NOAA FISHERIES

2012 Shark Finning Report to Congress

2012 Shark Finning Report to Congress

Pursuant to the

Shark Finning Prohibition Act

(Public Law 106-557)

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

Prepared by the
National Marine Fisheries Service

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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 Fisheries 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
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 2000 Shark Finning Prohibition Act amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit the practice of shark finning by any person under U.S. jurisdiction. The 2000 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 2011.

Sharks in Federal waters are currently managed under 11 different fishery management plans under authority of the MSA. In the U.S. Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, oceanic sharks and other highly migratory species (HMS) are under the jurisdiction of the Secretary of Commerce, who delegates management authority to 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 2011, domestic management of sharks included the following major actions:

- NMFS published a final rule on August 10, 2011, authorizing the limited retention of HMS, including smoothhound sharks, incidentally caught in the squid trawl fishery (76 FR 49368).
- On August 29, 2011, NMFS published a final rule (76 FR 53652) to implement the International Commission for the Conservation of Atlantic Tunas (ICCAT) requirements, which prohibit the retention, transshipping, landing, storing, or selling of hammerhead sharks in the family *Sphyrnidae* (except for bonnethead sharks, *Sphyrna tiburo)* and oceanic whitetip sharks (*Carcharhinus longimanus)* caught in association with fisheries managed by ICCAT.
- Based on new stock assessments, NMFS announced new stock status determinations for five stocks of Atlantic and Gulf of Mexico sharks. On April 28, 2011, NMFS announced that the Atlantic and Gulf of Mexico scalloped hammerhead stock was overfished with overfishing occurring. On October 6, 2011, NMFS announced that the Atlantic and Gulf of Mexico sandbar shark stock was overfished but not experiencing overfishing, the Atlantic and Gulf of Mexico dusky shark stock was overfished with overfishing condition, the Atlantic blacknose shark stock was overfished with overfishing occurring, and the Gulf of Mexico blacknose shark stock status was unknown.

- On October 6, 2011, NMFS announced the intention to begin the scoping phase of the rulemaking process to address the new stock status determinations of scalloped hammerhead, sandbar, dusky, and blacknose sharks.
- On November 10, 2011, NMFS announced that implementation of the smoothhound shark management measures contained in Amendment 3 to the 2006 Consolidated HMS fishery management plan (FMP) would be delayed indefinitely (76 FR 70064). The measures were delayed to allow time to complete Endangered Species Act Section 7 consultation on the fishery and to fully consider the smoothhound-shark-specific portions of the Shark Conservation Act of 2010. The effective date will be the same as the forthcoming final rule to implement the smoothhound shark provisions in the Shark Conservation Act of 2010.
- Beginning in 2011, NMFS reformed management of the Pacific groundfish trawl sector to an individual quota system (also called catch shares) for most groundfish species. The Pacific Fishery Management Council (PFMC) decided to continue managing spiny dogfish and "other fish" (which includes leopard and soupfin shark) with 2-month cumulative trip limits at this time. A benchmark assessment for spiny dogfish was conducted for the first time and reviewed in 2011. That assessment indicated that the portion of the Pacific coast stock found off theUnited States was likely well above its target spawning output level.
- The North Pacific Fishery Management Council (NPFMC) manages the groundfish fisheries in federal waters off Alaska. In 2011, the "other species" category in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) was dissolved into its major taxonomic groups and sharks are now managed as a separate category. The NPFMC recommended and NMFS specified overfishing levels (OFLs), acceptable biological catch (ABCs), and total allowable catch (TACs) amounts for GOA and BSAI sharks.

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 2011, the United States was successful in the following international efforts:

- At Kobe III, the third joint meeting of the Tuna Regional Fisheries Management Organizations (RFMOs), seven recommendations related to sharks were presented. These recommendations were the result of the first meeting of the working group on bycatch held in La Jolla, California, in 2011. This working group also suggested that full stock assessments should be conducted for shark stocks that have the appropriate data, and that precautionary, science-based management should be followed for species lacking data.
- The International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) created a shark working group, which met for the first time in 2011. The group prioritized blue and shortfin mako as species of interest based on their interaction in North Pacific fisheries. The working group sponsored two workshops in 2011 to work on a blue shark stock assessment that should be completed by 2013, and to address uncertainties in ageing pelagic sharks.

- At the annual Inter-American Tropical Tuna Commission (IATTC) meeting, a requirement was approved thatprohibits retaining, landing, or selling any part of oceanic whitetip sharks in the fisheries covered by the Antigua Convention.
- In 2011, ICCAT adopted a requirement, co-sponsored by the United States, thatrequires the release of silky sharks caught in association with ICCAT fisheries as well as the prohibition of retention on board, transshipment, and landing of the species.
- In 2011, the Southwest Fisheries Science Center (SWFSC) and the Southwest Regional Office (SWRO) began a multi-year collaboration with Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) to collect data for blue, shortfin mako, and thresher sharks throughout Baja, Mexico. With this data, the first U.S.-Mexico collaborative shark stock assessment is being completed for the common thresher shark.
- At its annual meeting, the Northwest Atlantic Fisheries Organization (NAFO) adopted provisions to require shark bycatch to be reported at the species level, which will increase our understanding of species-specific bycatch rates.

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'2011research 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 signed into law by President Obama on January 4, 2011. The 2010 Act amended two previous acts—the High Seas Driftnet Fishing Moratorium Protection Act and the MSA—to improve the existing domestic and international shark conservation measures. Rulemaking is currently underway to implement the Shark Conservation Act.

1. Introduction

Sharks, as well as their close relatives skates and rays, have skeletons made of cartilage instead of boneand are thus calledcartilaginous fishes. 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).

As international awareness of the plight of sharks has increased, a few countries (Palau, Maldives, Bahamas, 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, Hawaii (2010), California (2011), Oregon (2011), and the Commonwealth of the Northern Mariana Islands (2011) havemade it unlawful for any person to “possess, sell, offer for sale, trade, or distribute”shark fins. Guam (2011) prohibits those activities and also makes it

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

unlawful to “take, purchase, barter, transport, export, [or] import” shark fins. In addition, Washington State passed a bill in 2011 prohibiting the sale or purchase of shark fins.

For 2011, in United States fisheries, four out of thirty-four shark stocks or stock complexes (12%) were subject to overfishing[2] and five shark stocks (15%) were overfished[3] (Table 1). Twenty shark stocks or stock complexes (59%) had an unknown or undefined status in terms of their overfishing status and nineteen shark stocks or stock complexes (56%) 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, 16 U.S.C. 1826d et seq., and the Magnuson-Stevens Fishery Conservation and Management Act (MSA), 16 U.S.C. 1801 et seq., to improve the existing Federal and international shark conservation measures.

The Shark Conservation Act amended the High Seas Driftnet Fishing Moratorium Protection Act to require the Secretary of Commerce to identify in a biennial report to Congress a nation if fishing vessels of that nation have been engaged during the preceding calendar year in fishing activities or practices in waters beyond any national jurisdiction that target or incidentally catch sharks and the nation has not adopted a regulatory program to provide for the conservation of sharks, including measures to prohibit removal of shark fins at sea, that is comparable to that of the United States. The Shark Conservation Act also amends the High Seas Driftnet Fishing Moratorium Protection Act to direct the United States to urge international fishery management organizations to which the United States is a member to adopt shark conservation measures, including measures prohibiting removal of shark fins at sea, and seeking to enter into international agreements that require measures for the conservation of sharks, including measures prohibiting the removal of shark fins at sea.

The Shark Conservation Act of 2010 amended the 2000 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 percentof 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 that it is illegal “to remove any of the fins of a shark (including the tail) at sea; to have custody, control, or possession of any such fin aboard a fishing vessel unless it is naturally attached to the corresponding carcass; to transfer any such fin from one vessel to another vessel at sea, or to receive any such fin in such transfer, without the fin naturally attached to the corresponding carcass; or to land any such fin that is not naturally attached to the corresponding carcass, or to land any shark carcass without such fins naturally attached.” The 2010 Act retains the 5-percent rule implemented by the Shark Finning Prohibition Act as a rebuttable presumption of a violation after landing. The 2010 Act includes a

[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.

savings clause that states that 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% of the total weight of smooth dogfish carcasses landed or found on board."

NMFS will address the requirements of the 2010 Shark Conservation Act by publishing three regulations: (1) the Office of International Affairs is redefining the definition of illegal, unreported, or unregulated (IUU) 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 Actwas 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;
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 are available from the FAO and data on U.S. import and export of shark fins are 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 information for 2011 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 2011. Source: NMFS 2012.

Status of Shark Stocks and Stock Complexes in U.S. Fisheries in 2011				
Fishery Management Council (FMC)	**Fishery Management Plan (FMP) or Fishery Ecosystem Plan (FEP)**	**Stock or Stock Complex**	**Overfishing**	**Overfished**
New England FMC & Mid Atlantic FMC	Spiny Dogfish FMP	Spiny dogfish – Atlantic coast	No	No
NMFS Highly Migratory Species Division	Consolidated Atlantic Highly Migratory Species FMP	Atlantic large coastal shark complex[A]	Unknown	Unknown
		Atlantic pelagic shark complex[B]	Unknown	Unknown
		Atlantic sharpnose shark[C]	No	No
		Atlantic small coastal shark complex[D]	No	No
		Blacknose shark – Atlantic[C]	Yes	Yes
		Blacknose shark – Gulf of Mexico[C]	Unknown	Unknown
		Blacktip shark – Gulf of Mexico[E]	No	No
		Blacktip shark – South Atlantic[E]	Unknown	Unknown
		Blue shark – Atlantic[F]	No	No
		Bonnethead – Atlantic[C]	No	No
		Dusky shark – Atlantic[G]	Yes	Yes
		Finetooth shark – Atlantic[C]	No	No
		Porbeagle – Atlantic[F]	No	Yes
		Sandbar shark – Atlantic[E]	No	Yes
		Scalloped hammerhead shark – Atlantic[E]	Yes	Yes
		Shortfin mako – Atlantic[F]	Yes	No
Pacific FMC	Pacific Coast Groundfish FMP	Leopard shark – Pacific Coast	Unknown	Unknown
		Spiny dogfish – Pacific Coast	Unknown	No
		Soupfin (Tope)- Pacific Coast	Unknown	Unknown
Pacific FMC & Western Pacific FMC	U.S. West Coast Fisheries for Highly Migratory Species &Pacific Pelagic FEP	Thresher shark – North Pacific	Unknown	Unknown
		Shortfin mako shark – North Pacific	Unknown	Unknown
		Blue shark – North Pacific	No	No
Western Pacific FMC	FEP for Pelagic Fisheries of the Western Pacific Region (Pacific Pelagic FEP)	Longfin mako shark – North Pacific	Unknown	Unknown
		Oceanic whitetip shark – Tropical Pacific	Unknown	Unknown
		Salmon shark – North Pacific	Unknown	Unknown
		Silky shark – Tropical Pacific	Unknown	Unknown
Western Pacific FMC	Hawaiian Archipelago FEP	Hawaiian Archipelago Coral Reef Ecosystem Multi-Species Complex[H]	Unknown	Unknown

Table 1. Continued

Fishery Management Council (FMC)	Fishery Management Plan (FMP) or Fishery Ecosystem Plan (FEP)	Stock or Stock Complex	Overfishing	Overfished
Western Pacific FMC	American Samoa FEP	American Samoa Coral Reef Ecosystem Multi-Species Complex[H]	Undefined	Undefined
Western Pacific FMC	Mariana Archipelago FEP	Guam Coral Reef Ecosystem Multi-Species Complex[H]	Undefined	Undefined
		Northern Mariana Islands Coral Reef Ecosystem Multi-Species Complex[H]	Undefined	Undefined
Western Pacific FMC	Pacific Remote Islands Areas FEP	Pacific Island Remote Areas Coral Reef Ecosystem Multi-Species Complex[I]	Undefined	Undefined
North Pacific FMC	Gulf of Alaska Groundfish FMP	Gulf of Alaska Shark Complex[J]	Unknown	Undefined
North Pacific FMC	Bering Sea/Aleutian Island Groundfish FMP	Bering Sea / Aleutian Islands Shark Complex[K]	Unknown	Undefined
Totals:			4 "yes" 10 "no" 16 "Unknown" 4 "Undefined"	5 "yes" 10 "no" 13 "Unknown" 6 "Undefined"

[A]In addition to sandbar shark, Gulf of Mexico blacktip shark, Atlantic blacktip shark, and scalloped hammerhead shark (which are assessed individually), the Large Coastal Shark Complex also consists of additional stocks including spinner shark, silky shark (authorized in the commercial fishery but not the recreational fishery), bull shark, tiger shark, lemon shark, nurse shark, great hammerhead shark, and smooth hammerhead shark.
[B]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.
[C]This stock is part of the Small Coastal Shark Complex, but is assessed separately.
[D]The Small Coastal Shark Complex consists of finetooth shark, Atlantic sharpnose shark, blacknose shark, and bonnethead shark.
[E]This stock is part of the Large Coastal Shark Complex, but it is assessed separately
[F]This stock is part of the Pelagic Shark Complex, but is assessed separately.
[G] In addition to dusky shark, the prohibited species under the 2006 Consolidated Atlantic HMS FMP include whale, basking, sandtiger, bigeye sandtiger, white, night, bignose, Galapagos, Caribbean reef, narrowtooth, longfin mako, bigeye thresher, sevengill, sixgill, bigeye sixgill, Caribbean sharpnose, smalltail, and Atlantic angel sharks. These species cannot be retained in Atlantic or Gulf of Mexico commercial or recreational fisheries.
[H]In 2009, the Western Pacific Crustaceans, Bottomfish & Seamount Groundfish, Precious Corals, and Coral Reef Ecosystem FMPs were replaced by 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 Islands Unit of the Marianas Trench (Mariana Islands) and within the Rose Atoll (American Samoa) Marine National Monuments.
[I]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 within the boundaries of the Pacific Remote Islands Marine National Monument.
[J]The Gulf of Alaska Shark Complex consists of: Pacific sleeper shark, salmon shark, spiny dogfish, and other/unidentified sharks.
[K]The Bering Sea/Aleutian Islands Shark Complex consists of: Pacific sleeper shark, salmon shark, spiny dogfish, and other/unidentified sharks.

2. Management and Enforcement

2.1 Management Authority in the United States

Development of fishery management plans (FMPs) is the responsibility of one or more of the eight regional fishery management councils, which were established under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), or the responsibility of the Secretary of Commerce in the case of Atlantic highly migratory species. Since 1990, shark fishery management in Federal waters of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (excluding dogfishes) has been the responsibility of the Secretary of Commerce. Dogfish in the Atlantic Ocean are managed by the New England Fishery Management Council (NEFMC), the Mid-Atlantic Fishery Management Council (MAFMC). In the Pacific, three regional councils are responsible for developing fishery management plans for sharks: the Pacific Fishery Management Council (PFMC), the North Pacific Fishery Management Council (NPFMC), and the Western Pacific Fishery Management Council (WPFMC). The PFMC's area of jurisdiction is the EEZ off California, Oregon, and Washington; the NPFMC covers Federal waters off Alaska, including the Gulf of Alaska and the Bering Sea / Aleutian Islands; and the WPFMC's jurisdiction covers Federal waters around Hawaii, Guam, American Samoa, the Northern Mariana Islands, and other U.S. non-self governing insular areas of the Pacific.

In general, waters under the jurisdiction of the individual states extend from the shoreline out to 3 miles (9 nautical miles off Texas, the west coast of Florida, and Puerto Rico), while U.S. waters under Federal management continue from state waters to 200 miles offshore except where intercepted by the EEZ of another nation. Management of elasmobranchs in state waters usually falls under the authority of state regulatory agencies, which are typically the marine division of the state fish and wildlife departments. Each state develops and enforces its own fishing regulations for waters under its jurisdiction (Federally permitted commercial fishermen in the Atlantic are required to follow Federal regulations regardless of where they are fishing as a condition of the permit). Many coastal states promulgate regulations for shark fishing in state waters that complement or are more restrictive than Federal shark regulations for the EEZ. Given that many shark nursery areas are located in waters under state jurisdiction, states play a critical role in effective shark conservation and management.

Cooperative management of the fisheries that occur in the jurisdiction of two or more states and Federal waters may be coordinated by an interstate fishery management commission. These commissions are interstate compacts that work closely with NMFS. Three interstate commissions exist: the Pacific States Marine Fisheries Commission (PSMFC), the Atlantic States Marine Fisheries Commission (ASMFC), and the Gulf States Marine Fisheries Commission (GSMFC). While states set fishery regulations in their own waters, they are encouraged to adopt compatible regulations between state and Federal jurisdictions. The Atlantic Coast Fisheries Cooperative Management Act (ACFCMA) established a special management program between NMFS, the Atlantic coast states, and the ASMFC. Under this legislation, Atlantic states must comply with the management measures approved by this Commission, or risk a federally mandated closure (by NMFS) of the subject fishery (50 CFR part 697).

2.2 Current Management Authority in the Atlantic Ocean

Atlantic Highly Migratory Species Management

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 within that management unit. 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 (64 FR 29090), 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.

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 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 2007–2011 commercial shark landings and the 2011 preliminary commercial shark landings are shown in Tables 2.2.2 and 2.2.3, respectively.

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.**

Table 2.2.2 Commercial landings for Atlantic large coastal, small coastal, and pelagic sharks in metric tons dressed weight, 2007–2011.
Source: Cortés pers. comm. (2012).

Commercial Shark Landings (mt)					
Species Group	2007	2008	2009	2010	2011
Large Coastal Sharks	1,056	618	686	689	708
Small Coastal Sharks	280	283	303	162	265
Pelagic Sharks	118	106	91	141	141
Total	**1,454**	**1,007**	**1,080**	**992**	**1,114**

From 2007 through 2008, NMFS published two rules (72 FR 5633, 73 FR 54721) requiring vessels to carry certain types of gear to aid in the safe release of sea turtles and other non-target 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.

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 and Florida smoothhound 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% with a 5-day notice upon filing in the *Federal Register*).

Table 2.2.3 Preliminary landings estimates in metric tons (mt) and pounds (lb) dressed weight (dw) for the 2011 Atlantic shark commercial fisheries. Landings are based on the quota monitoring system.

2011 Landings Estimates			
Species Group	2011 Quota	Estimated Total Landings	% of Quota
Non-Sandbar LCS[4] (Region = Gulf of Mexico)	351.9 mt dw (775,740 lb dw)	330.7 mt dw (729,099 lb dw)	94%
Non-Sandbar LCS[5] (Region = Atlantic)	190.4 mt dw (419,756 lb dw)	156.5 mt dw (345,070 lb dw)	82%
Shark Research Fishery (Non-Sandbar LCS)	37.5 mt dw (82,673 lb dw)	37.0 mt dw (81,627 lb dw)	99%
Shark Research Fishery (SRF) (Sandbar Only)	87.9 mt dw (193,784 lb dw)	62.0 mt dw[5] (136,569 lb dw) 8.7 mt dw[6] (19,145 lb dw)	80%
Non-Blacknose Small Coastal Sharks (SCS)	314.4 mt dw (693,257 lb dw)	229.7 mt dw (506,439 lb dw)	73%
Blacknose Sharks	19.9 mt dw (43,872 lb dw)	15.0 mt dw (32,878 lb dw)	75%
Blue Sharks	273 mt dw (601,856 lb dw)	7.2 mt dw (15,968 lb dw)	2%
Porbeagle Sharks	1.6 mt dw (3,479 lb dw)	2.6 mt dw (5,657 lb dw)	163%
Pelagic Sharks Other Than Porbeagle or Blue	488 mt dw (1,075,856 lb dw)	118.4 mt dw (261,073 lb dw)	24%

Shark Stock Assessments

A joint International Commission for the Conservation of Atlantic Tunas (ICCAT) / International Commission for the Exploration of the Seas (ICES) 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

[4]Non-sandbar Large Coastal Sharks (LCS) includes the following: silky, tiger, blacktip, spinner, bull, lemon, nurse, and hammerheads.
[5]Inside the shark research fishery.
[6] Outside the shark research fishery; these are from State landings.

sharks in the northwest Atlantic are overfished (biomass depleted to levels below MSY[7]), 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.

The first individual stock assessment for dusky sharks was completed in May 2006. 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 percent to 80 percent of the unfished virgin biomass. On October 6, 2011, NMFS announced the Southeast Data, Assessment, and Review (SEDAR) 21 stock assessment results for dusky sharks (SEDAR 21 also assessed sandbar and blacknose sharks, as discussed below). Dusky sharks were assessed as one stock across the Atlantic and Gulf of Mexico.The Review Panel for the Review Workshop of SEDAR 21 found that the data and methods used were appropriate and the best available for the dusky shark assessment. Based on this assessment, NMFS determined that the stock status for dusky sharks is overfished (biomass was 41% to 50% of the MSY level) with overfishing occurring (1.4 to 4.3 times the level of fishing mortality resulting in MSY).

In June 2006 a stock assessment was performed for LCS, which followed the SEDAR process. 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 sharksas necessary to achieve rebuilding by 2070. SEDAR 21 assessed sandbar sharks (in addition to dusky and blacknose sharks) and found that the stock was still overfished but that overfishing was no longer occurring (most scenarios estimated a fishing mortality ranging from 29% to 93% of the level resulting in MSY). Furthermore, current fishing mortality levels will still allow for rebuilding by 2070, as determined in the previous sandbar stock assessment. The Review Panel for the Review Workshop of SEDAR 21 found that the data and methods used were appropriate and the best available for the sandbar shark assessment.Blacktip sharks were also assessed in the June 2006 LCS stock assessment and 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. Gulf of Mexico blacktip sharks will be reassessed in 2012 through SEDAR 29.

In 2007, SEDAR performed stock assessments for the SCS management unit (and for Atlantic sharpnose, bonnethead, blacknose, and finetooth sharks individually). The Review Panel for the 2007 SCS SEDAR concluded that, although the assessment of the status of the management unit

[7]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.

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). For blacknose sharks, the 2007 assessment indicated the stock was overfished and overfishing was occurring.The assessments for Atlantic sharpnose and bonnethead sharks determined the stocks were not overfished and that overfishing was not occurring.On October 6, 2011, NMFS announced the SEDAR 21 stock assessment results for blacknose sharks (SEDAR 21 also assessed sandbar and dusky sharks, as discussed above). Blacknose sharks were assessed separately in the Atlantic and Gulf of Mexico. The Review Panel for the Review Workshop of SEDAR 21 found that the data and methods used were appropriate and the best available for the Atlantic blacknose shark assessment. Based on this assessment, NMFS determined that the Atlantic blacknose shark is overfished (biomass was 43% to 64% of the MSY level) with overfishing occurring (3 to 22 times the level of fishing mortality resulting in MSY). In the Gulf of Mexico, however, the assessment model for the Gulf of Mexico blacknose stock was unable to fit the apparent trends in some of the abundance indices and there was a fundamental lack of fit of the model to some of the input data. Therefore, the Review Panel did not accept the stock assessment for the Gulf of Mexico blacknose stock and its status is unknown.

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.

On April 28, 2011, NMFS accepted a scalloped hammerhead shark assessment performed by Hayes et al. (2009) to be appropriate for U.S. management decisions. Based on this stock assessment, in 2005 the population was estimated to be at 45% ofthe biomass that would produce MSY, and fishing mortality was estimated to be 129% of fishing mortality associated with MSY. The stock is estimated to be depleted by approximately 83% of virgin stock size (i.e., the current population is only 17% of the virgin stock size). In addition, it was estimated that a TAC of 2,853 scalloped hammerhead sharks per year (or 69% of2005 catch) would allow a 70% probability of rebuilding within 10 years. NMFS is currently preparing rulemaking to address this new stock status.

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% 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 monitoringtakes and estimating mortality of protected sea turtles, seabirds, 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. Spiny dogfish are typically landed whole, with fins attached, and processed on shore. Current dock prices for whole spiny dogfish are around $0.25 per pound, which includes the value of fins.

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 was therefore considered rebuilt. The quota was further increased in 2011 (20 million lb), but the possession limit remains at 3,000 pounds per trip to help avoid closures of the fishery. Due to several years of poor recruitment, the stock is projected to decline between 2014 and 2020.

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, 2011, and 2012 fishing years. However, for spiny dogfish, the Interstate Coastal Shark FMP allocates quota regionally in state waters, rather than seasonally, as in Federal waters. This misalignment is expected to 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 recommended the U.S. West Coast Highly Migratory Species (HMS) Fisheries FMP, which was implemented in 2004. This FMP's management area also covers adjacent highseas waters for fishing activity under the jurisdiction of the West Coast HMS FMP. The West Coast HMS FMP is implemented by the NMFS Southwest Regional Office in Long Beach, California. Under this FMP, NMFS manages fishing for three sharkspecies 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). On September 13, 2011, regulations implementing West Coast HMS FMP Amendment 2 were published in the *Federal Register* (76 FR 56327). Amdendment 2 and its supporting regulations reclassified bigeye thresher and pelagic thresher sharks as ecosystem component species. These species were originallyincluded in the West Coast HMS FMP as management unit species due to concern over their low resiliency to exploitation; their reclassification as ecosystem component species is based in part on the minor levels of West Coast commercial andrecreational catch that have been reported for these species since the FMP was implemented. However, given the presence of these species off the West Coast, particularly during El Niño warming periods, these species will continue to be monitored under the West Coast HMS FMP as an ecosystem component species.Lastly, the West Coast HMS FMP also designates three shark species as prohibited (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.

Table 2.3.1 Shark species in the West Coast Highly Migratory Species FisheryManagement Plan.

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

Sharks within the West Coast HMS FMP are managed to achieve Optimum Yield (OY) set at a precautionary level of 75% of MSY. The precautionary approach is meant to prevent localized depletion of these vulnerable species. The FMP proposed annual harvest guidelines for common thresher and shortfin mako sharks given the level of exploitation in HMS fisheries at the time the FMP was adopted (e.g., large mesh drift gillnet), and accounting for the uncertainty about catch in Mexico of these straddling stocks. High exploitation rates and their impact on HMS shark stocks, if not checked, could take decades to correct given the vulnerable life history characteristics of the species. 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 gillnet fishery data demonstrate that the nominal catch per unit effort (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 NMFS Pacific Islands Fisheries Science Cetner (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).

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. These shark species are mainly caught incidentially in groundfish fisheries and discarded at sea. 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 FMPmanages its shark species with a combined annual catch limit for all "other fish," which includes sharks, skates, ratfish, morids, grenadiers, kelp greenling, and some other groundfish species. This annual catch limit is reduced by a precautionary adjustment from the overfishing level. 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. A benchmark assessment for spiny dogfish was conducted for the first time and reviewed in 2011. That assessment indicated that the portion of the Pacific coast stock found off the United States was likely well above its target spawning output level. The results of the 2011 assessment have been used to inform management of the species in 2013–2014.

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*

Beginning in 2011, NMFS reformed management of the groundfish trawl sector from 2-month cumulative trip limits for all groundfish to an individual quota system (also called catch shares) for most groundfish species. While the PFMC considered including spiny dogfish as a species managed with individual quotas, it decided to continue managing spiny dogfish and "other fish" (which includes leopard and soupfin shark) with 2-month cumulative trip limits at this time. This new program for the groundfish trawl sector, also called the trawl rationalization program or trawl catch share program, includes a "gear switching" provision that allows a vessel having a trawl-endorsed limited entry permit to also fish using "non-trawl" gear, generally longline or pot/trap gear. This may change the impacts on shark species. In addition, the trawl rationalization program requires 100% at-sea monitoring on vessels participating in the program, making more data available on shark catch (including discards).

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

Table 2.3.3 Commercial Shark landings (round weight equivalent in metric tons) for California, Oregon, and Washington, 2002–2011. Source: PacFIN Database, datafor the Pacific Fishery Management Council area extracted using the "Explorer" tool on July 18, 2012[8].

Commercial Shark Landings (mt) for California, Oregon, and Washington										
Species Name	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bigeye thresher shark	--	6	5	10	4	5	6	7	1	1
Blue shark	1	1	1	1	<1	10	<1	1	<1	<1
Brown catshark	--	--	--	--	--	--	--	--	11	4
Common thresher shark	301	301	115	179	160	204	147	107	96	75
Leopard shark	13	10	11	13	11	11	3	2	3	2
Pacific angel shark	22	17	13	12	15	8	12	12	9	10
Pelagic thresher shark	2	4	2	<1	<1	2	<1	<1	<1	--
Shortfin mako	81	65	53	33	45	44	35	29	20	17
Soupfin shark	33	36	27	26	30	17	8	5	3	3
Spiny dogfish	876	451	418	468	394	425	638	264	230	393
Other shark	4	3	3	5	4	2	2	2	3	1
Unspecified shark	4	3	6	5	5	5	2	2	20	4
Total	**1,337**	**897**	**654**	**752**	**668**	**733**	**853**	**431**	**396**	**510**

[8] This extraction includes all commercial landings in West Coast U.S. ports of sharks caught in areas managed by the PFMC. This is a change from some prior years, in which West Coast landings of sharks caught in Alaska, Canada, and Puget Sound were included (via the use of PacFIN Report #307). This summary does not include estimates of commercial discards or any recreational catch.

North Pacific Fishery Management Council (NPFMC)
The NPFMC manages the groundfish fisheries in Federal waters off Alaska. In October 2010 NMFS issued a final rule to implement Amendments 95 and 96 to the BSAI FMP and Amendment 87 to the GOA FMP in order tocomply with statutory requirements for annual catch limits and accountability measures (under National Standard 1), and to rebuild overfished stocks. 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 Standard 1 Guidelines. In 2011, the "other species" category was dissolved in the GOA and BSAI into its major taxonomic groups: sharks, skates, octopi, and sculpins in the BSAI and sharks, octopi, squid, and sculpins in the GOA. For each of these species groups, the NPFMC recommended and NMFS specified overfishing levels (OFLs), acceptable biological catch (ABCs), and total allowable catch (TACs) amounts. Due to conservation concerns, the final rules to implement groundfish harvest specifications in the BSAI and GOA in 2011 and 2012 prohibited directed fishing for sharks in both management areas. In other groundfish fisheries open to directed fishing, the retention of sharks taken as incidental catch is limited to no more than 20% of the aggregated amount of sharks, skates, octopi, and sculpins in the BSAI and sharks, octopi, squid, and sculpins in the GOA.

At its December 2010 meeting, the NPFMC recommended OFLs, ABCs, and TACs for sharks in both the BSAI and GOA for the 2011 and 2012 fishing years. The TAC was based in large part on the natural mortality and biomass estimates for spiny dogfish and the recent average historical catch of other shark species. Table 2.3.4 lists the recent historical catch of sharks in the BSAI and GOA. In 2011 the 50 mt TAC for sharks in the BSAI was exceeded. At its December 2011 meeting, the NPFMC recommended an increased TAC of 200 mt in the BSAI for sharks, based on an estimate of incidental catch needs in other groundfish fisheries. The most recent assessments for sharks are in Chapter 20 to the 2011 Stock Assessment and Fishery Evaluation (SAFE) reports for the BSAI and GOA (available online at http://www.afsc.noaa.gov/refm/stocks/assessments.htm).

In order to comply with annual catch limit requirements, the shark assessment authors compiled two new datasets for inclusion as appendices to the 2011Stock Assessment and Fishery Evaluation (SAFE) reports for the BSAI and GOA. The first dataset, non-commercial removals, estimates shark catch not included in the NMFS catch accounting system, including NMFS trawl and hook-and-line surveys, the International Pacific Halibut Commission (IPHC) hook-and-line survey, experimental fishing permits, and sport and subsistence fishing. The second dataset are estimates of shark catch in the commercial halibut individual fishing quota (IFQ) fisheries. In the BSAI in 2010, the non-commercial removals were estimated to be approximately 10 mt while the catch in the commercial halibut fishery was estimated to be 89 mt. In the GOA in 2010, the non-commercial removals were estimated to be approximately 408 mt while the catch in the commercial halibut fishery was estimated to be 1,896 mt.

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 biennially for groundfish, including sharks. The most recent surveys were conducted in 2010 in the BSAI and in 2011 in the GOA, with the results incorporated into the SAFE reports for sharks. The next NMFS surveysare scheduled for 2012 and 2013 in the BSAI and GOA, respectively.

Table 2.3.4 Incidental catch and utilization (in metric tons) of sharks in the Gulf of Alaska and Bering Sea/Aleutian Islands commercial groundfish fisheries, 2002–2011.
(Values are rounded to nearest metric ton)
Source: NMFS Survey, Observer Data, and NMFS Catch Accounting System Data

Incidental Catch of Sharks (mt)											
Fishery	Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
GOA Groundfish	Spiny dogfish	117	362	205	485	1,232	850	534	1,085	401	518
	Pacific sleeper shark	226	297	286	486	253	297	66	51	167	26
	Salmon shark	58	37	41	60	34	151	7	9	107	7
	Unidentified shark	117	54	40	70	83	108	12	24	9	5
	Total	518	750	572	1101	1602	1406	619	1169	684	556
	% Retained	UNK	1.4	2.0	3.2	3.9	3.2	6.8	5.0	5.7	2.7
BSAI Groundfish	Spiny dogfish	9	11	9	11	7	3	17	19	15	8
	Pacific sleeper shark	839	280	420	333	313	256	120	47	21	47
	Salmon shark	47	196	26	47	63	45	42	72	12	114
	Unidentified shark	468	33	60	26	305	28	7	6	5	3
	Total	1,363	520	515	417	688	332	186	144	53	172
	% Retained	UNK	1.8	2.6	4.9	3.9	9.9	7	4.3	7.3	4

Eleven shark species are found in the Alaskan waters (Table 2.3.5; Goldman 2012).Pacific sleeper, salmon, and spiny dogfish sharks are taken incidentally in groundfish fisheries and are monitored in season by NMFS. The other eight species are very rarely taken in any sport or commercial fishery and are not targeted for harvest. Sharks are 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 andupper 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. The most recent estimates of the incidental catch of sharks in the BSAI and GOA are from 2011. These data are included in Chapter 20 in the 2011 BSAI and GOA SAFE reports and the NMFS catch accounting system. Estimates of the incidental catch of sharks in the groundfish fisheries from2002 through 2011 have ranged from 518 to 1,602 mt in the GOA and from 53 to 1,363 mt in the BSAI (Table 2.3.4). Very few of the sharks incidentally taken in the groundfish fisheries in the GOA and BSAI are retained. In 2006 two vessels targeted sharks using hook-and-line gear in the GOA: one vessel used a Federal Fisheries Permit and another vessel used a permit issued by the Commissioner of the Alaska Department of Fish and Game (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 the fishery was deemed unsuccessful by the participants. Since 2006 there has been no effort targeting sharks in the BSAI or GOA.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 are largely based on NMFS survey results, observer data, and the NMFS catch accounting system data (which was implemented in 2003).

Table 2.3.5 North Pacific shark species.

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

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 the 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. State regulations prohibit the intentional waste or destruction of any sport-caught species, and there have been no known incidents of sport-caught sharks being finned and discarded.

Recreational harvest of all shark species combined is estimated through a mail survey of sport fishing license holders. About 332 sharks of all species were harvested by the sport fishery in State and Federal waters of Southeast and Southcentral Alaska in 2010 (most recent estimate). The Southcentral Region accounted for 95% 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 mostly charter boats. Salmon sharks are also taken occasionally by anglers targeting halibut.

Harvest of salmon sharks by guided anglers is required to be reported in charter logbooks. Charter boats reported statewide salmon shark harvests of 63 fish in 2009, 22 fish in 2010, and eight fish in 2011. Although estimates of salmon shark harvest are not available for unguided anglers, the charter fleet is believed to have accounted for the majority of salmon shark harvest, at least in the past. Reasons for the decline in charter harvest are unclear; charter effort for salmon sharks has declined, and trends in abundance are unknown. 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 statewide regulation 5 AAC 28.084 prohibits 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 a 35% bycatch of spiny dogfish (5AAC 28.174 (1) and (2)). In addition, in the East Yakutat Section and the Icy Bay Subdistrict salmon gillnetters may retain all spiny dogfish taken as bycatch during salmon gillnet operations (5AAC 28.174 (3)). All sharks landed must be recorded on an ADF&G fish ticket. A single permit was issued in 2006 for the Cook Inlet spiny dogfish fishery, which resulted in a single landing. Harvest data are confidential if less than three landings occur. Since 2006 no additional 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 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 2000 Shark Finning Prohibition Act,the Shark Conservation Act of 2010, 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 Mariana Archipelago, and the Pacific Remote Islands Areas (Table 2.3.7) as currently harvested.[9]

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 decreased shark landings by almost 50%to 1,450 mt in 2000. With the subsequent enactment of the Federal Shark Finning Prohibition Act, shark landings from 2001 to 2010 were down by morethan 93% from their peak (Table 2.3.8). Landings in 2011 were approximately 100 mt,up slightly from 2010 which had 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.

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

Western Pacific Pelagic Fisheries FEP	
Common name	Scientific name
Common thresher shark	*Alopias vulpinus*
Pelagic thresher shark	*Alopias pelagicus*
Bigeye thresher shark	*Alopiassuperciliosus*
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*

[9] 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.

Table 2.3.7 Coastal sharks listed as management unit species and designated as currently harvested coral reef taxa in the four Western Pacific Fishery Ecosystem Plans. 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.

Western Pacific Fishery Ecosystem Plans					
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	*Carcharhinusalbimarginatus*	X	-	X	X
Grey reef shark	*Carcharhinusamblyrhynchos*	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

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 to 1 mt in 2001, with landings remaining low through 2011. The decline in shark landings by the American Samoa longline fishery is attributed to the Shark Finning Prohibition Act.

Table 2.3.8 Shark landings (in metric tons) from the Hawaii-based and American Samoa pelagic longline fisheries, 1998–2011.
Source: PacificIslands Fisheries Science Center, Fisheries Research and Monitoring Division.

	Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Hawaii-based Longline Fishery	Blue shark	2,500	2,400	1,200	30	30	20	60	30	12	6	7	9	6	13
	Mako shark	90	110	80	60	80	90	70	110	95	119	109	102	62	67
	Thresher shark	120	190	100	50	50	50	60	30	33	42	39	28	16	19
	Misc. shark	110	170	70	10	20	10	10	-	11	7	4	6	3	2
	Total shark landings	**2,820**	**2,870**	**1,450**	**150**	**180**	**170**	**200**	**170**	**151**	**174**	**159**	**145**	**87**	**101**
American Samoa	**Total shark landings**	**11**	**13**	**4**	**1**	**3**	**4**	**1**	**<1**	**1**	**2**	**1**	**1**	**2**	**4**

2.4 NOAA Enforcement of the Shark Finning Prohibition Act

The NOAA Fisheries Office of Law Enforcement (OLE) has responsibility for enforcing the Shark Finning Prohibition Act of 2000 and its implementing regulations. During calendar year 2011, violations of the Shark Finning Prohibition Act were detected, investigated, and referred for administrative prosecution in the Southeast and Southwest Enforcement Divisions, including one detected by the U.S. Coast Guard (USCG) and referred to OLE for further action. Violations thatwere investigated included finning by U.S. domestic fishing vessels and importing shark fins without the required Highly Migratory Species (HMS) International Trade Permit (ITP) as prohibited by the MSA.

- Officers with the Louisiana Department of Wildlife and Fisheries (LDWF), while conducting a Federal fisheries patrol pursuant to the NOAA OLE Joint Enforcement Agreement (JEA) Program, boarded a commercial shrimp fishing vessel actively fishing in Federal waters. During the course of the boarding, a crewman was found to be in possession of shark fins with no corresponding shark carcasses. Further investigation located 146 shark fins and revealed that the vessel did not possess the required HMS permit. The shark fins were seized as evidence and the case is currently under review by the NOAA Office of the General Counsel Enforcement Section.
- While conducting patrols in Florida, a U.S. Coast Guard boarding team discovered detached fins from a single shark onboard a commercial fishing vessel. There was no corresponding carcass. The operator was cited with a single count of shark finning for

failing to have the fins naturally attached to the carcass as required by law. The vessel operator later paid a monetary penalty under the Summary Settlement Program.
- In the Southwest Enforcement Division, an OLEspecial agent inspected a shipment ofshark fin soup that arrived at the Port of San Francisco from Hong Kong. The importer failed to possess the required HMS ITP to import sharks as well as shark parts and products. The OLE special agent educated the importer concerning ITP requirements, and the permit was subsequently obtained.

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 the HMS Management Division of NMFS developed an outreach brochure detailing safe catch and release techniques to maximize post-release survival of HMS, including sharks. The brochure was released on January 27, 2011, and is available online at (see Figure 2.5.1) http://www.nmfs.noaa.gov/sfa/hms/Compliance_Guide/Careful_release_brochure.pdf
- In 2011, staff from the NMFS HMS Management Division began an outreach effort to encourage the live release of shortfin mako sharks (*Isurus oxyrinchus*). In 2009, the International Commission for the Conservation of Atlantic Tunas (ICCAT) Standing Committee on Research and Statistics determined that North Atlantic shortfin mako ssharks are experiencing overfishing and approaching an overfished status. To reduce fishing mortality on shortfin mako sharks in the U.S. domestic fishery, the live release outreach effort encourages commercial and recreational fishermen to release any shortfin mako sharks that come to the vessel alive. To support this outreach effort, NMFS produced postcard-size mailers to send out to shark permit holders and shark tournament operators. In addition, NMFS staff developed an online live-release map where fishermen can post coordinates and pictures of where they have released a live shortfin mako shark. This information is available online at http://www.nmfs.noaa.gov/sfa/hms/shortfinmako/Map/index.htm
- NMFS' Offices of International Affairs and Science and Technology began capacity building efforts in West Africa in 2008. Since 2008, NMFS has provided observer training in Ghana, Senegal, Gabon, and Liberia. As part of these workshops, shark identification guides specific to West Africa are distributed and attendees are trained with specimens to use the identification guide. Finally, observers are instructed on measurement and biological sampling techniques; workshop attendees are also shown how to remove spines or vertebrae for ageing, gonads for reproductive analysis, and stomachs for diet studies.

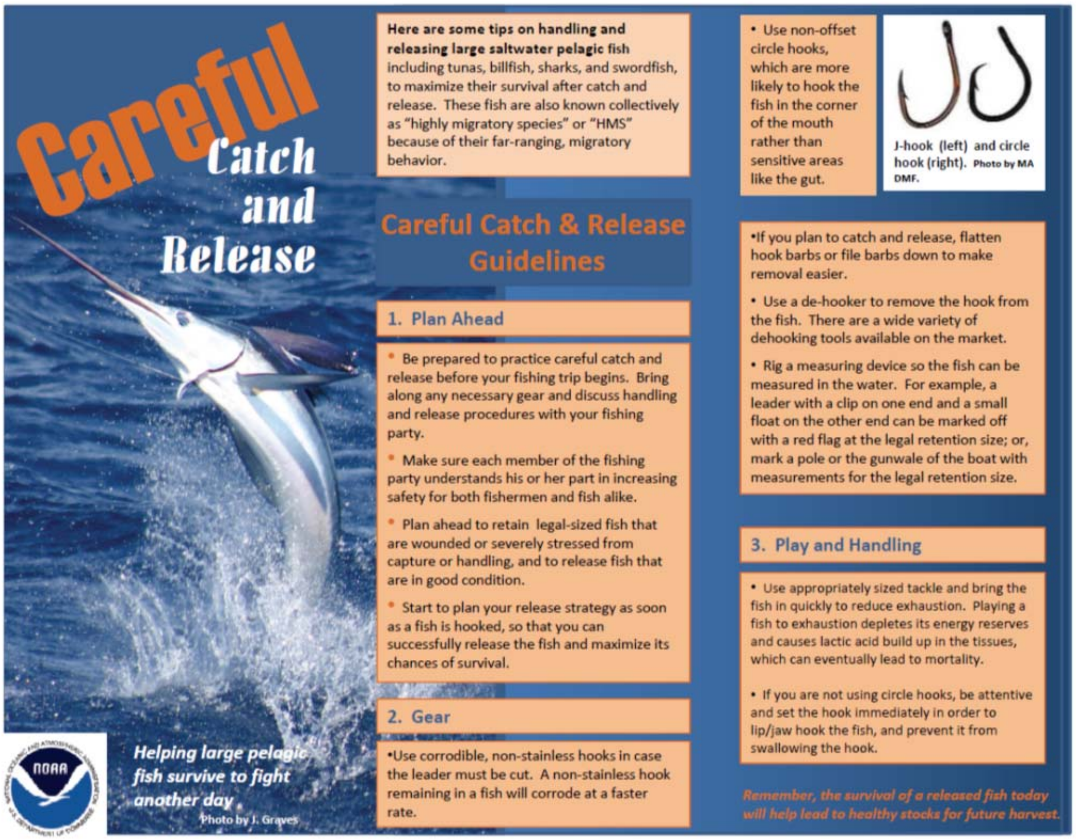

Figure 2.5.1. Brochure created by Highly Migratory Species division that details safe catch and release techniques.

- Staff from NMFS Northeast Fisheries Science Center (NEFSC) attended Northeast U.S. recreational shark fishing tournaments, captains meetings, and local sportfishing shows to inform participants on current shark management regulations and discuss current research. In 2011, a 20-page booklet was published detailing tagging and recapture instructions, catch and release guidelines, research results, length and weight information, management regulations, and contact websites and telephone numbers. This booklet, tags and identification guides, and placards are made available to the fishing public and are also mailed to NMFS Cooperative Shark Tagging Program participants. Feedback is given to tournament officials on historic tournament landings to encourage further shark conservation measures and to facilitate better catch and release practices.
- In response to declines in the eastern North Pacific basking shark (*Cetorhinus maximus*) population, the Southwest Fisheries Science Center (SWFSC) 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, California. A dedicated website (http://psrc.mlml.calstate.edu/current-research/basking-shark/) and hotline (858-334-2884) 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, and this outreach continued through 2011.

- Dr. Lisa Natanson, staff at NMFS NEFSC, appeared in episodes of the Discovery Channel series 'Swords: Life on the Line' (season 2was premiered and season 3was 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. 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.
- The Southwest Regional Office (SWRO) and the SWFSC have collaborated on public outreach toward the development of alternative fishing methods that reduce post-release mortality of thresher sharks (*Alopias spp*). This collaboration continued in 2011 with two seminars offered thatprovided over 200 recreational fishermen 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 was distributed at the seminars and at various fishing shows in 2011 (e.g., at the Fred Hall Fishing and Tackle Shows in Long Beach and Del Mar, California, and San Diego's Day at the Docks celebration; these events annually attract 50,000 to 75,000 participants).

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. From 2007 to 2010, exports of shark fins exceeded imports in both weight and value. Even though 2011 saw an increase in volume of imports and a decrease in volume of exports, the per unit value of exports remained higher than the per unit value of imports. In 2011, both the weight and value of imported shark fins were the highest since2007. The total weight and value of exports showed a decrease in 2011 compared to 2010.

3.1 U.S. Imports of Shark Fins

During 2011, imports of shark fins entered through the following U.S. Customs and Border Protection districts: Los Angeles, San Francisco, Miami, Seattle, and New York. In 2011, countries of origin (in order of importance based on quantity) were New Zealand, Hong Kong, and China. Shark fins were also imported in smaller numbers from Australia and India (Table 3.1.1). The mean value of imports per mt stayed steady between 2007 and 2008 with a subsequent decline in 2009, 2010, and 2011.The unit price of $31,000/mt in 2011 was the lowest mean value since 2007. 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 2011 were sent from the United States to Hong Kong, China, Poland, and Canada,with small amounts going to Germany and Japan (Table 3.2.1). The mean value of exports per metric ton (mt) has decreased from $73,000/mt in 2007 to $49,000/mt in 2009, the lowest value since 2007 with the 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. However, 2011 values showed a slight decrease from 2010. Using data from Table 3.2.1, mean values of dried shark fins for all countries combined has fluctuated significantly between 2007 and 2011: from a low of $49,000/mt in 2009to a high of $80,000/mt in 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 15,345 mt and 11,892 mt from 2005 to 2009, while the reported global exports of shark fins have fluctuated between 13,146 mt and 9,373 mt from 2005 to 2009. Imports decreased to $24,446/mt in 2009 from $25,234/mt in 2008. Exports also decreased to $19,523/mt in 2009 from $20,919/mt in 2008. Hong Kong remains the largest importer and exporter of shark fins.

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) indicatesthat the weight was less than 500 kilograms.
Source: U.S. Census Bureau

Country	2007		2008		2009		2010		2011	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	1	13	0	0	0	0	0	0	7	85
Canada	2	11	(1)	20	(1)	2	0	0	0	0
China	5	656	1	59	6	200	21	442	12	732
China, Hong Kong	20	954	23	1522	11	706	11	695	15	700
Colombia	0	0	(1)	4	0	0	0	0	0	0
India	0	0	0	0	0	0	0	0	(1)	3
Indonesia	(1)	7	(1)	8	0	0	0	0	0	0
Japan	0	0	2	82	0	0	(1)	3	0	0
New Zealand	0	0	1	14	3	57	1	37	24	275
Panama	0	0	(1)	4	0	0	0	0	0	0
Peru	2	36	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	(1)	3	0	0
South Korea	0	0	2	19	0	0	0	0	0	0
Vietnam	0	0	(1)	6	0	0	0	0	0	0
Total	**30**	**1677**	**29**	**1738**	**21**	**965**	**34**	**1180**	**58**	**1795**
Mean value	**$57,910/mt**		**$59,360/mt**		**$46,026/mt**		**$35,020/mt**		**$31,109/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 United States as imports and not sold, which, at the time of re-export, are in substantially the same condition as when imported). (1) indicatesthat the weight was less than 500 kilograms.
Source: U.S. Census Bureau

Country	2007		2008		2009		2010		2011	
	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	3	238	1	164	2	277	1	206	1	199
China	0	0	1	112	3	495	2	335	5	895
China, Hong Kong	32	2348	30	1531	71	2948	39	2785	29	1739
China,Taipei	0	0	(1)	35	0	0	(1)	6	0	0
Egypt	0	0	0	0	(1)	3	0	0	0	0
Finland	1	33	0	0	0	0	0	0	0	0
Germany	0	0	0	0	(1)	3	0	0	(1)	3
Indonesia	0	0	0	0	(1)	5	0	0	0	0
Japan	0	0	4	204	0	0	0	0	(1)	4
Mexico	(1)	21	0	0	0	0	0	0	0	0
Panama	0	0	0	0	(1)	21	0	0	0	0
Poland	0	0	0	0	1	15	(1)	22	3	86
Portugal	(1)	3	0	0	(1)	3	0	0	0	0
South Korea	0	0	0	0	(1)	6	0	0	0	0
Total	**36**	**2643**	**37**	**2059**	**77**	**3776**	**42**	**3354**	**38**	**2925**
Mean value	**$72,526/mt**		**$55,549/mt**		**$49,140/mt**		**$79,256/mt**		**$76,804/mt**	

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

Country	2005		2006		2007		2008		2009	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	9	1,056	7	891	11	1182	7	1351	7	902
Brazil	2	8	0	0	0	0	0	0	0	0
Cambodia	1	12	4	186	1	38	0	0	-	-
Canada	112	5,261	110	5,480	94	4,994	118	6,508	184	6,217
China	3,338	17,758	2,662	13,882	2,542	11,991	2,005	10,777	731	4,427
China, Hong Kong	10,348	306,968	9,363	253,427	10,183	276,302	9,950	287,510	9,358	245,936
China, Macao	120	3,324	106	3,728	118	5,306	122	5,911	125	5,886
China, Taipei	434	4,658	708	4,141	564	6,223	792	8,710	988	7,385
Djibouti	(1)	15	0	0	0	0	0	0	0	0
India	2	8	0	0	0	0	0	0	0	0
Indonesia	332	2,486	293	1,274	84	366	220	1,515	102	927
Laos	(1)	5	(1)	6	0	0	0	0	0	0
Malaysia	93	311	145	585	163	653	44	494	49	493
North Korea	1	331	2	1,222	2	1,084	1	579	(1)	22
Peru	1	4	8	52	2	12	28	141	54	246
Singapore	437	20,673	489	23,434	446	20,638	396	22,632	226	17,575
South Korea	2	109	6	157	2	82	4	167	2	119
Thailand	113	1,317	102	1,141	82	877	66	748	66	547
Timor-Leste	0	0	0	0	0	0	0	0	-	29
United Arab Emirates	0	0	(1)	15	0	0	0	0	0	0
Total	**15,345**	**364,304**	**14,005**	**309,621**	**14,294**	**329,748**	**13,753**	**347,043**	**11,892**	**290,711**
Mean value	**$23,741/mt**		**$22,108/mt**		**$23,069/mt**		**$25,234/mt**		**$24,446/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) indicatesthat the weight < 500 kilograms.
Source: Food and Agriculture Organization of the United Nations, FishStat database, www.fao.org

Country	2005		2006		2007		2008		2009	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Angola	4	265	4	224	3	179	2	149	4	282
Argentina	9	504	9	656	11	503	88	2,668	85	3,376
Bahrain	0	0	0	0	0	0	(1)	9	0	0
Bangladesh	0	0	195	623	351	1,407	17	403	15	347
Brazil	157	2,292	118	1,894	131	2,313	113	2,825	85	2,338
Brunei Darussalam	12	82	0	0	4	21	0	0	0	0
Burma	2	23	0	0	0	0	0	0	0	0
Cambodia	(1)	5	0	0	0	0	0	0	0	0
Chile	39	1,639	13	570	4	158	0	0	5	194
China	1,349	20,753	381	5,306	409	6,712	347	5,898	289	6,265
China, Hong Kong	7,134	127,102	5,962	103,818	5,670	97,074	5,294	100,877	4,919	79,843
China, Macao	0	0	29	800	23	711	7	410	8	501
China, Taipei	1,141	8,875	974	9,514	903	8,082	846	7,910	913	8,059
Colombia	14	1,034	17	1,132	19	1,146	16	1,074	19	600
Congo, Dem. Rep. of the	1	53	(1)	20	0	0	(1)	10	0	0
Congo, Republic of	18	848	10	246	10	314	15	509	17	508
Costa Rica	0	0	0	0	10	69	0	0	0	0
Cuba	0	0	0	0	0	0	0	0	2	262
Djibouti	0	0	2	47	0	0	0	0	0	0
Ecuador	(1)	8	1	5	12	257	124	2,526	131	2,627
Gabon	0	0	0	0	5	298	20	470	0	0
Guinea	47	2,163	47	1,872	35	1,613	52	2,665	40	2,228
Guinea-Bissau	3	110	0	0	5	276	0	0	2	160
India	104	3,663	145	5,037	96	3,879	95	7,496	107	12,504
Indonesia	1,554	8,065	1,073	9,174	801	7,303	1,320	7,047	1,367	8,477
Iran	0	0	0	0	(1)	2	(1)	14	0	0
Japan	168	8,140	181	9,091	197	8,735	163	8,457	164	6,824
Kiribati	1	70	1	111	1	69	(1)	30	2	181

Table 3.3.2 Continued

Country	2005		2006		2007		2008		2009	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Kuwait	0	0	(1)	9	1	91	2	78	0	0
Liberia	3	296	3	271	3	253	4	310	4	415
Libya	1	59	1	52	0	0	0	0	0	0
Malaysia	37	196	50	239	107	554	31	334	30	291
Maldives	43	598	16	192	15	107	9	70	9	57
Marshall Islands	0	0	0	0	55	825	17	305	16	495
Namibia	0	0	0	0	0	0	0	0	8	296
Nigeria	1	25	0	0	0	0	0	0	0	0
Panama	97	3,544	78	2,600	66	4,836	61	2,615	47	3,310
Papua New Guinea	9	652	10	495	17	1,412	17	1,526	2	388
Philippines	0	0	0	0	77	948	38	130	0	0
Saint Pierre & Miquelon	0	0	0	0	2	10	0	0	0	0
Saudi Arabia	0	0	0	0	0	0	5	122	5	131
Senegal	2	8	48	2,678	2	14	0	0	0	0
Seychelles	7	56	6	67	9	86	2	29	7	167
Sierra Leone	0	0	0	0	0	0	0	0	(1)	15
Singapore	333	17,253	410	21,394	374	20,296	380	22,703	189	12,904
Solomon Islands	0	0	0	0	0	0	3	78	1	39
Somalia	0	0	0	0	(1)	3	0	0	0	0
South Korea	7	357	9	438	7	224	16	610	34	1063
Suriname	7	312	8	487	4	260	4	243	93	192
Thailand	44	1,916	18	772	74	763	20	866	19	758
Togo	21	1760	24	1847	28	1863	25	1722	31	2,430
United Arab Emirates	539	14,381	427	13,592	472	13,965	515	16,220	466	15,080
Uruguay	39	570	27	509	21	324	22	335	17	269
Vanuatu	0	0	0	0	0	0	40	179	0	0
Venezuela	20	351	7	21	2	21	0	0	7	53
Yemen	179	5,846	284	8,442	351	11,333	228	10,760	214	9,065
Total	**13,146**	**233,874**	**10,588**	**204,245**	**10,387**	**199,309**	**9,958**	**210,682**	**9,373**	**182,994**
Mean value	**$17,685/mt**		**$19,764/mt**		**$19,922/mt**		**$20,919/mt**		**$19,523/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	2005	2006	2007	2008	2009
Bangladesh	1	4	0	266	276
Brazil	157	118	131	226	170
China, Hong Kong SAR	NA	NA	NA	NA	NA
China, Taipei	137	117	36	89	12
Ecuador	NA	1	12	124	131
El Salvador	149	194	44	0	19
Fiji Islands	160	160	0	0	0
Guyana	151	123	125	131	132
India	1,926	270	172	1,232	1,624
Indonesia	1,554	1,073	1,360	1,320	1,367
Korea, Republic of	7	33	7	16	34
Madagascar	NA	NA	NA	NA	NA
Maldives	13	11	11	9	9
Pakistan	81	62	69	78	80
Philippines	84	71	78	38	45
Senegal	34	27	16	22	27
Singapore	320	120	170	260	218
Sri Lanka	80	80	80	50	60
Uruguay	43	0	7	25	0
Yemen	179	284	351	228	214
TOTAL (mt)	**5,076**	**2,748**	**2,669**	**4,114**	**4,418**

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.

For example, in order to promote data collection in Mexico, NMFS Southwest Fisheries Science Center (SWFSC) and Southwest Regional Office (SWRO) began a multiyear effort with collaborators at Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) to coordinate artisanal fish camp monitoring and sampling in Baja California, Mexico, and help advance cooperative stock assessment efforts with Mexico, United States, and Inter-

American Tropical Tuna Commission (IATTC) scientists. CICESE scientists are conducting data collection for blue, shortfin mako, and thresher sharks at fish camps throughout Baja California. The 2011 sampling effort was completed in February 2012 and culminated with a workshop held February 21–22, 2012, at CICESE in Ensenada. The 2011 sampling was extensive and now supplements a time series begun as part of an earlier collaboration with investigators at Scripps Institution of Oceanography and CICESE. As a result of the new sampling program, fishery data for pelagic sharks now includes some size and sex sampling as well as several years of species-specific catch information. The sampling reaches over a dozen artisanal fish camps and also includes sampling of the mid-size longline fleet at the larger ports and complete coverage of a single swordfish drift gillnet vessel operating out of Ensenada. The data collected thus far are the most comprehensive species-specific pelagic shark fishery data from Baja Mexico and form the basis for what we hope will continue as an annual time series. The first U.S.–Mexico collaborative shark stock assessment is being conducted on the common thresher shark. While past analyses suggest that the population is rebounding after declines in the early 1980s, no official stock assessment has been conducted and analyses to date have only included data from the United States through 1999. Modeling efforts advanced significantly during the 2-day February 2012 workshop, and the assessment is expected to be completed later in 2012. Preliminary analyses confirm previous indications that the stock biomass may be increasing.

4.2 Regional Efforts

The U.S. Government continues to place priority on shark conservation and management globally and works within 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, The United States is a party to ICCAT, NAFO, CCAMLR, WCPFC, IATTC, ISC, and the South Pacific Tuna Treaty. Eight of the organizations or programs listed have adopted finning prohibitions: ICCAT, NAFO, WCPFC, IATTC, IOTC, GFCM, SEAFO, and NEAFC. Recent activities or planning of the RFMOs to whichthe United States is a Party are discussed below as a supplement to last year's Report to Congress.

Northwest Atlantic Fisheries Organization (NAFO)

At its 27th Annual Meeting in September 2005, NAFO 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. At the 33rd Annual Meeting in September 2011, the NAFO Fisheries Commission adopted revisions to its bycatch reporting provisions to require that all sharks be reported at the species level. However, when species-specific reporting is not possible, shark species can be recorded as either large sharks or dogfishes. This is a major step forward with gaining better information on shark byactch in NAFO fisheries.

In addition, 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 (TAC) for skates in Division 3LNO (the "nose" and "tail" of the Grand Bank) was initially set at 13,500 metric tons, for each of the years 2005–2009. This TAC was subsequently reduced to 12,000 mt for 2010 and 2011 and reduced again to 8,500 mt for 2012.

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)

<u>Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)</u>

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 managed 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.

In 2011, the United States proposed a prohibition on shark finning in the CCAMLR convention area, calling for all sharks that are retained to be landed with their fins naturally attached. Consensus could not be reached on this proposal.

Inter-American Tropical Tuna Commission (IATTC)

In August 2010, the IATTC convened the first 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. In May 2011 and December 2011, the IATTC convened their second and third technical meetings on sharks. The objectives of the workshops were to continue to develop a stock assessment model for silky sharks (*Carcharhinus falciformis*) in the EPO, identify collaborators and data sources, and collate data. NOAA scientists are contributing to ongoing work on silky shark stock structure in the EPO and participating in the assessment efforts.

During the 2011 IATTC Meeting in La Jolla, California, Resolution C-11-10 on the Conservation of Oceanic Whitetip Sharks Caught in Association with Fisheries in the Antigua Convention Area was approved. The resolution prohibits retaining onboard, transhipping, landing, storing, selling, or offering for sale any part or whole carcass of oceanic whitetip sharks (*Carcharhinus longimanus*) in the fisheries covered by the Antigua Convention. In addition, vessels will promptly release unharmed, to the extent practicable, whitetip sharks. This resolution entered into force in January 2012.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

Science

Assessments of Atlantic shortfin mako (*Isurus oxyrinchus*) and blue sharks (*Prionace glauca*) 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, the 2008 assessment indicated 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. NMFS determined that North Atlantic shortfin mako is not overfished, but is approaching an overfished status and is experiencing overfishing.

In 2008, the SCRS also conducted ecological risk assessments for 10 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. 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 the International Council for the Exploration of the Sea (ICES) conducted a joint assessment of porbeagle shark (*Lamna nasus*) 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.

In 2011, the SCRS conducted a Data Preparatory Meeting aimed at collecting and synthesizing all available information on fishing operations and life history of Atlantic pelagic shark species in preparation for an updated and extended Ecological Risk Assessment to be completed in 2012. In addition, new information on fisheries, relative abundance, and life history of the shortfin mako was also reviewed during this meeting in preparation for a stock assessment to be carried out in 2012.

Management

In 2004, ICCAT adopted a recommendation that prohibits finning by requiring full utilization of sharks and specifying that the total weight of shark fins onboard a vessel must not exceed 5% of the total carcass weight. This measure also requires all parties to annually report catch and effort data for sharks, in accordance with ICCAT data reporting procedures.

At ICCAT's 2008 annual meeting, several shark-related proposals were presented and two were adopted. The first proposal called for ICCAT and ICES to coordinate the assessment of porbeagle sharks, which occurred in June 2009, in Copenhagen, Denmark (see above). The second measure adopted by ICCAT in 2008 requires the release of bigeye thresher sharks (*Alopias superciliosus*) caught in association with fisheries managed by ICCAT and that are still alive when brought to the vessel.

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. ICCAT adopted a measure to prohibit retention of all species of hammerhead sharks (*Sphyrna spp*) (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, 2010, and again in 2011, Belize, Brazil and the United States submitted a proposal to require that all sharks be landed with their fins naturally attached. During the discussion of the 2011 proposal, several amendments were suggested by other parties (e.g., limiting the scope of this measure to fresh product; exempting parties that have 100% dockside monitoring.) However, there was no consensus on the measure either with or without the proposed amendments, and the proposal was not adopted.The issue is expected to be reconsidered at ICCAT's 2012 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. Competing EU and Canadian proposals were introduced again in 2011, but as in the previous year, 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.

In 2011, ICCAT adopted a recommendation, co-sponsored by the United States, which requires the release of silky sharks caught in association with ICCAT fisheries as well as the prohibition of retention on board, transshipment, and landing of the species. There are limited exceptions for developing coastal states that retain silky sharks for food, as well as for parties that prohibit silky shark fisheries and whose domestic law requires all dead fish be landed and prohibits fishermen from realizing any commercial profit from such fish. Parties not reporting species-specific data for sharks must submit a data collection improvement plan by July 2012. These plans will be evaluated by the SCRS.

Western and Central Pacific Fisheries Commission (WCPFC)

At its 5th Regular Session of the Commission 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 6th Regular Session of the Commission in December 2009, the Commission amended the 2008 measure to include silky shark on the list of key species and at the 7th Regular Session of the Commission in December 2010, the Commission amended the measure to include porbeagle and hammerhead sharks on the list of key species. This amendment raises the number of key shark species to be reported to the Commission to 13 but maintains the original 8 key species as the focus of the Shark Research Plan until further funding is made available.

Joint Meeting of Tuna Regional Fisheries Management Organizations

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. 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.

Kobe III – The Third Joint Meeting of the Tuna Regional Fisheries Management Organizations

Held in La Jolla, California, in July 2011, the Kobe III meeting was preceded immediately by the first meeting of the Bycatch Joint Technical Working Group. The Kobe III meeting recognized the work of the bycatch working group and recommended the meeting report be transmitted to each of the five tuna RFMOs for their consideration.

The Bycatch Joint Technical Working Group had broad discussions in the areas of data. Sharks, including ecological risk assessment, stock assessment and by-catch, emerged as a key issue for immediate consideration within RFMOs with participants noting that the issue was broader than by-catch and needed to acknowledge that full stock assessment should be conducted for those shark species where data are available. For those species lacking data, consistent with the FAO IPOA-Sharks, precautionary, science-based conservation and management measures for sharks should be taken in fisheries within each tuna RFMO, including as appropriate: (1) measures to improve the enforcement of existing finning bans; (2) prohibitions on retention of particularly vulnerable or depleted shark species, based on advice from scientists and experts; (3) concrete management measures in line with best available scientific advice with priority given to overfished populations; (4) precautionary fishing controls on a provisional basis for shark species for which there is no scientific advice; and (5) measures to improve the provision of data on sharks in all fisheries and by all gears. The Working Group, with WCPFC and ICCAT taking the lead, also agreed to harmonize guidance for shark identification, in collaboration with the IUCN shark specialist group and others.

The Working Group noted that sharks (as well as other elasmobranchs such as skates and rays) are often targeted as well as taken as incidental catch. The Working Group noted the previous Kobe recommendations on sharks, and these should not be lost in any further discussion on sharks. Shark recommendations were:

1. The Working Group is concerned with the practice of intentional sets on whale sharks (*Rhincodon typus*), in RFMOs where there is evidence of the practice occurring, and recommends that tuna RFMOs initiate research to determine the impact and outcome of this practice.

2. RFMOs should conduct risk assessment processes to develop their priorities for shark species which may need further assessment or mitigation. RFMOs may wish to consider the WCPFC key shark nomination processes.
3. RFMOs should take action to improve data collection on sharks, manta rays, and devil rays in targeted industrial and artisanal fisheries. As an example, the Working Group noted that a fins naturally attached requirement would improve species identification and enforcement and should be considered as part of existing shark finning bans.
4. RFMOs should consider supporting studies to investigate post-release survival of sharks in longline fisheries in relation to hook type and duration of set, among other factors.
5. RFMOs should consider supporting studies to further develop shark by-catch mitigation strategies for longline fisheries.
6. RFMOs should evaluate the costs and benefits of banning the use of wire leaders in tuna longline fisheries.
7. RFMOs should develop handling and release protocols for all sharks and manta and devil rays, taking into consideration the safety of the crews.

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

The Tenth Plenary session of the ISC 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 asrequired 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 (*Alopias pelagicus*), silky, oceanic whitetip, hammerhead, and any other shark species for which stock assessments may be needed. Theworking group will collaborate with other RFMOs of the Pacific and initially focus on stockassessments of blue and shortfin mako shark. Scientists from NMFS's SWFSC and Pacific Islands Fisheries Science Center (PIFSC) were nominated to work with other international scientists and the ISC Chairman inorganizing the first meeting of the working group.

The Eleventh ISC Plenary, held in San Francisco from 20-25 July 2011, was attended by members from Canada, Chinese Taipei, Japan, Korea, Mexico, and the United States as well as a member of the WCPFC Secretariat. The first meeting of the newly formed Shark Working Group was held in April, 2011 in Keelung, Chinese Taipei. The Plenary endorsed the work plan of the Shark Working Group developed at the April 2011 meeting and the prioritized list of ISC shark species of interest. Blue and shortfin mako sharks were ranked as the highest priorities based on interactions in North Pacific high-seas fisheries. The Shark Working Group met again at the SWFSC in La Jolla in late November 2011 to advance efforts on a North Pacific blue shark assessment, planned for completion in early 2013. The ISC Shark Working Group also sponsored a Shark Age and Growth Workshop at the SWFSC in La Jolla in December 2011 to address uncertainties in ageing pelagic sharks and establish collaborations.

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 onthe 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 Partiesin 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 (*Carcharhinusplumbeus*)) 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 EU 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 EU 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 National Plans of Action for the Conservation and Management of Sharks on FAO's website: Argentina, Australia, Canada, Ecuador, Japan, Malaysia, Mexico, Seychelles, Taiwan, the United Kingdom, the United States, Uruguay, and the Mediterranean Sea**.**

At the 29th Session of COFI, held January 31-February 2, 2011, the Committee, based on a request from the UNGA, requested FAO to prepare a report on the extent of the implementation of the 1999 FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks), and the challenges being faced by Members in implementing the instrument, for presentation to the 30th Session of COFI which will be held in July 2012.

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, including two NMFS representatives. 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.

United Nations General Assembly (UNGA)

The United States continues to work within the United Nations General Assembly (UNGA) process to develop specific calls to States and RFMOs to strengthen conservation and management measures for sharks. The United States was also successful in negotiating specific language for the conservation and management of sharks at the United Nations Fish Stocks Resumed Review Conference in 2010. 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 language and recommendations specific to sharks in the annual UNGA sustainable fisheries resolutions, including some aimed at reducing bycatch and inproving data collection. Since 2005, provisions have been adopted every year that call on States and RFMOs to significantly improve the conservation and management of sharks, including a call for sharks to be landed with their fins naturally attached.

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

The CMS, also known as the Bonn Convention, 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 at the time this report was written has 117 parties.Migratory species threatened with extinction are listed on Appendix I of the Convention. CMS Parties strive towards strictly protecting these animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them. Migratory species that need or would significantly benefit from international co-operation are listed in Appendix II of the Convention. For this reason, the Convention encourages the Range States to conclude global or regional agreements for those species.

There are several shark species listed on the CMS Appendices. The basking shark (*Cetorhinus maximus*), and great white shark (*Carcharodon carcharias*), as well as the manta ray (a non-shark species of elasmobranch) are listed under Appendix I. The whale shark (*Rhincodon typus*), basking shark, great white shark, shortfin mako (*Isurus oxyrinchus*), longfin mako (*Isurus paucus*), porbeagle, and the northern hemisphere populations of the spiny dogfish are listed under Appendix II.

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 (Congo, Costa Rica, Ghana, Guinea, Kenya, Liberia, Palau, Philippines, Senegal, and Togo), signed a global Memorandum of Understanding (MOU) for Migratory Sharks under the auspices of the Convention on Migratory Species. In 2011, twelve additional States (Nauru, Tuvalu, Australia, Chile, South Africa, Belgium, Denmark, Germany, Italy, Netherlands, Romania, and Monaco) and the European Union signed the MOU. The MOU aims to coordinate international action on the threats faced by sharks and works to improve their species conservation status. The MOU came into effect March 1, 2010 and it 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. The First Meeting of the Signatories will be held in September 2012 in Bonn, Germany.

West Africa Observer Training Workshops

NMFS' Offices of International Affairs and Science and Technology began capacity building efforts in West Africa in 2008. Several countries requested assistance in improving their observer program or developing a new program. In 2008, NMFS partnered with the Ministry of Fisheries in Ghana to provide observer training. Since the initial training workshop, additional workshops have taken place in Dakar, Senegal; Libreville, Gabon; and Monrovia, Liberia. As part of these workshops, fisheries personnel are trained in data collection on board commercial fishing vessels, safety-at-sea, and the identification of marine fish and sea turtles.

In addition, a one-day elasmobranch identification training session is given to all attendees.The elasmobranch training session includes a presentation on the most commonly occurring shark species in the respective area. Identification guides specific to West Africa are distributed and attendees are trained with specimens to use the identification guide. Finally, observers are instructed on measurement and biological sampling techniques. Workshop attendees are also shown how to remove spines or vertebrae for ageing, gonads for reproductive analysis, and stomachs for diet studies.

Eastern Pacific Ocean (EPO) Regional Workshops

The United States has worked cooperatively with Governments in the EPO 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 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 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 who could provide funds for the themes described above.

The third EPO 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 ontheir biology and the numbers caught (either as target species or bycatch)to make sure their populations are not depleted. NMFS Fisheries Science Centers are investigating shark catch, abundance, age, growth, diet, migration, fecundity, and requirements for habitat. Additional research aims to identify fishing methods that minimize the incidental catch of sharks and/or maximize the survival of captured sharks after release. A summary of the research completed in 2011 is presented here, but more complete descriptions of recent research are 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. 2011). 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 DataNMFS produced standardized CPUE time series for use as input for stock assessments for blue, whitetip, and silky shark in the Hawaii longline fishery using the Pacific Islands Regional Observer Program data (1995–2010) (Walsh and Clarke, 2011). This work is important because these species are taken in large but unknown numbers, primarily as bycatch, in many Pacific Ocean fisheries. The standardized CPUE for blue shark was adjusted for the effects of extrinsic factors (e.g., geographic position, sea surface temperature, and gear configuration), and will be used in an International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) stock assessment for this species in 2013.

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 mostly biennial (now triennial) 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 (2000–2010), the main Hawaiian Islands (2005–2010), the Pacific remote island areas (2000–2012), American Samoa (2002–2012), Guam and the Commonwealth of the Northern Marianas Islands 2003–2011), Johnston Atoll (2004–2012), and Wake Atoll (2005–2011).

Although 11 species of shark have been observed during CRED surveys (Table A.1.1), only four species are typically recorded by toweddivers in sufficient frequency to allowmeaningful analyses: grey reef shark (*Carcharhinus amblyrhynchos*), Galapagos shark(*Carcharhinus galapagensis*), whitetip reef shark(*Triaenodon obesus*), and blacktip reef shark(*Carcharhinus melanopterus*).

Similar to reports from previous years, spatial analyses show a highly significant negative relationship between gray reef and Galapagos shark densities and proximity to human population centers (e.g., proxy for potential fishing pressure and other human impacts).Even around islands with no human habitation but within reach of populated areas, gray reef and Galapagos shark densities are significantly lower. Trends in whitetip and blacktip reef shark numbers are similar but less dramatic (I.D. Williamset al., 2011). Analyses through time (~ 12 years) suggest 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.

Insular Shark Population Model

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

The shark count data were used to build a computer model capable of explaining observed reef shark abundances at various reefs by examining the effects of variables related to human impacts, oceanic productivity, sea surface temperature, and reef habitat physical complexity. This model was used to predict reef shark densities in the absence of humans (i.e., baseline or pristine abundance) and found that current reef shark numbers around populated islands in Hawaii, the Mariana Archipelago, and American Samoa are down to about 3% to 10% of their baseline values (Figure 5.1.1). These results show the extent of the detrimental effect of humans on reef shark population. However, the exact cause of the decline could not be determined. The likely causes are probably related to prey population depletion (i.e., reef fish biomass around populated islands is about 70% lower than on pristine reefs) and direct removal through fishing (bycatch, recreational, or targeted) (Nadon et al. 2012).

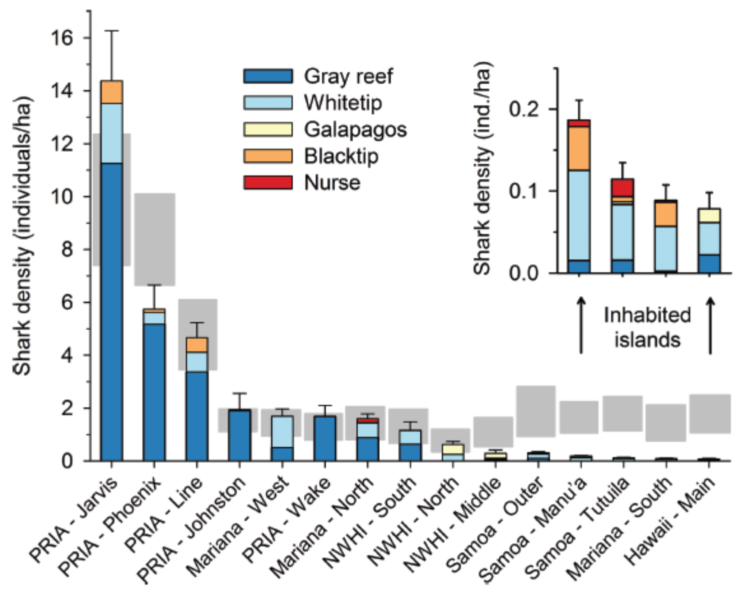

Figure 5.1.1. Mean (SE) observed densities of reef sharks in the U.S. Pacific. Colors represent actual densities; gray rectangles represent model predictions in the absence of humans.

Age Validation using Bomb Radiocarbon Dating

PIFSC scientists in collaboration with Northeast Fisheries Science Center (NEFSC) led a recent study to validate age estimates for the sandbar shark (*Carcharhinus plumbeus*), a cosmopolitan species of subtropical and tropical seas. The sandbar shark was the cornerstone species of western North Atlantic and Gulf of Mexico coastal bottom longline fisheries until 2008, when they were allocated to a research-only fishery. Despite decades of fishing on this species, important life history parameters, such as age and growth, have not been well known. Results from both tag-recapture data and bomb radiocarbon dating show longevity to exceed 30 years for this species (Andrews et al., 2011). The findings of this study indicated there was missing time in the growth structure of the vertebrae for this species, leading to an underestimation of longevity by more than 10 years.

PIFSC (with Southeast Fisheries Science Center) is currently involved in a project funded by the NMFS Office of Protected Resourcesthrough their Species of Concern Program to validate the age, growth, and longevity of sand tiger shark (*Carcharias taurus*). Preliminary results from bomb radiocarbon dating indicate a similar scenario, with vertebrae reaching a certain size limit and no noticeable or measureable growth beyond this size. Hence, age of large adult sand tiger sharks and longevity of the species have been underestimated by at least 15 years. At this time, additional samples are being analyzed to provide a more specific estimate of the missing time. In addition, alternate vertebrae preparation techniques are being explored to determine whether a micro-increment structure may account for the observed discrepancy in age and longevity.

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

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

Reducing shark predation on pups at FFS is one of several key activities identified in the Hawaiian Monk Seal Recovery Plan (NMFS 2007).Since 2000, NMFS has attempted to mitigate shark predation through harassment and culling of sharks, shark deterrents,and translocation of weaned pups to islets in the atoll with low incidence of shark attacks (Baker et al. 2011; Gobush 2010). NMFS implemented a highlyselective shark removal project to mitigate predation on monk seal pups from 2000-2012, with the exception of 2008–2009 when deterrents were tested (see appendix for more details). A total of 14 Galapagos sharks frequenting the nearshore areas of pupping islets have beenlethally removed to date. In 2009, the number of shark sightings and predation incidents at two pupping isletsdid not differ significantly between the control and two experimental treatments: (1) acoustic playback and a moored boat, and (2) continuous human presence, versus a control(Gobush and Farry 2012).

Southwest Fisheries Science Center (SWFSC)

Abundance Surveys

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

In 2011, the SWFSC conducted its 18th 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/VVentura II,* a total of 5,493 hooks were set inside seven focal areas during 27 daytime sets. Survey catch totaled 61 shortfin makos, 49 blue sharks, five pelagic rays (*Pteroplatytrygon violacea*), four opah (*Lampris guttatus*), and one common mola (*Mola mola*). The preliminary data indicate that the nominal survey catch rate was 0.28 per 100 hook-hours for shortfin mako and 0.22 per 100 hook-hours for blue sharks. The nominal CPUE for both blue and shortfin mako sharks were slightly higher than the previous year. However, while more detailed analyses are needed, there is a declining trend in nominal CPUE for both species over the time series of the survey (see Figure A1.3 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 abundance and has been conducted in each year since. In 2011, the SWFSC team worked aboard the *F/V Outer Banks* to conduct 47 longline sets with a total of 4,800 hooks in shallow, nearshore waters. The preliminary survey data indicate that the average nominal catch rate was 5.57 threshers per 100 hook-hours. This is the highest catch rate since the inception of the sampling program. Overall, 391 common thresher sharks were tagged and 409 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 2011, two shortfin mako sharks, five blue sharks, and two basking sharks (*Cetorhinus maximus*) were tagged with either SPOT tags or towed GPS tags. Of the five tags deployed on blue sharks, those deployed on smaller sharks (~165 cm fork length) lasted for an average of 62 days, whereas the tag deployed on a large male (226 cm fork length) lasted for almost 6 months. One tag deployed in 2010 continued to transmit through 2011, providing over a year of data. For mako sharks, five tags were still transmitting in late 2011: two from 2009, one from 2010, and twofrom 2011. The multiyear records reveal that mako sharks return to specific neighborhoods in successive years, with different sharks preferring different regions (see Figures A1.4 and A1.5 in Appendix 1).

Age Validation Studies
Age and growth of mako, common thresher, and blue sharks are being estimated from band formation in vertebrae. In addition to being important for studying basic biology, accurate age and growth curves are needed in stock assessments. SWFSC scientists are validating ageing 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 the beginning of the program in 1997, 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. An analysis of juvenile mako shark band deposition patterns was recently completed. Results from band counts of vertebrae indicate two band pairs are formed per year for shortfin mako of the size range examined (see Figure A1.6 in Appendix 1).

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. A synthesis comparing the foraging ecology of shortfin mako, blue, and common thresher sharks was recently completed and published in *Environmental Biology of Fishes* (Preti et al. 2012).Despite similarities in life history characteristics and spatial and temporal overlap, diets of these three species are strongly differentiated, indicating niche separation.

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 United States 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, California (see section 2.5). A dedicated website and hotline have been established as part of a sightings network. This information will help document patterns of occurrence and tagging efforts. A tri-nation team was formed with colleagues in Canada and Mexico to coordinate research efforts. The second meeting of the team was held in May 2011. Finally, two satellite tags were deployed on basking sharks off San Diego. One released early and was recovered in San Diego. The second tag popped off northeast of Hawaii in February, 8 months after it was deployed, highlighting the need for an international approach to management and conservation (see Figure A1.7 in Appendix 1).

Population Genetics Studies
An ongoing study using mitochondrial DNA control loop sequences to determine Pacific shortfin mako shark stock structure has been updated with additional samples collected in the western Pacific and is being prepared for publication. Results show a single stock in the North Pacific, and distinct eastern and western stocks in the South Pacific. The results have been reviewed by the ISC Shark Working Group and form the basis for the stock boundaries that will be used in their upcoming shortfin mako assessment. In addition to studies of stock structure, these markers will be used to develop estimates of effective population size within the California Current region. The SWFSC is also collaborating on population genetics studies on a number of other pelagic shark species, including common thresher, pelagic thresher, silky, and blue sharks. Results from both silky and pelagic thresher sharks reveal stock structure in the Pacific Ocean.

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 Pacific Fishery Management Council (PFMC) for use in management. The NWFSC conducted an assessment of spiny dogfish along the Pacific coast of the United States in 2011 (see section 2.3).

Movement Research

Over the past decade, the NWFSC has conducted extensive research on localized movements and seasonal migrations of three West Coast sharks: the bluntnose sixgill (*Hexanchus griseus*), broadnose sevengill (*Notorynchus cepedianus*), and northern spiny dogfish (*Squalus suckleyi*)(Andrews et al. 2007, 2009, 2010; Levin et al. 2012; Williams et al. 2011, 2012). These studies made use of acoustic tags, active tracking methods, and passive acoustic receiver arrays within estuaries and along coastal waters. Capture data, tracking data, and stable isotope data indicated that the population of sixgill sharks in Puget Sound is largely juveniles that remain resident for several years, while mature females appear to enter Puget Sound to pup. Active tracking methods revealed individual sixgill shark home range sizes and regular diel vertical migration patterns. Sevengill sharks made extensive use of coastal estuaries and shelf waters along the West Coast, and their movements and habitat use were related to season, sex, and size. Sevengill sharks appeared to display site fidelity, returning to the same areas of the same estuaries in several consecutive years. Puget Sound dogfish appear to undergo seasonal migrations, departing to waters along the West Coast in winter and spring months.

Spiny Dogfish Bioenergetics

The NWFSC developed an energy budget (bioenergetics) model for spiny dogfish based on published physiology data, in order to characterize predatory demands and to estimate how those demands might change owing to climate change effects on dogfish metabolic rates. This model is also being used to quantify how predatory impact is reduced in Puget Sound when the spiny dogfish population migrates out of the system in the winter and spring months (Harvey 2009).

<u>Alaska Fishery Science Center (AFSC, Auke Bay Laboratory)</u>

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

Stock assessments are currently completed on the shark species most commonly encountered as incidental catch: Pacific sleeper sharks (*Somniosus pacificus*), spiny dogfish (*Squalus suckleyi*), and salmon sharks (*Lamna ditropis*). In both the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) fishery management plans, sharks are managed as a complex. Directed fishing for all sharks is prohibited. Most shark species are considered Tier 6, where annual catch limits are based on estimated historical incidental catch. In the GOA, spiny dogfish is currently Tier 5, with annual catch limits based on biomass and natural mortality. Stock assessments are summarized annually and are available online (see Tribuzio et al. 2011a and 2011b).

Trophic Ecology of Pacific Sleeper Sharks in the Eastern North Pacific Ocean

Stable isotope ratios of nitrogen ($\delta^{15}N$) and lipid normalized carbon ($\delta^{13}C'$) were used to examine variability in the trophic ecology of Pacific sleeper sharks (Courtney and Foy 2012). Models identified significant variability in muscle tissue $\delta^{15}N$ values (3.3–5.7) across locations and across life stages, but the uncertainty was high (95% prediction intervals were 2.9–6.4). These results are similar to previously published results based on stomach content data.

Migration and Habitat Use of Spiny Dogfish and Pacific Sleeper Sharks

During 2003–2006, scientists deployed 138 numerical Floy tags, 91 electronic archival tags, 24 electronic acoustic tags, and 17electronic satellite popup tagson Pacific sleeper sharks (Courtney and Hulbert 2007).Two numerical tags and 10 satellite tags have been recovered. Information on temperature, depth, and movement will be used to identify habitat and potential interactions with other species. Analysis of tagging data is ongoing.

Since 2009 scientists from Auke Bay Laboratory (ABL) have deployed 80 pop-off archival tags on spiny dogfish in the GOA and will deploy an additional 90 tags in the summer of 2012 throughout the GOA and south to Washington State. Data have been successfully recovered from 70 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 results will elucidate the degree to which GOA spiny dogfish populations mix with other populations. Preliminary results suggest a general westward movement between August and December, with some animals moving south to waters off the coast of California. The data are showing a strong daily migration between deeper and shallower waters.

Age and Growth Methods
Scientists at Auke Bay Laboratory and AFSC's Resource Ecology and Fisheries Management Division age and growth lab will expand on a pilot study investigating a potential new method for ageing of spiny dogfish. The new method, which uses the vertebrae and histological staining, has been applied to spiny dogfish from the U.S. East Coast in efforts to reduce the uncertainty of age estimates. Scientists are working to establish a captive population of spiny dogfish, which will be used to validate the histological ageing methods, and generate improved age-at-length data that will be used to re-estimate growth models used in stock assessments. The second purpose of this study is to establish a method for ageing Pacific sleeper sharks. This new method has been successful on Squaloid sharks in the North Atlantic, and there is some suggestion that it will work for Pacific sleeper sharks.

Life History and Demographic Studies
The purpose of this study was to examine the basic life history of a lightly exploited stock of spiny dogfish in the GOA to establish a baseline for future comparison and to provide criticalinformation for stock assessments (Tribuzio and Kruse 2011, 2012). The delayed age of maturity, low natural mortality, and low rates of reproduction (see appendix for details) implythat only very low rates of fishing mortality are sustainable.

Demographic models may be an appropriate alternativeto cohort analyses for sharks due to their life history. In this study, age- and stage-based demographicanalyses were conducted to examine the intrinsic rebound potential (r) and potential risk of fishing for spiny dogfish in the GOA. For an unfished population, r was estimated to be 0.02–0.03 per year. Fishing mortalities (F) of F=0.04 and0.03 (age- and stage-based models respectively) resulted in r=0, indicating that populations fished at higher F are notsustainable. Harvest strategies targeting juveniles (age-based model) and subadults (stage-based model) caused the highestrisk of the population falling below defined thresholds after 20 years. Both models provided similar results, suggesting that the stage-based model is anappropriate substitute for the age-based model in this case.

ModelingSpiny Dogfish Distribution
The spiny dogfish is a common incidental catch species in commercial longline fisheries in the GOA. A better understanding of areas of high incidental catch would provide critical information to fishery managers, whether they seek to convert discards into fishery landings or to

manage fishing mortality. The spatial distribution of the spiny dogfish from fishery-dependent and fishery-independent data collected between 1996 and 2008 showed that longline catches were concentrated east of Kodiak Island, with increased spatial homogeneity between the eastern and western GOA. The number of dogfish caught generally showed a decreasing trend with increasing depth.

World Market Analysis of the Spiny Dogfish
The spiny dogfish is a globally distributed shark species that is an important trade commodity for Europe and Asia. Data on trade, capture, and informal interviews with dogfish suppliers were used to characterize market channels and sources of demand in Asia and Europe. Future increases in market share for dogfish will require differentiating the product from potential substitutes while using eco-labeling and marketing to inform consumers. In cooperation with the NMFS Alaska Regional Office, the University of Alaska Fairbanks School ofFisheries and Ocean Sciences was funded to study the policy implications of a spiny dogfish fishery in Alaska (Gasper 2011).

Policy Perspective of the Spiny Dogfish Market in Alaska
The purpose of this study is to describe historical dogfish harvests in Alaska and provide an analysis of potential harvest given the current and future regulatory environment. A robust dogfish market in Alaska is unlikely to occur unless regulations allow directed fishing. Such a regulatory change may create incentives to use dogfish as a guise to harvest other, more valuable species. In developing management options, agencies must establish target and limit reference points for fishing mortality commensurate with the vulnerability of this species to overfishing.

Northeast Fisheries Science Center (NEFSC)
Collection of Recreational Shark Fishing Data and Samples
The NEFSC has been attending recreational shark fishing tournaments since 1961,compiling data on species, sex, and size of the captured sharks as well as collecting biological samples for pelagic and coastal sharks. In 2011, biological samples and catch data for more than 150 pelagic sharks were collected at nine tournaments in the northeastern United States.

Pelagic Nursery Grounds
Pelagic shark biology, movements, and abundance studies continued in 2011 with further investigations of pelagic nursery grounds in collaboration with the high seas commercial longline fleet; an additional 250 sharks were tagged, bringing the total to over 2,750 with 190 recaptured.

Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program
Comprehensive and standardized investigations of coastal shark nursery habitat have been completed in Atlantic coastal waters from Florida to Massachusetts and in the USVI. In 2011, COASTSPAN participants included four state agencies (Georgia, Massachusetts, North Carolina, and South Carolina) as well as the University of North Florida. A collaborative study is ongoing between NMFS and the Massachusetts Division of Marine Fisheries (MDMF) to investigate the spatial and temporal use of nursery habitat by neonatal blacktip (*Carcharhinus limbatus*) and lemon (*Negaprion brevirostris*) sharks in two Baysin the USVI (Legare et al. 2011).

Juvenile Shark Survey for Delaware Bay Sandbar Sharks (Carcharhinus plumbeus)
The juvenile sandbar shark population in Delaware Bay is surveyed as part of COASTSPAN program. In 2011, a total of 286 sandbar sharks were caught and released with conventional tags.

Delaware Bay Sand Tiger (Carcharias taurus) Survey
This survey aims to identify essential fish habitat (EFH) and monitor abundance and size composition to allow for comparison between historic and current abundances. In 2011, a total of 46 sand tigers were caught and released with conventional tags, bringing the total since the beginning of the survey to 206 sand tigers.

Galapagos Shark (Carcharhinus galapagensis)
Acollaborative study (NMFS, University of Massachusetts,and MDMF) on the life history and ecological role of the Galapagos shark in Bermuda will investigate size-at-age and age-at-maturity estimates as well astrophic position and diet shifts (via stable isotope analysis of muscle, liver, and vertebrae)(Eddy et al. 2011a).

White Shark (Carcharodon carcharias)
White shark vertebrae, collected by the NEFSC since 1963, were used for an age study in 2011 incollaboration from MDMF. For validation,five samples were processed for bomb carbon analysis in conjunction with researchers at Woods Hole Oceanographic Institution. In all but one case, these validated age estimates. Further testing is underway to fine-tune the analysis.

Dusky Shark (Carcharhinus obscurus)
A collaborative study on the genetic stock structure of the dusky shark,initiated to delineate management units and monitor trade, suggest that replenishment of the collapsed U.S. Atlantic management unit via immigration of females from elsewhere is unlikely (Benavides et al. 2011).

A revision of the age and growth of the dusky shark (with the Southeast Fisheries Science Center), using 150 new vertebrae, indicated that preliminary growth curves were similar to previous estimates. Preliminary results from one vertebra, processed for bomb carbon analysis, indicated that band pair periodicity was not annual. More samples are being processed.

Bull Shark (Carcharhinus leucas)
In 2011, in collaboration with the Florida Fish and Wildlife Conservation Commission, vertebrae from 124 bull sharks were collected and processed for age studies. The preliminary count was completed, but counts from a second reader need to be done.

Sandbar Shark (Carcharhinus plumbeus)
In collaboration with PIFSC, a bomb radiocarbon and tag-recapture dating study determined that current age estimates based on vertebrae are accurate to 10 or 12 years (Andrews et al. 2011). Ages of large adult sharks were underestimated with vertebrae counts.Both bomb radiocarbon and tag-recapture methods supported a longevity upwards of 30 years for this species.

Results from the non-lethal stomach eversion technique for sandbar sharks show great promise for trophic studies. This technique was considered effective at limiting sampling mortality, as

1.8%of 1,051 tagged and everted sharks were recaptured to date. The tag return rate and movements were similar to other studies on sandbar shark in the region.

Cooperative Shark Tagging Program (CSTP)
The CSTP provides information on distribution, movements, and EFH for shark species in U.S. Atlantic and Gulf of Mexico waters and involves thousands of volunteer fishermen, scientists, and fisheries observers since 1962. In 2011, information was received on 7,300 tagged and 415 recaptured fish, bringing the total numbers tagged to 230,000 sharks of more than 50 species and 13,600 sharks recaptured of 33 species.

Spiny Dogfish (Squalus acanthias) Tagging Study
To assess stock structure, movement patterns, and lifehistory of thespiny dogfish, the NEFSC is tagging sharks in two consecutive years during winter and summer in three regions: Southern New England, Gulf of Maine, and Georges Bank. In 2011, a total of nine cruises were conducted, with 16,034 sharks tagged and released.

Scalloped Hammerhead Shark (Sphyrna lewini) Movement Patterns
The objective of this study is to analyze mark/recapture data from the CSTP to investigate movement patterns and habitat selection, as well as the possible role that gender and age may play in determining these characteristics(Eddy et al. 2011b).

Southeast Fisheries Science Center (SEFSC)
Stock Assessments of Large Coastal, Small Coastal, Pelagic, and Prohibited Sharks
In 2011, SEFSC staff completed stock assessments of sandbar, blacknose (Gulf of Mexico and Atlantic), and dusky sharks under Southeast Data, Assessment, and Review (SEDAR) 21. As described in Section 2, the assessments found that dusky and Atlantic blacknose sharks were overfished with overfishing occurring, sandbar shark was overfished but overfishing was no longer occurring, and the status of the Gulf of Mexico blacknose shark could not be determined.

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 Fishery Management Plan have significantly modified the major directed shark fishery and implemented a shark research fishery. NMFS selects a limited number of commercial shark vessels (10 in 2011) on an annual basis to collect life history data and catch data for future stock assessments. Outside the research fishery,vessels targeting shark and possessing valid directed shark fishing permits were randomly selected for coverage with a target coverage level of 4% to 6%. In 2011, 121 trips with a total of 211 hauls were observed on the 10 vessels in the shark research fishery. Observations outside the research fishery comprised a total of 13 hauls from eight trips aboard five vessels. In the research fishery, sharks comprised 97.6% of the catch. Catch composition was 41.4% large coastal shark species (excluding sandbar), 47.3% sandbar shark, 8.3% small coastal shark species, 0.08% deep water sharks, and 0.01% pelagic sharks. For observations outside the research fishery, sharks comprised 96.2% of the catch. Large coastal shark species (excluding sandbar shark) comprised 48.7% of the shark catch, followed by small coastal shark species (47.7%), sandbar sharks (3.2%) and other prohibited sharks (0.4%).

Since 1993, an observer program has been underway to estimate catch and bycatch in the direct and indirect shark gillnet fisheries along the southeastern Atlantic coast. A total of 402 sets comprising various gillnet fisheries were observed in 2011.

Habitat Use and Movement Patterns of Smalltooth Sawfish (Pristis pectinata)
Research on rare and threatened species is often limited by access to sufficient individuals to acquire information needed to design appropriate conservation measures. Using a synthesis of data from pop-off archival transmitting (PAT) tags across multiple institutional programs, movements and habitat use of endangered smalltooth sawfish were determined for animals from southern Florida and the Bahamas. All smalltooth sawfish generally remained in coastal waters within the region where they were initially tagged. Females showed significantly greater movements in fall and winter. Smalltooth sawfish spent the majority of their time at shallow depths (<10 m) and warm water temperatures (22°–28° C). The results underscore the importance of shallow, mangrove-lined coastal habitats to this critically endangered species.

Relative Abundance and Size of Coastal Sharks Derived from Commercial Data
While the status of commercially important species is available, abundance trends for other coastal shark species are unavailable. Relative abundance indices were derived from 1994 to 2009 using observer data collected in a commercial bottom longline fishery. Trends in abundance and average size were estimated for four shark species. Increases in relative abundance ranged from 14% for spinner shark (*Carcharhinus brevipinna*), 12% for bull shark (*C. leucas*), 6% for lemon shark (*Negaprion brevirostris*), and 3% for tiger shark (*Galeocerdo cuvier*). There was no significant change in the size at capturefor any of the species. While the status of populations should not be based exclusively on abundance trends, results from this study provide cause for optimism on the status of these species.

Elasmobranch Feeding Ecology
Studies are currently underway describing the diet and foraging ecology, habitat use, and predator–prey interactions of elasmobranchs. The diets of multiple shark species caught by commercial longline gear—including dusky (*Carcharhinus obscurus*), sandbar (*C. plumbeus*), silky (*C. falciformis*), and tiger (*Galeocerdo cuvier*) sharks—are currently being investigated. Along with basic diet analysis, stomach contents will be examined for evidence of line feeding, or depredation, on longline gear. This study will help to test the hypothesis that diet studies based on longline-caught animals could be biased due to longline depredation.

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. A database currently includes over 10,000 tagged animals and 205 recaptured animals from 1993 to the 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 2013.

Monitoring the Recovery of Smalltooth Sawfish (Pristis pectinata)
The smalltooth sawfish was the first marine fish listed 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**.**Surveys identify the presence or absence of neonates, young-of-the-year, and juveniles in southwestFlorida.

Life History Studies of Elasmobranchs
Age, growth, and reproduction of blacktip sharks (*Carcharhinus limbatus*) in the Gulf of Mexico were reanalyzed for SEDAR 29. Data were collected from over 750 sharks during 2006–2011. In collaboration with the NMFS Mississippi Laboratory and the University of Southern Mississippi, age, growth, and reproduction for the finetooth shark (*C. isodon*) in the Gulf of Mexico are being examined in anticipation of a stock assessment in the next 2years. Research with PIFSC to validate ageing in sand tiger shark (*Carcharias Taurus*) using bomb radiocarbon analysis was begun in 2011. Endangered smalltooth sawfish were aged by counting opaque bands in sectioned vertebrae with the estimated age ranging from 0.4 to 14.0 years.

Cooperative Research: Uruguay–U.S.Pelagic Shark Research Project
A collaborative project with Uruguay's fisheries agency (DINARA) aims to advance knowledge on the susceptibility of pelagic sharks to longline fisheries in the western South Atlantic. Eight satellite tags have been deployed on blue sharks to date. An identification guide for carcharhinid sharks of the Atlantic Ocean was created in 2011 (ICCAT 2012).

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 (29 surveys have been completed through 2011). 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.

<u>NOAA Chesapeake Bay Office</u>
Life History, Trophic Ecology, and Prey Handling by Cownose Rays (Rhinoptera bonasus)
Perceived increases in the population of cownose rays that use Chesapeake Bay, coupled with increases in damage to shellfish culture, grow-out, and restoration operations, have generated growing interest in management of cownose rays, including the development of a commercial fishery for the species. To better understand the biology and ecology of this species, NOAA's Chesapeake Bay Office provided funding to the Virginia Institute of Marine Science for a 3-year study that will document the age and growth and predation for cownose rays, focusing on the population that usesthe Chesapeake Bay for pupping and mating during summer months. Male and female rays were found to reach sexual maturity between ages 6and 8, with females not contributing to recruitment until year 8or 9due to length of gestation.Mean disk width at maturity for males and females was about 85cm, corresponding to age at maturity of 6 to 7 years for males and 7 to 8 years for females. Oysters and clams were not found to make up a significant portion of the diet of cownose ray sampled from across the Cheseapeake Bay. Cownose ray was found to experience a gape limitation that reduced the likelihood of predation on larger prey, such as oysters. Trials also indicated that rays seem to show preference for single, cultchless

oysters as opposed to aggregated, cultched oysters, indicating that the spat-on-shell growout method may minimize cownose ray predation.

<u>NOAA Center for Coastal Environmental Health and Biomolecular Research</u>
Ongoing Sample Collection and Methods Development for Molecular Shark Species Identification
The Marine Forensics program at the NOAA's National Ocean Service (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.

5.2 Incidental Catch Reduction

<u>Pacific Islands Fisheries Science Center (PIFSC)</u>
Management strategies for mitigating bycatch in large-scale commercial fisheries require estimates of post-release survival as well as information about habitats and movement patterns in captured teleosts, elasmobranchs, and sea turtles. Large pelagic sharks (particularly blue shark (*Prionace glauca)*) are the majority of the bycatch in pelagic gill nets and longline fisheries targeting swordfish (*Xiphias gladius*).Pop-up satellite archival tags (PSATs)[10] deployed on pelagic sharks caught in commercial longline fisheries can be used to determine species-specific horizontal and vertical movement patterns and survival after release from longline fishing gear. Analysis of PSATs deployed on pelagic sharks released in the Hawaii-based longline fishery in the central Pacific Ocean revealed sharks displayed species-specificdepth and temperature ranges, although with significant individual temporal and spatial variability in vertical movement patterns. Distinct thermal niche partitioning based on daytime temperature preferences was evident: (1) epipelagic species (silky and oceanic whitetip sharks), which spent more than 95% of their time at temperatures within 2°C of sea surface temperature; (2) mesopelagic-I species (blue sharks and shortfin makos), which spent 95% of their time at temperatures from 9.7° to 26.9°C and from 9.4° to 25.0°C, respectively; and (3) mesopelagic-II species (bigeye threshers), which spent 95% of their time at temperatures from 6.7° to 21.2°C (Musyl et al. 2011a). This

[10] 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 (~1,200–1,500 m; can tell shed tag from mortality), and (3) remains stationary at a depth above the threshold depth for (usually) 4 consecutive days.

knowledge could allow targeting of longline gear to create mismatches between hook depth and the sharks' habitat (i.e., minimize vulnerability of the species to be avoided) (Beverly et al. 2009).

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% 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, 2011).The use of large circle hooks instead of conventional tuna hooks in the world's pelagic tuna longline fleets hasdisplayed conservation potential for some highly migratory species(Curran and Bigelow 2010, 2011).

Electromagnetic Deterrents to Bycatch (additional details provided in Appendix 1, PIFSC)

Bycatch of sharks in longline fisheries has contributed to declines in shark populations and prompted the need for exploring novel technologies to reduce the incidental capture of sharks. One potential strategy is to exploit the unique electrosensory system of sharks, which are capable of detecting weak electric fields. Several shark species have been shown to be repulsed by powerful magnets and rare earth metals such as the electropositive metals from the lanthanide series, made up of neodymium (Nd) and praseodymium (Pr). For this reason, electromagnetic deterrents have become a potential bycatch solution on pelagic longline fisheries, as they may selectively reduce the bycatch of sharks and other elasmobranchs without affecting the catch of commercially targeted pelagic teleosts.

In this study, we tested the effects of an Nd/Pr alloy on shark catch rates in four experiments conducted in different regions of the Pacific Ocean. Using longline fishing gear, we compared the catch rates of baited hooks affixed with either a block of the metal alloy (experimental) or a lead weight (control). Two bottom longline experiments were conducted inside and offshore of Kaneohe Bay, Hawaii. One of these experiments targeted young of the year scalloped hammerhead sharks (*Sphyrna lewini*), while the other targeted sandbar (*Carcharhinus plumbeus*) and tiger sharks (*Galeocerdo cuvier*). In the Southern California Bight (SCB), as part of SWFSC juvenile mako (*Isurus oxyrinchus*) and blue shark (*Prionace glauca*) surveys, pelagic longlines were deployed to test the use of metal alloys on the catch rates of these two species.In the Eastern Tropical Pacific (ETP) off Ecuador, experiments were conducted in collaboration with the Ecuadorian dolfinfish longline fisheries and targeted thresher sharks, silky sharks, and scalloped hammerhead sharks. There was a significant reduction in juvenile hammerhead sharks in Hawaii caught on hooks with the lanthanide metal compared to the controls. In contrast, there was no difference in the catch rates for experiments targeting sandbar sharks in Hawaii or those conducted in the SCB and Ecuador. These results suggest that there are inter-specific differences regarding the effects of lanthanide metals on catch rates. This may reflect the diverse feeding strategies and sensory modalities used by shark species for detecting and attacking prey (Hutchinson et al. 2012).

While electropositive metal deterrents have been tested experimentally as a potential bycatch solution on pelagic longline fisheries, controlled trials under commercial fishing conditions are still lacking. Another study in the northwest Atlantic was conducted in collaboration with the Canadian pelagic longline swordfish fishery where blue sharks comprise a significant proportion of unwanted bycatch.In 2011 a total of seven sets (6,300 hooks) with three hook treatments—standard hooks, hooks with rare-earth alloys (Nd/Pr), and hooks with lead weights—were deployed near Sambro, Nova Scotia. Results suggest that rare-earth metals do not have any significant deterrent effect on the most common shark bycatch species and as such do not appear to be a practical bycatch mitigation option in the Canadian fishery. Nonetheless, stakeholderparticipation in this study improved the methodology, creating tests that follow realistic commercial-scale conditions (Godin et al., in review).

A new project has been initiated that investigates the effects of visual cues on the catch composition of coastal gillnets in Baja California. Preliminary results show that UV illumination of gillnets significantly reduce the catch rates of sharks and other elasmobranchs. In particular, results indicated a 53% decrease in the catch rates of scalloped hammerheads in UV illuminated nets. This work is currently being analyzed and additional experiments are being planned to follow up on these results.

Southwest Fisheries Science Center (SWFSC)

Testing Deep Longline Gear

In the California pelagic drift gillnet fishery that targets swordfish, blue sharks have historically been one of the main bycatch species. The majority (63%) of the blue sharks entangeled are discarded dead. To reduce the bycatch and/or post-release mortality of multiple species, the SWFSC has been conducting tests to target swordfish using deep-set longline gear off California at depths below 200 m. These deeper depths coincide with the daytime distribution of swordfish, putting hooks below the epipelagic waters inhabited by sea turtles and shortfin mako sharks. A first test of the deep-set longline was conducted in October 2011. During 11 sets, 105 blue sharks were caught with 96% released alive, although 51% were considered to be in poor condition. No shortfin mako sharks were caught. Further research is needed to quantify the survivorship of released sharks. Additional tests will be conducted in fall 2012 and the composition and condition of all catch will be documented.

5.3Post-Release Survival

Pacific Islands Fisheries Science Center (PIFSC)

Successful management strategies in both sport and commercial fisheries require information about long-term survival of released fish.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.Shark PSAT reporting rates were highest in species such as oceanic whitetip (81%) thatwere 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 (Musyl et al. 2011b).Meta-analysis on blue shark mortality from published reports and the current study (n=78 reporting PSATs) indicated the summary effect of post-release mortality from longline gear was 15% (95% CI, 9 – 25%), and suggested that catch-and-release in longline fisheries can be a viable management tool to protect parental biomass in shark populations (Musyl et al., 2011a).PIFSC studies also demonstrated a high rate of post-release survival of pelagic sharks captured and released from longline gear fished with circle hooks. See Appendix 1, PIFSC, for more information.

Southwest Fisheries Science Center (SWFSC)

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 thatcatches 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 fishermen are often interested only 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 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 use their elongate upper caudal fin to stun live prey before it is consumed, and therefore 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.)

To examine post-release mortality associated with the recreational fishery, PSATs have been deployed on eight common thresher sharks (132–175 cm FL, median 141 cm) captured using fishery standard techniques and released with trailing gear. Of the eight sharks, five died within 24 hours, two sharks survived with the trailing gear, and one of the PSATs did not report. Additional tags will be deployed during spring 2012.

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

The final phase of the research will quantify hooking mortality rates associated with sharks being hooked in the mouth rather than by the tail. Mouth-based hooking techniques have been promoted in the local recreational fishery for thresher sharks. To date, five mouth-hooked thresher sharks have been caught and tagged with PSATs. Three of the sharks survived the acute effects of capture and we have not yet received the data for the remaining two sharks. The final tag deployments are slated for spring–summer 2012.

After deployments are complete, a multi-media outreach campaign will be launched to share the results with the general public. A major objective of the project is to reach out to the recreational fishing community in order to promote fishing practices that enhance thresher shark catch and release survival(see section 2.5).

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 sharks are discarded at sea due to lack of market value. A 2009 analysis of the 1990–2008 observer data reveals that 32%of blue sharks captured were released alive, and an additional 5%were discarded with their disposition unknown. The remaining 63% 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 (roughly 60:40 male:female), range of sizes, and condition at release were comparable to those released from the fishery. 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, 12 blue sharks (100–200 cm fork length, median 149 cm) have been tagged by fishery observers. Nine of these animals were male, one was female,and the sex of two animals was unknown. Three of the 12 sharks were released in "good" condition while the remaining 9 were released in "fair" condition. To date, no sharks released in "poor" condition have been tagged, even though 29% of blue sharks released from 2007 to 2010 (the only seasons for which this information has yet been compiled) were in poor condition. 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.

Tagging efforts during the 2010–2011 and 2011–2012 seasons 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, fewer observed trips, and the small number of blue sharks caught, particularly of the desired size and condition ranges, only one shark was tagged in the 2011–2012 season. The shark was in fair condition and survived after release. Results to date suggest a 100% survival rate for sharks released in fair or better condition, but additional deployments are needed.

<u>Northeast Fisheries Science Center (NEFSC)</u>

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 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 recreationallycaptured 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 real-time satellite (SPOT) and PSAT tags on shortfin makos and blue sharks in the northeast United States and on their pelagic nursery grounds; (4) placing PSAT tags on sand tigers in Delaware Bay and Plymouth Bay (Massachusetts) as part of a fishery-independent survey and habitat study; and (5) placing PSAT and SPOT tags on dusky and tiger sharks in conjunction with Monterey Bay Aquarium, University of California Long Beach, and MDMF. Integration of data from new-technology tags and conventional tags from the CSTP is necessary to provide a comprehensive picture of the movements and migrations of sharks along with possible reasons for the use of particular migratory routes, swimming behavior, and environmental associations. In addition, the results of this research will be critical to evaluate the extensive current catch-and-release management strategies for sharks.

Southeast Fisheries Science Center (SEFSC)

Determination of Alternate Fishing Practices to Reduce Mortality of ProhibitedDusky 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. Preliminary logistic modeling analysis indicates median mortality occurs after 6.6 hours of being hooked, and 13.5 hours of soak time. Water temperature was not a significant factor in analysis.The difference in the mortality rates of hooking time versus soak time suggest that soak time is longer than the tolerance of dusky sharks to longline fishing. These preliminary results reflect the potential of bycatch mortality rates to influence already depleted populations, and these results could be used to propose regulations on longline soak time that could aid in population recovery of this species

The Capture Depth, Time, and Hooked Survival Rate for Bottom Longline Caught Scalloped Hammerhead Shark

Recent stock assessments for the Atlantic population of scalloped hammerhead, *Sphyrna lewini*, in U.S. waters estimated the population was overfished and overfishing was occurring (Hayes and Cortes 2009). In order to reduce levels of fishing mortality, management measures could reduce quotas or prohibit the landings of scalloped hammerhead sharks. However, these management measures may not be totally effective for longline fisheries because scalloped hammerhead sharks suffer from high hooking mortality. Data collected by onboard observers indicate that 91% of scalloped hammerheads are dead prior to being landed on the fishing vessel. Experiments began in 2011 to determine the relationship between soak time and capture depth on fishing mortality and CPUE of scalloped hammerhead sharks using hook timers and time depth recorders. The data and results produced from this study will provide critical information for fishery managers to help with the development of management measures to rebuild overfished scalloped hammerhead sharks and end overfishing for this species.

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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 Fishery Management Plan (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.

Domestic stock assessments under the SEDAR process are available online at http://www.sefsc.noaa.gov/sedar/.

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

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

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

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. 2011). 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% of the shark bycatch, exhibits a high rate of survival (about 95%) 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.

Insular Shark Surveys

Densities of insular sharks (Table A.1.1) 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 the Commonwealth of the Northern Marianas Islands (2003, 2005, 2007, 2009, 2011), Johnston Atoll (2004, 2006, 2008, 2010), and Wake Atoll (2005, 2007, 2009, 2011).

Table A.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*

Although 11 species of shark have been observed during CRED surveys (see Table A.1.1), only four species are typically recorded in sufficient frequency by toweddivers 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% 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% 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 to 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 (I.D. 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 were gathered by

SCUBA divers: (1) safe diving practices limited surveys to reefs areas of 30m or shallower, which is the upper end of reef sharks' potential depth distribution; and (2) 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.

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

Shark predation on Hawaiian monk seal pups (*Monachus schauinslandi*) has become unusually common at one breeding site, French Frigate Shoals (FFS) in the Northwestern Hawaiian Islands (NWHI). Between 1997 and 2010, the number of shark predation incidents on pups (pre-weaned and newly weaned) was 207 of 854 (24.2%) born at FFS compared to 10 of 520 (1.9%) born at Laysan island and 13 of 334 (3.9%) born at Lisianski island. Shark attacks on monk seal pups at FFS peaked in 1999 with the death of 22 pups (24% of the annual cohort). Thereafter, pup losses declined to 5 to 11 pups a year, but the percentage of pups lost to predation (12-28% annually) remains high as pup production has fallen for other reasons at FFS (Gobush 2010; unpublished data).

Since 1997, NMFS has frequently observed Galapagos sharks (*Carcharhinus galapagensis*) patrolling and attacking monk seal pups. Tiger sharks (*Galeorcerdo cuvier*) also prey on monk seals and are abundant at FFS; however,tiger sharks have not been observed to attack pups of this age class during daytime monitoring (approximately between 6:00amand8:00pm) spanning the past 15 years (Gobush 2010; unpublished data). For these reasons, NMFS' monitoring and mitigation efforts at FFS continue to be focused on Galapagos sharks. Shark tagging studies at FFS indicate that, although Galapagos sharks are the most abundant shark species in the atoll, they generally prefer deeper water and only a small fraction of the population, equating to a few tens of individuals, likely frequents the shallow areas around monk seal pupping islets (Dale et al. 2011).

Reducing shark predation on pups at FFS is one of several key activities identified in the Hawaiian Monk Seal Recovery Plan (NMFS 2007). Since 2000, NMFS has attempted to mitigate shark predation through harassment and culling of sharks, shark deterrents, and translocation of weaned pups to islets in the atoll with low incidence of shark attacks (Baker etal. 2011; Gobush 2010). NMFS implemented a highlyselective shark removal project to mitigate predation on monk seal pups between 2000 and 2012, with the exception of 2008–2009 when deterrents were tested (detailed below). A total of 14 Galapagos sharks frequenting the nearshore areas of pupping islets have been lethally removed to date. Thirteen Galapagos sharks were captured with handlines or harpoons from shore or small boats and culled in 2000, 2001, 2003, 2005, and 2011 (Gobush 2010). An additional Galapagos shark was caught with a five-hook bottomset longline and culled in 2010. Also in 2010, invited members of the Native Hawaiian community deployed with NMFS staff to perform Mano i'a harvest ceremonies at Ka'ula rock (while en route to FFS) and Tern Island, FFS, to offer respect to the sharks that would be caught for the mitigation project. The skin and teeth of the Galapagos shark removed in 2010 were retained and preserved for Native Hawaiian community members and used for educational purposes.

The feasibility of possible deterrents was tested in 2008 around Trig islet (FFS). Deterrents included visual devices (moored boat and floats suspended in the water column), auditory playbacks (boat noise broadcast by underwater speakers), and electronic diver devices (suspended in the water column along a nearshore pathway typical for patrolling sharks).The electronic diver devices functioned poorly and were omitted from further testing.In 2009, the number of shark sightings and predation incidents at two pupping islets at FFS was compared across two experimental treatments: (1) acoustic playback and a moored boat, and (2) continuous human presence, versus a control. Sharks were sighted with a remote camera system; predation incidents were evident from bite wounds or the disappearance of pups. However, the number of shark sightings and predation incidents did not differ significantly between the two treatments and the control (Gobush and Farry 2012).

Stock Assessment of Blue Shark

In 2000 as a collaborative effort with scientists at the National Research Institute for Far Seas Fisheries (NRIFSF) in Shimizu, Japan, analyses indicated that the blue shark stock was not being overfished(Kleiber et al. 2001). PIFSC and NRIFSF subsequently renewed this collaboration, along with scientists from Japan'sFisheries 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 sharks caught in the North Pacific from 1980 to 2002. This was achieved by estimating the number of blue sharks used in the global fin trade (Clarke 2004, Clarke et al. 2004, 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 samepattern 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 expended 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) 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. 2011a). 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-specificdepth 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 usinga 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 more than 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 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. 2011a).

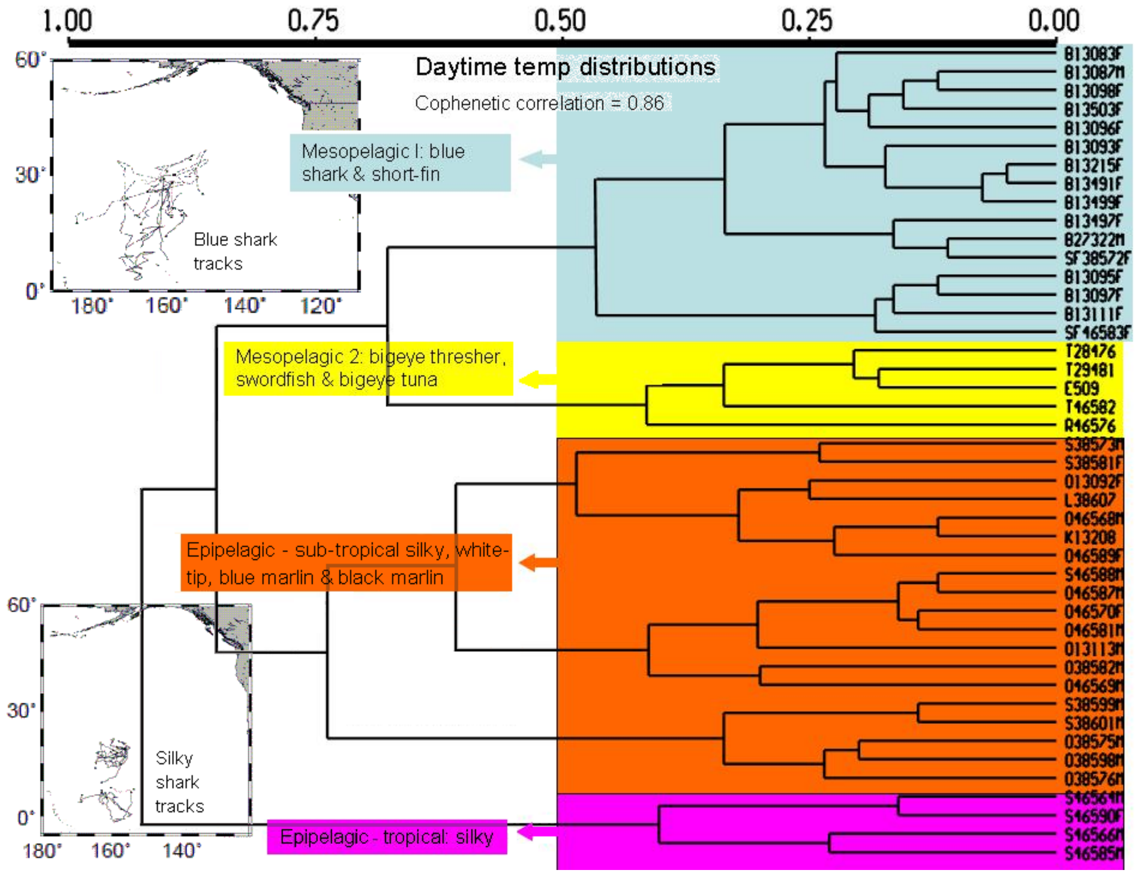


Figure A1.1. Clustered relationships among pelagic animals using daytime temperature preferences from pop-up satellite archival tags (PSATs). B = blue shark, SF = shortfin mako, T = bigeye thresher, E = bigeye tuna, R = swordfish, S = silky shark, O = oceanic whitetip shark, K = black marlin, L = blue marlin, M = male, and F = female. Inset maps show the horizontal movement patterns.

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.

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 1,000 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, 2007).

Chemical and Electromagnetic Deterrents to Bycatch

One study under way since 2005 with funding from NMFS 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 that 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 and magnets was conducted in early 2006 with demersal longline sets in South Bimini 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 coast 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 size ofa 60g lead fishing weight).

Initial experiments to examine the effects on shark catch rates of 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). Two experiments were initiated, one focusing on the effects of Nd/Pr (peodymiun/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 fieldtrials in Kaneohe Bay, Hawaii, suggest that catch rates of juvenile scalloped hammerhead sharks are reduced by 63% on branchlines with the Nd/Pr alloy attached as compared to lead weightcontrols (Figure A1.2). 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 Southwest Fisheries Science Center (SWFSC)(see section 5.2). 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.

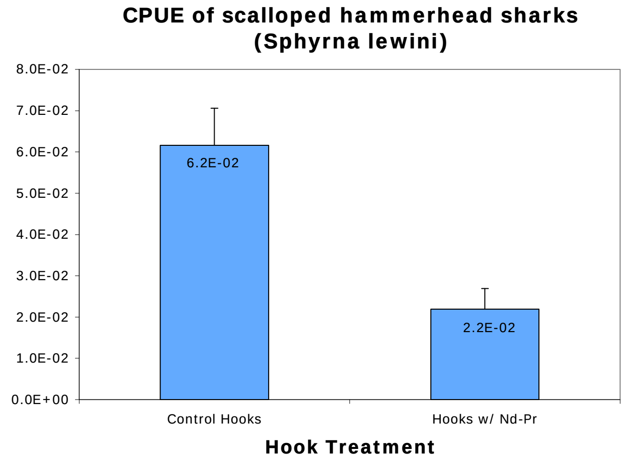


Figure A1.2. Catch per unit effort of scalloped hammerhead sharks on longlines with Nd/Pr alloy attached versus control hooks.

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. 2012).

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% of the total catch bynumber. Catch rates on large 18/0 circle hooks were significantly reduced—by 17% for blue shark, 27% for bigeye thresher shark, and 69% 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 deeperset longline gear conducted in 2006 altered current commercial tuna longline setting techniques by eliminating all shallow set hooks (less than 100 m depth) from tuna longline sets(Beverley et al. 2009). 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.

Improved Release Technology

The recently resumed Hawaii-based swordfish longline fishery, as well as the tuna longline fishery, are required to carry and use dehookers for removing hooks from sea turtles. These dehookers can also be used to remove external hooks and ingested hooks from the mouth and upper digestive tract of fish, and could improve post-release survival and condition of released sharks. Sharks are generally released from the gear by one of the following methods: (1) severing the 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 NMFS 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% success rate in dehooking and releasing live sharks on barbless hooks, compared to a 0% success rate when used with sharks caught on barbed hooks. In 2007, PIFSC and Pacific Islands

Regional Office (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% with barbed hooks and 72% with barbless hooks. During the study a new dehooker was developed and tested. Preliminary results were more than 90% effective in removing both barbed and barbless circle hooks from sharks; however, the prototype appears to be more efficient on smaller 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 survivalis 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% 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 by 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%) fish of known fate and predicted that 21 of 22 (96%) 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% 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 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 thatsuccumbed 7days 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% (95% CI, 9 – 25%).

Antecedent stress variables to explain mortality have been examined (i.e., capture temperature, soak time, etc.) but NMFS 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% based on PSATs [all sharks studied)). In summary, 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 and 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% reported and 65% 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., 2011b).

Southwest Fisheries Science Center (SWFSC)

NMFS SWFSC 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

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 fishermen, especially off Southern California. Although the blue shark is targeted in Mexico, it has little market importance in the United States but is a leading bycatch species in the California drift gillnet fishery (CDGN) 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 (SCB) 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 depending upon the species.

Offshore longline surveys from relatively large research vessels have proved most effective for sampling and estimating abundance trends of the more oceanic 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 a former experimental shortfin mako longline fishery in the SCB 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 a small commercial longline vessel. 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, to the north and the U.S.-Mexico border to the south. 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. Representative areas were initially 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 offshore CDGN fishery to provide measures of relative abundance of common thresher sharks for stock assessment models.

Juvenile Mako and Blue Shark Survey

In 2011, the SWFSC conducted its 18thjuvenile shark survey for mako and blue sharks since 1994. The annual abundance survey was completed between June 24 and July 13, 2011. Working aboard *F/VVentura II*, a team of scientists and volunteers fished a total of 5,493 hooks during 27 daytime sets inside seven focal areas within the SCB. Survey catch totaled 61 shortfin makos, 49 blue sharks, five pelagic rays (*Pteroplatytrygon violacea*), four opah, and one common mola (*Mola mola*). The preliminary data indicate that the nominal survey catch rate was 0.28 per 100 hook-hours for shortfin mako and 0.22 per 100 hook-hours for blue sharks. The nominal CPUE for both blue and shortfin mako sharks were slightly higher than the previous year. However, while more detailed analyses are needed, there is a declining trend in nominal CPUE for both species over the time series of the survey (Figure A1.3).

Other objectives of the cruise were to deploy satellite and conventional tags, and to collect biological samples from sharks and other fish. A total of 366 conventional spaghetti tags were released on sharks for movement and stock structure studies. A total of 452 DNA samples were collected, including samples from 315 blue sharks, 68 shortfin makos, three pelagic rays, and one common thresher; the rest were collected from teleost fish. In a cooperative effort with TOPP (Tagging of Pacific Pelagics), seven electronic tags were deployed on sharks to examine the habitat-use patterns in the California Current System. Two shortfin mako sharks (182 and 235 cm FL) and four blue sharks (161 to 226 cm FL) were released with radio position transmitting (SPOT) tags (see below for results).

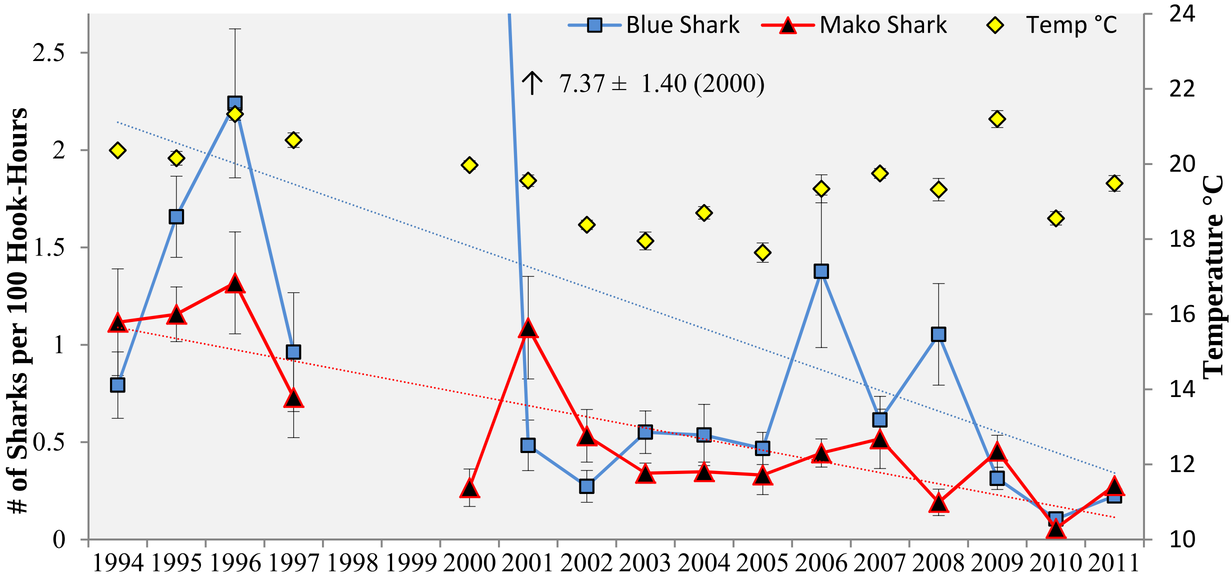


Figure A1.3. Average (± standard error) catch and temperature per survey set for shortfin mako and blue sharks, 1994–2011. No data were collected in 1998 and 1999. Blue shark catch per 100 hook-hours was 7.37 in 2000.

Neonate Common Thresher Shark Survey

In 2011, the SWFSC team conducted the survey aboard the *F/V Outer Banks*. Forty-seven longline sets were made in relatively shallow, nearshore waters and a total of 4,800 hooks were fished during the 18-day cruise. A total of 556 fish including a range of species were sampled during the survey. Threehundred ninety-one common thresher sharks were tagged with conventional tags for movement and stock structure data and 409 DNA samples were collected.

The preliminary survey data indicate that the average nominal catch rate by set was 5.57 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, shark tag deployments have been carried out in collaboration with CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada); Pacific Biological Station in Nanaimo, British Columbia; and the TOPP program (www.topp.org). 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 2011, two shortfin mako sharks, five blue sharks, and two basking sharks were tagged with either SPOT tags or towed GPS tags. Since 1999, a total of 97 mako, 90 blue, 28 common thresher, two hammerhead, and three basking sharks have been satellite tagged through collaborative projects.

SPOT tags continue to provide excellent information on the movements of blue and mako sharks, and we now have a decade's worth of data for both species. Of the five tags deployed on blue sharks, those deployed on smaller sharks (~165 cm FL) lasted for an average of 62 days, whereas the tag deployed on a large male (226 cm FL) lasted for almost 6 months. With the large amount of data obtained from SPOT tags, we can begin to look at large-scale patterns and whether there is habitat separation based on sex or size as is seen in the Central Pacific. Figure A1.4 shows the tracks from male and female blue sharks. Both sexes spend considerable time in the California Current, with the females possibly extending farther to the north and south. When offshore, the females generally move south into the subtropical convergence zone, whereas the males generally make more westerly migrations. There is some suggestion in two of the longer tracks that the males may return to the California Current in subsequent years. Habitat separation by sex and site fidelity have implications for the management of blue shark populations. For example, fidelity to specific areas is increasingly recognized in fish from swordfish to salmon sharks and increases the potential for regional local depletion where fisheries exist.

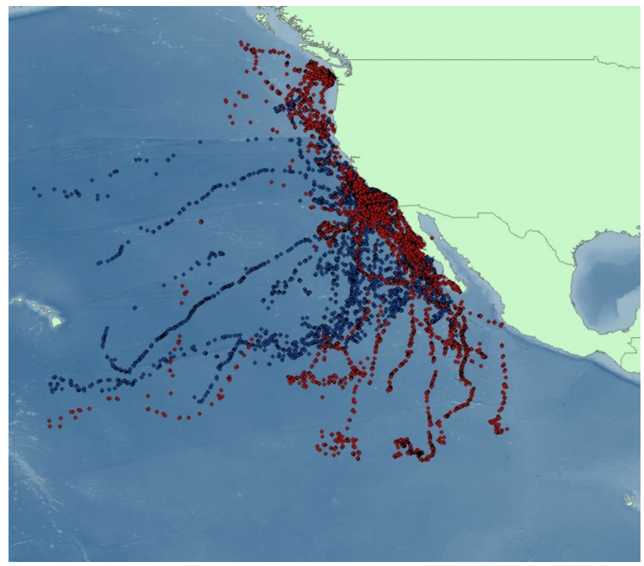


Figure A1.4. Comparison of the tracks of blue sharks for males (blue) and females (red) over the course of the study.

For mako sharks, five tags were still transmitting in early 2012. Two of these were deployed in 2009, one was deployed in 2010, and the remaining two were deployed in 2011. The SPOT tags continue to be an excellent tool for studying the movements of mako sharks, and the multiyear records provide an incredible opportunity to examine seasonal movement patterns and regional fidelity. For the two tags deployed in 2009, both returned for the third year in a row to the same destination. The large female (205 cm FL at tagging) traveled southeast of Hawaii and the 174 cm FL male traveled into the Sea of Cortez (Figure A1.5). Additional analyses are needed to determine (1) how patterns link to sex and size, (2) what triggers the onset of migration and (3) what characterizes the ultimate destinations. As with blue sharks, this type of regional site fidelity has important implications for management.

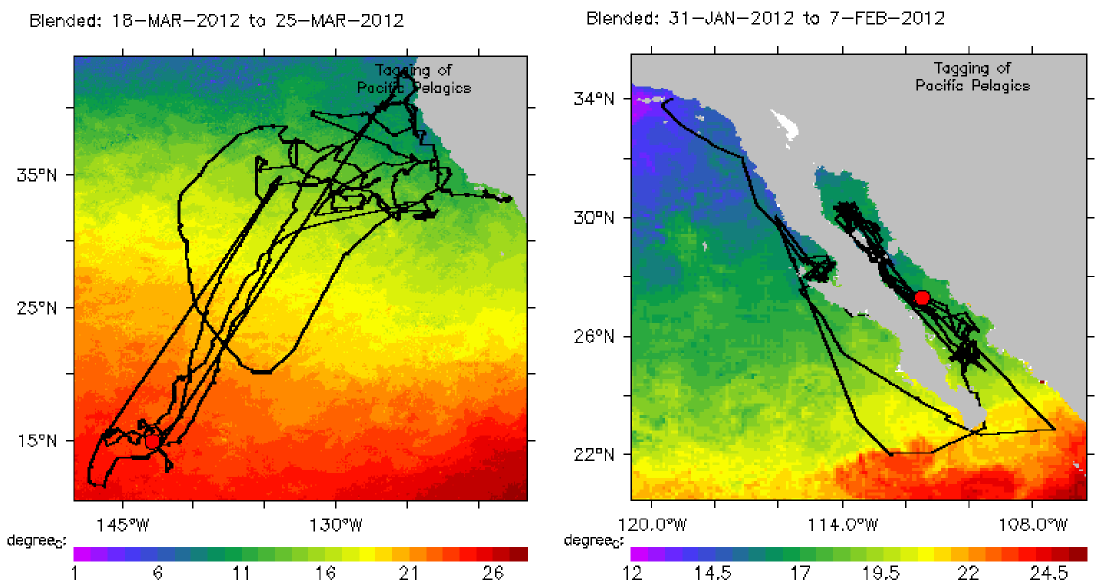


Figure A1.5. Tracks from two mako sharks showing nearly 3 years' worth of data and apparent preferences for specific regions (left 205 cm FL female, right 174 FL male).

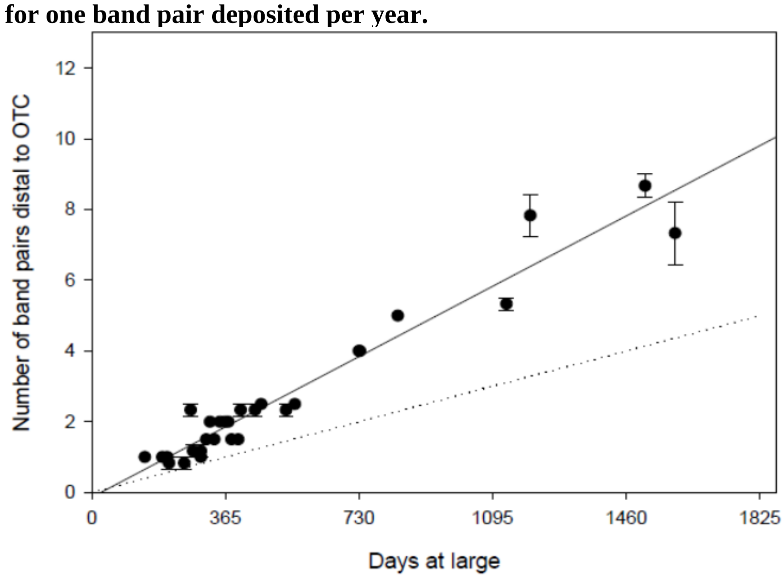
Age Validation Studies

Age and growth of mako, common thresher, and blue sharks are being estimated from band formation in vertebrae. In addition to being important for studying basic biology, accurate age and growth curves are needed in stock assessments. SWFSC scientists are validating ageing 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 the beginning of the program in 1997, 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.

Oxytetracycline Age Validation of Juvenile Shortfin Makos

The purpose of this study was to validate vertebral band counts for ageing juvenile shortfin mako and to resolve the discrepancy between the fast observed growth rates and the much slower growth predicted by age-at-length models that assume that only one band pair is deposited per year. OTC-labeled vertebrae of 29 juvenile shortfin mako were obtained from tag-recapture activities. Time at liberty for the 29 sharks ranged from 4 months to 4.4 years (mean=1.3 years). Growth information was also obtained from length frequency modal analyses (MULTIFAN and MIXDIST) using a 29-year dataset of commercial and research catch data, in addition to tag-recapture growth models (GROTAG) using lengths and timeatliberty. For samples used for age validation, shark size at time of release ranged from 79 to 142 cm FL and from 98 to 200 cm FL at recapture. Results from band counts of vertebrae distal to OTC marks indicate two band pairs (two translucent and two opaque) are formed per year for shortfin mako of the size range examined (Figure A1.6). Growth rates calculated from length frequency modal analyses estimate 26.5 to 35.5 cm per year for the first age class mode (85 cm FL), and 22.4 to 28.6 cm per year for the second age class mode (130 cm FL). In addition, the GROTAG model also resulted in a rapid growth rate during time at liberty for tagged fish of the two youngest age classes, with estimates of 28.7 and 19.6 cm FL per year at 85 and 130 cm FL, respectively. Collectively, these methods suggest rapid growth of juvenile shortfin mako in the SCB and suggest biannual deposition in vertebrae.

Figure A1.6. Number of band pairs between OTC mark and outer edge of shortfin mako shark vertebrae relative to the number of days at large. Average readings are based on three independent readers (± 1 standard error). Solid line shows the expected number of band pairs if two band pairs are deposited per year versus the dotted line for one band pair deposited per year.



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 1999. Stomachs are obtained primarily from the CDGN observer program.

A synthesis comparing the foraging ecology of shortfin mako, blue, and common thresher sharks was recently completed (Preti et al. 2012). In this study, stomach contents of sharks collected from 2002 to 2008 were identified to the lowest taxonomic level and analyzed using univariate and multivariate methods. Of 330 mako sharks sampled, 238 stomachs contained 42 prey taxa, with jumbo squid (*Dosidicus gigas*) and Pacific saury (*Cololabis saira*) representing the most important prey based on the geometric index of importance (GII). Of the 158 blue sharks sampled, 114 stomachs contained 38 prey taxa, with jumbo and *Gonatus* spp. squids representing the most important prey. Lastly, 225 thresher sharks were sampled and 157 stomachs contained 18 prey taxa with northern anchovy (*Engraulis mordax*) and Pacific sardine (*Sardinops sagax*) identified as the most important prey. Overall, mako sharks had the most diverse diet, feeding on many species of teleosts and cephalopods, followed by blue sharks which consumed a wide range of prey (primarily cephalopods), while thresher sharks were most specialized, feeding primarily on coastal pelagic teleosts. Despite similarities in habitat, the diets of these three common shark species are distinct in the California Current, indicating niche separation.

The data on shark foraging ecology were also used to develop a new approach for characterizing habitat use and improving our understanding of ecological interactions. SWFSC scientists introduced a resampling method to indirectly estimate foraging habitat based on diet data and knowledge of prey habitat use. The method is unique in that: (1) it is based on resampling by bootstrapping and (2) it does not require quantitative prey distribution information. For this study we combined diet data with qualitative prey distribution information for six different habitats segregated by depth and distance from shore. The combined data were organized into various matrices and resampled by bootstrapping to create an estimate of predator distribution based on prey habitat occupancy. Results from the new method indicate a significant difference in foraging habitat. Generally, blue sharks foraged more frequently in offshore habitats, thresher sharks foraged mostly in nearshore epipelagic habitats, and makos foraged both nearshore and offshore in epipelagic and mesopelagic habitats. The flexibility of the new method should allow for wide application, adding to the suite of possible indirect techniques available to infer foraging habitat use. The results of this research are being prepared for publication.

In addition to foraging ecology, SWFSC scientistshave started to investigate algal toxins (domoic acid) in thresher sharksin the SCB. Thresher sharks forage nearshore and feed on small schooling fish such as sardine and anchovy, making them prime candidates for exposure to domoic acid. Domoic acid was detected in stomach contents and blood samples collected from thresher sharks along the southern California coast during September 2011. For stomach contents, six of eight samples were positive with values ranging from 4.5–44.6 ng/g. Stomach contents of sharks positive for domoic acid included market squid, Pacific mackerel, and Pacific sardine—species well known to harbor domoic acid. Blood samples were positive in three of six cases with values ranging from 0.9–47.9 ng/g. The value of 47.9 ng/g is one of the highest reported concentrations of domoic acid measured in blood from a field-collected fish or animal. These levels are, however, far below what would be considered toxic to humans. The regulatory limit for domoic acid in shellfish is 20,000 ng/g. Our findings confirm that thresher sharks are exposed to domoic acid, and measurable levels of this toxin can occur in their blood stream. Further studies are needed to document domoic acid in muscle and the potential implications of measured concentrations for shark and human health.

Basking Shark Research Program

The eastern North Pacific basking sharkpopulation appears to have declined dramatically in the past 50 years, with no evidence of recovery. Hundreds to thousands of individuals were observed off the U.S. West Coast in the early- to mid-1900s, but 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 United States in 2010. Unfortunately, efforts to understand trends 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 basking shark fishery in the early 1900s was based.

This research program has progressed at a number of different levels. A dedicated website (http://swfsc.noaa.gov/baskingshark/), e-mail address (basking.shark@noaa.gov), and hotline (858-334-2884) have been established as a part of a sightings network. Information on sightings will help document patterns of occurrence and tagging efforts. SWFSC scientists havealso developed a tri-nation team with colleagues in Canada and Mexico to coordinate research efforts. The second meeting of the tri-nation team took place in May 2011. In addition, two satellite tags were deployed on basking sharks off San Diego in the summer of 2011.

The use of satellite tags is critical for examining large-scale movement patterns and habitat use, which are essential for understanding patterns and trends in abundance. The first tag deployed in 2011 released early after 8 days and floated to a beach where the tag was recovered. No track was estimated for this tag given the short deployment duration. The second remained on the shark for 8 months and popped up northeast of Hawaii. Using both the light-based and GPS locations, an estimated track between tag and release was obtained (Figure A1.7). It appears that the second shark moved northwest from San Diego shortly after being tagged, toward the Channel Islands, then northward around Point Conception toward Morro Bay. This is the same area visited by a single shark tagged in 2010. In mid-August the shark moved offshore, ultimately finding an area off Hawaii where it remained for approximately 3months before the tag popped off in February 2012.

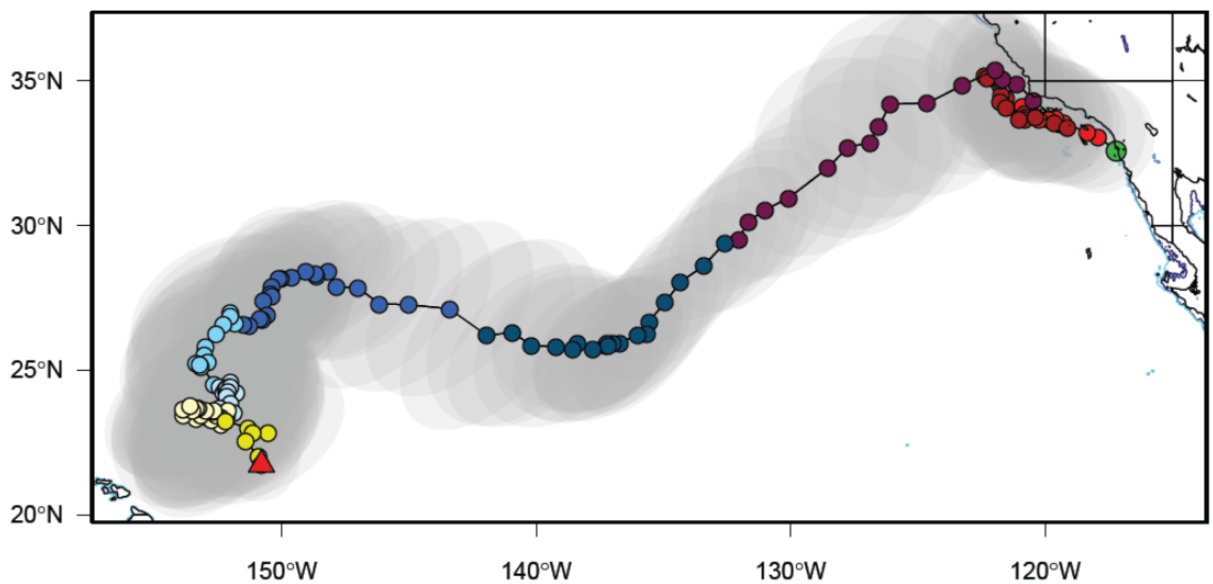


Figure A1.7. Argos and light-based geolocation estimates for a basking shark. Different colors represent different months. The tag was deployed off San Diego in June 2011 and popped up 8 months later off Hawaii.

The tagged basking sharks have shown distinct onshore-offshore patterns in vertical habitat use. Nearshore behaviors are characterized by high variability in vertical habitat use. At some times sharks remain in near surface waters while at other times they are deep in the water column. Diel patterns are also apparent during some periods but not others. This is in sharp contrast to their offshore behavior, where vertical habitat use is quite consistent. Offshore they remain exclusively below the mixed layer and exhibit a deep vertical migration. For example, off Hawaii the daytime depths were about 500 m whereas nighttime depths were about 200 m. These depths are consistent with the diel migrations of the deep scattering layer in this area. The diversity of prey in the DSL raises the potential that, if their vertical behavior reflects foraging on the DSL, then their offshore diet may be more variable than nearshore where they seem to target Calanoid copepods. Basking sharks have shown impressive plasticity in vertical behaviors in this study as well as in the Atlantic. 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

Shortfin Mako Shark

The shortfin mako shark is a commonly encountered shark in temperate marine fisheries but little is known about regional connectivity. An ongoing study using mitochondrial DNA control loop sequences to determine Pacific shortfin mako shark stock structure has been updated with additional samples collected in the western Pacific and is being prepared for publication. Results show three potential substocks in the Pacific with a single stock in the North Pacific, and distinct eastern and western stocks in the South Pacific. As the next step for mako sharks, a suite of nuclear microsatellite markers are being developed to further refine the spatial and temporal distribution 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. Data generation and analyses are underway for the Pacific studies. These markers have also been shared with international collaborators and are being applied to global studies of shortfin makos.

Other Pelagic Sharks

The SWFSC is collaborating on population genetics studies on a number of other pelagic shark species including common thresher, pelagic thresher, silky, and blue sharks. Samples are being collected from across the Pacific basin with the assistance of scientists and fishery observers from several nations. Some of the noteworthy results to date include indication of stock structure of silky sharks in the eastern Pacific with differentiation of northeast and southeast populations at roughly the equator. More samples are needed to determine where specifically the separation occurs and the potential overlap. For pelagic thresher sharks, there is a remarkably high degree of stock partitioning. At least three subpopulations have been identified across the Pacific using cytochrome oxidase I sequencing with distinct genotypes found in the eastern, central, and western Pacific.

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 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 conducted an assessment of spiny dogfish along the Pacific coast of the United States in 2011 (see section 2.3).

Research on Bluntnose Sixgill Sharks (Hexanchus griseus) in Puget Sound
The NWFSC, in collaboration with Washington Department of Fish and Wildlife (WDFW) and the Seattle Aquarium, has completed several studies estimating movement parameters of 34 bluntnose sixgill sharks in Puget Sound from 2005 to 2009. Sharks were weighed, measured, sexed, surgically tagged with Vemco© ultrasonic tags, and released at their capture site. Tags transmitted a signal every few minutes containing a unique identification code and a depth estimate; these signals were detected when they were within the range of Vemco© receivers that were either deployed at fixed listening stations (passive tracking) or towed by a small boat (active tracking).

Acoustic telemetry data allowed estimation of movement parameters (e.g., depth changes, move length, and turning angles) that allowed estimation of home range sizes (Andrews et al. 2007); daily, seasonal, and interannual movement patterns (Andrews et al. 2009, 2010, Levin et al. 2012); and use of different habitat types (Andrews et al. 2009, 2010). 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. The juveniles make regular diel vertical migrations, the rate and magnitude of which appear to be based on season, tide, and bathymetry; these migrations were most likely related to foraging.

Biological data (e.g., genetic samples, blood samples, gut contents, and stable isotope ratios of tissues) were also collected. Genetic analysis indicated that the Puget Sound sixgill shark population has a high degree of relatedness and polyandry (i.e., multiple mates per litter for mature females) (Larson et al. 2011). Stable isotope data were consistent with large-scale movement patterns of juveniles and females as determined by the tagging studies, and are being analyzed to estimate trophic position of juvenile sixgill sharks in the Puget Sound food web.

Research on Broadnose Sevengill Sharks (Notorynchus cepedianus) along the West Coast
The NWFSC, in collaboration with WDFW, examined the biology, distribution, and movements of broadnose sevengill sharks in coastal estuaries and shelf waters along the West Coast from 2003 to 2006. All sevengill sharks were captured in Willapa Bay on the southern Washington

coast. Sharks were weighed, measured, examined to determine sex and maturity, and then released. In addition, 32 individuals were surgically tagged with Vemco© ultrasonic tags.

Sevengill sharks were found to make seasonal use of Willapa Bay and other coastal estuaries (G.D. Williams et al. 2012). During spring and summer months, individuals returned to Willapa Bay in consecutive years, showing site fidelity to specific areas within Willapa Bay. Spatiotemporal patterns of habitat use within the bay were size- and sex-dependent. Later in the year, sevengill sharks generally departed Willapa Bay for coastal waters ranging from Puget Sound to Southern California. Sevengill sharks fed on harbor seals (*Phoca vitulina*) while in Willapa Bay (G.D. Williams et al. 2011).

Research on Spiny Dogfish (Squalus acanthias)Bioenergetics and Movements

NWFSC researchers have studied spiny dogfish energy budget (bioenergetics) models and applied them to spiny dogfish populations along the West Coast and in Puget Sound waters, the latter in conjunction with movement studies.

A basic spiny dogfish bioenergetics model was developed to estimate the effect of temperature variation on spiny dogfish in shelf waters of the West Coast (Harvey 2009). The study specifically examined how climate variability affected three important indicator metrics: prey consumption, age-1 size, and maturation rate of spiny dogfish, sablefish (*Anoplopoma fimbria*), and yelloweye rockfish (*Sebastes ruberrimus*). Spiny dogfish were highly sensitive to temperature variation in terms of age at maturity, and also responded strongly in terms of total prey consumption; thus, climate variability could potentially affect spiny dogfish demography and food web dynamics.

Recently, NWFSC researchers have examined movements of northern spiny dogfish in Puget Sound, using acoustic telemetry methods similar to those outlined previously for sixgill and sevengill sharks. In a forthcoming manuscript, K. S. Andrews and C. J. Harvey describe how a large portion of the spiny dogfish population in Puget Sound emigrates from the system in the fall and moves into waters along the West Coast, remaining there until at least the following spring before returning. There is some evidence of interannual site fidelity by individuals returning to Puget Sound. Using the bioenergetics model described above, the researchers have concluded that the seasonal dogfish migration represents a major decrease in predation pressure in the Puget Sound ecosystem.

Alaska Fishery Science Center (AFSC, Auke Bay Laboratory)

Stock assessment and research efforts at the Alaska Fishery Science Center's Auke Bay Laboratory are focused on:

- Improving stock assessments and collection of data to support stock assessments of shark species subject to incidental harvest in waters off Alaska.
- Migration and habitat use of Pacific sleeper sharks.
- Migration and habitat use of spiny dogfish in the Gulf of Alaska.
- Development and validation of improved ageing methods for spiny dogfish and Pacific sleeper sharks.
- Investigations into life history characteristics and population demography.
- Examination of spiny dogfish markets and modeling incidental catch.

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

Species currently assessed in Alaskan waters include Pacific sleeper sharks (*Somniosus pacificus*), spiny dogfish (*Squalus suckleyi,* note that this was formerly referred to as *S. acanthias*; see Ebert et al. 2010 for details of the species redescription), and salmon sharks (*Lamna ditropis*). These are the shark species most commonly encountered as incidental catch in Alaskan waters. In both the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) fishery management plans, sharks are managed as a complex. There are no directed fisheries for sharks in either area and directed fishing for all sharks is prohibited. Most shark species are considered Tier 6, where annual catch limits are based on estimated historical incidental catch in the groundfish fisheries. In the GOA, spiny dogfish is currently Tier 5, with annual catch limits based on biomass and natural mortality. Biomass is currently estimated from the NMFS fishery-independent bottom trawl survey; however, it is thought that other surveys may better reflect the populations. Efforts are underway to develop a model to estimate biomass for spiny dogfish that would include data such as the NMFS and International Pacific Halibut Commission annual longline surveys. Stock assessments are summarized annually in the North Pacific Fishery Management Council's Stock Assessment and Fishery Evaluation Report (see Tribuzio et al. 2011a and 2011b).

Trophic Ecology of Pacific Sleeper Sharks in the Eastern North Pacific Ocean

Stable isotope ratios of nitrogen ($\delta^{15}N$) and lipid normalized carbon ($\delta^{13}C'$) were used to examine geographic and ontogenetic variability in the trophic ecology of Pacific sleeper sharks in the eastern North Pacific Ocean (Courtney and Foy 2012). Mean muscle tissue $\delta^{13}C'$ values of Pacific sleeper sharksdiffered significantly among geographic regions of the eastern North Pacific. Linear models identified significant ontogenetic and geographic variability in muscle tissue $\delta^{15}N$ values. The trophic position of Pacific sleeper sharks in the eastern North Pacific estimated from previously published stomach content data (4.3) was within the range of Pacific sleeper shark trophic position predicted from a linear model of muscle tissue $\delta^{15}N$ (3.3–5.7) for sharks of the same mean total length (L_T; 201.5 cm), but uncertainty in predicted trophic position was very high (95% prediction intervals ranged from 2.9–6.4). The relative trophic position of Pacific sleeper sharksdetermined from a literature review of $\delta^{15}N$ by taxa in the eastern North Pacific was lower than would be expected based on stomach content data alone when compared tofish, squid,and filter feeding whales. Stable isotope analysis revealed wider variability in the feeding ecology of Pacific sleeper sharksin the eastern North Pacific than shown by diet data alone, and expanded previous conclusions drawn from analyses of stomach content data to regional and temporal scales meaningful for fisheries management.

Migration and Habitat Use of Pacific Sleeper Sharks

During the summers of 2003–2006, scientists from Auke Bay Laboratory deployed 138 numerical Floy tags, 91 electronic archival tags, 24 electronic acoustic tags, and 17electronic satellite popup tagson 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 Auke Bay Laboratory have deployed 80 pop-off archival tags on spiny dogfish in the GOA and will deploy an additional 90 tags in summer 2012 throughout the GOA, inside waters of Southeast Alaska, British Columbia, and Washington State. Data have been successfully recovered from 70 tags to date (with eight tags still at liberty). 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 GOA spiny dogfish populations mix with those populations of British Columbia, Canada, and off the U.S. Pacific Coast. Preliminary results suggest a general westward movement from Yakutat Bay toward Cook Inlet and Kodiak Island between August and December, with some animals moving far south to waters off the coast of California. Further, these data are showing a strong daily migration between deeper and shallower waters.

Age and Growth Methods
Scientists at Auke Bay Laboratory and the NMFS AFSC Resource Ecology and Fisheries Management Division age and growth lab received funding from the North Pacific Research Board to expand on a pilot study that examined a potential new method for ageing of spiny dogfish. Traditional age determination methods used the dorsal fin spine, which can be worn or broken over time, thus introducing a source of uncertainty in the ageing estimation process (Tribuzio et al. 2010). The new method, which uses the vertebrae and histological staining, has been applied to spiny dogfish from the U.S. East Coast in efforts to reduce the uncertainty of age estimates. This project will compare the results of both ageing methods to determine whether the vertebrae method is appropriate for GOA spiny dogfish. The second purpose of this study is to establish a method for ageing 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 Auke Bay Laboratory are 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 ageing. The improved age-at-length data will be used to re-estimate growth models used in stock assessments.

Life History and Demographic Studies
The purpose of this study was to examine the basic life history of a lightly exploited stock of spiny dogfish (*S. sucklelyi*) in the GOA to establish a baseline for future comparison and to provide criticalinformation for stock assessments (Tribuzio and Kruse 2011, 2012). Average total length (total length extended) of females (87.7 cm)was significantly larger (*t*-test, $t = -12.57$, d.f. = 1533, $P< 0.01$) than males (80.3 cm); size at 50% maturity (74.5 and 97.3 cm, males and females, respectively) and age at 50% maturity (21 and36 years, respectively) were also significantly different between the sexes (i.e.,bootstrapped 95%c.i. did not overlap). Total average fecundity was 8.5 pups per female, and individual fecundity wasa linear function of either length or whole mass. The best estimate of instantaneous natural mortalitywas 0.097. The delayed age of maturity, low natural mortality, and low rates of reproduction implythat only very low rates of fishing mortality are sustainable.Finally, this paper provides the first reported

evidence that a small percentage of the adult females may undergo an extended resting period of 1 year or more between pregnancies.

Demographic models are useful tools for assessing data-limited species and may be an appropriate alternative to cohort analyses for sharks due to their long-lived, slow-growing nature. In this study, age- and stage-based demographicanalyses were conducted to examine the intrinsic rebound potential (*r*) and potential risk of fishing for spiny dogfish (*S. suckleyi*) in the GOA. Monte Carlo simulations were conducted to incorporate input parameteruncertainty. For an unfished population, *r* was estimated to be 0.02–0.03 per year. Fishing mortalities (*F*) of *F*=0.04 and0.03 (age- and stage-based models, respectively) resulted in *r*=0, indicating that populations fished at higher *F* are notsustainable. Harvest strategies targeting juveniles (age-based model) and subadults (stage-based model) caused the highestrisk of the population falling below defined thresholds (*B*MSY, *B*40% and *B*50%) after 20 years. The age- and stage-basedmodels provided similar estimates of *r* and sustainable fishing mortality, suggesting that the stage-based model is anappropriate substitute for the age-based model in this case. Spiny dogfish (*S. suckleyi*) and the closely related dogfish (*S. acanthias*) are oftenharvested around the world and this modeling approach could be useful to the management of these species and othersharks where data are limited.

Modeling of Spiny Dogfish Incidental Catch in the GOA and a Policy Analysis for a Potential Market forSpiny Dogfish Products
University of Alaska Fairbanks School of Fisheries and Ocean Sciences was funded by Alaska Sea Grant and the U.S. Department of Agriculture to study the policy implications of a spiny dogfish fishery in Alaska in cooperation with the Alaska Regional Office (Gasper 2011).

Modeling Spiny Dogfish Distribution
The spiny dogfish is a common incidental catch species in commercial longline fisheries in the GOA. This small shark is widely considered a nuisance and most dogfish catch is discarded. Their spatial distribution in the GOA is poorly understood. A better understanding of areas of high incidental catch would provide critical information to fishery managers, whether they seek to convert discards into valuable fishery landings or to manage fishing mortality on this long-lived species. We analyzed the spatial distribution of the spiny dogfish from fishery-dependent and fishery-independent data collected between 1996 and 2008 using generalized additive and generalized linear modeling techniques. Poisson, negative binomial, and quasi-Poisson error structures were investigated using goodness of fit statistics. The quasi-Poisson generalized additive model provided the best fit. Modeling results showed that longline catches of spiny dogfish were concentrated east of Kodiak Island, Alaska, with increased spatial homogeneity of dogfish between the eastern and western GOA. The number of dogfish caught generally showed a decreasing trend with increasing depth and decreasing number of hooks. However, depths between 1 and 100 meters had the greatest positive influence on dogfish catch. Areas of high dogfish incidental catch indicate core areas that may be important to future considerations of stock assessments, at-sea discard estimation, and fishery management.

World Market Analysis of the Spiny Dogfish
The spiny dogfish is a globally distributed shark species that is an important trade commodity for Europe and Asia. Dogfish have been overexploited in areas that are important for market supply,

primarily U.S., Canadian, and European fisheries in the northern Atlantic Ocean. Market impacts from the decline of dogfish are poorly understood, but recent media campaigns by environmental groups discouraging consumption of dogfish may reduce product demand. Data on trade, capture, and informal interviews with dogfish suppliers were used to characterize market channels and sources of demand in Asia and Europe. Market trends in Europe show drastic reductions in demand for dogfish, while market patterns in Asia are less clear. Structurally, the markets are segmented, with European markets segmented into frozen and fresh products and Asian markets comprised of frozen dogfish and fins. Future increases in market share for dogfish will require differentiating the product from potential substitutes while using eco-labeling and marketing to inform consumers.

Policy Perspective of the Spiny Dogfish Market in Alaska

Spiny dogfish is a common species caught incidentally in Alaskan trawl, longline, and salmon fisheries. Markets for dogfish (mainly *Squalus suckleyi* and *S. acanthias*) exist in Europe and Asia. The purpose of this study is to describe historical dogfish harvests in Alaska and provide an analysis of potential harvest given the current and future regulatory environment, including suggestions for improving marketing efforts in Alaska. Regulations currently allow dogfish to be retained in proportion to the amount of target species retained in a directed fishery. This specification will not result in significant retention of dogfish unless ex-vessel prices dramatically increase relative to target species. Even with an increased ex-vessel value, few vessels may be able to capitalize on dogfish revenue due to restrictions on harvest of bycatch species and limited access programs for vessels focusing on other, more valuable target species. Substantial marketing efforts by the Alaska seafood industry are necessary to establish dogfish marketsleading to increased ex-vessel prices. A robust dogfish market in Alaska is unlikely to occur unless regulations allow directed fishing. Such a regulatory change may create incentives to use dogfish as a guise to harvest other, more valuable species under regulations for bycatch retention allowances. In developing management options, agencies must establish target and limit reference points for fishing mortality commensurate with the vulnerability of this species to overfishing.

Figure A1.8. Bringing in a sandbar shark during the NEFSC Coastal Shark Bottom Longline Survey. Source: Peter Cooper /NMFS photo.

<u>Northeast Fisheries Science Center (NEFSC)</u>

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

<u>Fishery-Independent Coastal Shark Bottom Longline Survey</u>

The fishery-independent survey of Atlantic large and small coastal sharks is conducted biennially in U.S. waters, depending on funding. Its primary objective is to conduct a standardized, systematic survey of the shark populations off the U.S. Atlantic coast to provide unbiased indices of relative abundance for species inhabiting the waters from Florida to the Mid-Atlantic(see Figure A1.8). 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.

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 U.S. East Coast 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 spring 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 2011, a total of 286 sandbar sharks were caught and released with conventional tags. The mark-recapture data from this study has been used to examine the temporal and spatial relative abundance and distribution of sandbar sharks in Delaware Bay, and the juvenile index of abundance from this standardized survey has been used as an input into various stock assessment models in the SEDAR process. In the 2010 SEDAR(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 sharkfor identifying Essential Fish Habitat (EFH) and for future stock assessment purposes, continued in 2011(see Figure A1.9). This study incorporates historical NEFSC sampling stations to allow for comparison between historic and current abundances. This survey is also used to monitor the Delaware Bay sand tiger population and to evaluate long-term changes in abundance and size composition. In 2011, a total of 46

sand tigers were caught and released with conventional tags, bringing the total since the beginning of the survey to 206 sand tigers.

Figure A1.9. Measuring a sand tiger during the NEFSC Delaware Bay Sand Tiger Survey.
Source: Corey Eddy/NMFS photo.

<u>Collection of Recreational Shark Fishing Data and Samples</u>
Historically, species-specific landings data from recreational fisheries are lacking for sharks. In an effort to augment these data, the NEFSC has been attending recreational shark tournaments continuously since 1961 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 (1961–2011) 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 2011, biological samples for life history studies and catch and morphometric data for more than 150 pelagic sharks were collected at nine 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 critical specimens and tissue for life history and genetic studies, provide outreach opportunities for recreational fishermen and the public, and to provide additional information on movements that complement the NMFS Cooperative Shark Tagging Program.

<u>NEFSC Historical Longline Survey Database</u>
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 havebeen 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 provides an opportunity to better understand seasonal distribution patterns and relative vulnerability of various species to different fishing practices.

Southeast Data, Assessment, and Review (SEDAR) Process
Staff participated in the 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 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 2011 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 (see Figure A1.10). In 2007 and 2008, two real-time satellite (SPOT) tags and five pop-up satellite archival tags (PSAT) tags were deployed on shortfin makos and one PSAT tag was deployed on a blue shark. A total of 500 blue sharks have been double-tagged using two different tag types to help evaluate tag-shedding rates used in sensitivity analyses for population estimates and to calculate fishing mortality and movement rates for this pelagic shark species. In 2011, an additional 250 sharks were tagged, bringing the total to more than2,750 with 190 recaptured. These fish were primarily blue sharks recovered by commercial fishermen working in the mid-Atlantic Ocean. This research was featured as part of

Figure A1.10. Tagging a blue shark during the NEFSC Pelagic Nursery Ground Survey. Source: Lisa Natanson /NMFS photo.

the Discovery Channel's "Swords: Life on the Line" 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 FigureA1.11). In 2011, COASTSPAN participants were the Georgia Department of Natural Resources, South Carolina Department of Natural Resources, North Carolina Division of Marine Fisheries, and University of North Florida. The NEFSC staff conducts the survey in Narragansett and 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 summarized 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).

Figure A1.11. Tagging a juvenile sandbar shark during the NEFSC COASTSPAN Program Survey. Source: W. David McElroy / NMFS photo.

In collaboration with MDMF and NMFS, 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 Fish Bay and Coral Bay on the island of St. John, U.S. Virgin Islands, 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 to determine site fidelity, residency, and migration patterns. Only 8% of lemon sharks and14.5% of blacktip sharks exhibited long-term residency (>180 days) within the bays, while most of the sharks moved out by the fall and early winter months. Although several sharks were detected outside of Fish and Coral Bays and a few (five blacktips) traveled between the two bays, each species exhibited strong site attachment to the bay in which they were tagged. Efforts to examine intra- and inter-specific patterns of habitat use as they relate to the biotic and abiotic characteristics of each embayment are ongoing. A presentation summarizing these results (Legare et al. 2011) was given at the 2011 American Elasmobranch Society Meeting.

Habitat Utilization and Essential Fish Habitat of Sand Tiger Sharks

Funding was received in 2006 through the NOAALivingMarineResourcesCooperativeScienceCenter to support a multi-year cooperative research project with staff from DelawareStateUniversity 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. Sand tiger movements continue to be monitored using passive acoustic telemetry.

Funding was received through the NMFS Species of Concern Internal Grant Program to study the regional movements, habitat use, and site fidelity of sand tigers off the U.S.East Coast using satellite telemetry. PSATs were deployed on four sand tigers; two caught in Massachusetts state waters and two caught in Rhode Island state waters. Results from these tags 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 participate on a working group with others from the NMFS Highly Migratory Species Division and Southeast Fisheries Science Center to update and refine the EFH designations for managed shark species. This process was ongoing in 2011 and entailed providing summaries from 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 with declines and management issues. Biological samples are obtained on research surveys and cruises, on commercial vessels, at recreational fishing tournaments, and opportunistically 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 (Figure A1.12) 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.

Figure A1.12. Blue shark ready to be tagged and released.
Source: Lisa Natanson /NMFS photo.

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 (CSTP) 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 collected from recreational fishing tournaments and research cruises, a genetic approach for identifying pelagic shark tissues was streamlined by researchers at NOVA Southeastern University. 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 CSTP in the North Atlantic Ocean from 1962 to 2000. Of these, 5,410 were recaptured for an overall recapture rate of 5.9%. 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, lifehistory strategies, and population structure is needed to develop informed management of this open ocean species.

Usingthis 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 (1990s) in the eastern side of the ocean are rapidly approaching 0.2 year^{-1}. Because of the particular lifehistory 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 lifehistory studies and preliminary stock assessments.

Biology of the White Shark (*Carcharodon carcharias*)
An update to an NEFSC western North Atlantic white shark distribution paper is being finalized for publication. This study is a joint effort with NMFS staff from the NEFSC, Southeast Fisheries Science Center (SEFSC), and Northeast Regional Office (NERO) and scientists from MDMF and the Florida Museum of Natural History. The update 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 are used to quantify the seasonal distribution and habitat use of various subcomponents of the population. In 2011, relative indices of abundance from historical NEFSC surveys, NEFSC tournament data, the observer program for the directed shark longline fishery, and visual records of white sharks in New England waters were analyzed to determine temporal trends of white shark abundance in the northwest Atlantic.

Researchers from Stony Brook University, Field Museum of Chicago, Nova Southeastern University, and NEFSC are 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.

Biology of the Thresher Shark (*Alopias vulpinus*)
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. In 2011, 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.

Biology of the Galapagos Shark (*Carcharhinusgalapagensis*)
The Galapagos shark is distributed worldwide in warm, temperate waters and is known to prefer oceanic islands. As such, it is the most common species in Bermuda, where commercial fishermen land approximately 200 sharks each year, primarily for their liver oil or as bait in lobster traps. Despite its ubiquitous presence, Bermuda's Department of Environmental Protection has only limited regulations in place to manage this species.This study was begun to investigate the life history and ecological role of these sharks. Size-at-maturity is being investigated by examining the reproductive system of sharks collected from landings of commercial fishermen. Size-at-age and age-at-maturity estimates will be derived from band pairs in the vertebral centra of these sharks. Elements of feeding ecology, such as trophic

position and diet shifts, are being investigated via stable isotope analysis of muscle, liver, and vertebrae with stomach contents analysis to reinforce these results. This study is being done in conjunction with staff from the University of Massachusetts and Massachusetts Division of Marine Fisheries. A presentation summarizing these results (Eddy et al. 2011a) was given at the 2011 American Elasmobranch Society Meeting.

Biology of the Atlantic Torpedo (*Torpedo nobiliana*)

A Master's thesis was completed on the biology of the Atlantic torpedo (Mataronas 2010). 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 Point 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; therefore, 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 whether 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 whether 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.

Biology of the Smooth Skate (*Malacoraja senta*)

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 the 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. 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 $_{L\mathrm{T}}$), collected from the western Gulf of Maine (Sulikowski et al. 2009). Fifty percent maturity occurs between 9 and 10 years and 560 mm $_{L\mathrm{T}}$ for males, and occurs at age 9 years and 540 mm $_{L\mathrm{T}}$ 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 Northeastern Skate Fishery Management Plan 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 prohibited from both commercial and recreational fisheries. However, off the northeast coast of the United States, this species is encountered in several commercial fisheries, including the bottom otter trawl and gillnet fisheries. The NEFSC Observer Program and survey vessels have collected 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 have also been collected to examine the angel shark evolutionary history and population structure using mitochondrial DNA control region sequences. DNA from the northwest Atlantic and from western and eastern populations inthe Gulf of Mexico will be compared. Results from this collaborative study supports current U.S. fisheries management banning all landings of the Atlantic angel shark, with management and conservation units established for a single genetic stock until further genetics 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.

Dusky Shark (*Carcharhinus obscurus*) Genetics

A collaborative study on the genetic stock structure of the dusky shark was conducted to delineate management units and monitor trade in sharks(Benavides et al. 2011). This is the first assessment of global stock structure of *C. obscurus*, and it was completed via analysis of the mitochondrial control region in 255 individuals sampled from eight geographically dispersed locations.These analyses suggest that replenishment of the collapsed U.S. Atlantic management unit via immigration of females from elsewhere is unlikely. In addition, these mitochondrial control region sequences can be used to reconstruct the relative contributions of U.S. Atlantic, South Africa, and Australia management units to the Asian fin trade.

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 10band 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 total length), 16 males (311 to 840 cm total length), and 11 specimens of unknown sex (376 to 853 cm total length). 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 Shark (*Carcharhinus obscurus)*

A revision of the age and growth of the dusky shark in the Northwestern 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. In addition, in conjunction with scientists from Woods Hole Oceanographic Institution, one vertebra is being processed for bomb carbon analysis in an attempt to validate the periodicity of band pair formation for this species. In 2011, preliminary results were obtained from this bomb carbon analysis that indicated band pair periodicity was not annual. In order to obtain a better picture of the periodicity we decided to process more samples. Results are still pending for these analyses.

White Shark (*Carcharodon carcharias*)

The white shark is well documented in the western North Atlantic from Newfoundland to the Gulf of Mexico, including the Bahamas and parts of the Caribbean. However, the species is relatively elusive in the western North Atlantic and efforts to study its life history and ecology have been hampered by the inability of researchers to predictably encounter these sharks. Vertebrae for age and growth have been collected by members of the Apex Predators Program since 1963. Because they are a prohibited species and new samples are not likely to be obtained in sufficient quantity, in 2011 an age study was undertaken with the archived samples in conjunction with MDMF. Vertebrae from 105 samples were processed and band pairs were counted. Preliminary data indicated higher counts than previously obtained for white sharks in other parts of the world. To validate these counts, samples from five specimens were processed for bomb carbon analysis in conjunction with researchers at WHOI. In all but one case, these validated our age estimates. In the last case, the bomb carbon indicated a significant underestimation using band pair counts. Further testing is currently underway to fine-tune the analysis. Results are still pending.

Bull Shark (*Carcharhinus leucas)*

The bull shark is a common coastal carcharhinid that is widely distributed in tropical and subtropical areas of the world's oceans. Bull sharks can also travel into warm rivers and lagoons. In the western North Atlantic, the bull shark is distributed from Massachusetts to southern Brazil, including the Gulf of Mexico and Caribbean Sea and the Bahamas. It also occurs in the Mississippi and Atchafalaya Rivers in the southwestern United States. In 2011, in conjunction with Doug Adams of the Florida Fish and Wildlife Conservation Commission, vertebrae from 124 bull sharks were collected and processed for age studies. The preliminary count was accomplished by the primary reader. More counts need to be done and a secondary reader needs to be identified.

Sandbar Shark (*Carcharhinus plumbeus*)

In collaboration with PIFSC, a bomb radiocarbon and tag-recapture dating study was completed to determine valid age-estimation criteria and longevity estimates for the sandbar shark (Andrews et al. 2011). Results indicated that current age interpretations based on counts of growth bands in vertebrae are accurate to 10 or 12 years. Beyond these years, bomb radiocarbon and tag-recapture data indicated that large adult sharks were considerably older than the estimates derived from counts of growth bands. Three adult sandbar sharks were 20 to 26 years old based on bomb radiocarbon results—a 5- to 11-year increase over the previous age estimates for these sharks. The tag-recapture data provided results that were consistent with bomb radiocarbon dating and further supported a longevity that exceeds 30 years for this species.

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.

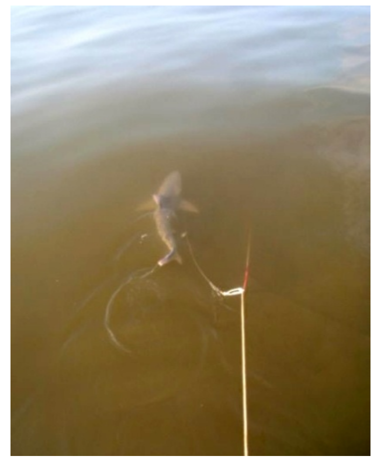


Figure A1.13. Juvenile sandbar shark on NEFSC COASTSPAN Survey bottom longline. Source: NMFS photo.

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. 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% of the current diet by weight and 86.9% 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% 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.

Sandbar Shark (*Carcharhinusplumbeus*)
Non-lethal diet sampling of juvenile sandbar sharks (Figure A1.13) 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.

Results from the non-lethal stomach eversion technique for sandbar sharks shows great promise for trophic ecology studies. The technique involves inserting PVC pipe appropriately sized to the mouth and pharynx into the throat and the stomach past the cardiac sphincter. The pipe is slowly removed generating negative pressure, which draws the stomach into the pipe and down into the mouth. In most cases, the stomach returned to its natural position when the shark was held upright; otherwise forceps were used. Only four sharks could not be everted and had to be sacrificed; all contained extremely large meals (>3.3 %BM) of either teleost or elasmobranch prey in the earliest stages of digestion. This technique was considered effective at limiting sampling mortality, as 19 (1.8 %) of 1,051 tagged and everted sharks were recaptured to date. Time at liberty (3–1,732 days) and straight line distance traveled (0–506 km) varied, though 68 % of sharks were recaptured in Delaware Bay. The tag return rate and movements were similar to other studies on *C. plumbeus* in the region. In addition, sharks kept in tanks for feeding experiments survived multiple eversions.

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% of the stomachs containing 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 predominantly 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 the MDMF, 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 past 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 analyses 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 Shark Species
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 Shark 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 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 4-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, MDMF, and 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.

SableIsland Seal Predation
An investigation into shark predation on five species of seals on Sable Island, Nova Scotia, was completed in conjunction with Sable Island researcher Zoe Lucas (Lucas and Natanson 2010). Between 1993 and 2001, 4,906 seal corpses bearing wounds likely inflicted by sharks were examined on Sable Island. 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 SableIsland. 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 SableIsland. 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 CSTP provides information on distribution, movements, and essential fish habitat for shark species in U.S. Atlantic and Gulf of Mexico waters. This program has involved more than 7,000 volunteer recreational and commercial fishermen, scientists, and fisheries observers since 1962. In 2011, information was received on 7,300 tagged and 415 recaptured fish, bringing the total numbers tagged to 230,000 sharks of more than 50 species and 13,600 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 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% observer coverage on the recreational boats,withobservers 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 I-MARK system provides a platform to keep multispecies 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 thatcheck 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 and information on size, location, time at liberty, and distance traveled. In 2011, all scanned tag card images from the CSTP were linked to the existing I-MARK system.

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 being completed in conjunction with scientists from 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 seasonallydependent 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 northeast Atlantic, this work also supports the two stock hypotheses for the North Atlantic.

Spiny Dogfish (Squalus acanthias) Tagging Study

The NEFSC Apex Predators and Cooperative Research Programs have joined forces to conduct a spiny dogfish tagging study to better assess stock structure, movement patterns, and lifehistory for this species. The goal of this study is to tag spiny dogfish in two consecutive years during the winter and summer months in each of three designated regions: Southern New England, Gulf of Maine, and Georges Bank. In 2011, nine cruises were conducted, one in each area during the months of February, July, and late November/early December, with 16,034 spiny dogfish tagged and released during these cruises.

Scalloped Hammerhead Shark (*Sphyrna lewini*) Movement Patterns

The scalloped hammerhead shark is found circumglobally in temperate to tropical seasand range from shallow coastal waters to the continental shelf and beyond. In the northwest Atlantic Ocean, this species is found from New York to the Caribbean Sea, and throughout the Gulf of Mexico. Despite their worldwide range and encounterswith both benthic and pelagic fisheries, very little is known of this species' habitat preferences or movement patterns.The objective of this study is to analyze mark/recapture data from the CSTP and to investigate movement patterns and habitat selection as well as the possible role that gender and age may play in determining these characteristics. A poster summarizing these results (Eddy et al. 2011b) was given at the 2011 American Elasmobranch Society Meeting.

Southeast Fisheries Science Center (SEFSC)

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

In 2011, SEFSC staff participatedin the International Commission for the Conservation of Atlantic Tunas (ICCAT) Shark Working Group Data Preparatory Meeting in Madrid, with the main goal of collecting and synthesizing all available information on fishing operations and life history of Atlantic pelagic shark species in preparation for an updated and extended Ecological Risk Assessment to be completed in 2012. In addition, new information on fisheries, relative abundance, and life history of the shortfin mako was reviewed during this meeting in preparation for a stock assessment to be carried out in 2012.

In 2011, SEFSC staff completed domestic, benchmark stock assessments of sandbar, blacknose (Gulf of Mexico and 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. The main findings of these assessments follow. The Dusky shark stock was still overfished (biomass in 2009 was estimated to be 41 to 50% of the MSY level) and overfishing was still occurring (F in 2009 was 1.4 to 4.3 times the level of fishing mortality resulting in MSY). Sandbar shark stock was still overfished, but no longer subject to overfishing (most scenarios estimated a fishing mortality rate ranging from 29 to 93% of the level resulting in MSY). Two separate stocks of blacknose shark were idenitifed and assessed separately. Atlantic blacknose shark was overfished (biomass was 43 to 64% of the MSY level) and overfishing was occurring (3 to 22 times the level of fishing mortality resulting in MSY). The Gulf of Mexico blacknose shark assessment was rejected by the SEDAR 21 Review Panel because the assessment model was unable to fit apparent trends in the abundance indices unless implausible additional historical catches were also estimated.

Observer Programs

Shark Longline Program

This program is designed to meet the intent of the Endangered Species Act and the Consolidated Atlantic HMS Fishery Management Plan (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, nine in 2010 and 2011. These vessels carried observers on 100% 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%. From June 2005 to September 2011 a total of 398 trips on 74 vessels with a total of 1066 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% observer coverage during the right whale calving season (November 15 to April 1). Outside the right whale calving season, observer coverage equivalent to 38% 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% observer coverage for drift gillnet vessels during the right whale calving season, but now prohibit all gillnets in an expanded southeast United States 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[11] 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. There were no vessels observed fishing with drift gillnets in 2011 but a total of 2 vessels were observed making 4 strike sets on 4 trips.A total of 71 trips totaling 398 sink net sets on 23 vessels were observed in 2011. Trips were made targeting one or more of the following: shark (including spiny dogfish (*Squalus acanthias*), finetooth shark (*Carcharhinus isodon*) and sandbar shark (*Carcharhinus plumbeus*), Spanish mackerel, Atlantic croaker (*Micropogonias undulates*), and mixed teleosts (including king mackerel, southern kingfish (*Menticirrhus americanus*), kingfish species, and spot (*Leiostomus xanthurus*)).

[11] 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.

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 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 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. While data for some species are limited, these results will be useful in providing habitat use data as inputs to Ecological Risk Assessments.

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 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 per day 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 United States to the North Carolina/Virginia border in June. Asecond 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.

Elasmobranch Feeding Ecology

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).

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 hammerhead sharks 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 bonnethead sharks have been documented to feed mostly on crustaceans and plant material in northwest Florida. Plant material contributed little to the diet of hammerhead sharks (4.98 DC, 3.08 DC, 7.59% FO DC, 1.99 DC). Estimated daily ration was significantly lower for hammerhead sharks (4.6% BW d-1) than for bonnethead sharks 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 hammerheads and 2.6 for bonnetheads. Stable isotope analysis showed hammerhead sharks had significantly higher □15N values and significantly lower □13C values than bonnethead sharks, 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 2011).

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% 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.

Sandbar Shark (*Carcharhinus plumbeus*)

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% 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.

Atlantic angel shark (*Squatina dumeril*) reproduction, diet and feeding
Atlantic angel sharks were collected by fishery-dependent and fishery-independent trawls from 2002 to 2008 for reproductive analysis. Female Atlantic angel sharks 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 approximately 12 months, and embryo data support a seasonal trend in reproduction, with parturition occurring in the spring months (February to June). Mature male Atlantic angel sharks 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% 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 total length). 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.

Great hammerhead shark (*Sphyrna mokarran)*
The great hammerhead sharkis 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, t0= -1.99 year for males and L_∞= 307.8 cm FL, k= 0.11 year-1, t0= -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 great hammerhead sharks, 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: sandbar, blacktip, spinner (*Carcharhinus brevipinna*), bull, silky (*Carcharhinus falciformis*),oceanic whitetip, blacknose (*Carcharhinus acronotus*), finetooth, lemon (*Negaprion brevirostis*), tiger, scalloped hammerhead, great hammerhead, smooth hammerhead (*Sphyrna zygaena*), bonnethead, blue, porbeagle, shortfin mako, common thresher, *and* nurse (*Ginglymostoma cirratum*). Fin sets we had hoped to obtainfrom sharks that are currently prohibited from commercial landings from U.S. Atlantic federal and/or state fisheries include the following species: smalltooth sawfish (*Pristis pectinata*), dusky, bignose (*Carcharhinus altimus*), night (*Carcharhinus signatus*), Caribbean reef (*Carcharhinus perezii*), longfin mako (*Isurus paucus*), bigeye threshser, white, sand tiger, and lemon (in Florida State waters). In the United States, 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

Brazil (Universidade Federal Rural de Pernambuco) and the United States (NMFS SEFSC Panama City Laboratory and the University of Florida's Florida Museum of Natural History) initiated a cooperative shark research project 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 United States and Brazil. Electronic equipment (hook-timer recorders [HTR] and temperature and depth recorders [TDRs]) was sent from the United States 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 (oceanic whitetip (n = 7), blue (n = 23), hammerhead spp. (n = 5), shortfin mako (n = 4), thresher spp. (n = 3), night (n = 2), and crocodile shark (*Pseudocarcharias kamoharai*) (n = 7)) represented 6.6% 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.

This project was expanded to use the HTRs to compare catches in longlines using circle hooks (15/0 and 17/0) and 10/0 "J"- hooks to measure differences in fishing mortality associated with the time fish are hooked and on the line and hook type in the southwest Atlantic Ocean off the coast of Brazil. A total of 431 HTRs were activated, showing a clear increase in the mortality rate of fish caught with increasing time between capture and boarding; however, some species endured long capture periods surviving until the time of boarding. Swordfish had high mortality rates, unlike blue sharks, which had low mortality rates regardless of hook type and the location in which the hook was set. The species of tuna and billfish examined in this study showed a strong association between hook location and the animal's release condition, with reduced mortality in individuals hooked externally. A trend of increased survival with increased individual fish length was observed for most species. However, in sharks, increased survival with increased individual fish length was only observed for the blue shark, while other shark species showed an opposite pattern, although the difference was only statistically significant for crocodile sharks. Results suggest that knowledge of factors affecting the survival of pelagic fish caught in longline fisheries may enable the development and adoption of fishing methods to reduce mortality of longline bycatch.

In addition, the use of 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 PSATs 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.

Figure A1.14. Scalloped hammerhead captured in the Gulf of Mexico during a bottom longline survey.
Source: NMFS Mississippi Laboratories, Shark Team

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

The SEFSC is collaborating with Uruguay's fisheries agency (DINARA) 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) have been successfully deployed on blue sharks to date. Two additional satellite tags (SPLASH) have also been deployed 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 carcharhinid sharks of the Atlantic Ocean for ICCAT (ICCAT 2012).

Shark Assessment Research Surveys

The SEFSC Mississippi Laboratories have conducted bottom longline surveys in the Gulf of Mexico (see Figure A1.14), Caribbean, and Southern North Atlantic since 1995 (29 surveys have been completed through 2011). 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.