*X*
Galapagos shark	*Carcharhinus galapagenis*	*X*	*X*	*X*	*X*
Blacktip reef shark	*Carcharhinus melanopterus*	*X*	*X*	*X*	*X*
Whitetip reef shark	*Triaenodon obesus*	*X*	*X*	*X*	*X*

Table 2.3.8 Shark landings (in metric tons) from the Hawaii-based and American Samoa pelagic longline fisheries, 2001-2010.
Source: Pacific Islands Fisheries Science Center, Fisheries Monitoring and Analysis Program, and Western Pacific Fisheries Information Network (WPacFin).

Shark Landings (mt)											
Fishery	Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Hawaii-based Longline Fishery	Blue shark	30	30	20	60	30	12	6	7	9	6
	Mako shark	60	80	90	70	110	95	119	109	102	62
	Thresher shark	50	50	50	60	30	33	42	39	28	16
	Misc. shark	10	20	10	10	-	11	7	4	6	3
	Total shark landings	**150**	**180**	**170**	**200**	**170**	**151**	**174**	**159**	**145**	**87**
American Samoa Longline Fishery	**Total shark landings**	**1**	**3**	**4**	**1**	**<1**	**1**	**2**	**1**	**1**	**2**

2.4 NOAA Enforcement of the Shark Finning Prohibition Act

NOAA Fisheries Office of Law Enforcement (OLE) has responsibility for enforcing the Shark Finning Prohibition Act (SFPA) and its implementing regulations. During calendar year 2010, violations of the SFPA were detected, investigated, and referred for administrative prosecution in the Southeast, Pacific Islands, and Alaska Enforcement Divisions, including one detected by the United States Coast Guard (USCG) and referred to OLE for further investigation. Violations which were investigated included finning by U.S. domestic fishing vessels and illegal fishing for sharks by a foreign vessel in the U.S. Exclusive Economic Zone (EEZ) as prohibited by the Magnuson-Stevens Fishery Conservation and Management Act.

- A NOAA OLE special agent responded to the USCG Station at South Padre Island, TX in conjunction with the interdiction of a Mexican-flagged vessel by the USCG. The vessel was detected by the USCG while it was engaged in illegal, unreported, and unregulated (IUU) fishing activities 23 miles from the U.S. mainland and 58 miles within the U.S. Exclusive Economic Zone (EEZ). Incident to the boarding conducted by the USCG, 12 sharks and 158 red snapper were found on the vessel. The vessel and three-man crew were transported to the U.S. Coast Guard Station at South Padre Island. The vessel was retained by the USCG and the crew was transferred to the custody of the U.S. Border Patrol. The fishing violations were referred to OLE for further action.

- During October of 2010, in the U.S. EEZ surrounding American Samoa, a U.S.- flagged American Samoa based longline fishing vessel caught and finned a shark. The fins were initially retained and possessed after the carcass was disposed at sea. The case is currently under review by the NOAA Office of General Counsel for Enforcement and Litigation (GCEL).

- While conducting patrols in Alaska, a USCG boarding team discovered a single shark tail in a bucket on board a commercial fishing vessel that was engaged in a State salmon fishery. The vessel operator indicated that he was unaware that the shark tail had been taken by a crew member. This case was referred to NOAA GCEL.

2.5 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 and other U.S. shark management entities have completed the following actions:

- Staff from Northeast Fisheries Science Center attend 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. Tags, tagging information, length and weight conversions, identification guides and placards, research results, as well as management and regulation pamphlets are made available to the fishing public. This information is also mailed to NMFS Cooperative Shark Tagging Program participants. Feedback is given to tournament officials on historic tournament landings to apply further shark conservation measures and to facilitate better catch and release practices and encourage catch and release prizes.
- NMFS and its Office of Law Enforcement partnered with the National Museum of Crime and Punishment (NMCP) in Washington, D.C., through an exhibit to raise awareness of crimes against marine wildlife in conjunction with National Oceans Month. A special section of the exhibit was dedicated to raising awareness regarding illegal shark finning for commercial gain.
- In response to declines in the eastern North Pacific basking shark population, the Southwest Fisheries Science Center initiated a basking shark research program in 2010. One of the goals of the program is to improve national sightings information by developing a sightings website and an education and outreach program centered around Monterey Bay, CA. A dedicated website and hotline have been established as a part of a sightings network. A considerable amount of education and outreach has been conducted to advertise the sightings network.

- Dr. Lisa Natanson, staff at Northeast Fisheries Science Center, was shown in episodes of the Discovery Channel series 'Swords: Life on the Line' (season two was premiered and season three was filmed in 2010). These episodes highlight Dr. Natanson's pelagic shark nursery ground research, movements, and abundance studies in conjunction with the U.S. high seas commercial longline fleet as well as the NEFSC Cooperative Shark Tagging Program.
- The Southwest Regional Office and the Southwest Fisheries Science Center have collaborated on public outreach towards the development of alternative fishing methods that reduce post-release mortality of thresher sharks. Three seminars offered in 2010 provided over 500 recreational fishers with a thorough review of thresher shark life history, reproductive biology, history of the fishery, fishing tactics, current fisheries management, and possible ways to improve current practices. Seminars also focused specifically on the development of techniques that reduce trailing gear in sharks that are hooked in the tail but not landed. The project team participated in numerous fishing radio shows and submitted informative articles to popular recreational fishing publications. An outreach brochure developed in 2008 (see figure 2.5.1) was distributed at the seminars and at various fishing shows in 2010 (e.g., at the Fred Hall Fishing and Tackle Shows in Long Beach and Del Mar, California, which annually attracts in excess of 50,000 participants).
- The 2006 Consolidated Highly Migratory Species Fishery Management Plan requires that all federally permitted shark dealers in the Atlantic Ocean and Gulf of Mexico attend Atlantic Shark Identification Workshops. The ASMFC Interstate Coastal Shark FMP now requires that all state shark dealers must obtain a Federal shark dealer permit and therefore must attend the Atlantic Shark Identification Workshop. The objectives of these workshops is to reduce the number of unknown and misidentified sharks reported on the dealer reporting form and increase the accuracy of species-specific dealer-reported information.
- Starting in 2007, all Atlantic commercial shark fishermen using gillnet and/or longline gear were required to attend a mandatory handling and release workshop on protected resources and non-target bycatch prior to renewing their permits.
- The United States has worked cooperatively with Governments in the Eastern Pacific Ocean (EPO) to hold a series of regional workshops aimed at improving shark conservation and management efforts in the EPO. Two workshops occurred in 2008 (in Ecuador and Mexico) and a third workshop occurred in 2010 in Ecuador. See section 4.2 for more information on this effort.
- In an effort to increase international collaboration and capacity building, Southwest Fisheries Science Center staff taught a genetic species identification course at the III Taller Interregional de Tiburones en el Océano Pacífico Oriental (OPO) in Manta, Ecuador July 6-9, 2010. This course involved hands-on experience using locally collected shark fins. The goals were to both genetically identify species groups that are commonly misidentified such as the hammerhead and thresher sharks, as well as species common in this region. Some of the techniques are now being applied to studies of shark landings in Columbia and the initial results and methods are being prepared for publication.
- As part of the joint relationship between NMFS and the Shelby Center for Ecosystem based Management in Dauphin Island, Alabama, three scientists from the Southeast

Fisheries Center taught a 2-week summer course on the biology of sharks for the third year in a row. The course is open to upper level undergraduates from a number of Alabama Universities. The course is a comprehensive, interdisciplinary introduction to the evolution, biology, ecology, and conservation of elasmobranch fishes.

- Staff from OLE's Southeast Division traveled to Chalmette, Louisiana to conduct formal training for the USCG regarding various aspects of fishery enforcement, including the enforcement of regulations pertaining to sharks and other federally managed species, and investigative case package preparation. The training session was held at the Gulf Regional Fishery Training Center (GRFTC). Approximately 30 USCG personnel were in attendance.

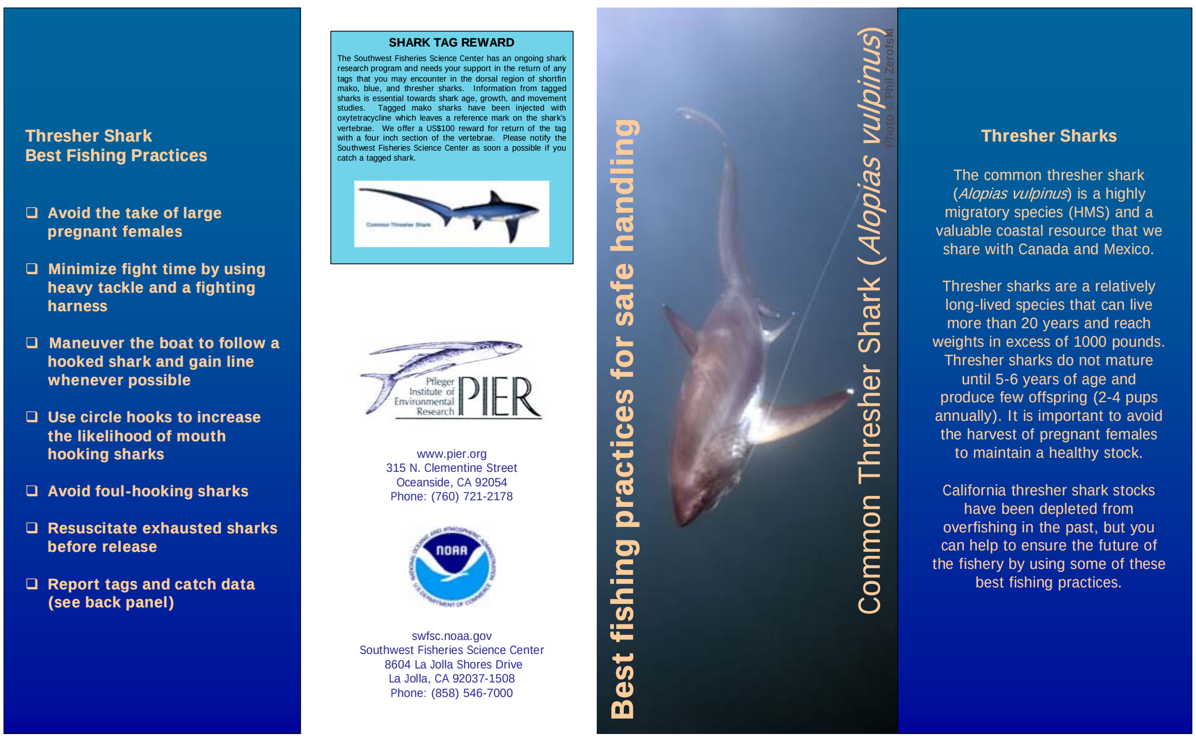

Fig. 2.5.1. Page 1 of informational brochure on best fishing practices for safe release of common thresher shark captured in the southern California recreational fishery.

3. Imports and Exports of Shark Fins

The summaries of annual U.S. imports and exports of shark fins in Tables 3.1.1 and 3.2.1 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. In recent years, exports of shark fins exceeded imports in both weight and value. The total weight and value of imports remained steady between 2006 and 2008, but dropped by more than 25% in 2009. In 2010, both the weight and value of imported shark fins increased from the 2009 levels and imports of shark fins were the highest since 2006. The total weight of exports showed a large decrease in 2010 compared to 2009 figures whereas the mean value of shark fin exports was the highest since 2007.

3.1 U.S. Imports of Shark Fins

During 2010, imports of shark fins entered through the following U.S. Customs and Border Protection districts: Anchorage, Los Angeles, San Francisco, Miami and Seattle. In 2010, countries of origin (in order of importance based on quantity) were Hong Kong, China, and New Zealand. Shark fins were also imported in small numbers from Japan and Spain (Table 3.1.1). The mean value of imports per metric ton (mt) increased from $48,000/mt to $59,000/mt between 2006 and 2008 with a subsequent decline to $46,000/mt in 2009. In 2010, value decreased further to $35,000/mt, the lowest mean value since 2006. It should be noted that, due to the complexity of the shark fin trade, fins are not necessarily produced in the same country from which they are exported. In the United States, factors such as availability of labor, overseas contacts, and astute trading can play a role in determining the locale from which exports are sent.

3.2 U.S. Exports of Shark Fins

The vast majority of shark fins exported in 2010 were sent from the United States to Hong Kong, China and Canada with small amounts going to Poland and Taipei (Table 3.2.1). The mean value of exports per metric ton (mt) has decreased from $81,000/mt in 2006 to $49,000/mt in 2009, the lowest value since 2006 with the second largest weight of 77 mt. The 2009 decrease in value of exported shark fins was followed by a large increase in value in 2010 from $49,000/mt to $80,000/mt. Using data from Table 3.2.1, mean values of dried shark fins for all countries combined has fluctuated between $49,039/mt and $81,000/mt from 2006 to 2010.

3.3 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 3.3.1, 3.3.2, and 3.3.3 are based on information provided in FAO's FishStat database. The quantities and values in those tables are totals for all dried, dried and salted, fresh, or frozen shark fins. Reported global imports of shark fins have fluctuated between 13,709 mt and 17,692 mt from 2004 to 2008, while the reported global exports of shark fins have fluctuated between 9,894 mt and 16,153 mt from 2004 to 2008. The level of both imports and exports was lower in 2008 than in any other year in the period 2004–2007. Hong Kong remains the largest importer and exporter of shark fins. FAO had not released updated data at the time of printing this report, so the data shown is the same as provided in last year's report.

Table 3.1.1 Weight and value of dried 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. (1) means that the weight was less than 500 kilograms.
Source: U.S. Census Bureau

Country	2006		2007		2008		2009		2010	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	0	0	1	13	0	0	0	0	0	0
Canada	(1)	5	2	11	(1)	20	(1)	2	0	0
China	4	132	5	656	1	59	6	200	21	442
China, Hong Kong	16	1053	20	954	23	1522	11	706	11	695
Colombia	0	0	0	0	(1)	4	0	0	0	0
Indonesia	0	0	(1)	7	(1)	8	0	0	0	0
Japan	0	0	0	0	2	82	0	0	(1)	3
Mexico	(1)	4	0	0	0	0	0	0	0	0
New Zealand	1	26	0	0	1	14	3	57	1	37
Nicaragua	(1)	22	0	0	0	0	0	0	0	0
Panama	7	139	0	0	(1)	4	0	0	0	0
Peru	0	0	2	36	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	(1)	3
South Korea	0	0	0	0	2	19	0	0	0	0
Vietnam	0	0	0	0	(1)	6	0	0	0	0
Total	**29**	**1382**	**29**	**1677**	**29**	**1738**	**21**	**966**	**34**	**1180**
Mean value	**$48,000/mt**		**$58,000/mt**		**$59,000/mt**		**$46,000/mt**		**$35,000/mt**	

Table 3.2.1 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 U.S. 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	2006		2007		2008		2009		2010	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	0	0	0	0	1	13	0	0	0	0
Canada	2	246	3	238	1	164	2	277	1	209
China	0	0	0	0	1	112	3	495	2	335
China, Hong Kong	42	3536	32	2348	30	1531	71	2948	39	2785
China,Taipei	0	0	0	0	(1)	35	0	0	(1)	6
Egypt	0	0	0	0	0	0	(1)	3	0	0
Finland	0	0	1	33	0	0	0	0	0	0
Germany	3	91	0	0	0	0	(1)	3	0	0
Indonesia	0	0	0	0	0	0	(1)	5	0	0
Japan	2	35	0	0	4	204	0	0	0	0
Mexico	(1)	17	(1)	21	0	0	0	0	0	0
Netherlands	1	22	0	0	0	0	0	0	0	0
Panama	0	0	0	0	0	0	(1)	21	0	0
Poland	0	0	0	0	0	0	1	15	(1)	22
Portugal	0	0	(1)	3	0	0	(1)	3	0	0
South Korea	0	0	0	0	0	0	(1)	6	0	0
Total	**49**	**3945**	**36**	**2643**	**37**	**2059**	**77**	**3776**	**42**	**3357**
Mean value	**$81,000/mt**		**$73,000/mt**		**$56,000/mt**		**$49,000/mt**		**$80,000/mt**	

Table 3.3.1 Weight and value of shark fins imported by countries other than the United States.
Note: (1) means that the weight was less than 500 kilograms.
Source: Food and Agriculture Organization of the United Nations, FishStat database, www.fao.org

Country	2004		2005		2006		2007		2008	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	0	0	9	1,056	7	891	11	1182	7	1351
Brazil	4	20	2	8	0	0	0	0	0	0
Brunei Darussalam	2	3	0	0	0	0	0	0	0	0
Cambodia	0	0	1	12	4	186	1	38	0	0
Canada	69	5,134	112	5,261	110	5,480	94	4,994	118	6,508
Chile	(1)	11	0	0	0	0	0	0	0	0
China	4,776	27,523	3,338	17,758	2,662	13,882	2,542	11,991	2,005	10,777
China, Hong Kong	11,040	329,778	10,348	306,968	9,363	253,427	10,183	276,302	9,950	287,510
China, Macao	96	2,831	120	3,324	106	3,728	118	5,306	122	5,911
China, Taipei	525	4,052	434	4,658	708	4,141	564	6,223	792	8,710
Djibouti	0	0	(1)	15	0	0	0	0	0	0
India	0	0	2	8	0	0	0	0	0	0
Indonesia	193	2,407	332	2,486	293	1,274	84	366	220	1,515
Laos	0	0	(1)	5	(1)	6	0	0	0	0
Malaysia	293	480	93	311	145	585	163	653	0	0
Maldives	(1)	1	0	0	0	0	0	0	0	0
North Korea	1	268	1	331	2	1,222	2	1,084	1	579
Peru	1	4	1	4	8	52	2	12	28	141
Singapore	566	25,524	437	20,673	489	23,434	446	20,638	396	22,632
South Korea	5	268	2	109	6	157	2	82	4	167
Thailand	121	1,256	113	1,317	102	1,141	82	877	66	748
United Arab Emirates	0	0	0	0	(1)	15	0	0	0	0
Total	**17,692**	**399,560**	**15,345**	**364,304**	**14,005**	**309,621**	**14,294**	**329,748**	**13,709**	**346,549**
Mean value	**$22,584/mt**		**$23,741/mt**		**$22,108/mt**		**$23,069/mt**		**$25,279/mt**	

Table 3.3.2 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). (1) means that the weight < 500 kg.
Source: Food and Agriculture Organization of the United Nations, FishStat database, www.fao.org

Country	2004		2005		2006		2007		2008	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Angola	5	249	4	265	4	224	3	179	2	149
Argentina	4	133	9	504	9	656	11	503	99	3,019
Bahrain	0	0	0	0	0	0	0	0	(1)	9
Bangladesh	166	689	0	0	195	623	351	1,407	17	403
Brazil	179	2,405	157	2,292	118	1,894	131	2,313	113	2,825
Brunei Darussalam	0	0	12	82	0	0	4	21	0	0
Burma	0	0	2	23	0	0	0	0	0	0
Cambodia	0	0	(1)	5	0	0	0	0	0	0
Chile	54	2,474	39	1,639	13	570	4	158	0	0
China	2,476	40,966	1,349	20,753	381	5,306	409	6,712	347	5,898
China, Hong Kong	8,560	138,005	7,134	127,102	5,962	103,818	5,670	97,074	5,294	100,877
China, Macao	0	0	0	0	29	800	23	711	7	410
China, Taipei	1,241	4,259	1,141	8,875	974	9,514	903	8,082	846	7,910
Colombia	17	1,130	14	1,034	17	1,132	19	1,146	16	1,074
Congo, Dem. Rep. of the	0	0	1	53	(1)	20	0	0	(1)	10
Congo, Republic of	14	430	18	848	10	246	10	314	15	509
Costa Rica	6	123	0	0	0	0	10	69	0	0
Côte d'Ivoire	(1)	1	0	0	0	0	0	0	0	0
Djibouti	0	0	0	0	2	47	0	0	0	0
Ecuador	102	2,243	(1)	8	1	5	12	257	124	2,526
Gabon	0	0	0	0	0	0	5	298	20	470
Guinea	(1)	4	47	2,163	47	1,872	35	1,613	0	0
Guinea-Bissau	0	0	3	110	0	0	5	276	0	0
India	218	4,513	104	3,663	145	5,037	96	3,879	95	7,496
Indonesia	943	10,936	1,554	8,065	1,073	9,174	801	7,303	1,320	7,047
Iran	0	0	0	0	0	0	(1)	2	(1)	14
Japan	205	10,262	168	8,140	181	9,091	197	8,735	163	8,457
Kiribati	(1)	25	1	70	1	111	1	69	(1)	30
Kuwait	0	0	0	0	(1)	9	1	91	2	78

Table 3.3.2 Continued

Country	2004		2005		2006		2007		2008	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Liberia	0	0	3	296	3	271	3	253	4	310
Libya	1	27	1	59	1	52	0	0	0	0
Malaysia	463	565	37	196	50	239	107	554	0	0
Maldives	57	647	43	598	16	192	15	107	9	70
Marshall Islands	1	52	0	0	0	0	55	825	17	305
Nigeria	0	0	1	25	0	0	0	0	0	0
Panama	103	3,860	97	3,544	78	2,600	66	4,836	61	2,615
Papua New Guinea	12	271	9	652	10	495	17	1,412	17	1,526
Philippines	54	411	0	0	0	0	77	948	38	130
Saint Pierre & Miquelon	0	0	0	0	0	0	2	10	0	0
Saudi Arabia	0	0	0	0	0	0	0	0	5	122
Senegal	72	2,537	2	8	48	2,678	2	14	0	0
Seychelles	5	33	7	56	6	67	9	86	2	29
Singapore	453	25,965	333	17,253	410	21,394	374	20,296	380	22,703
Solomon Islands	0	0	0	0	0	0	0	0	3	78
Somalia	0	0	0	0	0	0	(1)	3	0	0
South Korea	5	293	7	357	9	438	7	224	16	610
Suriname	6	218	7	312	8	487	4	260	4	243
Thailand	29	1,036	44	1,916	18	772	74	763	20	866
Togo	0	0	0	0	24	207	0	0	25	193
Tonga	0	0	0	0	0	0	0	0	8	470
United Arab Emirates	468	10,149	539	14,381	427	13,592	472	13,965	515	16,220
Uruguay	38	977	39	570	27	509	21	324	22	335
Vanuatu	0	0	0	0	0	0	0	0	40	179
Venezuela	40	874	20	351	7	21	2	21	0	0
Yemen	156	5,434	179	5,846	284	8,442	351	11,333	228	10,760
Total	**16,153**	**272,196**	**13,125**	**232,114**	**10,588**	**202,605**	**10,359**	**197,446**	**9,894**	**206,975**
Mean value	**$16,851/mt**		**$17,685/mt**		**$19,764/mt**		**$19,922/mt**		**$20,919/mt**	

Table 3.3.3 Production of shark fins in metric tons by country.
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.
Source: Food and Agriculture Organization of the United Nations, FishStat database, www.fao.org

Country	2004	2005	2006	2007	2008
Bangladesh	4	1	4	0	17
Brazil	179	157	118	131	226
China, Hong Kong SAR	NA	NA	NA	NA	NA
China, Taipei	134	137	117	36	89
Ecuador	59	NA	1	12	124
El Salvador	136	149	194	44	40
Fiji Islands	175	160	160	0	0
Guyana	82	151	123	125	131
India	827	1,926	270	172	1,232
Indonesia	943	1,554	1,073	1,360	1,320
Korea, Republic of	5	7	33	7	16
Madagascar	NA	NA	NA	NA	NA
Maldives	20	13	11	11	9
Pakistan	68	81	62	69	78
Philippines	54	84	71	78	38
Senegal	33	34	27	16	22
Singapore	246	320	120	170	260
Sri Lanka	110	80	80	80	50
Uruguay	35	43	0	7	25
Yemen	156	179	284	351	228
TOTAL (mt)	**3,266**	**5,076**	**2,748**	**2,669**	**3,905**

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

The key components of a comprehensive framework for international shark conservation and management have already been established in global agreements, organizations and fora. These relevant mechanisms and fora have identified, adopted, and/or published detailed language, provisions, or guidance to assist States and regional fisheries management organizations (RFMOs) in the development of conservation and management 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 shark conservation and management by having ongoing consultations regarding the development of international agreements consistent with the Act. Discussions have focused on possible bilateral, multilateral, and regional work with other nations. The law calls for the United States to pursue an international ban on shark finning and to advocate 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 reaching agreements to decrease the incidence of finning worldwide.

4.1 Bilateral Efforts

NMFS has participated in bilateral discussions with a number of States and entities, which included issues relating to international shark conservation and management. Emphasis in these bilateral consultations has been on the collection and exchange of information, including requests for data such as shark and shark fin landings, transshipping activities, and trade. In addition, the United States continues to encourage other countries to implement the FAO's International Plan of Action (IPOA) for the Conservation and Management of Sharks by finalizing and implementing their own National Plans of Action.

4.2 Regional Efforts

The U.S. Government continues to place priority on shark conservation and management globally and works within regional fishery management organizations (RFMOs) and other regional entities to facilitate shark research, data collection, monitoring, and management initiatives, as appropriate. In recent years, the United States has successfully led efforts to ban shark finning and implement shark conservation and management measures within a number of such organizations. Table 4.2.1 lists RFMOs and regional/multilateral programs in which the United States has worked to address shark conservation and management. Of the list in Table 4.2.1, ICCAT, NAFO, WCPFC, and the IATTC have adopted finning prohibitions. Other RFMOs the United States is not a Party to also have adopted finning prohibitions, such as IOTC, GFCM, SEAFO, and NEAFC. Recent activities or planning of the RFMOS that the United States is a Party to are discussed below as a supplement to last year's *Report to Congress*.

Table 4.2.1 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 Commission for the Conservation of Atlantic Tunas (ICCAT)
• Western and Central Pacific Fisheries Commission (WCPFC)
• Indian Ocean Tuna Commission (IOTC)
• South East Atlantic Fisheries Organization (SEAFO)
• General Fisheries Commission for the Mediterranean (GFCM)
• North East Atlantic Fisheries Commission (NEAFC)
• Commission for the Conservation of Southern Bluefin Tuna (CCSBT)
• Treaty on Fisheries Between the Governments of Certain Pacific Island States and the Government of the United States of America (South Pacific Tuna Treaty)
• International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC)

North Atlantic Fisheries Organization (NAFO)

At its 26th Annual Meeting in September 2004, the NAFO Fisheries Commission became the first regional fisheries management organization in the world to establish a catch limit for a directed elasmobranch fishery. The total allowable catch for skates in Division 3LNO (the "nose" and "tail" of the Grand Bank) was set at 13,500 metric tons, for each of the years 2005–2007 and 2009. The total allowable catch was subsequently reduced to 12,000 mt for 2010. This total allowable catch was higher than the United States had initially sought, but the U.S.

delegation ultimately joined the consensus of which this measure was a part. In addition to this catch limit, NAFO adopted a U.S.-proposed resolution regarding data collection and reporting relative to elasmobranchs in the NAFO Regulatory Area. At its 27th Annual Meeting in September 2005, the NAFO Fisheries Commission adopted a ban on shark finning in all NAFO-managed fisheries and mandated the collection of information on shark catches. At the 2006 NAFO Annual Meeting, a U.S.-Japan proposal for improving elasmobranch data collection was also adopted.

Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)

Five shark species (*Lamna nasus*, *Somniosus antarcticus*, *Etmopterus cf. granulosus*, *Centroscymnus coelolepis,* and *Squalus acanthias*) are known to occur in the northern part of the area addressed by CCAMLR. Only the first three species appear to be abundant enough to have the potential to attract commercial interest. The identification of a sixth species (*Halaelurus canescens*) from observer reports at South Georgia has yet to be confirmed.

In 2006, CCAMLR adopted a conservation measure prohibiting directed fishing on shark species in the Convention Area, other than for scientific research purposes. The Commission agreed that the prohibition shall apply until such time as the CCAMLR Scientific Committee has investigated and reported on the potential impacts of this fishing activity and the Commission has agreed on the basis of advice from the Scientific Committee that such fishing may occur in the Convention Area. It also agreed that any bycatch of shark, especially juveniles and gravid females, taken accidentally in other fisheries, shall, as far as possible, be released alive.

During the discussion of the conservation measure at CCAMLR, the United States stated that the issue of management of shark-related fisheries, with a particular focus on the practice of shark finning, is an important one for CCAMLR to consider. The United States noted that it has enacted legislation and regulations banning the practice of shark finning, and has been using educational efforts and enforcement actions to ensure that U.S.-flagged vessels and foreign vessels making U.S. port calls comply with the statutory ban on retaining shark fins without retention of the shark carcasses to the first point of landing.

The United States expressed hope that the investigations of the Scientific Committee would yield analysis of the stock abundance, shark bycatch levels, and other important biological data of the shark species of the Southern Ocean. It is believed that this conservation measure is an important first step to an eventual ban on the practice of shark finning. The United States also mentioned the need for future efforts to collect information on the extent of shark finning in the Convention Area and the amount of trade/transshipment through ports of Contracting and non-Contracting parties. The United States urged all Contracting Parties to prepare and submit their respective National Plans of Action for the Conservation and Management of Sharks to the FAO Committee on Fisheries, as set forth in the IPOA for the Conservation and Management of Sharks, if they have not already done so.

Inter-American Tropical Tuna Commission (IATTC)

In August 2010, the IATTC convened the 1st technical meeting on sharks to discuss the new role of the IATTC in the conservation and management of sharks under the Antigua Convention, stock assessment methods for sharks, life-history studies, the availability of data from national and regional programs, bycatch mitigation methods, and data collection needs and standardization.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

Science

Assessments of Atlantic shortfin mako and blue sharks were completed in 2008 by the Standing Committee on Research and Statistics (SCRS). The assessment findings, characterized by high levels of uncertainty due to data limitations, indicated that blue sharks in the North and South Atlantic are not overfished and overfishing is not occurring. With respect to North Atlantic shortfin mako sharks, there is a non-negligible probability that this stock could be below the biomass that could support MSY and above the fishing mortality rate associated with MSY. Recent biological data show decreased productivity for this stock. NMFS has determined that North Atlantic shortfin mako is not overfished, but is approaching an overfished status and is experiencing overfishing. The status of South Atlantic shortfin mako sharks remains unknown.

In 2008, the SCRS also conducted ecological risk assessments for ten shark species and one stingray species based on biological productivity and potential susceptibility to ICCAT longline fisheries. The results indicated that most Atlantic pelagic sharks have exceptionally limited biological productivity and can be overfished even at very low levels of fishing mortality. Bigeye thresher, longfin mako, and shortfin mako sharks have the highest biological vulnerability of the shark species examined. All species considered in the ecological risk assessments are in need of improved data. The SCRS recommended that precautionary measures be considered for shark stocks with the greatest biological vulnerability and that management measures be species-specific whenever possible. SCRS is planning to conduct another round of ecological risk assessments for a number of sharks, as well as stock assessments for North and South Atlantic shortfin mako sharks in 2012.

The SCRS and ICES conducted a joint assessment of porbeagle shark in 2009, including four stocks (northwest, northeast, southwest, and southeast Atlantic). The northwest Atlantic porbeagle stock is overfished, but overfishing is not occurring. Despite the improving status of the northwest stock, rebuilding is projected to take decades due to low productivity. While conclusions for the northeast Atlantic stock were also characterized by uncertainty, it was estimated that the stock is overfished and that overfishing is occurring or close to occurring. Stock recovery in the northeast Atlantic is predicted to take between 15 and 34 years under a no fishing scenario. No conclusions on the status of the two South Atlantic porbeagle stocks could be reached due to data limitations.

Management

At ICCAT's 2008 annual meeting, several shark-related proposals were presented and two were adopted. The first proposal called for ICCAT and the International Council for the Exploration of the Sea (ICES) to coordinate the assessment of porbeagle sharks, which occurred in June 2009, in Copenhagen, Denmark (see above). The measure also contemplated that a meeting of concerned RFMO Chairs be convened just after the joint assessment to consider compatible management measures for the species. At the time of this writing, this meeting had not yet been scheduled. The second measure adopted by ICCAT in 2008 requires the release of bigeye thresher sharks caught in association with fisheries managed by ICCAT and that are still alive when brought to the vessel, as well as the recording and reporting to ICCAT of incidental catches and live releases of this species.

In 2009, the United States proposed to reduce mortality of North Atlantic shortfin mako sharks with a cap on shortfin mako landings from pelagic longline vessels. While the proposal received broad support, it did not achieve consensus. Some parties wanted to exempt mako sharks taken as bycatch despite the fact that bycatch is the primary cause of mortality on this species. In 2010, the United States again proposed a cap on shortfin mako landings. Instead, the Commission adopted a measure that reinforces existing requirements to reduce mortality on the North Atlantic stock and requires reporting on actions taken in this regard for review by the Compliance Committee beginning in 2012. This recommendation underscores obligations to report data on shortfin mako stocks to SCRS and prohibits parties that do not report shortfin mako catch data from retaining this species, beginning in 2013.

Two other shark recommendations were agreed on at the 2010 meeting. ICCAT adopted a measure that prohibits retention of oceanic whitetip sharks caught in association with ICCAT fisheries and requires parties to collect and report the number of dead discards and live releases of this species. ICCAT adopted a measure to prohibit retention of all species of hammerhead sharks (with the exception of bonnethead sharks) that are caught in association with ICCAT fisheries, with limited exceptions for developing countries that rely on sharks as an important food source. Parties taking advantage of this exception must ensure that these sharks and their parts do not enter international trade. Given the coastal nature of hammerhead sharks, a statement was included in the record noting that several ICCAT members, including the United States, consider that this measure does not apply to directed fisheries in coastal waters.

In 2009, and again in 2010, Belize, Brazil and the United States submitted a proposal to require that all sharks be landed with their fins naturally attached. There was support for this proposal from several ICCAT members but consensus could not be reached as some parties noted such a significant change in management required additional research. The issue is expected to be reconsidered at ICCAT's 2011 annual meeting.

Canada and the EU submitted a proposal for Northeast Atlantic and Northwest Atlantic porbeagle stocks at ICCAT's 2009 annual meeting. Several ICCAT parties, including the United States, expressed concerns that the proposal was not in line with scientific advice and that porbeagle measures should be coordinated with other relevant RFMOs. No consensus on this proposal could be reached. In 2010, the EU proposed a prohibition on the retention of porbeagle sharks, which the United States supported. Canada, however, sought an exception for its directed fishery on the Northwest Atlantic stock, arguing that Canadian management measures are based on the 2009 stock assessment. After vigorous debate, including a willingness by Canada to consider some reduction in its national quota for this stock, consensus could not be reached.

In 2009, EU proposed a prohibition on retention of all thresher sharks (*Alopias spp)* but consensus could not be reached. Instead ICCAT adopted a recommendation prohibiting retention of bigeye thresher sharks in all fisheries with the exception of a small-scale Mexican coastal fishery, which is allowed to retain 110 bigeye thresher sharks. It includes a requirement to submit catch and effort data for *Alopias* species other than bigeye thresher, and mandates that the number of discards and releases of bigeye threshers be recorded with the indication of status (dead or alive) and reported to ICCAT. In 2010, Mexico withdrew its claim to its retention allowance for bigeye thresher. Also in 2010, the EU again proposed a prohibition on the retention of common thresher sharks. The proposal was not adopted as there were questions about the scientific basis for the proposal.

Western and Central Pacific Fisheries Commission (WCPFC)
At its 5th Regular Session in December 2008, the Parties to WCPFC adopted a U.S. proposal to modify and strengthen a 2006 measure for the conservation and management of sharks. The revised measure applies to all vessels regardless of size or gear type. Commission Members, Cooperating non-Members, and participating Territories (CMMs) must report annually regarding their retention and discards of total shark catches as well as their annual catch and effort by gear type for key shark species. The 2008 measure identified blue shark, oceanic whitetip shark, mako shark, and thresher shark as key species. At the annual meeting in December 2009, the Commission amended the 2008 measure to include silky shark on the list of key species and at the annual meeting in December 2010, the Commission amended the measure to include porbeagle and hammerhead sharks on the list of key species.

Joint Meeting of Tuna Regional Fisheries Management Organizations
The European Community organized and hosted the Second Joint Meeting of Tuna RFMOs from June 29 to July 3, 2009 in San Sebastian, Spain. The Participants of the Second Joint Tuna RFMOs Meeting agreed to call on RFMOs, consistent with the FAO IPOA-Sharks, to establish precautionary, science-based conservation and management measures for sharks taken in fisheries within the convention areas of each tuna RFMO, including as appropriate:

- Measures to improve the enforcement of existing finning bans;
- Prohibitions on retention of particularly vulnerable or depleted shark species, based on advice from scientists and experts;
- Concrete management measures in line with best available scientific advice with priority given to overfished populations;
- Precautionary fishing controls on a provisional basis for shark species for which there is no scientific advice; and
- Measures to improve the provision of data on sharks in all fisheries and by all gears.

Kobe II Bycatch Workshop
The Kobe II Bycatch Workshop (K2B), held in Australia in June 2010, was co-hosted by the United States and the Pacific Islands Forum Fisheries Agency. Dr. Rebecca Lent (NMFS IA) led the U.S. delegation. The workshop was part of a series of technical workshops developed as a result of the Kobe process, a collaboration of the five global tuna RFMOs to address cross-cutting issues. The goals of the K2B workshop, as outlined by the terms of reference agreed to at the second Kobe meeting, were to better assess, reduce, and mitigate bycatch and to improve coordination and cooperation on bycatch related issues, including sharks, across the tuna RFMOs. The workshop's recommendations call for assessment of bycatch in tuna and tuna-like fisheries, development of bycatch data collection standards, and enhancement of observer and port sampling programs. K2B participants further recommended that tuna RFMOs seek binding

measures or strengthen existing mitigation measures for bycatch that reflect international agreements, tools and guidelines, evaluate the effectiveness of current measures, and support bycatch related research. The recommendations include a list of elements necessary for successful bycatch measures such as being binding, clear and direct, measureable, science-based, and ecosystem-based. To assist the developing nations in carrying out the mandate of K2B, the recommendations call for RFMO members to consider capacity building programs for developing countries.

To enable greater coordination across the tuna RFMOs, participants agreed to support the creation of a joint tuna RFMO working group on bycatch with participants from each of the five tuna RFMOs. This working group was charged with identifying methods to harmonize data collection protocols, identify species of concern, review the efficacy of existing bycatch measures, and compile information on bycatch research. This joint working group will meet for the first time at the Kobe III meeting, held in La Jolla in 2011.

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

The Tenth Plenary session of the ISC (ISC10) was convened in Victoria, Canada July 21–26, 2010. The Plenary established a new Shark Working Group responsible for conducting stock assessments and other scientific studies as required on sharks. The new working group will focus on North Pacific fisheries for shark catch and bycatch particularly for blue, shortfin mako, bigeye thresher, pelagic thresher, silky, oceanic whitetip, hammerhead, and any other shark species for which stock assessments may be needed. The working group will collaborate with other RFMOs of the Pacific and initially focus on stock assessments of blue and shortfin mako shark. Scientists from NOAA's SWFSC and PIFSC were nominated to work with other international scientists and the ISC Chairman in organizing the first meeting of the working group to be held in Taiwan in April 2011. The agenda for the first meeting includes election of a working group chairperson and development of a work plan for blue and shortfin mako shark assessments.

4.3 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 4.3.1 lists these multilateral fora. Of the list in Table 4.3.1, the recent activities for four organizations are discussed below as a supplement to last year's *Report to Congress.*

Table 4.3.1 Other multilateral fora.

Other Multilateral Fora
• Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) • Food and Agriculture Organization of the United Nations (FAO) Committee on Fisheries (COFI) • United Nations General Assembly (UNGA) • Convention on the Conservation of Migratory Species of Wild Animals (CMS) • International Union for Conservation of Nature (IUCN) • World Summit on Sustainable Development • International Council for the Exploration of the Sea (ICES) • Asia Pacific Economic Cooperation Forum and the Convention on Migratory Species (APEC)

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

CITES has addressed the issue of sharks on several recent occasions. Whale sharks, great white sharks, and basking sharks have been listed in Appendix II of CITES as species that may become threatened with extinction unless trade is subject to regulation. In June 2007, at the 14th Conference of the Parties, the United States successfully proposed that sawfishes (Pristidae) be listed in Appendix I, thus banning commercial trade in sawfish and sawfish products, with the exception of largetooth sawfish (*Pristis microdon*). Largetooth sawfish is listed in Appendix II for the exclusive purpose of allowing international trade in live animals to appropriate and acceptable aquaria for primarily conservation purposes. CITES convened the 15th Conference of the Parties in Doha, Qatar from March 13 – 25, 2010. The United States developed and submitted proposals to add the oceanic whitetip shark (*Carcharhinus longimanus*), and scalloped hammerhead shark (*Sphyrna lewini* (with several look-alike species: great hammerhead shark (*Sphyrna mokarran*), smooth hammerhead shark (*Sphyrna zygaena*), dusky shark (*Carcharhinus obscures*), and sandbar shark (*Carcharhinus plumbeus*)) to Appendix II of CITES. Palau co-sponsored the U.S. proposal. In addition to these species proposals that were submitted by the United States and Palau, the European Union submitted proposals to add porbeagle (*Lamna nasus*), and spiny dogfish (*Squalus acanthias*), to Appendix II. During the meeting, the United States amended the scalloped hammerhead proposal to remove the sandbar shark and dusky shark as look-alike species. The United States also amended both shark proposals at the request of the United Arab Emirates and other Parties to delay implementation of the CITES listings for 24 months to allow time for capacity building and implementation guidance to be developed that would assist in the identification and enforcement of these proposals. The final proposal for hammerhead shark species was not adopted (there were 75 votes in support of the proposal, 45 votes in opposition, and 14 abstentions). The final proposal for the oceanic whitetip shark was also not adopted (there were 75 votes in support of the proposal, 51 votes in opposition, and 16 abstentions). Both proposals fell short of the two-thirds majority needed for adoption by a few votes. The proposals for porbeagle and spiny dogfish submitted by the European Union were also defeated.

Food and Agriculture Organization of the United Nations (FAO) Committee on Fisheries (COFI)

In 1999, the FAO adopted the IPOA for the Conservation and Management of Sharks, which is understood to include all species of sharks, skates, rays, and chimaeras (Class Chondrichthyes). The IPOA calls on 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. The United States was one of the first countries to prepare a National Plan, which was publicly released in 2001. At the time this report was written, the following entities had developed National Plans of Action for the Conservation and Management of Sharks: Argentina, Australia, Canada, Ecuador, Japan, Malaysia, Mexico, Seychelles, Taiwan, the United Kingdom, the United States, and Uruguay.

FAO convened a joint workshop between FAO and CITES to review the application and effectiveness of international regulatory measures for the conservation and sustainable use of elasmobranchs in Genazzano (Rome), Italy from 19-23 July 2010. The workshop was attended by experts from different geographic areas and sectors including scientific assessment, fisheries management, fishing industry, fish trade, monitoring and control, and government administration. The workshop attempted to outline the strengths and weaknesses of the various types of regulatory measures and regulations and to discuss their effectiveness with regard to implementation and stock recovery, as well as their impact on fisheries, livelihood, food security, markets and trade, and government administrations. A final report from that workshop is still pending.

United Nations General Assembly (UNGA)

The United States continues to use the United Nations General Assembly (UNGA) process to develop a more specific call to States and RFMOs to strengthen measures to reduce the bycatch of sharks. Most recently, the United States was successful in negotiating specific language for the conservation and management of sharks at the United Nations Fish Stocks Resumed Review Conference. Specifically, the Resumed Review Conference recommended that States and regional economic integration organizations, individually and collectively through regional fisheries management organizations or arrangements, strengthen the conservation and management of sharks. The United States has also worked with other countries to propose and successfully adopt conservation and management language and recommendations specific to sharks in the annual UNGA sustainable fisheries resolutions. Since 2005, provisions have been adopted that call on States and RFMOs to significantly improve the conservation and management of sharks.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)
Also known as the Bonn Convention, the CMS aims to conserve terrestrial, marine, and avian migratory species throughout their range. An intergovernmental treaty, the CMS was concluded under the aegis of the United Nations Environment Programme and currently has 116 parties. The United States is not a party to the CMS. However, non-parties are able to participate in the negotiation of and can sign onto individual instruments concluded under the CMS umbrella, including the newly signed global shark instrument.

In February 2010, the United States, along with 10 other States, signed a global Memorandum of Understanding (MOU) for Migratory Sharks under the auspices of the Convention on Migratory Species. The MOU aims to coordinate international action on the threats faced by sharks and works to improve their species conservation status. The MOU initially covers great white, basking, whale, porbeagle, shortfin mako, longfin mako, and the Northern Hemisphere population of spiny dogfish, but more species can be added later. NOAA and the Department of State are currently engaged in interagency discussions to draft a Plan of Work for International Shark Conservation to guide U.S. priorities and actions on this issue in the near term.

Eastern Pacific Ocean (EPO) Regional Workshops
The United States has worked cooperatively with Governments in the Eastern Pacific Ocean to hold a series of regional workshops aimed at improving shark conservation and management efforts in the EPO. The first workshop was held in Manta, Ecuador, July 9-11, 2008, and was co-hosted by the United States, Ecuador, and International Union for the Conservation of Nature (IUCN). National attendance was strong with representatives from nearly every country along the Eastern Pacific including Mexico, Guatemala, El Salvador, Nicaragua, Costa Rica, Panama, Colombia, Peru, and Chile. The workshop brought together a broad swath of stakeholders including commercial and artisanal fishermen, fisheries managers, scientists, (NGO's) and policymakers. As a result, a lively interactive discussion identified gaps and opportunities for capacity building and began a dialogue on developing regional cooperative measures for conserving and sustaining shark stocks in the Eastern Pacific. Presentations reviewed each country's National Plan of Action for shark conservation (NPOA), import/export trends in the shark fin trade, national laws prohibiting finning, and the latest science and forensic techniques used to identify species populations and enforce wildlife trafficking laws.

On December 3-5, 2008, the Government of Mexico hosted in Mazatlan, Mexico, the second workshop. It was organized by Mexico's National Commission of Fisheries and Aquaculture (CONAPESCA) with support from IUCN, and the U.S. Government. The Mazatlan workshop continued the dialogue undertaken in Ecuador to identify gaps and sampling needs along with assessing opportunities for capacity building efforts to conserve and sustain shark stocks in the EPO. The theme of the Mazatlan workshop focused on identifying what data exist and what data still need to be collected in order to develop some rudimentary stock assessment estimates for several key shark species including: silky shark (*Carcharhinus falciformis*), scalloped hammerhead shark (*Sphyrna lewini*), shortfin mako shark (*Isurus oxyrinchus*), pelagic thresher shark (*Alopias pelagicus*), and blue shark (*Prionace glauca*). The workshop also addressed the production of a regional shark guide for the Eastern Pacific in order to facilitate shark stock assessments.

The workshop also included a session for administrators, government representatives and regional fisheries organizations to discuss regional cooperation in shark management and conservation. The objective was to define regional activities that would be consistent with the FAO's International Plan of Action for Conservation and Management of Sharks (IPOA-SHARKS). Participants concluded that there was a need to establish a mechanism to strengthen regional cooperation in both the short-term and the long-term. Priority themes for cooperation include research, development of human resources, regulations and an exchange of technology and experience. Long-term activities include the development of a proposal to be presented to international donors that would provide funds for the themes described above.

The third Eastern Pacific Ocean Shark Conservation Workshop was held in Manta, Ecuador July 6-9, 2010. The following countries were represented at the workshop: Ecuador, Mexico, Guatemala, Nicaragua, Costa Rica, El Salvador, Panama, Honduras, Columbia, Peru, Chile, Uruguay, Argentina, Belize, and Venezuela. The group agreed on a set of minimum data collection protocols to take back to their respective sampling programs. This agreement is considered a very important step towards a more regional shark management regime. The group also discussed the need for developing a harmonized sampling manual to accompany the Spanish language guide and/or national guides. The issue of data collection in relation to the volume of information necessary to complete a non-detriment finding under CITES was addressed in a broad sense. Each country presented a summary of their data collection and monitoring programs, as well as some of the pressing conservation and management issues in play.

5. 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. In order to manage sharks sustainably, we need information on their biology and the numbers caught (either as target species or bycatch) to make sure their populations are not depleted. NMFS Science Centers are investigating shark catch, abundance, age, growth, diet, migration, fecundity, and habitat requirements. 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 being completed in 2010 is presented here, but a complete description of all recent research is available in Appendix 1.

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

Pacific Islands Fisheries Science Center (PIFSC)

Fishery Data Collection

Market data from the PIFSC shoreside sampling program contain detailed biological and economic information on sharks in the Hawaii-based 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 Hawaii. The Western Pacific Fishery Information Network (WPacFIN) is a Federal-State partnership collecting, processing, analyzing, sharing, and managing fisheries data on sharks and other species from American island territories and states in the central and western Pacific (Hamm et al. 2010). The WPacFIN program has also assisted other U.S. islands' fisheries agencies in American Samoa, Guam, and the Northern Mariana Islands to modify their data-collecting procedures to collect bycatch information. These modifications have improved the documentation of shark interactions with fishing gear. Shark catches in the Hawaii-based longline fishery have been monitored by a logbook program since 1990 and by an observer program since 1994.

Shark Catch Per Unit Effort (CPUE) Data Analysis from Longline Observer Program Data

NOAA Fisheries is currently producing standardized CPUE time series for blue shark, whitetip shark, and silky shark in the Hawaii longline fishery using the Pacific Islands Regional Observer Program data (1995–2010). This work can be used as input for stock assessment for these shark species.

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 or biennial surveys conducted by the PIFSC Coral Reef Ecosystem Division (CRED) since 2000.

These estimates include surveys of:

- 10 major shallow reefs in the Northwestern Hawaiian Islands (2000, 2001, 2002, 2003, 2004, 2006, 2008, 2010).
- The Main Hawaiian Islands (2005, 2006, 2008, 2010).
- 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).
- American Samoa including Rose Atoll and Swains Island (2002, 2004, 2006, 2008, 2010).
- Guam, and the Commonwealth of the Northern Marianas Islands (2003, 2005, 2007, 2009, 2011), Johnston Atoll (2004, 2006, 2008, 2010), and at Wake Atoll (2005, 2007, 2009, 2011).

To date, these surveys suggest that shallow (<30m) inshore shark populations appear to be relatively abundant at most reefs in the Northwestern Hawaiian Islands (NWHI), Pacific Remote Island Areas, and the Northern Mariana Islands, but are noticeably sparse and/or small-bodied at most reefs in the Main Hawaiian Islands (MHI), American Samoa, and the Southern Mariana Islands.

Table 5.1.1 Shark species observed in PIFSC-CRED Reef Assessment and Monitoring Program 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*
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*

In brief, although 11 species of shark have been observed during CRED surveys (Table 5.1.1), only four species of sharks are typically recorded in sufficient frequency for meaningful analyses: grey reef shark (*Carcharhinus amblyrhynchos*), Galapagos shark (*Carcharhinus galapagensis*), whitetip reef shark (*Triaenodon obesus*), and blacktip reef shark (*Carcharhinus melanopterus*). Analysis of data from rapid ecological assessment surveys (REA) conducted by SCUBA divers between 2008 and 2010, indicated significantly higher biomass of all sharks combined at remote islands (i.e., islands at least 100 km from the nearest human population center) compared to populated islands, with remote islands having, on average, 40 or more times the biomass of sharks than was recorded at populated islands in both the Hawaiian and Mariana Archipelagos (Williams et al. 2011). Differences between remote and populated portions of American Samoa were not statistically significant, reflecting low counts of sharks at all locations in that region. CRED is currently working on a scientific article using towed-diver data of shark distribution, and accounting for differences between reef areas in temperature and oceanic primary productivity. Preliminary results of that analysis similarly indicate that reef sharks are substantially depleted around populated islands: biomass at Tutuila, American Samoa, and at the populated islands in the Hawaiian and Mariana Archipelagos being 10% or less of modeled 'pristine' biomass (i.e., biomass in simulated absence of humans) for those locations. From our preliminary results we infer that some insular shark populations near human population centers are substantially depleted. However, data limitations include that all CRED shark data was gathered by SCUBA divers, and therefore: (i) safe diving practices limited surveys to reefs areas of 30m or shallower which is the upper end of reef sharks' potential depth distribution; and (ii) 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, CRED is pursuing opportunities for diver-independent assessments of shark populations, such as by deploying remote video systems.

Southwest Fisheries Science Center (SWFSC)

Abundance Surveys

Juvenile Shortfin Mako (*Isurus oxyrinchus*) and Blue Shark (*Prionace glauca*) Survey

In 2010, the SWFSC conducted its 17th juvenile shark survey for mako and blue sharks since 1994 to track trends in abundance on nursery grounds in the Southern California Bight. Working aboard F/V *Ventura II,* a total of 5,956 hooks were set inside seven focal areas during 29 daytime sets. Survey catch totaled 13 shortfin makos, 25 blue sharks, 18 pelagic rays (*Pteroplatytrygon violacea*), 10 opah (*Lampris guttatus*), and one mola (*Mola mola*). The preliminary data indicate that the nominal survey catch rate was 0.057 per 100 hook-hours for shortfin mako and 0.105 per 100 hook-hours for blue sharks. The nominal CPUE for both blue and shortfin mako sharks were the lowest in survey history. There is a declining trend in nominal CPUE for both species over the time series of the survey (see Figure A1.2 in Appendix 1).

Neonate Common Thresher Shark (*Alopias vulpinus*) Survey

The common thresher shark pre-recruit index and nursery ground survey was initiated in 2003 to develop a fisheries-independent index of pre-recruit. In 2010, the SWFSC team worked aboard the F/V *Outer Banks* to conduct forty-eight longline sets with a total of 4,800 hooks in shallow, nearshore waters. Shark catch included 295 common thresher, 5 smoothhound (*Mustelus sp.*), 2 spiny dogfish (*Squalus acanthias*), and 1 leopard (*Triakis semifasciata*) shark. The preliminary survey data indicate that the average nominal catch rate was 3.75 threshers per 100 hook-hours. This is the highest catch rate since the inception of the sampling program. Two hundred sixty-eight sharks were tagged and 280 DNA and other biological samples were collected to enhance ongoing research at SWFSC, including age and growth, feeding, and habitat utilization studies.

Electronic Tagging Studies
Since 1999, the SWFSC has been using satellite technology to study the movements and behaviors of primarily blue, shortfin mako and common thresher sharks in the northeast Pacific, while other species are tagged opportunistically. In 2010, 4 shortfin mako sharks, 9 blue sharks, 1 thresher shark and 1 basking shark (*Cetorhinus maximus*) were tagged with either SPOT tags or towed GPS tags. Three tags deployed on blue sharks are still transmitting after periods of up to 13 months providing some of the longest tracks obtained to date for this species. For mako sharks, eight tags were transmitting in early 2011, six of which were deployed in 2009 providing an opportunity to examine seasonal movement patterns and regional fidelity.

Age Validation Studies
Age and growth of mako, common thresher, and blue sharks are being estimated based on band deposition periodicity determined using oxytetracycline (OTC) tagging. Since the beginning of the program in 1997, 2463 OTC-marked individuals have been released during juvenile shark surveys. Two hundred and fifty OTC tagged sharks have been recaptured and the vertebrae are currently being analyzed. During 2010, analyses of shortfin mako shark vertebrae were carried out and the preliminary results demonstrate a pattern of two band pairs laid down per year in young sharks of the California Current.

Foraging Ecology of Shortfin Mako, Blue, and Common Thresher Sharks
To better understand niche separation and the ecological role of shortfin mako, blue and common thresher sharks, contents of stomachs collected by fishery observers have been examined at the SWFSC since 2002. During 2002–2010 a total of 713 shortfin mako, blue, and common thresher shark stomachs were collected and analyzed. Analytical approaches to characterize prey composition and examine inter- and intra-specific patterns included both univariate and multivariate methods. Despite similarities in life history characteristics and spatial and temporal overlap, diets of these three species are strongly differentiated. In 2010, the results from this research have been accepted for publication in a special proceeding of the American Elasmobranch Society (Preti et al. 2001, 2004, 2008, in press).

Basking Shark (Cetorhinus maximus) Research Program
Due to concern about basking shark populations along the west coast of North America, the northeast Pacific basking shark was listed as a NOAA Species of Concern in the U.S. in 2010. The SWFSC initiated a basking shark research program to (1) mine existing data for additional biological information, (2) conduct an electronic tagging study, (3) improve international data collection, and (4) improve national sightings information by developing a sightings website and an education and outreach program centered around Monterey Bay, CA (see section 2.5). A dedicated website and hotline have been established as a part of a sightings network. This information will help with documenting patterns of occurrence and tagging efforts. A tri-national team was formed with colleagues in Canada and Mexico to coordinate research efforts. The first meeting of the team was held in November 2010. Finally, a satellite tag was deployed

on a basking shark for the first time ever in the Pacific off Southern California. After its release it transmitted data collected during the track including four GPS locations, in addition to temperature, depth, and light data. Using both light-based and GPS locations, an estimated track between tag and release was obtained. Overall, the basking shark experienced a broad range of temperatures and depths. Depth and temperature data showed considerable variability across the track, coincident with changes in SST. Further tagging efforts will help reveal habitat utilization patterns of and environmental influences on this rare shark.

Population Genetics Studies

A recent master's thesis completed at the University of San Diego and SWFSC provided evidence of regional stock structure of shortfin mako sharks within the Pacific. Using mitochondrial haplotype data, the study showed a strong subdivision between northern and southern hemisphere populations, with additional subdivision between southeast and southwest Pacific populations; however, no subdivision was found in the North Pacific using this marker. A suite of nuclear microsatellite markers is being developed to further refine the spatial and temporal resolution of shortfin mako stocks within the Pacific. Similar population genetics studies were begun for common thresher sharks in 2010.

Northwest Fisheries Science Center (NWFSC)

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 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. 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. Biological data and tissue samples were also collected from leopard sharks and cat sharks during the bottom trawl surveys.

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 PFMC for use in management. The NWFSC will conduct an assessment of spiny dogfish along the Pacific coast of the United States in 2011.

Alaska Fishery Science Center (AFSC, Auke Bay Laboratory)

Shark Research and Assessments

Research efforts at the Alaska Fishery Science Center's Auke Bay Laboratory are focused on:

1. Collection of data to support stock assessments of shark species subject to incidental harvest in waters off Alaska.
2. Migration and habitat use of Pacific sleeper sharks.
3. Migration and habitat use of spiny dogfish in the Gulf of Alaska.
4. Estimation of incidental catch of sharks in unobserved fisheries.
5. Development and validation of improved aging methods for spiny dogfish and Pacific sleeper sharks

Stock Assessments of Shark Species Subject to Incidental Harvest in Alaskan Waters
Species currently assessed include Pacific sleeper sharks (*Somniosus pacificus*), spiny dogfish (*Squalus acanthias*), and salmon sharks (*Lamna ditropis*), which are the shark species most commonly encountered as incidental catch in Alaskan waters. The shark stock assessment is currently limited to an analysis of commercial bycatch relative to biomass, which is estimated from NMFS fishery-independent bottom trawl surveys in the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. Stock assessments are summarized annually in the North Pacific Fishery Management Council's Stock Assessment and Fishery Evaluation reports available online at http://www.afsc.noaa.gov/refm/stocks/assessments.htm (Tribuzio et al. 2010a and 2010b).

Migration and habitat use of Pacific sleeper sharks
During the summers of 2003–2006, scientists from the Auke Bay Laboratories (ABL) deployed 138 numerical Floy tags, 91 electronic archival tags, 24 electronic acoustic tags, and 17 electronic satellite popup tags on Pacific sleeper sharks in the upper Chatham Strait region of Southeast Alaska (Courtney and Hulbert 2007). Two numerical tags and 10 satellite tags have been recovered. The recovery of temperature, depth, and movement data from the electronic archival and acoustic tags will aid in the identification of Pacific sleeper shark habitat utilization and distribution in Southeast Alaska, and identify the potential for interactions between Pacific sleeper sharks and other species in this region. Analysis of tagging data is ongoing.

Migration and habitat use of spiny dogfish in the Gulf of Alaska
Since 2009 scientists from ABL have deployed in 35 pop-off archival tags on spiny dogfish in Yakutat Bay and will deploy 45 more in the summer of 2011 throughout the Gulf of Alaska. Data have been successfully recovered from 34 tags to date. Results will indicate habitat preference with respect to depth and temperature, which may play a role in examining the effects of climate changes in the North Pacific. Further, the geolocation data will elucidate the degree to which Gulf of Alaska spiny dogfish populations mix with those populations in British Columbia, Canada, and the U.S. Pacific Coast. Preliminary results suggest a general westward movement from Yakutat Bay towards Cook Inlet and Kodiak Island between August and December and some animals moving far south, to waters off the coast of Washington State. Further, data are showing a strong daily migration between deeper and shallower waters.

Estimation of shark bycatch from unobserved fisheries
In the Gulf of Alaska, some fisheries fall outside of the groundfish observer program (e.g. halibut IFQ) and data on the incidental catch of shark and skate species from those fisheries does not exist. Scientists at ABL are working with others from the Alaska Fisheries Science Center, Alaska Department of Fish and Game and the International Pacific Halibut Commission to determine a method for using existing survey data to estimate the bycatch of elasmobranch

species. This project will build off work reported in the 2006 shark assessment (Courtney et al. 2006). The goal of the working group is to develop a method to estimate catch of all non-halibut species in the IFQ fishery and methods will be reported to the NPFMC's Science and Statistical Committee for approval before implementation for the 2011 stock assessment cycle.

Age and Growth Methods

Scientists at ABL and the AFSC age and growth lab received funding from the North Pacific Research Board to expand on a pilot study conducted last year which examined a potential new method for aging of spiny dogfish. Traditional methods of aging used the dorsal fin spine, which can be worn or broken over time, thus introducing a source of uncertainty in the aging estimation process (Tribuzio et al. 2010c). The new method which uses the vertebrae and histological staining has been applied to spiny dogfish in the U.S. east coast in efforts to reduce the uncertainty of age estimates. This project will compare the results of both aging methods to determine if the vertebrae method is appropriate for Gulf of Alaska spiny dogfish. The second purpose of this study is to establish a method for aging Pacific sleeper sharks, which have not been successfully aged. This histological method has been successful on deep sea Squaloid sharks in the North Atlantic, and there is some suggestion that it will work for Pacific sleeper sharks. Scientists at ABL are also working to establish a captive population of spiny dogfish which will be used to validate the histological aging methods. Captive sharks will be injected with oxytetracycline (OTC) on an annual basis for up to 5 years. OTC binds with calcium and leaves a distinct mark on the hard structures that are used for aging. The improved age-at-length data will be used to re-estimate growth models used in stock assessments.

Northeast Fisheries Science Center (NEFSC)

SEDAR Process

Staff participated in the Southeast Data, Assessment, and Review (SEDAR) Data Workshop for the assessment of the blacknose, dusky, and sandbar sharks and contributed seven SEDAR working papers. These documents summarized blacknose, dusky, and sandbar shark mark-recapture data from the Cooperative Shark Tagging Program (Kohler and Turner 2010) and standardized indices of abundance for blacknose, dusky and/or sandbar sharks from the NEFSC historical longline surveys (McCandless and Hoey 2010), the NMFS Northeast shark longline surveys (McCandless and Natanson 2010), the University of North Carolina shark longline survey (Schwartz et al. 2010), and from the COASTSPAN surveys in Delaware Bay (McCandless 2010), South Carolina (McCandless and Frazier 2010) and Georgia (McCandless and Belcher 2010).

Deepwater Horizon C252 Pelagic Fish Sampling

Staff biologists participated in a pelagic longline cruise inside and adjacent to the area closed to fishing due to the Deepwater Horizon C252 oil spill. The objectives of this cruise were to collect highly migratory fish for food quality studies in the vicinity of the oil spill resulting from the sinking of the Deepwater Horizon oil platform; to monitor the distribution and abundance of highly migratory species in the Gulf of Mexico with reference to the oil sheen; and to collect CTD salinity and temperature profile data and water samples for hydrocarbon analysis. All commercially and recreationally valuable and legal sized pelagics were saved for seafood sampling.

Habitat Utilization and Essential Fish Habitat of Sand Tiger Sharks (Carcharias taurus)

Funding was received in 2010 through the NOAA NMFS Species of Concern Internal Grant Program to study the regional movements, habitat use, and site fidelity of sand tigers off the US east coast using satellite telemetry. Pop-up satellite archival tags (PSATs) will be deployed on sand tigers in regions where seasonal sand tiger movement patterns and habitat use are uncertain, and results will be examined to quantify large scale three-dimensional movements of these fish as they relate to oceanographic features (e.g., temperature), time of year, essential fish habitat, size, age, and sex.

Biology of the White Shark (Carcharodon carcharias)

An update to a NEFSC western North Atlantic white shark distribution paper is ongoing with NMFS staff from the NEFSC, SEFSC, and NERO and scientists from Massachusetts Division of Marine Fisheries and the Florida Museum of Natural History. This study builds upon previously published data combined with recent unpublished records to presents a synthesis of over 550 confirmed white shark records compiled over a 210-year period (1800-2009) and is the largest white shark dataset yet compiled for the western North Atlantic. Descriptive statistics and GIS analyses will be employed to quantify the seasonal distribution, habitat use, and relative abundance of various subcomponents of the population. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Researchers from Stony Brook University, Field Museum of Chicago, Nova Southeastern University, and NEFSC are currently employing a multi-analytical approach to test the hypothesis that northwest Atlantic white sharks have experienced a recent loss of genetic diversity due to a population bottleneck. Results show that contemporary northwest Atlantic white sharks are genetically distinct from other populations and comprise a demographically distinct unit. Ongoing work includes attempting to reconstruct the genetic diversity of white sharks in the 1960s and 1970s using DNA recovered from archived vertebrae. Historical genetic diversity will be directly compared to contemporary genetic diversity in this study, which could serve as a model for similar studies of other elasmobranchs. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Smalltooth Sand Tiger (Odontaspis ferox)

The smalltooth sand tiger—a large, deep-water shark species—has been reported as occurring in the western North Atlantic Ocean based on a single female caught off the North Carolina coast in September 1994 during a research vessel bottom trawl survey. This study documents two more cases where certified observers from the Northeast Fisheries Observer Program described and photographed captured specimens of this species during trawl trips targeting squid in waters off the eastern coast of the United States. The IUCN currently lists the smalltooth sand tiger as vulnerable for the following reasons: this species may be naturally rare, has an assumed low fecundity as seen in the closely related sand tiger shark, and developing deep-sea fisheries apply an increasing amount of pressure. However, as noted in previous accounts, it is only when an occasional individual of this deep water species comes onto the continental shelf that there is an opportunity for its capture, therefore the smalltooth sand tiger may be more common than suggested by the few documented captures. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Dusky Sharks (Carcharhinus obscurus)

A revision of the age and growth of the dusky shark in the Northwestern Atlantic Ocean was initiated via collaboration with the SEFSC Shark Observer Program. Approximately 150 new vertebrae were examined for age determination and preliminary growth curves were generated. Preliminary data indicated that the growth had not changed, however more analysis is needed to verify this finding and provide updated growth curves to the stock assessment. Additionally, in conjunction with scientists from WHOI, one vertebra is being processed for bomb carbon analysis in an attempt to validate the periodicity of band pair formation for this species. Results are still pending.

Temporal Changes in Diet between Blue Shark (Prionace glauca) and Shortfin Mako Shark (Isurus oxyrinchus) Species

Using the food habits data collected by the NEFSC Apex Predators Program over the past 38 years, we examined temporal changes in prey species, taxonomic and ecological prey groups, and overall trophic levels for two pelagic shark species: the blue shark and the shortfin mako. 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. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Sable Island Seal Predation

An investigation into shark predation on five species of seals on Sable Island, Nova Scotia, Canada, was completed in conjunction with Sable Island researcher Zoe Lucas (Lucas and Natanson 2010). Between 1993 and 2001, 4906 seal corpses bearing wounds likely inflicted by sharks were examined on Sable Island, Canada. Five seal species were involved: grey (*Halichoerus grypus*), harp (*Pagophilus groenlandica*), harbor (*Phoca vitulina*), hooded (*Cystophora cristata*), and ringed (*Phoca hispida*) seals. Flesh wounds on seal corpses indicated that two or more shark species prey on seals in waters around Sable Island. Wounds were categorized as either slash or corkscrew, with different predators identified for each type. Wound patterns, tooth fragments, and marks on bones indicated that white sharks (*Carcharodon carcharias*) were involved in the slash wounds, which comprised a small proportion of attacks. Ninety-eight percent of seal corpses, however, bore the corkscrew wounds that could not be attributed to shark species identified in attacks on pinnipeds in other regions and these wounds are previously unreported in the literature. Circumstantial evidence indicates that attacks by Greenland sharks (*Somniosus microcephalus*) were responsible for the clean-edged encircling corkscrew wounds seen on seal corpses washed ashore on Sable Island. This research was the basis of an episode of National Geographic Predator CSI 'Corkscrew killer'.

<u>Southeast Fisheries Science Center (SEFSC)</u>

Stock Assessments of Large Coastal, Small Coastal, Pelagic and Prohibited Sharks

In 2010, SEFSC staff conducted domestic, benchmark stock assessments of sandbar, blacknose (Gulf of Mexico and U.S. South Atlantic), and dusky sharks under SEDAR (Southeast Data, Assessment and Review) 21. Previous assessments of these species (in 2006 or 2007) found that all three stocks were overfished with overfishing occurring. A Data Workshop and multiple stock assessment webinars were conducted under SEDAR 21 during 2010, but the assessments were not completed and peer-reviewed until 2011.

Observer Programs

The shark longline observer program was created to obtain better data on catch, bycatch, and discards in the shark bottom longline fishery. Recent 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 (9 in 2010) on an annual basis to collect life history data and catch data for future stock assessments. These vessels carried observers on 100 percent of trips. Outside the research fishery, vessels targeting shark and possessing current valid directed shark fishing permits were randomly selected for coverage with a target coverage level of 4-6 percent. From June 2005 to December 2010, a total of 390 trips on 74 vessels with a total of 1053 hauls were observed.

Since 1993, an observer program has been underway to estimate catch and bycatch in the directed shark gillnet fisheries along the southeastern U.S. Atlantic coast. All observers must record information on all gear characteristics, species caught, condition of the catch, and the final disposition of the catch. A total of 4 drift gillnet vessels targeting either bluefish (*Pomatomus saltatrix*), or Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) were observed making 14 sets on 8 trips in 2010. A total of 53 trips making 281 sink net sets on 17 vessels were observed in 2010. Trips targeted one or more of the following: shark, Spanish mackerel (*Scomberomorus maculates*), king mackerel (*Scomberomorus cavalla*), southern kingfish (*Menticirrhus americanus*), Atlantic croaker (*Micropogonias undulates*), bluefish, weakfish (*Cynoscion regalis*), or smooth dogfish (*Mustelus canis*).

Critical habitat for the conservation of dusky shark (Carcharhinus obscurus)

In an attempt to improve the conservation status of dusky shark, NMFS established a time-area closure off North Carolina from January to July to reduce bycatch of neonate and juvenile dusky sharks. To better evaluate the closed area and determine critical habitat of dusky shark, we are deploying pop-off satellite archival tags (PSAT). To date, seven tags have been deployed. Sharks generally traveled about 10 km/day. Overall, dusky sharks spent the majority of their time in waters 20-40 m deep but did dive to depths of 400 m. Tagged sharks had varied movement patterns.

Habitat use and movements patterns of pelagic sharks based on archival satellite tags

As part of a larger program to determine the habitat use and movement patterns of pelagic and semi-pelagic sharks, PSAT tags have been deployed on sharks in the US south Atlantic Ocean and Gulf of Mexico. Since 2007, four species of sharks have been tagged with data obtained on three species (see Appendix 1 for details on the data collected to date). While data for some species are limited, these results will be useful in providing habitat use data as inputs to Ecological Risk Assessments.

Elasmobranch Feeding Ecology and Shark Diet Database

Several studies are currently under way describing the diet and foraging ecology, habitat use, and predator-prey interactions of elasmobranchs in various communities. The diet of the roundel skate (*Raja texana*) from the northern Gulf of Mexico is also being examined (Bethea and Hale in prep.). A database containing information on quantitative food and feeding studies of sharks conducted around the world has been in development for several years and currently includes over 400 studies. This fully searchable database was updated and fine-tuned in 2010.

A comparison of the foraging ecology and bioenergetics of the early life-stages of two sympatric hammerhead sharks

Juvenile scalloped hammerhead sharks (*Sphyrna lewini*), were collected in northwest Florida to examine foraging ecology, bioenergetics, and trophic level (n = 196). Diet composition and estimated daily ration were compared to previously published information on bonnethead sharks (*S. tiburo*). Diet overlap was low between species. Juvenile *S. lewini* feed on relatively small teleosts and shrimps, whereas *S. tiburo* have been documented to feed mostly on crustaceans and plant material in northwest Florida. These results provide evidence that small juvenile hammerhead species co-exist by feeding at separate trophic levels (Bethea et. al, in press).

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

The SEFSC Panama City 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 (EFH). A database containing tag and recapture information currently includes over 8,000 tagged animals and 155 recaptured animals from 1993 to present for both the Gulf of Mexico and U.S. southeast Atlantic Ocean. This fully searchable database is current through Spring 2010 with hopes to have it online in fiscal year 2012.

Monitoring the Recovery of Smalltooth Sawfish (Pristis pectinata)

The smalltooth sawfish was the first marine fish and first elasmobranch listed under as Endangered under the Endangered Species Act (ESA). The completion of the Smalltooth Sawfish Recovery Plan in early 2009 identified new research and monitoring priorities that are currently being implemented.

Life History Studies of Elasmobranchs

Sandbar shark (*Carcharhinus plumbeus)* age, growth, and reproduction were investigated following recommendations from SEDAR 11(Hale and Baremore 2010). A total of 1194 sandbar sharks from the Gulf of Mexico and southern Atlantic Ocean were examined. Males and females showed distinct seasonal reproduction patterns, with peak mating and parturition occurring from April through June. Female fecundity averaged 8.0 pups. Results suggest that sandbar sharks may have a triennial reproductive cycle (Baremore and Hale 2010).

The great hammerhead shark (*Sphyrna mokarran)* is a cosmopolitan species that is caught in a variety of fisheries throughout much of its range. The apparent decline of great hammerhead shark populations has reinforced the need for accurate biological data. Age and growth estimates were calculated for 216 great hammerheads ranging in size from 54 to 315 cm fork length (FL) captured in the Gulf of Mexico and northwestern Atlantic Ocean. Great hammerheads have one of the oldest reported ages for any elasmobranch (44 years) but grow at relatively similar rates to other large hammerhead species from this region. This study is the first to provide vertebral ages for great hammerheads (Passerotti et al. 2010).

Cooperative Research—Uruguay-U.S. pelagic shark research project
A collaborative project with Uruguay's fisheries agency (DINARA) aims to advance knowledge on the productivity and susceptibility of pelagic sharks to longline fisheries in the western South Atlantic Ocean. Eight satellite tags have been successfully deployed on blue sharks to date. Staff from DINARA and the SEFSC worked together in 2010 to create an identification guide for pelagic sharks of the Atlantic Ocean (ICCAT 2011) and will continue to work on another guide for carcharhinid sharks in 2011.

Shark Assessment Research Surveys
The SEFSC Mississippi Laboratories have conducted bottom longline surveys in the Gulf of Mexico, Caribbean, and Southern North Atlantic since 1995 (28 surveys have been completed through 2010). 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.

NOAA Center for Coastal Environmental Health and Biomolecular Research

Ongoing sample collection and methods development for molecular shark species identification
The Marine Forensics program at the National Ocean Service's (NOS) Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) in Charleston, South Carolina, conducts research on suitable molecular markers for identification of shark species. DNA identifications can be used to determine whether prohibited species are found among fish that are not landed intact as well as the identity of dried, processed fins. The Marine Forensics program uses a method developed in-house that is based on sequencing a ~1,400-base-pair fragment of 12s/16s mitochondrial DNA (Greig et al. 2005) to identify the species of suspected sharks seized by agents of Federal and State law enforcement agencies. This method works well on fresh tissue and whole, dried fins. Research into a smaller DNA fragment to increase success in identifying highly processed fins (skinless chips and "birds' nests" of ceratotrichia) is ongoing. The published method focuses on 35 species from the U.S. Atlantic shark fishery, but sample collection and research to expand the number and range of shark species sequenced for the diagnostic DNA fragment is continuing. In 2010, DNA-based species identification was conducted on evidence from three NOAA OLE on-going investigations. The submitted evidence was identified as *Cetorhinus maximus*, *Carcharhinus acronotus*, *Galeocerdo cuvier*, *Mustelus canis*, *Rhizoprionodon terranovae*, and *Squalus acanthias*.

5.2 Incidental Catch Reduction

Pacific Islands Fisheries Science Center (PIFSC)

Reducing Longline Shark Bycatch

The resumption of the previously closed Hawaii shallow-set longline fishery for swordfish in late 2004 and continuing through 2007 was anticipated to increase blue shark catches, as in the past blue sharks made up about 50 percent of the total catch in this fishery. With the ban on shark finning, these sharks are not retained and are categorized as regulatory bycatch. Although the anticipated increase in shark bycatch has been less than expected (perhaps due to the requirement to use fish bait instead of squid, or because of a shift toward an earlier fishing season in the reopened swordfish fishery), researchers at PIFSC have undertaken several projects to address shark bycatch on longlines (Swimmer et al. 2008).

Chemical and Electromagnetic Deterrents to Bycatch

One study under way since 2005 with funding from the National Bycatch Program seeks to test the use of chemical and electromagnetic deterrents to reduce shark bycatch. Previous research by Eric Stroud of SharkDefense LLC, was conducted to identify and isolate possible semiochemical compounds from decayed shark carcasses. Semiochemicals are chemical messengers that sharks use to orient, survive, and reproduce in their specific environments. Certain semiochemicals have the ability to trigger a flight reaction in sharks. Initial tests showed chemical repellents administered by dosing a “cloud” of the repellent into a feeding school of sharks caused favorable behavioral shifts, and teleost fishes such as pilot fish and remora accompanying the sharks were not repelled and continued to feed. This suggested other teleosts, such as longline target species (tunas or billfish), would not be repelled. Longline field testing of these chemicals was conducted in early 2006 with demersal longline sets in South Bimini using the chemicals, and similar testing of magnets, and were quite successful.

Beginning in early 2007, the PIFSC began testing the ability of electropositive metals (lanthanide series) to repel sharks from longline hooks. Electropositive metals release electrons and generate large oxidation potentials when placed in seawater. It is thought that these large oxidation reactions perturb the electrosensory system in sharks and rays, causing the animals to exhibit aversion behaviors. Since commercially targeted pelagic teleosts do not have an electrosensory sense, this method of perturbing the electric field around baited hooks may selectively reduce the bycatch of sharks and other elasmobranchs.

Feeding behavior experiments were conducted to determine whether the presence of these metals would deter sharks from biting fish bait. Experiments were conducted with Galapagos sharks and sandbar sharks off the coasts of the North Shore of Oahu. Results indicate that sharks significantly reduced their biting of bait associated with electropositive metals. In addition, sharks exhibited significantly more aversion behaviors as they approached bait associated with these metals. Further studies on captive sandbar sharks in tanks indicated sharks would not get any closer than 40 cm to bait in the presence of the metal (metal approximately the same size as a 60g lead fishing weight).

Initial experiments to examine the effects on shark catch rates on modified longlines are also being conducted. This is being accomplished through a collaboration with Dr. Kim Holland of the University of Hawaii’s Hawaii Institute of Marine Biology (HIMB) located on Coconut Island in Kaneohe Bay. Two experiments were initiated, one focusing on the effects of Nd/Pr

(Neodymiun/Praseodymium) alloy on the catch rates of sharks on bottom set longline gear and the other examining the effects of Nd/Pr alloy and other lanthanide alloys on the feeding and swimming behavior of scalloped hammerhead (*Sphyrna lewini)* and sandbar *(Carcharhinus plumbeus)* sharks. Preliminary results from longline field trials in Kaneohe Bay, Hawaii suggest that catch rates of juvenile scalloped hammerhead sharks are reduced by 63 percent on branchlines with the Nd/Pr alloy attached as compared to lead weight-controls (Figure 5.2.1). Initial behavioral experiments examining effects on swimming behavior have been initiated (Wang et al. 2009, Brill et al. 2009). In addition, field trials on pelagic sharks were initiated via collaboration with the SWFSC (see SWFSC contribution below).

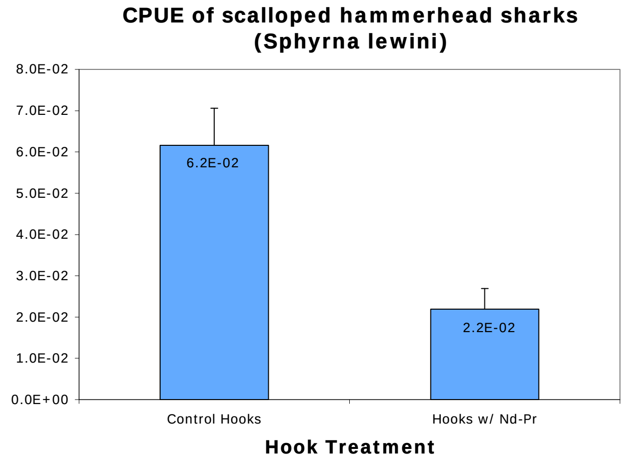

Figure 5.2.1. Catch per unit effort of scalloped hammerhead sharks on longlines with Nd/Pr alloy attached versus control hooks.

A collaborative pilot study in the Ecuadorian mahi-mahi longline fisheries was also conducted. Branchlines with lead weight were alternated with branchlines with Nd/Pr metal weight. However, analysis of catch data indicated no difference in the catch rates of thresher sharks, silky sharks, and scalloped hammerhead sharks between control branchlines and branchlines with Nd/Pr metal (Wang et al. 2010, Hutchinson et al. in press).

Longline Hook Effects on Shark Bycatch

To explore operational differences in the longline fishery that might reduce shark bycatch, the observer database is being used to compare bycatch rates under different operational factors (e.g., hook type, branch line material, bait type, the presence of light sticks, soak time, etc.). A preliminary analysis was completed that compared the catches of vessels using traditional tuna hooks to vessels voluntarily using size 14/0 to 16/0 circle hooks in the Hawaii-based tuna fleet. The study was inconclusive due to the small number of vessels using the circle hooks. Subsequently, 16 contracted vessels were used to test large (size 18/0) circle hooks versus traditional Japanese-style tuna hooks (size 3.6 sun) in controlled comparisons. Preliminary analysis does not indicate these large circle hooks increase the catch rate of sharks, in contrast to findings of increased shark catch on circle hooks in studies comparing smaller circle hooks with J hooks in other fisheries. The 18 most caught species were analyzed, representing 97.6 percent of the total catch by number. Catch rates on large 18/0 circle hooks were significantly reduced—by 17 percent for blue shark, 27 percent for bigeye thresher shark, and 69 percent for pelagic stingray. Bycatch rates for other incidental species such as billfish, opah (*Lampris guttatus*), and mahi mahi (*Coryphaena hippurus*) were also reduced compared to traditional tuna hooks. There was no significant difference in the catch rate of the target species, bigeye tuna, by hook type. In contrast to tuna hooks, large circle hooks have conservation potential for use in the world's pelagic tuna longline fleets for some highly migratory species based on demonstrated catch rate reductions (Curran and Bigelow 2010, 2011).

Testing Deeper Sets

An experiment with deeper-set longline gear conducted in 2006 has been analyzed and has been published (Beverley et al. 2009). The experiment altered current commercial tuna longline setting techniques by eliminating all shallow set hooks (less than 100 m depth) from tuna longline sets. The objective was to maximize target catch of deeper dwelling species such as bigeye tuna, and reduce incidental catch of many marketable but less desired species (e.g., billfish and sharks). The deep setting technique was easily integrated into daily fishing activities with only minor adjustments in methodology. The main drawback for the crew was increased time to deploy and retrieve the gear. Catch totals of bigeye tuna and sickle pomfret were greater on the deep set gear than on the controlled sets; but the bigeye results were not statistically significant. Catch of several less valuable incidental fish (e.g., blue marlin, striped marlin, shortbill spearfish, dolphinfish, and wahoo) was significantly lower on the deep set gear than the controlled sets. Unfortunately, no significant results were found for sharks.

Results from several of the bycatch studies suggest combining methods to avoid bycatch. Perhaps a combination of electropositive metals fashioned into weights attached to longline gear and setting the gear deeper might avoid bycatch of sharks and marlins. Research is also being initiated to develop safer weights, such as weights that do not spring back toward fishermen when branch lines holding large fish break during retrieval.

Southwest Fisheries Science Center (SWFSC)

Use of rare-earth metals to reduce shark bycatch

An experiment directed by graduate student Melanie Hutchinson of the University of Hawaii and John Wang of PIFSC was continued to examine the potential for using rare earth metals to reduce shark bycatch. The metal was secured close to the baited hooks and catch rates on treatment and control hooks were compared. Thirteen sets were completed for the experiment during the 2010 cruise to add to the 25 sets in 2009. Preliminary results indicate that the rare earth metals did not affect the catch rate of shortfin mako or blue sharks as they were caught on the experimental hooks and control hooks in almost equal numbers. These results differ from those found on some coastal shark species where the deterrents proved effective at lowering catch rates. The data are being further examined based on size, sex, and other potential factors before drawing final conclusions.

5.3 Post-Release Survival

Pacific Islands Fisheries Science Center (PIFSC)

Improved Release Technology

The recently resumed Hawaii-based swordfish longline fishery, as well as the tuna longline fishery, is 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 branchline, (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 Hawaii 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 the Narragansett Laboratory, 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. In 2007, PIFSC and PIRO personnel conducted longline trials along the eastern shore of Virginia to compare catches of sharks and rays on barbed and barbless circle hooks. In a randomization test, difference in the catches between the hook types was not significant. Circle hook removal trials were also conducted simultaneously and resulting effectiveness of removing hooks from sharks were 27 percent with barbed hooks and 72 percent with barbless hooks. During the study a new dehooker was developed and tested. Preliminary results were >90 percent effective in removing both barbed and barbless circle hooks from sharks; however, the prototype appears to be more efficient on smaller sized animals.

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—such as 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.

PIFSC scientists have been developing biochemical and physiological profiling techniques for use in estimating post-release survival of blue sharks, which are frequently caught as bycatch of Pacific longliners. Using NOAA research vessels, they captured 211 sharks, of which 172 were blue sharks. Using blue sharks, PIFSC scientists and collaborators developed a model to predict long-term survival of released animals (verified by PSAT data) based on analysis of small blood samples. Five parameters distinguished survivors from moribund sharks: plasma Mg2+, plasma lactate, erythrocyte Hsp70 mRNA, plasma Ca2+, and plasma K+. A logistic regression model incorporating a combination of Mg2+ and lactate successfully categorized 19 of 20 (95 percent) fish of known fate and predicted that 21 of 22 (96 percent) sharks of unknown fate would have survived upon release. These data suggest that a shark captured without obvious physical damage or physiological stress (the condition of 95 percent of the sharks they captured) would have a high probability of surviving upon release (Moyes et al. 2006).

In the second approach PIFSC and colleagues deployed 71 pop-up satellite archival tags (PSATs) on the five most commonly caught species of pelagic shark in the Hawaii-based commercial longline fishery (blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), silky shark (*Carcharhinus falciformes*), oceanic whitetip (*C. longimanus*), and bigeye thresher (*Alopias superciliosus*)) to determine species-specific horizontal and vertical movement patterns and survival after release from longline fishing gear. All five species have life-history characteristics that make populations vulnerable to exploitation and there is little or no information about their movement patterns and habitats. Results indicated that only a single post-release mortality could be unequivocally documented: male blue shark which succumbed seven days post-release. The depth and temperature data suggest that this one mortality was due to injuries sustained during capture and handling, rather than predation. Meta-analysis on blue shark mortality from published and ongoing research (n = 78 reporting PSATs) indicated the summary effect for post-release mortality from longline gear was 15 percent (95% CI, 9 – 25%).

Antecedent stress variables to explain mortality have been examined (i.e., capture temperature, soak time, etc.) but we could not conclusively demonstrate association with any of the variables and mortality in these two instances. These combined biochemical and PSAT analyses suggest that sharks landed in an apparently healthy condition are likely to survive long term if released (95% survival based on biochemical analyses [blue shark]; >95 percent based on PSATs [all sharks studied]). In summary, our studies demonstrate a high rate of post-release survival of pelagic sharks captured and released from longline gear fished with circle hooks. These tagging results are also used to chronicle these pelagic species in terms of migration routes, distribution patterns, and habitat association as well as developing bycatch mitigation methods (Musyl et al. 2009, Beverley et al. 2009, Hoolihan et al. 2011).

Pop-up Satellite Archival Tags (PSAT) Performance and Metadata Analysis Project

Satellite tagging studies have been used to investigate post-release mortality of animals, either as indicated by signal failure, early pop-up, or depth data indicating rapid descent to abnormal depth before pop-up. However, these signals, or the lack thereof, may have other origins besides mortality. The purpose of this study is to explore failure (or success) scenarios in PSATs attached to pelagic fish, sharks, and turtles. We quantify these issues by analyzing reporting rates, retention times, and data return from 27 pelagic species from 2,164 deployments (731 PSAT deployments from 19 species in the authors' database, and in 1,433 PSAT deployments from 24 species summarized from 53 published articles]. Shark species in the database include bigeye thresher, blue, shortfin mako, silky, oceanic whitetip, great white, and basking sharks. Other species include: black, blue, and striped marlins; broadbill swordfish; bigeye, yellowfin, and bluefin tunas; tarpon; and green, loggerhead, and olive ridley turtles. To date, of 731 PSATs attached to sharks, billfish, tunas, and turtles, 577 (79%) reported data. Of the tags that recorded data, 106 (18%) hit their programmed pop-off date and 471 tags popped off earlier than their program date. The 154 (21%) non-reporting tags are not assumed to reflect fish mortality. The metadata study is designed to look for explanatory variables related to tag performance by analyzing PSAT retention rates, percentage of satellite data (i.e., depth, temperature, geolocations) retrieved, and tag failure. By examining these factors and other information about PSATs attached to vastly different pelagic species, it is anticipated certain patterns/commonalties may emerge to help improve attachment methodologies, selection of target species, and experimental designs, particularly with respect to post-release survival studies. PSATs in the database had an overall reporting rate of 0.79 which was not significantly different ($p = 0.13$) from the PSAT reporting rate of 0.76 in the meta-analysis. Logistic regression models showed that reporting rates have improved significantly over recent years, are lower in species undertaking large vertical excursions with a significant interaction between species' depth class (i.e., littoral, epi-pelagic, meso-pelagic, bathy-pelagic) and tag manufacturer.

Of all the PSATs attached to sharks, 80 percent reported and 65 percent detached before the programmed pop-up date. Shark PSAT reporting rates were highest in species such as oceanic whitetip (81%) which were epipelagic and remained near the ocean surface. Reporting rates were lowest in species undertaking large (~1,000 m) vertical excursions, such as bigeye thresher (37%) and shortfin mako (40%). Tag retention for the three shark species averaged 155 days for oceanic whitetip, 220 days for bigeye thresher, and 164 days for shortfin mako. Species-specific reporting rates were used to make recommendations for future PSAT sampling designs for fisheries researchers. Information derived from this study should allow an unprecedented and critical appraisal of the overall efficacy of the technology (Musyl et al. in press_b).

Southwest Fisheries Science Center

Common thresher (*Alopias vulpinus),* shortfin mako (*Isurus oxyrinchus)*, and blue (*Prionace glauca*) sharks are captured in both commercial and recreational fisheries in the California Current. The California drift gillnet fishery (CDGN) is the commercial fishery which catches the greatest number of each of these species. While thresher and mako sharks are landed, almost all blue sharks are discarded. For thresher and mako sharks, regional recreational fisheries are growing in popularity. Recreational fishers are often only interested in the challenge of the fight and will frequently release their catch. The survival rate of sharks released both from the CDGN fishery and by recreational anglers is unknown. Reliable estimates of removals (i.e., mortality) are necessary in order to adequately assess the status of the stocks and determine the effects of the fisheries on their abundance.

Recreational fishery for the common thresher shark (Alopias vulpinus)

The common thresher shark is the target of a popular and expanding recreational fishery in Southern California. The primary techniques employed in the recreational thresher shark fishery entail trolling heavy baited lures with large J-type hooks. Thresher sharks utilize their elongate upper caudal fin to stun live prey before it is consumed, thus the majority of sharks are hooked by the caudal fin. The tremendous power of large tail-hooked threshers is often sufficient to part the line, making trailing gear an issue of concern in this fishery. Trailing gear refers to the heavy (0.5 kg) terminal tackle that is left embedded in the caudal fin of a free-swimming shark. This Bycatch Reduction Engineering Program (BREP) project was designed to quantify mortality rates associated with tail hooking and trailing gear in the Southern California recreational fishery. Survivorship was determined using pop-off satellite archival tags (PSATs) deployed on sub-adult and adult common thresher sharks released with trailing gear. Concurrent investigations on the effectiveness of degradable links and alternative fishing techniques were also performed to reduce overall post-release mortality in the recreational fishery.

PSATs have been deployed on five common thresher sharks (132 to 175 cm FL) captured using fishery standard techniques and released with trailing tackle. To date three tags reported early mortalities occurring within 31 hours of release. All three tags were recovered after the deployment period using a radio direction finder. One of the PSATs never reported data, while the final tag reported on time and indicated that the shark survived the trailing gear effect. Additional deployments to complete the study during summer-fall 2011 will complement our FY 2009 BREP-supported research and provide an overall mortality estimate for tail-hooked individuals in the recreational fishery. The project also includes a strong public outreach component aimed at promoting catch and release angling and using alternative fishing methods that improve post-release survival (see section 2.5).

Figure 5.3.1. One of 20 common thresher sharks captured and tagged with a PSAT tag to assess catch-and-release survivorship

Blue Sharks Released from the California Drift Gillnet Fishery (CDGN)

The CDGN fishery targets swordfish in the California Current. The most common bycatch species in this fishery are ocean sunfish and blue sharks. Nearly all blue shark are discarded at sea due to lack of market value. A 2009 analysis of the 1990–2008 observer data reveals that 32 percent of blue sharks captured were released alive, and an additional 5 percent were discarded with their disposition unknown. The remaining 63 percent were discarded dead.

In 2007, the SWFSC and the SWR began deploying PSAT tags on sharks released from the drift gillnet fishery to assess survivorship. The tags were programmed to pop off after 30 days. The goal was to tag sharks such that the sex ratio, range of sizes, and condition at release were comparable to those released from the fishery. As a part of the study, a set of criteria was developed to document the condition of all blue sharks released: good, fair, or poor.

Since initiating the study in 2007, 11 blue sharks (100 to 200 cm FL, median 155 cm) have been tagged by fishery observers. Nine of these animals were male, and the sex of 2 animals was unknown. Three of the 11 sharks were released in "good" condition while the remaining 8 were released in "fair" condition. To date, no sharks released in "poor" condition have been tagged. Satellite tag records suggest that all animals survived the acute effects of capture in the CDGN fishery. Temperature, depth, and movement data demonstrated behavior of blue sharks that was similar to that reported in other studies. One tag appeared to have been ingested after 17 days and regurgitated 3 days later.

To meet the goal of matching the general composition of the catch, additional tag deployments are necessary. In the fishery, 29 percent of blue sharks released during the 2007 through 2010 seasons (the only seasons for which this information has yet been compiled) were released in poor condition. To date no sharks in poor condition have been tagged. Based on observer records the sex ratio of blue sharks caught in this fishery is roughly 60 percent male and 40 percent female. As mentioned, when known, all sharks tagged to date were males.

Tagging efforts during the 2010–2011 season were focused on smaller sharks, females, and animals released in poor condition. Tags were distributed among observers as widely as possible in an attempt to ensure deployment. However, due to the decreased effort in the fishery during the season with fewer trips observed, and the small numbers of blue sharks caught overall, particularly of the desired size and condition ranges, no blue sharks were tagged for this study during the 2010–2011 drift gillnet season. The objectives for the 2011–2012 season will be the same. Results to date suggest a 100 percent survival rate for male blue sharks released in fair or better condition.

Northeast Fisheries Science Center

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 Massachusetts Division of Marine Fisheries (MDMF) 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 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 MDMF; (3) placing SPOT and PSAT tags on shortfin makos and blue sharks in the Northeast U.S. and on their pelagic nursery grounds; (4) placing PSAT tags on sand tigers in Delaware Bay and Plymouth Bay (MA) 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 MDMF. Integration of data from new-technology tags and conventional tags from the Cooperative Shark Tagging Prgram (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.

Southeast Fisheries Science Center (SEFSC)

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

NMFS' Panama City Laboratory has been conducting a series of fishing experiments using commercial fishing vessels participating in the Shark Research Fishery to investigate methods to reduce at vessel mortality of dusky shark, a prohibited species. Vessels set an average of 317 gangions with 18/0 Lingren Pitman Circle hooks with a 10 degree offset. Soak times averaged 15.0 hours. Hook timers (HT 600, Lindgren-Pitman Inc.) were attached to every fourth hook. A total of 25 sets were completed in 2010 in areas off the east coast of the United States and the Gulf of Mexico. In addition to dusky shark, data also are being collected on 13 other species. For all species, preliminary results indicate the mean time for hook timers to be activated (i.e., time to bite the hook) was 6.6 hours. Sharks remained on the hook for an average of 10.3 hours. For dusky shark captured with hook timers (n=3), all were reported dead at the vessel after a mean time on the hook of 13 hours. A full analysis of the data will be performed after data collection is complete in 2011.

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7. Internet Information Sources

Federal Management
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

Atlantic Ocean Shark Management
Copies of the 2006 Consolidated Atlantic HMS FMP and its Amendments and Atlantic commercial and recreational shark fishing regulations and brochures can be found on the Highly Migratory Species (HMS) Management Division website at http://www.nmfs.noaa.gov/sfa/hms/. Information on Atlantic shark fisheries is updated annually in the Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic HMS, which are 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.

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

Data reported in Table 2.3.3 (Shark landings (round weight equivalent in metric tons) for California, Oregon, and Washington, 2001–2010) 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/pelagic.htm.

Data reported in Table 2.3.8 (Shark landings (mt) from the Hawaii-based longline fishery and the American Samoa longline fishery, 2001-2010) was partially obtained from the Western Pacific Fisheries Information Network (WPacFIN). WPacFIN is a Federal-State partnership collecting, processing, analyzing, sharing, and managing fisheries data from American island territories and States in the Western Pacific. More information is available on their website at: 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: http://www.fakr.noaa.gov/npfmc/fmp/fmp.htm.

Stock assessments and other scientific information for sharks are summarized annually in an appendix to the NPFMC SAFE Reports that are available online: http://www.fakr.noaa.gov/npfmc/SAFE/SAFE.htm.

International Efforts to Advance the Goals of the Shark Finning Prohibition Act
NOAA Fisheries Office of International Affairs
http://www.nmfs.noaa.gov/ia/

FAO International Plan of Action for the Conservation and Management of Sharks
http://www.fao.org/figis/servlet/static?dom=org&xml=ipoa_sharks.xml

U.S. NPOA for the Conservation and Management of Sharks
http://www.nmfs.noaa.gov/sfa/hms/Final%20NPOA.February.2001.htm

NAFO Conservation and Enforcement Measures
http://www.nafo.int/fisheries/frames/regulations.html

IATTC
http://iattc.org/HomeENG.htm

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

WCPFC
http://www.wcpfc.int/

UNGA
http://www.un.org/en/law/

Memorandum of Understanding on the Conservation of Migratory Sharks
http://www.ecolex.org/server2.php/libcat/docs/TRE/Multilateral/En/TRE154630.pdf

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 the 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.gov/st1/trade/index.html

8. Species Index

Appendix 1: Detailed Information on NOAA Research on Sharks

Pacific Islands Fisheries Science Center (PIFSC)

Fishery Data Collection

Market data from the PIFSC shoreside sampling program contain detailed biological and economic information on sharks in the Hawaii-based 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 Hawaii. The Western Pacific Fishery Information Network (WPacFIN) is a Federal-State partnership collecting, processing, analyzing, sharing, and managing fisheries data on sharks and other species from U.S. island territories and states in the Central and Western Pacific (Hamm et al. 2010). The WPacFIN program has also assisted other U.S. islands' fisheries agencies in American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands to modify their data-collecting procedures to collect bycatch information. These modifications have improved the documentation of shark interactions with fishing gear. Shark catches in the Hawaii-based longline fishery have been monitored by a logbook program since 1990, and by an observer program since 1994.

Biometrical Research on Catch Statistics

Biometrical research on shark longline bycatch issues funded by the Pelagic Fisheries Research Program (University of Hawaii) was documented in Walsh et al. (2009). This work was based on analyses of shark catch data from the Pacific Islands Regional Observer Program. The results included a detailed description of the taxonomic composition of the shark catch, as well as additional information pertinent to either the management (e.g., nominal catch rates; disposition of caught sharks; distributions of shark catches relative to those of target species) or basic biology (e.g., mean sizes; sex ratios) of the common species. The results indicated that blue shark in particular, which comprises approximately 85 percent of the shark bycatch, exhibits a high rate of survival (about 95 percent) to the time of release. On the basis of these very low minimum mortality estimates, it was concluded that the Hawaii longline fishery has made substantial progress in reducing bycatch mortality compared to the period before the shark finning ban.

NMFS is currently producing standardized CPUE time series for blue shark, whitetip shark, and silky shark in the Hawaii longline fishery using the Pacific Islands Regional Observer Program data (1995–2010). This work can be used as input for stock assessment for these shark species.

Insular Shark Surveys

Densities of insular sharks (grey reef shark (*Carcharhinus amblyrhynchos,* galapagos shark (*Carcharhinus galapagensis*),whitetip reef shark (*Triaenodon obesus*), blacktip reef shark (*Carcharhinus melanopterus*), silvertip shark (*Carcharhinus albimarginatus*), tiger shark (*Galeocerdo cuvier*), tawny nurse shark (*Nebrius ferrugineus*), whale shark (*Rhincodon typus*), scalloped hammerhead shark (*Sphyrna lewini*),great hammerhead shark (*Sphyrna mokarran*), and zebra shark (*Stegostoma varium*)) have been estimated at most of the U.S. island possessions within the Tropical Central, Northern, and Equatorial Pacific on annual or biennial surveys conducted by the PIFSC Coral Reef Ecosystem Division (CRED) since 2000.

These estimates include surveys of:

- 10 major shallow reefs in the Northwestern Hawaiian Islands (2000, 2001, 2002, 2003, 2004, 2006, 2008, 2010).
- The Main Hawaiian Islands (2005, 2006, 2008, 2010).
- 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).
- American Samoa including Rose Atoll and Swains Island (2002, 2004, 2006, 2008, 2010).
- Guam, and the Commonwealth of the Northern Marianas Islands (2003, 2005, 2007, 2009, 2011), Johnston Atoll (2004, 2006, 2008, 2010), and at Wake Atoll (2005, 2007, 2009, 2011).

Although 11 species of shark have been observed during CRED surveys (see Table 5.1.1), only 4 species of sharks 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 1 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. Trends in whitetip and blacktip reef shark numbers are similar, but less dramatic.

Recent analysis of data from 2008–2010, also indicated significantly higher biomass of all sharks combined at remote islands (i.e., islands at least 100 km from the nearest human population center) compared to populated islands, with remote islands having, on average, 40 or more times the biomass of sharks than was recorded at populated islands in both the Hawaiian and Mariana Archipelagos (Williams et al. 2011). Differences between remote and populated portions of American Samoa were not statistically significant, reflecting low counts of sharks at all locations in that region. CRED is currently working on a scientific article using towed-diver data of shark distribution, and accounting for differences between reef areas in temperature and oceanic primary productivity. Because all CRED shark data was gathered by SCUBA divers: (i) safe diving practices limited surveys to reefs areas of 30m or shallower which is the upper end of reef sharks' potential depth distribution; and (ii) 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, CRED is pursuing opportunities for diver-independent assessments of shark populations, such as by deploying remote video systems.

Although the CRED time series is still relatively short (<9 years), certain temporal trends in reef shark densities are starting to appear. In brief, CRED has noticed apparent declines in reef shark densities in the Northwestern Hawaiian Islands and in the Northern Mariana Islands. Possible explanations for these patterns are currently being investigated.

Shark Predation Mitigation on Hawaiian Monk Seals at French Frigate Shoals

Galapagos shark predation has become the dominant mortality source for nursing and recently weaned endangered Hawaiian monk seal pups at French Frigate Shoals (FFS), the most important breeding site in the NWHI. Intense predation by a relatively small number of sharks (~20) on preweaned pups was first detected in the late 1990s, when 19 to 31 mortalities were documented each year from 1997 to 1999. This equated to 17–32 percent of the annual cohort. Subsequent mitigation efforts resulted in the removal of 12 sharks known to be preying on monk seal pups and the ensuing predation losses dropped to 8–12 pups from 2000 to 2008 (12–21 percent of the annual cohort born at FFS). Sharks were removed using a combination of shore-based handline fishing, boat fishing, and hand-held harpoon. We elected to place a temporary moratorium on shark removals in 2008 as we investigate the efficacy and feasibility of non-lethal shark deterrents.

Deterrents deployed in 2008 and 2009 included: visual deterrents (boat anchored offshore near Trig Island, assorted visual stimuli in the water column); auditory deterrents (boat noise broadcast by an underwater loudspeaker); magnetic deterrent (permanent magnets deployed in association with the visual stimuli); and electromagnetic deterrents (powered *Shark Shield*–type device deployed at strategic access points near Trig Island). Also, a remote camera system is currently in place at Trig with the aim of capturing shark activity and incidents on pups this season. Results from the 2008-2009 deterrent research demonstrated that deterrents were not successful in deplacing sharks and preventing pup predation.

In 2010, we reinitiated shark removals at FFS and worked hard to facilitate understanding with the Native Hawaiian community. Predatory activity at FFS resulted in 8 pup deaths out of 36 pups born. Two shark fishers were hired to fulfill the objectives of the permit granted in June 2010. These two staff and 3 invited members of the Native Hawaiian community deployed on a chartered vessel, the Kahana, bound for FFS; the cruise dates were from July 5 through July 11, 2010. The vessel's course was based on the suggestions by the members of the Native Hawaiian community, which included timed arrival at select islands. The course included a visit to Ka'ula rock to perform the Mano i'a Harvest Ceremony at approximately noon on July 6, with the ship stationed off a cave on the northwest side of the rock. Hawaiian greetings were chanted from the vessel during two morning circumnavigations around Nihoa Island, as well as at Mokumanamana during the night as the ship passed by en route to Tern Island, FFS. The stay at Tern Island, FFS was extended by a few hours beyond the scheduled drop-off of supplies and personnel to perform a second Manu i'a Harvest Ceremony. Our shark staff, monk seal staff, as well as the Refuge manager and other Fish & Wildlife staff participated in the ceremony, led by the members of the Native Hawaiian Community.

At Trig Island, monitoring of sharks occurred via camping and video recording. The fishing effort initially focused on off-shore activities. Bottomsets and drumlines were deployed according to the permit's provisions with staff observing from island ready to alert the fishers (who were in their small boat monitoring the off-shore gear) of any near-shore shark activity.

Thirty-four days of fishing occurred at Trig with 413 bottomset hook hours and 519.5 drumline hook hours (as of August 23, 2010). One Galapagos shark was captured via the bottomset on the third day of fishing; the male shark (165cm total length) was euthanized with a bang stick, sampled (muscle, liver, stomach contents, skin clipping) and skin and teeth retained and preserved for Native Hawaiian community members. Remaining tissue was used as bait for subsequent fishing efforts.

Bycatch was minimal and all non-target fishes caught were released alive (three ulua, one whitetip shark, and three tiger sharks). In addition, two tiger sharks took bait, bent the hooks, and escaped, and therefore were not considered true bycatch. No monk seals or turtles showed interest in gear or bait. Human observations, video recordings, and low catch success at Trig provide continued support for the long-standing hypothesis that a small subset of Galapagos sharks is primarily responsible for the predation of pups. It is also noteworthy that tiger shark hooking at Trig occurred throughout the 34 days of fishing reported here (five incidents) and this tiger shark presence was not coincident with predation activity.

Stock Assessment of Blue Shark

Work was initiated in 2000 as a collaborative effort with scientists at the National Research Institute for Far Seas Fisheries (NRIFSF) in Shimizu, Japan. A report was produced (Kleiber et al. 2001) that indicated that the blue shark stock was not being overfished. PIFSC and NRIFSF subsequently renewed this collaboration, along with scientists from Japan's Fisheries Research Agency, to update the blue shark assessment with the latest Japanese and Hawaiian longline fishery data, as well as with better estimates of Taiwanese and Korean catch and effort data.

Objectives were to determine the degree to which the blue shark population has been affected by fishing activity and whether current fishing practices need to be managed to ensure continued viability and utilization of the resource. In addition to re-estimating catch and effort data based on a longer time series of data (Nakano and Clarke 2005, 2006), this study incorporated several new features: (1) effort data were obtained from the Fisheries Administration of Taiwan, (2) catches for the Japanese inshore longline fleet were included, (3) catch estimates were contrasted with estimates from the shark fin trade, (4) catch per unit effort was standardized using both a generalized linear model and a statistical habitat model, and (5) two different stock assessment models were applied.

Detailed records from daily fin auctions in the world's largest trading center, Hong Kong, and national customs statistics, were used to estimate the number of blue shark caught in the North Pacific for the years from 1980 to 2002. This was achieved by estimating the number of blue sharks utilized in the global fin trade (Clarke et al. 2004, Clarke 2004, Clarke et al. 2006) and partitioning these estimates to represent blue shark catches in the North Pacific only. Despite considerable uncertainty in this extrapolation algorithm, the North Pacific blue shark catch estimates based on the shark fin trade are very similar to estimates from Kleiber et al. (2001).

The two shark assessment models—a surplus production model and an integrated age and spatially structured model—were found to be in general agreement even though they represent opposite ends of the spectrum in terms of data needs (Kleiber et al. 2009). The trends in abundance in the production model and all alternate runs of the integrated model show the same pattern of stock decline in the 1980s followed by recovery to a biomass that was greater than that at the start of the time series. One of the several alternate analyses indicated some probability (around 30%) that the population is overfished and a lower probability that overfishing may be occurring. There was an increasing trend in total effort expanded by longline fisheries toward the end of the time series, and this trend may have continued thereafter. The uncertainty could well be reduced by a vigorous campaign of tagging and by continuous, faithful reporting of catches and details of fishing gear.

Electronic Tagging Studies and Movement Patterns

PIFSC scientists are using acoustic, archival, and pop-up satellite archival tags (PSATs)[13] 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 (Musyl et al. in press_a). In a review paper, Bernal et al. (2009) summarizes the eco-physiology of large pelagic sharks while Sibert et al. (2009) report on the error structure of light-based geolocation estimates afforded by PSATs and Nielsen et al. (2009) show how reconstructed PSAT tracks can be optimized.

The research, sponsored by the Pelagic Fisheries Research Program (University of Hawaii) and PIFSC, has shown that some large pelagic fishes have much greater vertical mobility than others. Pelagic sharks displayed species-specific depth and temperature ranges, although with significant individual temporal and spatial variability in vertical movement patterns, which were also punctuated by stochastic events (e.g., El Niño-Southern Oscillation [ENSO]). Pelagic species, including some other species that have been PSAT tagged (swordfish, bigeye tuna, and marlins) can be separated into three broad groups (Fig. A1.1) based on daytime temperatures occupied using a clustering algorithm. These groups, and the temperatures occupied by the sharks are characterized as: (1) epipelagic species (including silky and oceanic whitetip sharks) which spent > 95% of their time at temperatures within 2°C of sea surface temperature, (2) mesopelagic I species (including blue and shortfin mako sharks) which spent 95% of the time at temperatures from 9.7–26.9°C and 9.4–25.0°C, respectively, and (3) mesopelagic II species (including bigeye thresher shark) which spent 95% of the time at temperatures from 6.7–21.2°C. For the most part, the topology of clusters did not appear to correlate with ENSO variability, phylogeny, life history characteristics, ecomorphotypes, neural anatomy, relative eye size, physiology, or the presence of regional endothermy—indicating other factors (e.g., ontogeny, latitude, locomotion, diet, and dimensionality of the environment) influence the structure as well as the spatial and temporal stability of thermal habitats. The results suggest that habitat structure for the epipelagic silky and oceanic whitetip sharks can be adequately estimated from two dimensions (these species spend

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[13] PSAT tags record measurements such as temperature, pressure (depth), and ambient light-level irradiance (some model tags also have the ability to measure salinity). At a preset time, an electronic link is activated that dissolves the tag's nosecone attachment, allowing the tag to float to the surface where it sends its broadcast of data to satellites under three conditions: (1) meets set pop-up date, (2) exceeds threshold depth (~1200-1500 m; can tell shed tag from mortality), and (3) remains stationary at a depth above the threshold depth for (usually) 4 consecutive days.

most of their time in the warmest available water). By contrast, three dimensions will be required to describe the extended vertical habitat of the species that we classified as mesopelagic I (blue shark, shortfin mako shark) and mesopelagic II (bigeye thresher shark) (Musyl et al., in press_a).

Mesopelagic II species remain in the vicinity of prey organisms comprising the deep Sound Scattering Layer (SSL) during their extensive diel vertical migrations. The SSL comprises various species of squids, mesopelagic fish, and euphausiids that undertake extensive diurnal vertical migrations. This composition of organisms is referred to as the SSL because the migration of these organisms was first discovered by the sound waves that reflect off gas-filled swim bladders or fat droplets within the migrating organisms. PIFSC scientists have also found one of the most ubiquitous large-vertebrate species in the pelagic environment—the blue shark—occasionally displays vertical movement behaviors similar to those of swordfish, bigeye tuna, and bigeye thresher sharks.

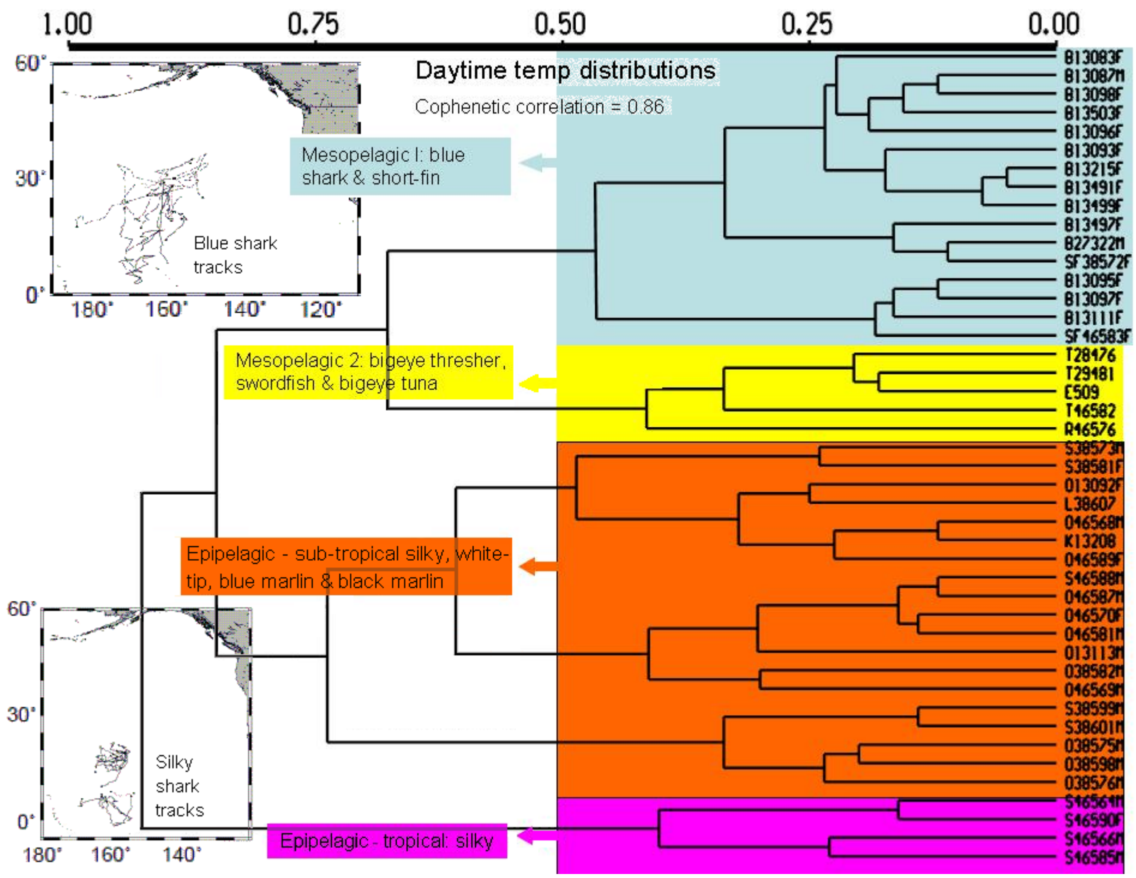

Figure A1.1. Clustered relationships among pelagic animals using daytime temperature preference readings from pop-up satellite archival tags (PSATs). B = blue shark (Prionace glauca), SF = shortfin mako (Isurus oxyrinchus), T = bigeye thresher (Alopias superciliosus), E = bigeye tuna (Thunnus obsesus), R = swordfish (Xiphias gladius), S = silky shark (Carcharhinus falciformes), O = oceanic whitetip shark (C. longimanus), K = black marlin (Makaira mazara), L = blue marlin (M. nigricans), M = male, and F = female. Inset maps show the horizontal movement patterns.

Electronic Tagging of Whale Sharks (*Rhincodon typus*)

The PIFSC, in collaboration with Australian Institute for Marine Science and the Commonwealth Scientific and Industrial Research Organization, has for the past several years been deploying electronic tags on whale sharks at Ningaloo Reef, Western Australia, to describe their vertical and horizontal movements. The work has documented that whale sharks dive below 1000 m, deeper than previously thought. After the whale sharks leave Ningaloo Reef, some travel to Indonesia while others head across the Indian Ocean (Wilson et al. 2006, Wilson et al. 2007).

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: common thresher (*Alopias vulpinus),* bigeye thresher (*A. superciliosus),* and pelagic thresher (*A. pelagicus)*. Center scientists are studying the sharks' biology, distribution, movements, stock structure, population status, and potential vulnerability to fishing pressure. This information is provided to international, national, and regional fisheries conservation and management bodies having stewardship for sharks. Some of the recently completed and ongoing shark research activities being carried out at the SWFSC are discussed below.

Abundance Surveys

The blue, shortfin mako, and thresher sharks are all taken in regional commercial and recreational fisheries. Common thresher and mako sharks have the greatest commercial value and are also specifically targeted by sport fishers, especially off Southern California. Although the blue shark is targeted in Mexico, it has little market importance in the U.S. but is a leading bycatch species in the California Drift Gillnet (CDGN) swordfish fishery and high-seas longline fisheries. Although catches of adult blue, thresher, and shortfin mako sharks do occur, the commercial and sport catch of these species off Southern California consists largely of juvenile sharks.

To track trends in the abundance of juvenile and subadult blue and shortfin mako sharks and neonate common thresher sharks, surveys are carried out in the Southern California Bight each summer. Efforts to determine abundance trends from commercial fishery data have been complicated by changes in regulations, targeted areas, and fishing methods over time. These changes have resulted in inconsistent capture rates and catch distributions that are difficult to interpret. Therefore, fishery-independent sampling was initiated, with slightly different survey strategies required for the more oceanic shortfin mako and blue sharks compared to the more coastal common thresher shark.

Offshore longline surveys from relatively large research vessels have proved most effective for sampling and estimating abundance trends of the oceanic species (shortfin mako and blue sharks). For mako sharks, the surveys have enabled the SWFSC to obtain a valuable abundance index, which can be linked to a historical time series of logbook and landings data from an experimental shortfin mako longline fishery in the Southern California Bight that occurred during 1988–1991. Abundance trend information is also obtained for the blue shark, which is compared to that obtained by observers of the CDGN and U.S. and Japanese high-seas longline fisheries.

Surveys for neonate thresher sharks are conducted using small commercial driftnet and longline vessels. Initial studies demonstrated that neonate threshers are rarely encountered in waters deeper than about 90 m. Therefore, surveys are conducted in the shallower nearshore waters between Point Conception, California and the U.S.-Mexico border. The primary purpose of the surveys is to produce a relative abundance index for the west coast population by periodically sampling 0-year pups (neonates) in their nursery grounds off Southern California. Once the core nursery area was defined, representative areas were identified and are now sampled annually. The resulting neonate index of abundance should mirror adult abundance because adult population and recruitment should be tightly linked in K-selected species such as sharks. This study complements the fishery-dependent data available through the nearshore small mesh net fisheries and pelagic driftnet fishery to provide measures of relative abundance of common thresher sharks for stock assessment models.

Juvenile Mako and Blue Shark Survey

In 2010, the SWFSC conducted its 17th juvenile shark survey for mako and blue sharks since 1994. The annual abundance survey was completed between July 14 and August 12, 2010. Working aboard F/V *Ventura II*, a team of scientists and volunteers fished a total of 5,956 hooks during 29 daytime sets inside seven focal areas within the Southern California Bight. Survey catch totaled 13 shortfin makos, 25 blue sharks, 18 pelagic rays (*Pteroplatytrygon violacea*), 10 opah (*Lampris guttatus*), and one mola (*Mola mola*). The preliminary data indicate that the nominal survey catch rate was 0.057 per 100 hook-hours for shortfin mako and 0.105 per 100 hook-hours for blue sharks. The nominal CPUE for both blue and shortfin mako sharks were the lowest in survey history. There is a declining trend in nominal CPUE for both species over the time series of the survey (Figure A1.2).

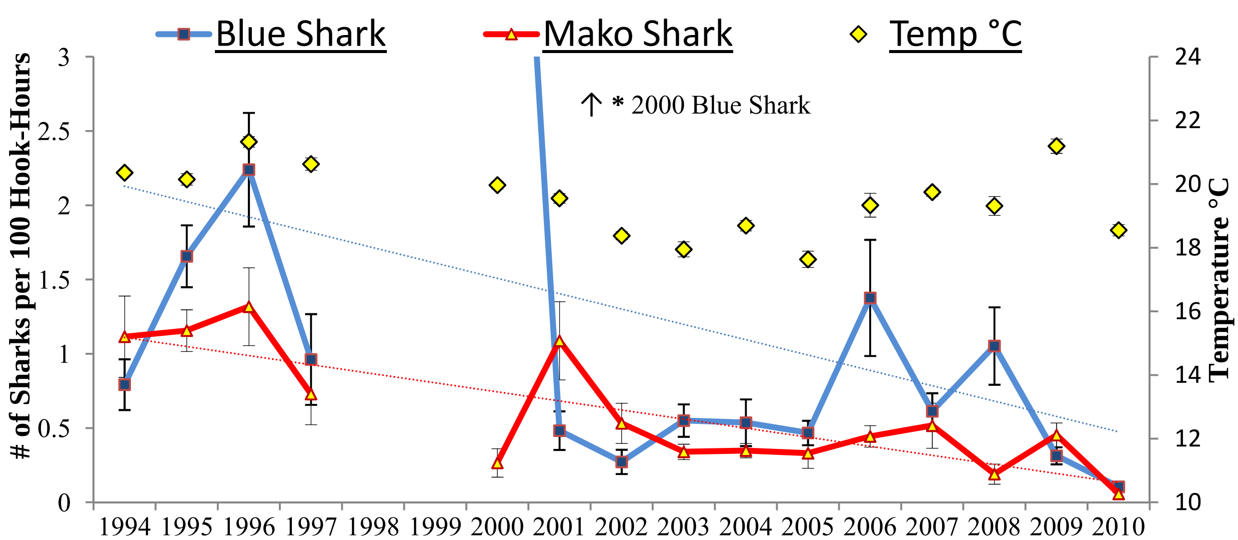

Figure A1.2. Average (± standard error) catch and temperature per survey set for shortfin mako and blue sharks, 1994–2010. No data were collected in 1998 and 1999. Blue shark catch per 100 hook-hours was 7.372 in 2000.

Other objectives of the cruise were to deploy satellite and conventional tags, and to collect biological samples from sharks and swordfish. A total of 242 conventional tags were deployed on a total of 50 shortfin mako sharks and 192 blue sharks. A total of 310 DNA samples were collected including samples from 53 shortfin mako and 244 blue sharks. In a cooperative effort with TOPP (Tagging of Pacific Pelagics, a Census of Marine Life project), 10 electronic tags were deployed on sharks to examine the habitat-use patterns in the California Current System. Four shortfin mako sharks ranging from 147 to 203 cm fork length were released with a radio position transmitting tag (SPOT). Six blue sharks ranging from 175 to 221 cm fork length were also released with SPOT tags (see below for results).

Neonate Common Thresher Shark Survey

The common thresher shark pre-recruit index and nursery ground survey was initiated in 2003 to develop a fisheries-independent index of pre-recruit abundance and has been conducted each year since. Common thresher sharks are the most valuable sharks taken in commercial fisheries off California and are also frequently caught by recreational fishermen. In 2010, the SWFSC team worked aboard the F/V *Outer Banks*. Forty-eight longline sets were made in relatively shallow, nearshore waters and a total of 4,800 hooks were fished during the 18-day cruise. Shark catch included 295 common thresher, five smoothhound (*Mustelus sp.*), two spiny dogfish (*Squalus acanthias*), and one leopard (*Triakis semifasciata*) shark. Two hundred sixty-eight sharks were tagged with conventional tags and 280 DNA samples were collected.

The preliminary survey data indicate that the average nominal catch rate by set was 3.75 per 100 hook-hours for common thresher sharks. This is the highest catch rate since the inception of the sampling program. The distribution of common threshers is very patchy and areas of high abundance are not consistent across years. In all years, a large percentage of the catch has been neonates, which were found in all areas surveyed. In addition to providing important information on abundance and distributions, the thresher shark pre-recruit survey enhances other ongoing research at SWFSC, including age and growth, feeding, and habitat utilization studies.

Electronic Tagging Studies

Since 1999, NOAA has been using satellite technology to study the movements and behaviors primarily of blue, shortfin mako and common thresher sharks, while other species are tagged opportunistically. In recent years, tag deployments have been carried out in collaboration with the TOPP program (www.topp.org), Mexican colleagues at Centro de Investigación Científica y de Educación Superior de Ensenada, and Canadian colleagues at the Department of Fisheries and Oceans Pacific Biological Station in Nanaimo, British Columbia. The goals of the projects are to document and compare the movements and behaviors of these species in the California Current and to link these data to physical and biological oceanography. This approach will allow us to characterize the essential habitats of sharks and subsequently to better understand how populations might shift in response to changes in environmental conditions on short or long time scales.

In 2010, four shortfin mako sharks, nine blue sharks, one thresher shark, and one basking shark were tagged with either SPOT tags or towed GPS tags. Since 1999, a total of 95 makos, 85 blue sharks, 28 common threshers, two hammerheads, five ocean sunfish, and one basking shark have been satellite tagged through collaborative projects.

SPOT tags continue to provide excellent information on the movements of blue and mako sharks. Three tags deployed on blue sharks are still transmitting after periods of up to 13 months, providing some of the longest tracks obtained to date for this species. Two of the tags were deployed off California and the longest deployment is from a tag deployed off Canada in February of 2010. The sharks traveled offshore in different directions after tagging. Movements ranged from offshore of Mexico to the central Pacific (north and south of Hawaii), highlighting the diversity of movements in blue sharks.

For mako sharks, eight tags were transmitting in early 2011, six of which were deployed in 2009 providing well over a year's worth of data. These multiyear records provide an incredible opportunity to examine seasonal movement patterns and regional fidelity. Mako sharks often undertake a seasonal migration to the subtropical convergence zone in the winter or spring. Where tracks include two migratory cycles, there is a remarkable similarity in movement patterns during their southward migration. While sharks ranged from the Sea of Cortez to the Central Pacific, individuals return to the same region in subsequent years. Fidelity to specific areas is increasingly recognized in fish from swordfish to salmon sharks and increases the potential for regional depletion where fisheries exist.

Age Validation Studies

Age and growth of mako, common thresher, and blue sharks are being estimated from band formation in vertebrae. SWFSC scientists are validating aging methods for these three species based on band deposition periodicity determined using oxytetracycline (OTC). Our annual research surveys provide an opportunity to tag animals with OTC. When the shark is recaptured and the vertebrae recovered, the number of bands laid down since the known date of OTC injection can be used to determine band deposition periodicity.

Since 1997 when the program began, 2,463 OTC-marked individuals have been released during juvenile shark surveys. Sharks tagged include 987 shortfin mako, 918 common thresher, 539 blue, 16 silky, and three pelagic thresher sharks. As of March 2011, recaptured OTC-marked sharks included 110 mako, 76 common thresher, and 63 blue, and two silky sharks. Vertebrae were returned for roughly 60 percent of the recaptures. Time at liberty ranged from 1 to 1,938 days, and the maximum net movement for an individual shark was 3,597 nmi. An analysis of mako shark band deposition patterns is now nearly complete and a manuscript is being drafted.

Foraging Ecology of Shortfin Mako, Blue, and Common Thresher Sharks

The California Current is a productive eastern boundary current that is an important nursery and foraging ground for a number of highly migratory shark species. As mentioned above, three of the most abundant juvenile sharks in the California Current are the shortfin mako, blue, and common thresher sharks. To better understand niche separation and the ecological role of these overlapping species, stomach content analyses have been ongoing at the SWFSC since 2002. Stomachs are obtained primarily from the CDGN observer program.

During 2002–2010 a total of 713 shortfin mako, blue, and common thresher shark stomachs were collected and analyzed. Stomach contents were identified to the lowest possible taxonomic level. Analytical approaches to characterize prey composition and examine inter- and intra-specific patterns included both univariate and multivariate methods including the Geometric Index of Importance (GII), Shannon and Simpson diversity, Sorensen and Morisita-Horn overlap indices, regression trees, Analysis of Similarity (ANOSIM), non metric multidimensional scaling (MDS), and Bio-Environmental step-wise (BVSTEP) analysis.

Of the 330 shortfin mako shark stomachs examined (53 to 248 cm FL), 238 contained 43 prey taxa. Jumbo squid (*Dosidicus gigas,* GII=46.0) and Pacific saury (*Cololabis saira*, GII=25.5) were the most important prey. Of the 158 blue shark stomachs examined (76 to 248 cm FL), 114 contained 38 prey taxa. Jumbo (GII=33.9) and *Gonatus* spp. squids (GII=33.6) were the most important prey. Of the 225 thresher shark stomachs examined (sizes 108 to 228 cm FL), 157 stomachs contained 18 prey taxa. Northern anchovy (*Engraulis mordax,* GII=68.4) and Pacific sardine (*Sardinops sagax*, GII=48.5) were the most important prey.

The Sorensen index shows that blue and mako shark diets were most similar, while dietary overlap was lowest between blue and thresher sharks as revealed by the Morisita-Horn index and regression tree analysis. Inter-annual variation in diet was greatest for blue sharks. Overall, results from the Sorensen index and multivariate analyses reveal that mako sharks have the most diverse diet, feeding on a range of teleosts and cephalopods; blue sharks generally prefer cephalopods; and thresher sharks are more specialized, feeding primarily on coastal pelagic teleosts. Despite similarities in life history characteristics and spatial and temporal overlap, diets of these three species are strongly differentiated. In 2010, the results from this research were accepted for publication in a special proceeding of the American Elasmobranch Society (Preti et al. 2001, 2004, 2008, in press).

The diet data collected for the sharks were also used to develop an indirect method of estimating foraging habitat. The method uses available data on prey distributions combined with stomach content data for predators to estimate which habitats are used for foraging. With respect to sharks in the Southern California Bight, this method confirmed conclusions of previous studies: thresher sharks foraged mostly in the epipelagic environment while makos spent relatively more time in mesopelagic and offshore habitats. Blue sharks spent the most time out of the three species foraging in offshore habitats. Results suggest that the new approach is effective and can be used for any organism in which the diet of the predator is known and the habitat distribution of prey is fairly well described.

Basking Shark research program

The eastern North Pacific basking shark population appears to have declined dramatically in the last 50 years with no evidence of a recovery. Where hundreds to thousands of individuals were observed off our coast, sighting even a few individuals is now rare. The apparent reduced abundance in the eastern North Pacific is likely linked to targeted fisheries off California in the first half of the 1900s and the eradication program established off Canada to keep basking sharks from destroying salmon nets. Due to concern about basking shark populations along the west coast of North America, the basking shark was listed as endangered in Canada and as a Species of Concern (SOC) in the U.S in 2010. Unfortunately, efforts to understand trends and develop a recovery plan are hampered by the lack of basic data on movements, the influence of environment on abundance and distribution, information on the full geographic range of the eastern North Pacific stock, and basic life-history information. Given the severe data gaps for this population, the SWFSC initiated a basking shark research program in 2010 with SOC funding to (1) mine existing data for additional biological information, (2) conduct an electronic tagging study, (3) improve international data collection, and (4) improve national sightings information by developing a sightings website and an education and outreach program centered around Monterey Bay, California. Monterey is a historic basking shark hotspot where the California fishery in the early 1900s was based.

This research program has progressed at a number of different levels. A dedicated website and hotline have been established as a part of a sightings network. This information will help with documenting patterns of occurrence and tagging efforts. We also developed a tri-national team with colleagues in Canada and Mexico to coordinate research efforts. The first meeting was held in November 2010 and a second is planned for May 2011. In addition, we deployed a satellite tag on a basking shark off Southern California on June 6, 2010. The tag released after 53 days off Morro Bay, California. After its release it transmitted data collected during the track including four GPS locations, in addition to temperature, depth, and light data. No transmissions were sent by the tag before it released.

Using both light-based and GPS locations, an estimated track between tag and release was obtained. It appears that the animal moved northwest from San Diego, shortly after being tagged, toward the Channel Islands where it remained for some time before it moved north of Point Conception. Over the course of the deployment the shark appears to have remained over the continental shelf and slope with general focal areas being the Channel Islands and Morro Bay. Basking sharks in the Atlantic show a similar preference for near-shore regions where complex flow patterns and convergence zones act to concentrate prey, which is critical to filter feeders.

Overall, the basking shark experienced a broad range of temperatures and depths. Sea surface temperature (SST) ranged from 10.7 to 18.3^{o}C [average 12.8 ± 1.9^{o}C (SD)] and daily minimum temperatures ranged from 6 to 10.2^{o}C [average 8.9 ± 1.4^{o}C (SD)]. The maximum depth was 544 m and during most 6-h time intervals, the shark came to the surface. Depth and temperature data showed considerable variability across the track, coincident with changes in SST. At SSTs below 12-13^{o}C, the maximum and modal depths were less than 200 m compared to depths up to 500 m in areas of higher SST. In addition, there was a significant correlation between SST and the temperature range experienced with a maximum of a 10^{o}C temperature range where SST was 18^{o}C. The shift to shallower depths at cooler temperatures may be associated with a thermal constraint on vertical movements; however, additional information on resource distribution is necessary. Basking sharks show impressive plasticity in vertical behaviors in our study as well as in the Atlantic. They can apparently adjust their foraging strategy according to the vertical distribution of their prey. These dramatic shifts in behavior make estimating abundance based on aerial surveys and predicting overlap with fisheries challenging. Additional information on the patterns in vertical and horizontal movements is needed.

Population Genetics Studies

<u>Shortfin Mako Shark</u>
The shortfin mako is a commonly encountered shark in temperate marine fisheries but little is known about regional connectivity. Amber Michaud's recent master's thesis completed at the University of San Diego and SWFSC provided evidence of regional stock structure within the Pacific. Using mitochondrial haplotype data, the study showed a strong subdivision between northern and southern hemisphere populations, with additional subdivision between southeast and southwest Pacific populations; however, no subdivision was found in the North Pacific using this marker. The results of this study are being prepared for publication. As part of his Ph.D. work at UC Davis, San Diego State University and the SWFSC, Dovi Kacev has been developing a suite of nuclear microsatellite markers to further refine the spatial and temporal resolution of shortfin mako stocks within the Pacific. In addition to studies of stock structure, these markers will be used to develop estimates of effective population size within the California Current region. Application of these markers will commence in 2011.

<u>Common Thresher Shark</u>
Common threshers are commonly encountered in temperate coastal marine fisheries but little is known about regional connectivity. In recent years they have become part of an increasingly important recreational fishery in Southern California in addition to being an important component of local gillnet fisheries. In order to better understand population connectivity, Dovi Kacev has been developing nuclear microsatellite markers for this species as well. Application of these markers will also commence in 2011.

<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 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. 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. Biological data and tissue samples were also collected from leopard sharks and cat sharks during the bottom trawl surveys.

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 PFMC for use in management. The NWFSC will conduct an assessment of spiny dogfish along the Pacific coast of the United States in 2011.

Movement studies

The NWFSC, in collaboration with Washington Department of Fish and Wildlife (WDFW) and the Seattle Aquarium, recently completed a study estimating movement parameters of sixgill and sevengill sharks in Puget Sound and Willipa Bay. Vemco ultrasonic tags were surgically implanted into the body cavity of each shark and released at their capture site. Automated listening stations were used to detect the ultrasonic transmitters, thus allowing shark movement to be monitored. In addition, movement was monitored with active, boat-based tracking. These data have allowed estimation of movement parameters (e.g., move length and turning angles) that allow home ranges to be estimated; daily, seasonal, and interannual movements to be described; and important habitats to be quantified. In particular, the researchers found that Puget Sound is an important habitat for pupping and provides a nursery ground for the juveniles. The adults return to the coast after pupping, while the juveniles stay in Puget Sound for several years until they mature, and then move out to the coast. Biological data (e.g., genetic samples, blood samples, gut contents, and length/weight) were also collected and used by the WDFW to support management of these species.

Northeast Fisheries Science Center (NEFSC)

Fishery-Independent Surveys and Recreational Monitoring of Coastal and Pelagic Sharks

Fishery-Independent Coastal Shark Bottom Longline Survey

The fishery-independent survey of Atlantic large and small coastal sharks is conducted bi-annually 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, inject with oxytetracycline for age validation studies, and collect biological samples and determine life history characteristics (age, growth, reproductive biology, trophic ecology, etc.). In addition, the collection of morphometric information provides data needed to calculate length to length and length to weight conversions. The time series of abundance indices from this survey is critical to the evaluation of coastal Atlantic shark species. Standardized indices of abundance from this survey for sandbar and dusky sharks were used in the 2010 Southeast Data Assessment and Review (SEDAR) process (McCandless and Natanson 2010). The next survey is scheduled for spring 2012.

Figure A1.3. Bringing in a sandbar shark during the NEFSC Coastal Shark Bottom Longline Survey. Source: Peter Cooper / NMFS photo.

Fishery Independent Pelagic Shark Longline

Survey
NMFS and its predecessor agencies, the Bureau of Commercial Fisheries and the Bureau of Sport Fish and Wildlife, conducted periodic longline surveys for swordfish, tunas, and sharks off the East Coast of the United States starting in the early 1950s. Surveys first targeted tunas and swordfish along the edge of the continental shelf, and subsequently focused on pelagic and coastal sharks over a variety of depths, including inshore bays and estuaries. The last large-scale pelagic fishing trip was conducted in 1985; however, the NEFSC Narragansett Laboratory completed a pilot survey in the spring of 2006 and conducted additional pelagic sets in 2007. The goal of this research is to initiate a standardized fishery-independent pelagic shark survey in order to conduct research and monitor shark abundance and distribution.

Juvenile Shark Survey for Monitoring and Assessing Delaware Bay Sandbar Sharks (*Carcharhinus plumbeus*)
The juvenile sandbar shark population in Delaware Bay is surveyed by NEFSC staff as part of the Cooperative Atlantic States Shark Pupping and Nursery (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 2010, a total of 211 sandbar sharks were caught and released with conventional tags. The mark-recapture data has been used to examine the temporal and spatial relative abundance and distribution of sandbar sharks in Delaware Bay. The juvenile index of abundance from this standardized survey has been used as an input into various stock assessment models; most recently to assess sandbar sharks during the 2010 SEDAR process (McCandless 2010). Catch per unit effort (CPUE) in number of sharks per 50-hook set per hour was used to examine the relative abundance of young of the year, age 1+, and total juvenile sandbar sharks between the summer nursery seasons in Delaware Bay from 2001 to 2009. All three juvenile sandbar shark time series showed stability in relative abundance from 2001 to 2005 with only a brief decrease in abundance in 2002, which may be attributed to a large storm (associated with a hurricane offshore) that passed through the Bay that year. There was a subsequent decreasing trend from 2005 to 2008 that ends with an increase in relative abundance in 2009.

Delaware Bay Sand Tiger (*Carcharias taurus*) Survey
A survey, initiated in 2006 targeting the sand tiger shark for identifying Essential Fish Habitat (EFH) and for future stock assessment purposes, continued in 2010 (see Figure A1.4). This study incorporates historical NEFSC sampling stations to allow for comparison between historic and current abundances. Preliminary results indicate that this survey will be a successful monitoring tool for the Delaware Bay sand tiger population and for evaluating long-term changes in abundance and size composition. In 2010, a total of 28 sand tigers were caught and released with conventional tags.

Figure A1.4. Measuring a sand tiger during the NEFSC Delaware Bay Sand Tiger Survey.
Source: Corey Eddy / NMFS photo.

Collection of Recreational Shark Fishing Data and Samples
Historically, species-specific landings data from recreational fisheries is lacking for sharks. In an effort to augment these data, the NEFSC has been attending recreational shark tournaments continuously since 1961 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 samples for pelagic and some coastal sharks to aid in our biological research. Analysis of these tournament landings data was initiated by creating a database of historic information (1961–2010) and producing preliminary summaries of some long-term tournaments. These analyses have been used to provide advice on future minimum size catch requirements for these tournaments. The collection and analysis of these data are critical for input into species and age specific population and demographic models for shark management. In 2010, biological samples for life history studies and catch and morphometric data for more than 200 pelagic sharks were collected at 10 recreational fishing tournaments in the northeastern United States. Participation at recreational shark tournaments and the resultant information is very valuable as a monitoring tool to provide long-term data that can detect trends in species and size composition, provide valuable specimens and tissue for life history and genetic studies, provide outreach opportunities for recreational fishermen and the public, and finally, to provide additional information on movements that complement the NMFS Cooperative Shark Tagging Program (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. During the 2010 SEDAR process, abundance indices were summarized for sandbar and dusky sharks caught during the NEFSC exploratory longline surveys (McCandless and Hoey 2010) and for blacknose, sandbar, and dusky sharks caught during the UNC shark survey (Schwartz et al. 2010). Work on the recovery of environmental data for both the NEFSC and the UNC time series, as well as the associated individual shark data, is ongoing to further refine these indices and to develop indices of abundance for other shark species, and for future use in shark EFH designations. Analyzing catch rates according to differences in time, space, or methods provide an opportunity to better understand seasonal distribution patterns and relative vulnerability of various species to different fishing practices.

SEDAR Process

Staff participated in the Southeast Data, Assessment, and Review (SEDAR) Data Workshop for the assessment of the blacknose, dusky, and sandbar sharks and contributed seven SEDAR working papers. These documents summarized blacknose, dusky, and sandbar shark mark-recapture data from the Cooperative Shark Tagging Program (Kohler and Turner 2010) and standardized indices of abundance for blacknose, dusky and/or sandbar sharks from the NEFSC historical longline surveys (McCandless and Hoey 2010), the NMFS Northeast shark longline surveys (McCandless and Natanson 2010), the University of North Carolina shark longline survey (Schwartz et al. 2010), and from the COASTSPAN surveys in Delaware Bay (McCandless 2010), South Carolina (McCandless and Frazier 2010) and Georgia (McCandless and Belcher 2010).

Deepwater Horizon C252 Pelagic Fish Sampling

Staff biologists participated in a pelagic longline cruise inside and adjacent to the area closed to fishing due to the Deepwater Horizon C252 oil spill. The objectives of this cruise were to collect highly migratory fish for food quality studies in the vicinity of the oil spill resulting from the sinking of the Deepwater Horizon oil platform; to monitor the distribution and abundance of highly migratory species in the Gulf of Mexico with reference to the oil sheen; and to collect CTD salinity and temperature profile data and water samples for hydrocarbon analysis. All commercially and recreationally valuable and legal sized pelagics were saved for seafood sampling.

Essential Fish Habitat

Pelagic Nursery Grounds

Pelagic shark biology, movements, and abundance studies continued in 2010 with further investigations of pelagic nursery grounds in conjunction with the high seas commercial longline fleet. This collaborative work 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. To date, over 2,500 sharks have been tagged with 151 recaptured. These fish were primarily blue sharks (114) that were recovered by commercial fishermen working in the mid-Atlantic Ocean. In 2010, 250 blue sharks were 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. This makes a total of 500 sharks double tagged. In 2007 and 2008, two real-time satellite (SPOT) tags and five PSAT tags were deployed on shortfin makos and one PSAT tag was deployed on a blue shark. This research was featured as part of the Discovery Channel's "Swords: Life on the Line," a series documenting the lives of commercial longline fishermen.

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 and in the U.S. Virgin Islands (USVI) by conducting cooperative, comprehensive, and standardized investigations of coastal shark nursery habitat. COASTSPAN surveys are used to describe habitat preferences, and to determine the relative abundance, distribution, and migration of shark species through longline and gillnet sampling and mark-recapture data (see Figure A1.5). In 2010, COASTSPAN participants were the Georgia Department of Natural Resources, the South Carolina Department of Natural Resources, the North Carolina Division of Marine Fisheries, and the University of North Florida. The NEFSC staff conducts the survey in Narragansett and

Figure A1.5. Tagging a juvenile sandbar shark during the NEFSC COASTSPAN Program Survey. Source: W. David McElroy / NMFS photo.

Delaware Bays and additional sampling in the USVI and Massachusetts in conjunction with the Massachusetts Division of Marine Fisheries (MDMF). Data from COASTSPAN surveys are used to update and refine EFH designations for multiple life stages of managed coastal shark species. Standardized indices of abundance from COASTPAN surveys are used in the stock assessments for large and small coastal sharks. During the 2010 SEDAR process, three COASTSPAN documents were contributed summarizing abundance indices for sandbar sharks in Delaware Bay (McCandless 2010), blacknose and sandbar sharks in South Carolina waters (McCandless and Frazier 2010), and blacknose and sandbar sharks in Georgia waters (McCandless and Belcher 2010).

In collaboration with MDMF and NMFS (Galveston, Texas, and Silver Spring, Maryland), a study was initiated in 2006 to investigate the spatial and temporal use of nursery habitat by neonatal blacktip (*Carcharhinus limbatus*) and lemon (*Negaprion brevirostris*) sharks in St. John, USVI, using both active and passive acoustic telemetry. Acoustic transmitters were surgically implanted in blacktip and lemon sharks and their movements are currently being monitored using passive acoustic telemetry.

Habitat Utilization and Essential Fish Habitat of Sand Tiger Sharks

Funding was received in 2006 through the NOAA Living Marine Resources Cooperative Science Center to support a multi-year cooperative research project with staff from Delaware State University and the University of Rhode Island on habitat use, depth selection, and the timing of residency for sand tigers in Delaware Bay. Sand tigers were implanted with standard acoustic or depth-sensing transmitters to monitor their movements and habitat use of Delaware Bay during the summer months. Currently sand tiger movements are being monitored using passive acoustic telemetry.

Funding was received in 2010 through the NMFS Species of Concern Internal Grant Program to study the regional movements, habitat use, and site fidelity of sand tigers off the US east coast using satellite telemetry. Pop-up satellite archival tags (PSATs) will be deployed on sand tigers in regions where seasonal sand tiger movement patterns and habitat use are uncertain, and results will be examined to quantify large scale three-dimensional movements of these fish as they relate to oceanographic features (e.g. temperature), time of year, essential fish habitat, size, age, and sex.

Essential Fish Habitat (EFH) Designations

NEFSC staff participates on a working group with others from the NMFS HMS Division and SEFSC to update and refine the EFH designations for managed shark species. This process was ongoing in 2010 and entailed providing summaries from our COASTSPAN surveys to update EFH for coastal shark species and information for the EFH section of the annual Stock Assessment and Fisheries Evaluation Report.

Elasmobranch Life History Studies

NEFSC life history studies are conducted on Atlantic species of elasmobranchs to address priority knowledge gaps and focus on species of concern. Biological samples are obtained on research surveys and cruises, on commercial vessels, at recreational fishing tournaments, and opportunistically from observers on commercial fishing vessels and from strandings. 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, and reproductive biology essential to estimate parameters for demographic, fisheries, and ecosystem models.

Atlantic Blue Shark (*Prionace glauca*) and Shortfin Mako (*Isurus oxyrinchus*) Life History and Assessment Studies

Collaborative programs to examine the biology and population dynamics of the blue shark and shortfin mako in the North Atlantic are ongoing. Fishery-independent published research on blue shark demographics has allowed for the construction of an age-structured population model. This model confirms the importance of juvenile survival for population growth. In addition, a risk analysis is proposed as a supplement to the data-limited stock assessment to better evaluate the probability that a given management strategy will put the population at risk of decline.

Shortfin mako survival was estimated from NMFS Cooperative Shark Tagging Program mark-recapture data. Estimates of survival (0.705–0.873 per year) were generated with the computer software MARK by analyzing tagged (n=6,309) and recaptured (n=730) animals. An estimate of survival is a key variable for stock assessments and subsequent demographic analyses, and is crucial when it comes to directly managing exploited or commercially viable species.

From samples provided from recreational fishing tournaments and on research cruises, a genetic approach for identifying pelagic shark tissues was streamlined and simplified by researchers at NOVA Southeastern University, facilitating rapid and unambiguous species identification. The result is a rapid, accurate, and relatively inexpensive genetic assay for identifying tissues and body parts from the shortfin mako and four other shark species (silky, dusky, sandbar, and longfin mako).

Regional sizes, sex ratios, maturation, and movement patterns were analyzed for 91,450 blue sharks tagged by members of the NMFS Cooperative Shark Tagging Program (CSTP) in the North Atlantic Ocean from 1962 to 2000. Of these, 5,410 were recaptured for an overall recapture rate of 5.9 percent. Blue sharks made frequent trans-Atlantic crossings from the western to eastern regions, and were shown to move between most areas; the mean distance traveled was 857 km, and the mean time at liberty between tagging and recapture was 0.9 year. North Atlantic blue sharks are believed to constitute a single stock, and a better understanding of their complex movements, life-history strategies, and population structure is needed to develop informed management of this open ocean species.

Utilizing this blue shark tag-recovery data from the NMFS CSTP (1965–2004), a spatially structured tagging model was used to estimate blue shark movement and fishing mortality rates in the North Atlantic Ocean (Aires-da-Silva et al. 2009). Four major geographical regions (two on each side of the ocean) were assumed with the blue shark fishing mortality rates (F) found to be heterogeneous across the four regions. While the estimates of F obtained for the western North Atlantic Ocean were historically lower than 0.1 year^{-1}, the F estimates over the most recent decade (1990’s) in the eastern side of the ocean are rapidly approaching 0.2 year^{-1}. Because of the particular life-history of the blue shark, these results suggest careful monitoring of the fishery as the juvenile and pregnant female segments of the stock are highly vulnerable to exploitation in the eastern North Atlantic Ocean.

The blue shark has been subject to bycatch fishing mortality for almost a half-century and has even become the target species in pelagic longline fisheries in the North Atlantic Ocean. Nevertheless, stock status is ambiguous and improved input data are needed for stock assessments. It is particularly important to obtain reliable indices of abundance because of the uncertainty in estimates of bycatch. An index of relative abundance was developed for western North Atlantic blue sharks, starting from the mid-1950s, when industrial pelagic longline tuna fisheries began. Longline catch and effort records from recent observer programs (1980–1990s) were linked with longline survey records from both historical archives and recent cruises (1950–1990s). Generalized linear models were used to remove the effects of diverse fishing target practices, and geographical and seasonal variability that affect blue shark catch rates. The analysis revealed a decline in blue shark relative abundance of approximately 30% in the western North Atlantic from 1957 to 2000. The magnitude of this relative abundance decline was less than other recently published estimates and seems reasonable in light of the high productivity of the blue shark revealed by life-history studies and preliminary stock assessments.

<u>Biology of the White Shark (*Carcharodon carcharias*)</u>

An update to a NEFSC western North Atlantic white shark distribution paper is ongoing with NMFS staff from the NEFSC, SEFSC, and NERO and scientists from MDMF and the Florida Museum of Natural History. This study builds upon previously published data combined with recent unpublished records to presents a synthesis of over 550 confirmed white shark records compiled over a 210-year period (1800-2009) and is the largest white shark dataset yet compiled for the western North Atlantic. Descriptive statistics and GIS analyses will be employed to quantify the seasonal distribution, habitat use, and relative abundance of various subcomponents of the population. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Researchers from Stony Brook University, Field Museum of Chicago, Nova Southeastern University, and NEFSC are currently employing a multi-analytical approach to test the hypothesis that northwest Atlantic white sharks have experienced a recent loss of genetic diversity due to a population bottleneck. Results show that contemporary northwest Atlantic white sharks are genetically distinct from other populations and comprise a demographically distinct unit. Ongoing work includes attempting to reconstruct the genetic diversity of white sharks in the 1960s and 1970s using DNA recovered from archived vertebrae. Historical genetic diversity will be directly compared to contemporary genetic diversity in this study, which could serve as a model for similar studies of other elasmobranchs. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

<u>Biology of the Thresher Shark (*Alopias vulpinus*)</u>

Life history studies of the thresher shark in the western North Atlantic continued with analysis of age and reproductive parameters. Reproductive organs from 134 male and 257 female thresher sharks were examined to determine size at maturity and reproductive cycle. Males ranged in size from 78 to 237 cm FL and females ranged from 62 to 263 cm FL. Reproductive tissues were processed and sectioned using histological techniques. Age and growth estimates were generated using vertebral centra from 173 females, 135 males, and 11 individuals of unknown sex ranging in size from 56 to 264 centimeters fork length. These results will be combined with the morphological reproductive data to determine sexual sizes at maturity for this species. Additional work on demography was initiated using the values from the reproduction and age and growth papers. Two papers will be submitted in tandem for publication.

<u>Biology of the Atlantic Torpedo (*Torpedo nobiliana*)</u>
A master's thesis was completed on the biology of the Atlantic torpedo (Mataronas 2010). *The Life History of Torpedo cf. nobiliana Caught off the Coast of Southern New England* will be the basis for a future publication. This research is ongoing due to a lack of large females for reproductive analysis. Samples for age and growth, reproduction, and food habits were obtained from the bycatch of bottom trawl, trap net and gillnet fisheries operating primarily out of Pt. Judith, Rhode Island. Males mature between 79 and 86 cm TL (50% maturity was estimated to be 83.6 cm TL). Females mature between 113 and 123 cm TL (50% maturity was estimated to be 120.9 cm TL). The fecundity appears to be low, although it is higher than other torpedinid species, probably because it is the largest of the torpedo rays. Seasonality in the reproductive cycle could not be defined due to the inability to obtain rays during all months of the year. However, based on the observed reproductive condition of the females, data support a biennial reproductive cycle, with a fall mating season and parturition occurring the following spring. Size at birth was estimated to be 20-21 cm TL. The strong relationship of vertebral radius to total length suggests that vertebrae should be a useful ageing structure for this species. However, vertebral banding patterns vary widely among individuals; thus, ageing has not been completed due to the inability to define a working criterion for the identification of band pairs. Work with researchers at other institutions is ongoing to determine if it is possible to develop a criterion for band identification. There are approximately 21 validated species in the genus *Torpedo*, of which only the Atlantic torpedo (*Torpedo nobiliana*), is believed to be found in the Northwest Atlantic Ocean. The torpedo rays caught off New England were originally named *T. occidentalis* and were later synonymized as a junior synonymy of a Mediterranean species, *Torpedo nobiliana*. As a result of this study, the population of torpedo rays off the coast of Rhode Island is being more closely examined to determine if the species is actually distinct and should revert to the name *T. occidentalis*. Currently, an effort is being made to obtain samples from the eastern North Atlantic to compare with the samples from this study to validate the species.

<u>Biology of the Smooth Skate (*Malacoraja senta*)</u>
The smooth skate is one of the smallest (<70 cm TL; <2.0 kg wet weight) species of skate endemic to the western North Atlantic and has a relatively broad geographic distribution, ranging from Newfoundland and southern Gulf of St. Lawrence in Canada to New Jersey in the United States. Age and growth estimates for the smooth skate were derived from 306 vertebral centra from skates caught in the North Atlantic off the coast of New Hampshire and Massachusetts (Natanson et al. 2009). Male and female growth diverged at both ends of the data range and the sexes required different growth functions to describe them. Males and females were aged to 15 and 14 years, respectively.

Age and size at sexual maturity was determined for 185 male and 96 female smooth skates (ranging in size from 370 to 680 mm total length $_{LT}$), collected from the western Gulf of Maine

(Sulikowski et al. 2009). Fifty percent maturity occurs between 9 and 10 years and 560 mm $_{LT}$ for males, and occurs at age 9 years and 540 mm $_{LT}$ for females.

Northeast Skate Complex

Skates caught off Rhode Island for use in the lobster bait industry were sampled from January through September 2009 in response to the FMP objectives to collect information critical for improving knowledge of the identification of these species, monitoring their status, and improving management approaches. Data including date, catch location, species name, total length, disk width, and weight were collected from 2,213 skates from boats out of Point Judith and Little Compton, Rhode Island. Of the skates sampled, 2,024 were identified as little skate (*Leucoraja erinacea*), and 189 were identified as winter skate (*Leucoraja ocellata*). Length frequency graphs were produced for both species and weight to length conversion equations were calculated. Reproductive measurements and vertebrae were also collected from 39 individuals for future analysis.

Atlantic Angel Shark (*Squatina dumeril*)

The Atlantic angel shark is among 20 species of sharks that are prohibited from both commercial and recreational fisheries. However off the northeast coast of the U.S., this species is encountered in several commercial fisheries including the bottom otter trawl and gillnet fisheries. Staff from the NEFSC Observer Program and survey vessels has combined to collect 54 angel sharks to date. Dissections of these specimens have resulted in preliminary maturity estimates of greater than 1 m fork length for both male and female angel sharks. Preliminary age determination estimates from the vertebrae are similar to results from angel sharks from the Gulf of Mexico and Pacific; there does not appear to be any correlation between band periodicity and time. Further work is required to determine band periodicity in this species. DNA samples from the western North Atlantic population have also been collected to examine the angel shark evolutionary history and population structure using mitochondrial DNA control region sequences from the northwest Atlantic, and western and eastern populations from the Gulf of Mexico. Results from this collaborative study supports current US fisheries management banning all landings of the Atlantic angel shark, with management and conservation units established for a single genetic stock until further genetic and tagging programs can be conducted.

Smalltooth Sand Tiger (*Odontaspis ferox*)

The smalltooth sand tiger—a large, deep-water shark species—has been reported as occurring in the western North Atlantic Ocean based on a single female caught off the North Carolina coast in September 1994 during a research vessel bottom trawl survey. Recently, certified NEFSC observers described and photographed two more captured specimens of this species during trawl trips targeting squid in waters off the eastern coast of the United States. The International Union for Conservation of Nature currently lists the smalltooth sand tiger as vulnerable for the following reasons: this species may be naturally rare, has an assumed low fecundity as seen in the closely related sand tiger shark, and developing deep-sea fisheries apply an increasing amount of pressure. However, as noted in previous accounts, it is only when an occasional individual of this deep water species comes onto the continental shelf that there is an opportunity for its capture, therefore the smalltooth sand tiger may be more common than suggested by the few documented captures. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Age and Growth of Elasmobranchs

Tiger Shark (*Galeocerdo cuvier*)
Age and growth estimates for the tiger shark in the western North Atlantic were derived from band counts of 238 sectioned vertebral centra. Growth functions fit to length at age data demonstrated that growth rates were similar for males and females up to approximately 200 cm fork length after which male growth slowed. Both sexes appear to reach maturity at age 10. Males and females were aged to 20 and 22 years, respectively, although longevity estimates predict maximum ages of 27 and 29 years, respectively. Bomb radiocarbon analysis of ten band pairs extracted from four vertebral sections suggested that band pairs are deposited annually up to age 20. This study provides a rigorous description of tiger shark age and growth in the western North Atlantic and further demonstrates the utility of bomb radiocarbon as an age validation tool for elasmobranch fishes.

Basking Shark (*Cetorhinus maximus*)
Age and growth of the basking shark was examined using vertebral samples from 13 females (261 to 856 cm TL), 16 males (311 to 840 cm TL) and 11 specimens of unknown sex (376 to 853 cm TL). Vertebral samples were obtained worldwide from museums and institutional and private collections. Examination of multiple vertebrae from along the vertebral column of 10 specimens indicated that vertebral morphology and band pair (alternating opaque and translucent bands) counts changed dramatically along an individual column. Smaller sharks had similar band pair counts along the length of the vertebral column while large sharks had a difference of up to 24 band pairs between the highest and lowest count along the column. Evidence indicates that band pair deposition may be related to growth and not time in this species and thus the basking shark cannot be directly aged using vertebral band pair counts.

Dusky Sharks (*Carcharhinus obscurus)*
A revision of the age and growth of the dusky shark in the North western Atlantic Ocean was initiated in conjunction with the SEFSC Shark Observer Program and staff of the NEFSC. Approximately 150 new vertebrae were examined for age determination, and preliminary growth curves were generated. Preliminary data indicated that the growth is similar to previous estimates; however more analysis is needed to verify this finding and provide updated growth curves to the stock assessment. Additionally, in conjunction with scientists from WHOI, one vertebra is being processed for bomb carbon analysis in an attempt to validate the periodicity of band pair formation for this species. Results are still pending.

Elasmobranch Feeding Ecology

Scalloped Hammerhead (*Sphryna lewini*)
Scalloped hammerheads are apex predators with circumglobal distribution in tropical and warm temperate waters. Their role in the western North Atlantic ecosystem was explored by examining indices of standardized diet composition derived from stomach contents of sharks caught from research and commercial vessels, and in recreational tournaments. Impacts on the diet caused by biotic and abiotic factors were evaluated. Sample location had the strongest influence on diet with sharks occurring in inshore waters feeding primarily on inactive demersal

fish and secondarily on pelagic fish. Cephalopods were by far the largest food group found in sharks caught offshore. There were fewer empty stomachs found in the offshore sample (33%) than in the inshore sample (45%), but the volume of stomach contents in those with food was higher inshore (0.6% body weight (BW) versus 0.4% BW). Season also played a significant role in the diet. The lowest percentage empty (9.6%), the largest average stomach content volume (0.8% BW), and the largest number of prey items per stomach (8.1) occurred in the summer. The summer sample also had the largest number of different prey types (1.8), although this was not statistically different from the other seasons. Most of these seasonal differences were found in sharks caught both inshore and offshore. Shark sex, state of maturity, decade caught, and gear type or source had little or no significant influence on diet. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Shortfin Mako (*Isurus oxyrinchus*)

The diet and daily ration of the shortfin mako in the inshore waters of the western North Atlantic were re-examined to determine whether fluctuations in prey abundance and availability are reflected in these two biological variables (Wood et al. 2009). During the summers of 2001 and 2002, stomach content data were collected from fishing tournaments along the northeast coast of the United States. These data were quantified by using four diet indices and were compared to index calculations from historical diet data collected from 1972 through 1983. Bluefish (*Pomatomus saltatrix*) were the predominant prey in the 1972–1983 and 2001–2002 diets, accounting for 92.6 percent of the current diet by weight and 86.9 percent of the historical diet by volume. From the 2001–2002 diet data, daily ration was estimated and it indicated that shortfin makos must consume roughly 4.6 percent of their body weight per day to fulfill energetic demands. The daily energetic requirement was broken down by using a calculated energy content for the current diet of 4,909 KJ/kg. Based on the proportional energy of bluefish in the diet by weight, an average shortfin mako could consume roughly 500 kg of bluefish per year off the northeast coast of the United States.

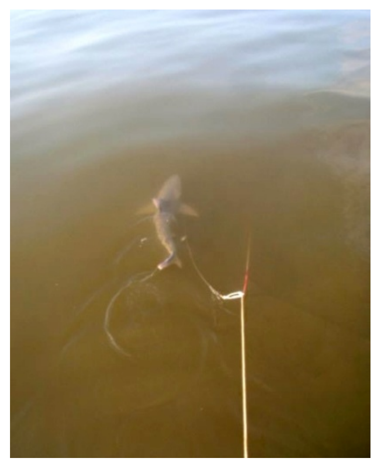

Figure A1.6. Juvenile sandbar shark on NEFSC COASTSPAN Survey bottom longline. Source: NMFS photo.

Sandbar Shark (*Carcharhinus plumbeus*)

Non-lethal diet sampling of juvenile sandbar sharks was conducted during summer months in Delaware Bay, one of the largest nurseries for the species in the western North Atlantic. Overall, sandbar sharks had a pattern characterized by a diverse diet, intermittent feeding, and occasional consumption of large meals. Significant ontogenetic changes in diet to progressively higher trophic-level prey were discovered. Sharks fed principally on teleosts, with crustaceans important to young sharks, and elasmobranchs an increasing dietary component for large juveniles. Small teleost prey, were consumed more frequently by small sharks; whereas large teleosts became more common in big sharks. Significant monthly changes in feeding patterns were exhibited by young of the year (YOY) where June YOY contained less total prey, ate smaller meals, and consumed predominantly less mobile species. August YOY diet was similar in composition to small juvenile diet from June and July, and small juvenile diet in August was more consistent with the diet of large juvenile sharks. The dramatic monthly changes in feeding by YOY suggested improvement in hunting capability by late summer, with some shifts to larger or more mobile prey continuing in juveniles. Overall, monthly peaks in consumption of some prey were consistent with reported times of peak abundance for those species, and this suggested a generally opportunistic strategy of feeding on abundant species.

Smooth Dogfish (*Mustelus canis*)

Quantitative ontogenetic, sexual, and monthly differences in food habits and feeding patterns of smooth dogfish were examined in Delaware Bay with 98 percent of the stomachs contained food with an average of 8 prey items in various digestive states per stomach, indicating a continuous feeding pattern. This shark species fed upon an array of invertebrate prey with significant ontogenetic shifts in prey composition. Young of the year consumed smaller and less mobile invertebrates; larger sharks had a diet of predominately benthic macro-invertebrates, including most common large crab species, several gastropods, and a few teleosts. Differences in meal size, diet diversity, prey number, and total biomass among size classes were limited, indicating limited ontogenetic changes in foraging patterns. Some changes in diet composition between months occurred but likely reflected shifts in prey availability or habitat usage. The continuous feeding pattern of this species may help compensate for the lower energetic value of many of the prey. The large number and mass of prey items per stomach, as well as the abundance of this species, indicate that this species plays an important role in the trophic relationships of the macro-invertebrate community in the bay.

In collaboration with Massachusetts Division of Marine Fisheries, staff are also working to examine the feeding ecology of smooth dogfish in Massachusetts waters. This study was designed to characterize the diet of smooth dogfish where there is significant overlap with higher densities of American lobster (*Homarus americanus*). Consumption of lobster by predators such as smooth dogfish is thought to be extensive in this area, and may have led to the drastic decline in local abundance of the lobster over the last decade. Preliminary analysis found CPUE was greatest in the earlier months of the survey largely because of the abundance of male smooth dogfish. The sex ratio was dominated by males in May and June and then shifted toward females in the summer months. A dramatic decrease in the number of males occurred in July which coincided with peak water temperatures within the bay during the same period. Stomach contents of all dogfish were everted and analyzed. The diet of the smooth dogfish consisted mostly of crustaceans, with lobster, rock crab, common spider crab, and mantis shrimp among the most common prey items. Preliminary analysis suggest that smooth dogfish may be an underestimated predator of the American lobster population in Buzzards Bay, but the extent to which they impact the lobster population remains to be determined.

Resource Partitioning Between Sandbar Shark and Smooth Dogfish

Comparative feeding ecology and size-specific resource partitioning was examined between two abundant shark species in Delaware Bay, the sandbar shark and smooth dogfish. Foraging patterns differed distinctly; the smooth dogfish exhibited continuous feeding with numerous small meals, whereas the sandbar shark consumed larger less frequent meals. Diet overlap between the species was restricted to adult smooth dogfish and YOY sandbar shark, which exhibited differences in temporal and spatial distribution within the Bay. Adult smooth dogfish were captured in deeper regions, especially after June, more often than YOY sandbar shark, which were principally captured in very shallow regions, particularly early in the summer. Thus, these two shark species partition resources by a combination of ontogenetic and monthly differences in diet and habitat use.

Temporal Changes in Diet Between Blue Shark and the Shortfin Mako

Using the food habits data collected by the NEFSC Apex Predators Program over the past 38 years, we examined temporal changes in prey species, taxonomic and ecological prey groups, and overall trophic levels. 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. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Basking Shark Isotope Analysis

Researchers at the Woods Hole Oceanographic Institution, Massachusetts Division of Marine Fisheries, and the NEFSC are using isotopic analysis on vertebrae to determine the trophic position of the basking shark as well as to learn more about their migratory behavior and ocean connectivity. This type of retrospective trophic-level reconstruction has broad applications in future studies on the ecology of this shark species to determine lifelong feeding and migratory patterns and to augment electronic tag data.

Sable Island Seal Predation

An investigation into shark predation on five species of seals on Sable Island, Nova Scotia, Canada, was completed in conjunction with Sable Island researcher Zoe Lucas (Lucas and Natanson 2010). Between 1993 and 2001, 4906 seal corpses bearing wounds likely inflicted by sharks were examined on Sable Island, Canada. Five seal species were involved: grey (*Halichoerus grypus*), harp (*Pagophilus groenlandica*), harbor (*Phoca vitulina*), hooded (*Cystophora cristata*), and ringed (*Phoca hispida*) seals. Flesh wounds on seal corpses indicated that two or more shark species prey on seals in waters around Sable Island. Wounds were categorized as either slash or corkscrew, with different predators identified for each type. Wound patterns, tooth fragments, and marks on bones indicated that white sharks (*Carcharodon carcharias*) were involved in the slash wounds, which comprised a small proportion of attacks. Ninety-eight percent of seal corpses, however, bore the corkscrew wounds that could not be attributed to shark species identified in attacks on pinnipeds in other regions and these wounds are previously unreported in the literature. Circumstantial evidence indicates that attacks by Greenland sharks (*Somniosus microcephalus*) were responsible for the clean-edged encircling corkscrew wounds seen on seal corpses washed ashore on Sable Island. This research was the basis of an episode of National Geographic Predator CSI "Corkscrew killer."

Movements and Migrations using conventional and electronic tag technology

Cooperative Shark Tagging Program (CSTP)

The Cooperative Shark Tagging Program 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 7,000 volunteer recreational and commercial fishermen, scientists, and fisheries observers since 1962. In 2010, information was received on 3,800 tagged and 270 recaptured fish bringing the total numbers tagged to 220,000 sharks of more than 50 species and 13,100 sharks recaptured of 33 species. 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 online reporting to collect information on recaptures for all species.

Alternative tag testing is underway utilizing recreational tag and release tournaments; the most recent in February of 2009. These events offer an opportunity to investigate the use of two new dart tags on coastal and pelagic sharks. Many of these events have 100 percent observer coverage on the recreational boats and observers alternatively using each tag type and recording tag data, release condition, and total catch and effort. This will allow an initial evaluation of these tags by getting feedback from the participants on how easy each tag is to handle, how well they stay on the tagging needle, and how easily the dart head penetrates the shark skin. This feedback on tag use and subsequent recaptures will enable us to begin to evaluate these tag types for future use.

Integrated Mark-Recapture Database Management System (I-MARK)

The NEFSC Integrated Mark-Recapture Database System (I-MARK) provides a platform to keep multi-species tagging program data in a common format for management and analysis. Initiated by the Cooperative Research Program, the database design and application were developed collaboratively by the shark, yellowtail flounder, black sea bass, and scup tagging programs, and Data Management Systems. A web application is used for data input and quality control. I-MARK was designed to track fish and tags independently. It consists of several web application modules including inventory of tags, initial release events, subsequent recapture events, bulk data entry of cruise releases, contact name and address information, map display, reports and statistical queries. Fate of animal, fate of tag, double tags, and multiple recaptures can be accommodated within the database. Extensive quality control is achieved using the web application to enter and maintain the I-MARK data. These audits can be applied to data for all fisheries or a specific fishery and encompass standard audits such as checking data type, land locations, and allowable values as well as more complex validations which check relationships between the fate of animal, fate of tag and event type. A constituent release recapture letter is generated by the web application with a map, size, location, time at liberty and distance traveled information. Scanning of the majority of the historic tag cards was accomplished in 2010 with future plans to link them to the existing I-MARK database.

Porbeagle (*Lamna nasus*) Movement Patterns

A study on the movement patterns, habitat utilization, and post-release survivorship of porbeagles captured on longline gear in the North Atlantic is in conjunction with scientists from Massachusetts Division of Marine Fisheries (MDMF) and the University of Massachusetts. The primary objective of this research is to deploy PSAT tags to examine the migratory routes, potential nursery areas, swimming behavior, and environmental associations that characterize habitat utilization by porbeagles. Information will be obtained to validate the assessment of the physiological effects of capture stress and post-release recovery in longline-captured porbeagles. These efforts will potentially allow the quantification of the stress cascade for this shark species captured using commercial gear, thereby providing fishery managers with data showing the minimum standards for capturing (e.g., longline soak time) and releasing these fishes to ensure post-release survival. Based on known and derived geopositions, the porbeagles exhibited broad seasonally-dependent horizontal (77-870 km) and vertical (surface to 1,300 m) movements. All of the sharks remained in the western North Atlantic from the Gulf of St. Lawrence and the coast of Nova Scotia to Georges Bank and oceanic and shelf waters south to North Carolina. In general, the population appears to contract during the summer and fall with more expansive radiation in the winter and spring. Although sharks moved through temperatures ranging from 2–26°C, the bulk of their time was spent in water ranging from 8–16°C. In the spring and summer months, the sharks remained epipelagic in the upper 200 m of the water column. In the late fall and winter months, some of the porbeagles moved to mesopelagic depths (200–1,000 m). Temperature records indicate that these fish were likely associated with the Gulf Stream. Additional analyses, which include the integration of these data with those from the long-term conventional tag-recapture database, are ongoing. Since none of these fish moved to the NE Atlantic, this work also supports the two stock hypotheses for the North Atlantic.

Southeast Fisheries Science Center (SEFSC)

Stock Assessments of Large Coastal, Small Coastal, Pelagic and Prohibited Sharks

SEFSC scientists actively participated in the ICCAT intersessional assessment of blue and shortfin mako stocks described in section 4.2. Specifically, SEFSC staff prepared 5 documents for the stock assessment workshop held in Spain in 2008, in addition to being centrally involved in conducting the actual stock assessments (ICCAT 2008). SEFSC staff also developed two Ecological Risk Assessments (ERAs) of pelagic sharks for the 2008 ICCAT stock assessment meeting (see ERA section below). In 2009, SEFSC staff also actively participated in the joint ICCAT/ICES porbeagle shark stock assessment held in Denmark, conducting some of the assessments and preparing 2 documents for the assessment meeting.

In 2010, SEFSC staff conducted domestic, benchmark stock assessments of sandbar, blacknose (Gulf of Mexico and U.S. South Atlantic), and dusky sharks under SEDAR 21. The sandbar shark has historically been the main species targeted by U.S. commercial fishers and was last assessed in 2006; blacknose sharks are a small coastal species, last assessed as a single stock in 2007; the dusky shark has been a prohibited species since 1999 and was assessed for the first time in 2006. These previous assessments found that all three stocks were overfished with overfishing occurring. A Data Workshop and multiple stock assessment webinars were conducted under SEDAR 21 during 2010, but the assessments were not completed and peer-reviewed until 2011.

Ecological Risk Assessments (ERA) of Atlantic sharks

SEFSC staff conducted several ERAs of Atlantic sharks in 2008. These analyses evaluate the productivity of a stock and its susceptibility to the fisheries exploiting it, which allow for an assessment of the potential vulnerability of the stock. Two ERAs were carried out for stocks in the Atlantic shark complex, one as part of activities by the NMFS Vulnerability Evaluation Working Group (for more information see Patrick et al. 2009 and http://www.nmfs.noaa.gov/msa2007/vulnerability.htm), the other for presentation at the American Elasmobranch Society 24th annual meeting (Cortés et al. 2008a). Additionally, two ERAs were conducted in support of ICCAT's 2008 assessment activities for pelagic sharks (Cortés et al. 2008b; Simpfendorfer et al. 2008). Results of these analyses provided categorizations of the relative vulnerability and associated risk of the different stocks to being overfished.

Observer Programs

Shark Longline Program

This program is designed to meet the intent of the Endangered Species Act and the Consolidated Atlantic HMS FMP. It was created to obtain better data on catch, bycatch, and discards in the shark bottom longline fishery. While on board the vessel, the observer records information on gear characteristics and all species caught, condition of the catch (e.g., alive, dead, damaged, or unknown), and the final disposition of the catch (e.g., kept, released, finned, etc.). Recent amendments to the Consolidated Atlantic HMS FMP based on updated stock assessments have significantly modified the major directed shark fishery in the U.S. Atlantic. The amendments implement a shark research fishery, which allows NMFS to select a limited number of commercial shark vessels on an annual basis to collect life history data and catch data for future stock assessments. Furthermore, the revised measures drastically reduce quotas and retention limits, and modify the authorized species in commercial shark fisheries. Specifically, commercial shark fishers not participating in the research fishery are no longer allowed to land sandbar sharks (*Carcharhinus plumbeus*), which have been the main target species. Outside the research fishery, fishers are permitted to land 33 non-sandbar large coastal sharks. In 2008, NMFS announced its request for applications for the shark research fishery from commercial shark fishers with a directed or incidental permit. Based on the temporal and spatial needs of the research objectives, and the available quota, 11 qualified applicants were selected for observer coverage in 2008, seven in 2009, and nine in 2010. These vessels carried observers on 100 percent of trips. Outside the research fishery, vessels targeting shark and possessing current valid directed shark fishing permits were randomly selected for coverage with a target coverage level of 4 to 6 percent. From June 2005 to December 2010, a total of 390 trips on 74 vessels with a total of 1053 hauls were observed.

Shark Gillnet Program

Since 1993, an observer program has been underway to estimate catch and bycatch in the directed shark gillnet fisheries along the southeastern U.S. Atlantic coast. This program was designed to meet the intent of the Marine Mammal Protection Act, the Endangered Species Act, and the 1999 revised FMP for HMS. It was also created to obtain better data on catch, bycatch, and discards in the shark fishery. Historically, the Atlantic Large Whale Take Reduction Plan and the Biological Opinion issued under Section 7 of the Endangered Species Act mandated 100 percent observer coverage during the right whale calving season (November 15 to April 1). Outside the right whale calving season (i.e., April 1 to November 14), observer coverage equivalent to 38 percent of all trips was maintained. In 2007, the regulations implementing the

Atlantic Large Whale Take Reduction Plan were amended and included the removal of the mandatory 100 percent observer coverage for drift gillnet vessels during the right whale calving season, but now prohibit all gillnets in an expanded southeast U.S. restricted area that covers an area from Cape Canaveral, Florida, to the North Carolina-South Carolina border, from November 15 through April 15. The rule has limited exemptions, only in waters south of 29 degrees N latitude, for shark strikenet fishing[14] during this same period, and for Spanish mackerel gillnet fishing in December and March. Based on these regulations and on current funding levels, the shark gillnet observer program now covers a portion of all anchored (sink, stab, set), strike, or drift gillnet fishing by vessels that fish from Florida to the North Carolina year-round. All observers must record information on all gear characteristics, species caught, condition of the catch, and the final disposition of the catch. A total of four drift gillnet vessels were observed making 14 sets on eight trips in 2010. Vessels targeted either bluefish (*Pomatomus saltatrix*), or Atlantic sharpnose shark (*Rhizoprionodon terraenovae*). There were no vessels observed fishing gillnets in a strike fashion in 2010. A total of 53 trips making 281 sink net sets on 17 vessels were observed in 2010. Trips were made targeting one or more of the following: shark, Spanish mackerel (*Scomberomorus maculates*), king mackerel (*Scomberomorus cavalla*), southern kingfish (*Menticirrhus americanus*), Atlantic croaker (*Micropogonias undulates*), bluefish, weakfish (*Cynoscion regalis*), or smooth dogfish (*Mustelus canis*).

Determination of critical habitat for the conservation of dusky shark (Carcharhinus obscurus) using satellite archival tags

In an attempt to improve the conservation status of dusky shark, NMFS established a time-area closure off North Carolina from January to July to reduce bycatch of neonate and juvenile dusky sharks. To better evaluate the closed area and determine critical habitat of dusky shark, we are deploying pop-off satellite archival tags (PSAT). To date, seven tags have been deployed: two tags are pending pop-off, two tags transmitted unusable data, and three provided data that could be analyzed. Based on geolocation data, sharks generally traveled about 10 km day^{-1} with an average of 691 km in total. Overall, mean proportions of time at depth revealed dusky sharks spent the majority of their time in waters 20–40 m deep but did dive to depths of 400 m. Tagged sharks had varied movement patterns. One shark that was tagged off Key Largo, Florida, in January moved north along the east coast of the U.S. to the North Carolina/Virginia border in June. A second shark also tagged off Key Largo in March traveled south toward Cuba. The third shark, tagged off North Carolina in March, moved little from where it was initially tagged but problems with estimating the geolocation precluded fully determining its movement patterns in and around the closed area. Data from this study, along with future deployments, will be used to determine the efficacy of the time area closure for dusky sharks.

Habitat use and movements patterns of pelagic sharks based on archival satellite tags

As part of a larger program to determine the habitat use and movement patterns of pelagic and semi-pelagic sharks, pop-up satellite archival transmitting (PSAT) tags have been deployed on sharks in the U.S. south Atlantic Ocean and Gulf of Mexico. Since 2007, four species of sharks have been tagged, with data obtained on three species. An oceanic whitetip shark (*Carcharhinus*

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[14] When a vessel fishes for sharks with strikenets, the vessel encircles a school of sharks with a gillnet. This is usually done during daylight hours, to allow visual observation of schooling sharks from the vessel or by using a spotter plane.

longimanus) tagged in the western Gulf of Mexico moved a straight-line distance of 238 km during one track. During the track, the shark rarely dove below 150 m and instead, stayed above the thermocline. The deepest depth attained was recorded from one dive to 256 m. The most frequently occupied depth during the entire track was 25.5–50 m (49.8% total time) and temperature was 24.05–26 °C (44.7% total time). One bigeye thresher shark moved 51 km from the initial tagging location and exhibited a diurnal vertical diving behavior. The most common depths and temperatures occupied were between 25.5–50 m (27.3% total time) and 20.05–22 °C (52.5% total time). The bigeye thresher dove up to 528 m and deeper dives occurred more often during the day with time spent above the thermocline during night. Tags have been deployed on dusky sharks; one tag is pending pop-off, four tags transmitted unusable data, and three provided data that could be analyzed. Based on geolocation data, dusky sharks generally traveled an average of 691 km in total. Overall, mean proportions of time at depth revealed dusky sharks spent the majority of their time in waters 0–40 m deep but did dive to depths of 400 m. Dusky sharks occupied temperatures of 20.5–24 °C over 50 percent of the time. Tagged sharks had varied movement patterns. One shark tagged off Key Largo in January moved north along the east coast of the U.S., then meandered around the Charleston Bump before continuing north to the North Carolina/Virginia border in June. A second shark also tagged off Key Largo in March traveled south toward Cuba before the tag sent data 2 weeks later. The third shark, tagged off North Carolina in March, moved little from where it was initially tagged. While data for some species are limited, these results will be useful in providing habitat use data as inputs to Ecological Risk Assessments.

Elasmobranch Feeding Ecology and Shark Diet Database

The current Consolidated Atlantic HMS FMP gives little consideration to ecosystem function because there are 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. A study on prey selection by the Atlantic angel shark (*Squatina dumeril*) in the northeastern Gulf of Mexico was recently published (Baremore et al. 2008). The diet of the roundel skate (*Raja texana*) from the northern Gulf of Mexico is also being examined (Bethea and Hale in prep.). A database containing information on quantitative food and feeding studies of sharks conducted around the world has been in development for several years and currently includes over 400 studies. This fully searchable database was updated and fine-tuned in 2010, and is being used as part of a collaborative study on ecosystem effects of fishing large pelagic predatory fish with researchers from the University of Washington, University of Wisconsin, and the Inter-American Tropical Tuna Commission. It is also expected that this shark trophic database will be very useful for other ecosystem-level studies using Ecopath/Ecosim or similar approaches and ultimately for population assessments.

A comparison of the foraging ecology and bioenergetics of the early life-stages of two sympatric hammerhead sharks

Juvenile scalloped hammerhead sharks (*Sphyrna lewini*) were collected in northwest Florida to examine foraging ecology, bioenergetics, and trophic level (30-60 cm FL; mean FL = 41.5 cm; n = 196). Diet analysis was performed using single and compound measures of prey quantity. Diet was also analyzed using seven broad diet categories (DC). Diet composition and estimated daily ration were compared to previously published information on bonnethead sharks (*S.*

tiburo). Diet overlap was low between species. Juvenile *S. lewini* feed on relatively small (85% of prey items < 5% shark length) teleosts (48.70 DC, 44.32 DC, 40.51 %FO DC, 53.71 DC; mostly bothids and sciaenids) and shrimps (24.87 DC, 30.17 DC, 23.42 %FO DC, 26.35 DC), whereas *S. tiburo* have been documented to feed mostly on crustaceans and plant material in northwest Florida. Plant material contributed little to the diet of *S. lewini* (4.98 DC, 3.08 DC, 7.59% FO DC, 1.99 DC). Estimated daily ration was significantly lower for *S. lewini* (4.6% BW d-1) than for *S. tiburo* in northwest Florida, regardless if plant material was included in the model (p=0.02 including and p<0.00001 excluding plant material). Trophic level was calculated at 4.0 for *S. lewini* and 2.6 for *S. tiburo*. Stable isotope analysis showed *S. lewini* had significantly higher □15N values and significantly lower □13C values than *S. tiburo*, supporting the difference observed in calculated trophic level. These results provide evidence that small juvenile hammerhead species co-exist in coastal northwest Florida by feeding at separate trophic levels (Bethea et. al in press).

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

The SEFSC Panama City 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 essential fish habitat (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 and NMFS Mississippi Laboratories currently includes over 8,000 tagged animals and 155 recaptured animals from 1993 to present for both the Gulf of Mexico and U.S. southeast Atlantic Ocean. This fully searchable database is current through spring 2010 with hopes to have it online and searchable by all participants in FY 2012.

Monitoring the Recovery of Smalltooth Sawfish (Pristis pectinata)

The smalltooth sawfish was listed as endangered under the Endangered Species Act (ESA) in 2003. Smalltooth sawfish are the first marine fish and first elasmobranch 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 the population to decline by up to 95 percent during the second half of the twentieth century. Today they exist mostly in southern Florida.

The completion of the Smalltooth Sawfish Recovery Plan in early 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 of the number of juvenile sawfish in various regions throughout Florida to provide a baseline and time series of abundance. One of the more important regions for smalltooth sawfish identified in previous research is the section of coast from Marco Island to Florida Bay, Florida. This region encompasses the coast of the Ten Thousand Islands National Wildlife Refuge and Everglades National Park. Scientists from the Panama City Laboratory conduct monthly surveys in southwest Florida to capture, collect biological information, tag, and then release smalltooth sawfish. Preliminary results indicate that juvenile sawfish are highly specific to certain areas. Genetic identification of recaptured individuals indicates that sawfish caught on the same mudflat, for example, are siblings and a single adult female sawfish may give birth on that same mudflat year after year. Determination of critical habitat and movement and migration corridors for larger juvenile and adult sawfish is being undertaken using PSAT and SPOT tags. Preliminary results indicate sawfish are found at greater depths than originally anticipated and may be found in offshore aggregations in specific areas of the Gulf of Mexico.

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.

<u>Sandbar Shark (*Carcharhinus plumbeus*)</u>

Sandbar shark age, growth, and reproduction were investigated following recommendations from SEDAR 11 (Hale and Baremore 2010). A total of 1194 (701 females, 493 males) sandbar sharks from the Gulf of Mexico and southern Atlantic Ocean were examined with vertebral samples primarily gathered from the sandbar shark research fishery. Three parameter von Bertalanffy growth curves were run for male and female sandbar sharks separately and growth parameters were estimated as a male $L\infty = 172.97 \pm 1.30$ cm FL, female $L\infty = 181.15 \pm 1.45$ cm FL, male $k = 0.15 \pm 0.005$, female $k = 0.12 \pm 0.004$, male $t0 = -2.33 \pm 0.19$, and female $t0 = -3.09 \pm 0.16$. The oldest aged sandbar shark was a 27 year old female. Size (and age) at 50 percent maturity for males was 151.6 cm FL (12.1 years) and 154.9 cm FL (13.1 years) for females, while the size at which 50% of females were in reproductive condition was 162.6 cm FL (15.5 years). Males and females showed distinct seasonal reproduction patterns, with peak mating and parturition occurring from April through June. Female fecundity averaged 8.0 pups; there was a weakly significant increase in fecundity with size and a significant increase in fecundity with age. Results suggest that sandbar sharks may have a triennial reproductive cycle (Baremore and Hale 2010). These studies represented a concerted effort to collect current samples from the commercial shark bottom longline fishery to better describe the age structure of the sandbar shark population.

<u>Atlantic angel shark (*Squatina dumeril*) reproduction, diet and feeding</u>

Atlantic angel sharks were collected by fishery-dependent and fishery-independent trawls from 2002 to 2008 for reproductive analysis. Female *S. dumeril* have only one functional ovary (left), with an average litter size of seven pups. The reproductive cycle is at least biennial, though the seasonality of vitellogenesis could not be determined. Gestation is ~12 months, and embryo data support a seasonal trend in reproduction, with parturition occurring in the spring months

(February to June). Mature male *S. dumeril* have spines on the outer margins of their pectoral fins, and there is an apparent peak in gonad size in the spring. The total length at which 50 percent of the population is mature is 85.8 and 92.9 cm for females and males, respectively.

Atlantic angel sharks were collected for stomach contents (n = 437) from November 2002 through April 2005 from a butterfish (*Peprilus burti*) bottom trawl fishery in the northeastern Gulf of Mexico. Teleost fishes—especially Atlantic croaker (*Micropogonias undulates*), butterfish, and goatfishes (Mullidae)—dominated the diet of Atlantic angel sharks and were the most important prey items for sharks of all sizes (305 to 1160 mm TL). Squid (*Loligo sp.*) were also important prey for all shark sizes, although they became less important with increasing shark size. Crustaceans such as mantis shrimp (*Lysosquilla sp.*), brown rock shrimp (*Sicyonia brevirostris*), and portunid crabs (Portunidae) were also eaten by angel sharks of all sizes in all seasons sampled. Seasonal differences in diet were detected with niche breadth, which was narrowest in winter and broadest in fall. Niche breadth was also size related and narrowed with increasing shark size. Size of prey was also related to shark size, with sharks mostly consuming prey <30% of their total length and prey with body depths <60% of their gape width.

<u>Great hammerhead shark (*Sphyrna mokarran*)</u>

The great hammerhead shark is a cosmopolitan species caught in a variety of fisheries throughout much of its range. The apparent decline of great hammerhead shark populations has reinforced the need for accurate biological data to enhance fishery management plans. To this end, age and growth estimates for the great hammerhead were determined from sharks (n = 216) ranging in size from 54 to 315 cm fork length (FL) captured in the Gulf of Mexico and northwestern Atlantic Ocean. The von Bertalanffy growth model was the best fitting model with resulting growth parameters of L_∞= 264.2 cm FL, k= 0.16 year-1, to= -1.99 year for males and L_∞= 307.8 cm FL, k= 0.11 year-1, to= -2.86 year for females (Piercy et al. 2010). Annual band pair deposition was confirmed through marginal increment analysis and a concurrent bomb radiocarbon validation study (see below). Great hammerheads have one of the oldest reported ages for any elasmobranch (44 years) but grow at relatively similar rates (based on von Bertalanffy k value) to other large hammerhead species from this region. This study is the first to provide vertebral ages for great hammerheads (Passerotti et al. 2010).

Bomb radiocarbon validation

Preliminary validation of annual growth band deposition in vertebrae of great hammerhead shark, *Sphyrna mokarran*, was conducted using bomb radiocarbon analysis. Adult specimens (n = 2) were collected and thin sections of vertebral centra removed for visual ageing and radiocarbon assays. Vertebral band counts were used to estimate age, and year of formation was assigned to each growth band via subtraction from year of capture. Samples for radiocarbon analysis were extracted from 10 individual bands. Calculated Δ14C values from dated bands were compared to known-age reference chronologies, and resulting trends indicate annual periodicity of growth bands up to 42 years. Patterns of Δ14C across time in individual specimens indicate that radiocarbon is conserved through time and that habitat and diet may influence Δ14C levels in elasmobranchs. Results of this study are limited to a partial validation of age due to low sample size and narrow age range of individuals sampled. However, they do represent the first evidence of age validation in *S. mokarran*, further illustrating the usefulness of bomb radiocarbon analysis as a tool for life history studies in elasmobranchs.

Cooperative Research-Visual identification guide for the fins of coastal elasmobranchs in the U.S. Atlantic Ocean.

The SEFSC is currently collaborating with Stony Brook University to develop a visual key that would be useful for field identification of fins from shark species caught in U.S. fisheries along the Atlantic coast that are important to the global fin trade. Specifically, if fisheries agents and customs inspectors were able to recognize fins from CITES-listed species among groups of fins, this would revolutionize how we monitor the fin trade and manage threatened or endangered shark species. The development of a concise field guide to fins of shark species listed (white, basking, whale) or proposed for listing (scalloped hammerhead, smooth hammerhead, great hammerhead, porbeagle) on CITES, is aimed at providing unique morphological characters that can be used to rapidly isolate fins potentially originating from these species in large fin consignments.

The primary goal thus far has been to obtain fins sets from the following species: *Carcharhinus plumbeus, Carcharhinus limbatus, Carcharhinus brevipinna, Carcharhinus leucas, Carcharhinus falciformis, Carcharhinus longimanus, Carcharhinus acronotus, Carcharhinus isodon, Negaprion brevirostis, Galeocerdo cuvier, Sphyrna lewini, Sphyrna mokarran, Sphyrna zygaena, Sphyrna tiburo, Prionace glauca, Lamna nasus, Isurus oxyrinchus, Alopias vulpinus and Ginglymostoma cirratum.* Fin sets we had hoped to obtain from sharks that are currently prohibited from commercial landings from U.S. Atlantic federal and/or state fisheries include the following species: *Pristis pectinata*, *Carcharhinus obscurus, Carcharhinus altimus, Carcharhinus signatus, Carcharhinus perezi, Isurus paucus, Alopias superciliosus, Carcharodon carcharias, Carcharias taurus and Negaprion brevirostis* (in Florida State waters). In the U.S., fins were obtained from the Shark Bottom Longline and Gillnet Observer Programs, recreational shark fishing tournaments held in the NE, from researchers working in the field with access to fins due to mortality events, and fins confiscated by law enforcement from a commercial fishing vessel in the Gulf of Mexico. Since July 2010, 172 fin sets (first dorsal fin and paired pectoral fins) have been sampled from the U.S. Atlantic, comprising 22 shark species. Shark fins have also been sampled (measured and photographed) opportunistically from a number of locations outside the U.S. Atlantic (Belize in the Caribbean, Chile and Fiji in the Pacific Ocean, South Africa in the Indian Ocean). When including these locations, 468 fins (by fin type) from 35 species have been collected and/or photographed for analysis.

Cooperative Research—Brazil-U.S. pelagic shark research project

A cooperative shark research project between Brazil (Universidade Federal Rural de Pernambuco) and the U.S. (NMFS SEFSC Panama City Laboratory and the University of Florida's Florida Museum of Natural History) was initiated in 2007. The main goal of this cooperative project was to conduct simultaneous research on pelagic sharks in the North and South Atlantic Ocean. Central to conducting the research is development of fisheries research capacity in Brazil through graduate student training and stronger scientific cooperation between the U.S. and Brazil. Electronic equipment (hook-timer recorders [HTR] and temperature and depth recorders [TDRs]) was sent from the U.S. to Brazil for deployment aboard commercial longline fishing vessels to investigate preferential feeding times of pelagic sharks and associated fishing depths and temperatures for potential use in habitat-based models and estimation of catchability. To date, one fishing survey has been conducted, with 17 sets on a commercial pelagic longline fishing vessel during April and May 2009; each set made use of 300 HTRs. In this first survey only HTRs were used; the deployment of the TDRs is scheduled for the next survey. A total of 772 individuals, represented by 22 species were caught. The target species, swordfish (*Xiphias gladius*), was the most commonly fish caught, (n = 297, 38.5%). Sharks (*Carcharhinus longimanus* (n = 7), *Prionace glauca* (n = 23), *Sphyrna* spp. (n = 5), *Isurus oxyrinchus* (n = 4), *Alopias* spp. (n = 3), *Carcharhinus signatus* (n = 2), and *Pseudocarcharias kamoharai* (n = 7)) represented 6.6 percent of the total catch. A total of 415 activated HTRs were recovered with fish (or identifiable fish parts) on the leader. Time at hooking varied among species. Almost all blue sharks (96%) were hooked at night, and all shortfin makos and crocodile sharks caught on leaders with HTRs were caught at night. Thresher and hammerhead sharks showed no clear preference between daylight and nighttime feeding. Only one oceanic whitetip shark was caught during the night, and this animal was hooked just prior to sunrise. The results from an additional 15 surveys in 2009 and 2010 using both HTRs and TDRs are currently being analyzed. In addition, the use of pop-up satellite archival tags (PSATs) on blue, shortfin mako, and other pelagic sharks is intended to provide critical knowledge on daily horizontal and vertical movement patterns, depth distribution, and effects of oceanographic conditions on the vulnerability of these pelagic sharks to pelagic longline fishing gear. Six pop-off satellite archival tags have been deployed to date (two oceanic whitetip sharks, three bigeye threshers and one longfin mako) in U.S. Atlantic waters. Archival satellite pop-up tags were also attached to three female blue sharks and two female shortfin mako sharks by pelagic longline fishing vessels in the southwestern Atlantic Ocean. Data collected by these tags are still being analyzed; however, preliminary findings were presented at ICCAT in 2010.

Cooperative Research—Uruguay-U.S. pelagic shark research project

As part of a project entitled "Sustainable fisheries and bycatch reduction of pelagic sharks in the Atlantic Ocean: a collaborative project between Uruguay and the USA," the SEFSC and Uruguay's fisheries agency (DINARA) aim to advance knowledge on the productivity and susceptibility of pelagic sharks to longline fisheries in the western South Atlantic Ocean, aspects of which are largely unknown for pelagic sharks in the southern hemisphere. To that end, six satellite transmitters (four PSATs and two SPOTs)—obtained through a grant awarded to conduct this project—have been successfully deployed on blue sharks to date. Two additional satellite tags (SPLASH) have also been deployed very recently on blue sharks to continue to characterize spatio-temporal habitat use in these pelagic sharks. Staff from DINARA and the SEFSC also worked cooperatively on the creation of an identification guide for pelagic sharks of the Atlantic Ocean for ICCAT (ICCAT 2011) and are continuing to work on another guide for carcharhinid sharks.

Figure A1.7. Scalloped hammerhead captured in the Gulf of Mexico during a bottom longline survey.
Source: NMFS Mississippi Laboratories, Shark Team

Shark Assessment Research Surveys

The SEFSC Mississippi Laboratories have conducted bottom longline surveys in the Gulf of Mexico (see Figure A1.7), Caribbean, and Southern North Atlantic since 1995

(28 surveys have been completed through 2010). 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 5 and 200 fathoms, were designed to satisfy five important assessment principles: stockwide survey, synopticity, well-defined sampling universe, controlled biases, and useful precision. 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 the Dauphin Island Sea Lab and Gulf Coast Research Laboratory. 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.