NOAA FISHERIES

2014 Shark Finning Report to Congress

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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

Introduction

This Report describes the efforts of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) during calendar year 2013 to implement the Shark Finning Prohibition Act and more recent shark conservation legislation. 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 Shark Finning Prohibition Act requires NMFS to promulgate regulations to implement its provisions, initiate discussion with other nations to develop international agreements on shark finning and data collection, provide Congress with annual reports describing efforts to carry out the Shark Finning Prohibition Act, and establish research programs.

Background

The practice of shark finning and high shark bycatch in some fisheries has led to growing concern about the status of shark stocks and the sustainability of their exploitation in world fisheries. Global shark catches reported to the Food and Agriculture Organization of the United Nations (FAO) have tripled since 1950 reaching an all-time high in 2000 of 888,000 tons. Since then, there has been about a 15 percent decrease in catches, to 765,000 tons in 2012 (FAO 2014). However, research suggests actual numbers of sharks landed annually internationally is underestimated (Clarke et al. 2006). In response to concerns about growing shark harvests internationally, more than 10 countries have banned shark fishing in their waters in favor of promoting tourism opportunities. In addition, Palau, Maldives, Bahamas, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, the Dominican Republic, Taiwan, and many other nations have adopted finning bans.

The MSA is the Federal law governing the conservation and management of Federal fisheries. Along with a suite of conservation and management measures required of all Federal fisheries, including shark fisheries, by the MSA, the Shark Finning Prohibition Act, and the Shark Conservation Act, the United States has been established as a leader in the sustainable management of domestic shark fisheries and the global conservation of sharks. The United States has some of the strongest shark management measures worldwide. In 2013, three out of 34 U.S. shark stocks or stock complexes (9 percent) were listed as subject to overfishing and five shark stocks (15 percent) were listed as overfished. Eighteen stocks or stock complexes (53 percent) had an unknown overfishing status and 19 shark stocks or stock complexes (56 percent) had an unknown overfished status (Table 1).

In the U. S., shark finning has been prohibited since 2000. In 2011, President Obama signed the Shark Conservation Act of 2010, which amended the High Seas Driftnet Fishing Moratorium Protection Act and the 2000 Shark Finning Prohibition Act provisions of the MSA to further improve domestic and international shark conservation measures, including even stronger prohibitions against shark finning. In addition, several U.S. States and territories have passed laws addressing the possession, sale, trade, or distribution of shark fins, including Hawaii (2010), California (2011), Oregon (2011), Washington (2011), the Commonwealth of the Northern Mariana Islands (2011), Guam (2011), American Samoa (2012), Illinois (2012), Maryland (2013), Delaware (2013), New York (2013), and Massachusetts (2014).

Domestically, the Shark Conservation Act states that it is illegal "to remove any of the fins of a shark (including the tail) at sea; to have custody, control, or possession of any such fin aboard a fishing vessel unless it is naturally attached to the corresponding carcass; to transfer any such fin from one vessel to another vessel at sea, or to receive any such fin in such transfer, without the fin naturally attached to the corresponding carcass; or to land any such fin that is not naturally attached to the corresponding carcass, or to land any shark carcass without such fins naturally attached." These provisions improved the U.S.'s ability to enforce shark finning prohibitions in domestic shark fisheries. The 2010 Act also created an exemption for smooth dogfish (*Mutelis canis*) in the Atlantic "if the individual holds a valid State commercial fishing license, unless the total weight of smooth dogfish fins landed or found on board a vessel to which this subsection applies exceeds 12 percent of the total weight of smooth dogfish carcasses landed or found on board."

The Shark Conservation Act amended the High Seas Driftnet Fishing Moratorium Protection Act in two important ways. First, it requires the Secretary of Commerce to identify a nation if two or more fishing vessels of that nation have been engaged in fishing activities or practices in international waters that target or incidentally catch sharks and if that nation has not adopted a regulatory program to provide for the conservation of sharks, including measures to prohibit removal of shark fins at sea. Second, it directs the U.S. to urge international fishery management organizations to which the U.S. is a member to adopt shark conservation measures, such as prohibiting removal of shark fins at sea. It also directs the U.S. to enter into international agreements that require measures for the conservation of sharks.

Table 1

Status of Shark Stocks and Stock Complexes in U.S. Fisheries in 2013

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	Unknown	Unknown
		Atlantic pelagic shark complex	Unknown	Unknown
		Atlantic sharpnose shark	No	No
		Atlantic small coastal shark complex	No	No
		Blacknose shark – Atlantic	Yes	Yes
		Blacknose shark – Gulf of Mexico	Unknown	Unknown
		Blacktip shark – Gulf of Mexico	No	No
		Blacktip shark –Atlantic	Unknown	Unknown
		Blue shark – Atlantic	No	No
		Bonnethead – Atlantic	No	No
		Dusky shark – Atlantic	Yes	Yes

		Finetooth shark – Atlantic	No	No
		Porbeagle – Atlantic	No	Yes
		Sandbar shark – Atlantic	No	Yes
		Scalloped hammerhead shark – Atlantic	Yes	Yes
		Shortfin mako – Atlantic	No	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	American Samoa FEP	American Samoa Coral Reef Ecosystem Multi-Species Complex	Unknown	Unknown
Western Pacific FMC	Mariana Archipelago FEP	Guam Coral Reef Ecosystem Multi-Species Complex	Unknown	Unknown
		Northern Mariana Islands Coral Reef Ecosystem Multi-Species Complex	Unknown	Unknown
Western Pacific FMC	Pacific Remote Islands Areas FEP	Pacific Island Remote Areas Coral Reef Ecosystem Multi-Species Complex	Unknown	Unknown
North Pacific FMC	Gulf of Alaska Groundfish FMP	Gulf of Alaska Shark Complex	No	Unknown
North Pacific FMC	Bering Sea/Aleutian Island Groundfish FMP	Bering Sea / Aleutian Islands Shark Complex	No	Unknown
Western Pacific FMC	Hawaiian Archipelago FEP	Hawaiian Archipelago Coral Reef Ecosystem Multi-Species Complex	Unknown	Unknown
Totals:			**3 "yes" 13 "no" 18"Unknown"**	**5 "yes" 10 "no" 19 "Unknown"**

2013 Accomplishments in Response to Requirements of the Shark Finning Prohibition Act Report to Congress

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

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

NMFS accomplishments to carry out the Act are discussed below. An appendix including detailed information on U.S. shark management and enforcement (Section 1), imports and exports of shark fins (Section 2), international shark efforts (Section 3), 2013 NOAA research on sharks (Section 4), ongoing NOAA shark research (Section 5), and references (Section 6) has been posted online. A copy of this report and the appendix are available online at: http://www.nmfs.noaa.gov/sfa/laws_policies/sca/shark_finning_reports.html.

Regarding the first requirement for this Report, no reliable information exists to determine whether a nation's vessels caught sharks on the high seas or conducted finning. However, data on the international trade of shark fins are available from the FAO and data on U.S. imports and exports of shark fins are available from the U.S. Census Bureau. It is important to note that due to the complexity of the shark fin trade fins are not necessarily harvested by the same country from which they are exported. During 2013, shark fins were imported through the following U.S. Customs and Border Protection districts: Los Angeles, Miami, and New York. In 2013, countries of origin (in order of importance based on quantity) were New Zealand, China, and Hong Kong. Shark fins were also imported in smaller numbers from Spain, South Africa, and Indonesia (see table 2.1.1 in section 2 of the appendix). The mean value of imports per metric ton has consistently declined since 2008 with a more pronounced drop between 2011 and 2013. The unit price of $12,000 per metric ton (mt) in 2013 was well below the mean value in 2008 of $59,000/mt. The majority of shark fins exported in 2013 were sent from the U.S. to Hong Kong, with smaller amounts going to China (Taipei), China, and Turkey (Table 2.2.1). The mean value of exports per metric ton has decreased from $56,000/mt in 2008 to $49,000/mt in 2009, the lowest value since 2007, with the largest weight of 77mt. Detailed information regarding imports and exports of shark fins can be found in section 2 of the appendix associated with this report.

Consistent with the second requirement for this Report to Congress, all recent shark-related management**,** enforcement, international, and research activities in support of the Shark Finning Prohibition Act are summarized. Sharks in Federal waters are managed under 11 fishery management plans under the authority of the MSA. The New England, Mid-Atlantic, Pacific, North Pacific, and Western Pacific fishery management councils have developed 10 of those plans. The Secretary of Commerce has developed the fishery management plan for oceanic sharks and other highly migratory species of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea as required by the MSA. In July 2013, NMFS published a final rule to implement Amendment 5a to the 2006 Consolidated Atlantic Highly Migratory Species Fishery

Management Plan, which maintained the rebuilding of sandbar sharks, implemented a rebuilding plan for scalloped hammerhead and Atlantic blacknose sharks, established total allowable catches and commercial quotas for Gulf of Mexico blacknose and blacktip sharks, and established new recreational shark fishing management measures.

During calendar year 2013, shark-related research took place at all six science centers and included research on data collection, quality control, stock assessments, biological information, incidental catch reduction, and post-release survival. Major management actions took place both domestically and internationally. Domestically, a proposed rule to list four populations of scalloped hammerhead sharks as threatened and two populations as endangered under the Endangered Species Act also published in 2013. NMFS also conducted stock assessments, and issued three 90-day findings in response to petitions to list great hammerhead, dusky, and whale sharks. In addition, violations of the Shark Finning Prohibition Act, and noncompliance with regulations designed to protect sharks, were detected, investigated, and referred for administrative prosecution in the Northeast, Southeast, and Pacific Islands. Details on specific shark management, enforcement, and education activities can be found in section 1 of the appendix, and information on 2013 shark research activities can be found in Sections 4 and 5 of the appendix.

In 2013, work continued to implement the requirements of the Shark Conservation Act of 2010. NMFS published a final rule in January 2013, which amended the identification and certification procedures under the High Seas Driftnet Fishing Moratorium Protection Act and amended the definition of illegal, unreported, or unregulated fishing, consistent with the Shark Conservation Act. NMFS published a proposed rule in May 2013 to implement provisions of the Shark Conservation Act that prohibit any person from removing any of the fins of a shark at sea, possessing shark fins on board a fishing vessel unless they are naturally attached to the corresponding carcass, transferring or receiving fins from one vessel to another at sea unless the fins are naturally attached to the corresponding carcass, landing shark fins unless they are naturally attached to the corresponding carcass, or landing shark carcasses without their fins naturally attached. NMFS is developing regulations to modify the smooth dogfish fishery regulations, to be consistent with the Shark Conservation Act.

Regarding the third requirement, the U.S. participated in the development of and endorsed the FAO International Plan of Action (IPOA) for the Conservation and Management of Sharks. The IPOA-Sharks 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. In addition to meeting the statutory requirement of the Shark Finning Prohibition Act, this annual Report to Congress serves as a periodic update of information called for in both the International and National Plans of Action for sharks. Consistent with the IPOA, the United States developed a National Plan of Action for the Conservation and Management of Sharks in February 2001. Eleven other FAO members have developed national plans of action, and a regional plan of action for the Mediterranean Sea has been developed.

Regarding the fourth report requirement, NMFS continues to work with the Department of State to promote the development of international agreements consistent with the Act. The U.S. brings forward recommendations through bilateral, multilateral, and regional efforts. As agreements are developed, the U.S. implements those agreements.

Throughout 2013, NMFS participated in meetings of international regional fishery management organizations. At many of these meetings the U.S. delegations supported or introduced proposals to strengthen international shark management. Topics supported by the U.S. included increasing biological sampling efforts and research, requiring fins to be attached for incidentally caught sharks, stock assessments, and stock status updates. International 2013 actions included endorsement of the North Pacific blue shark stock assessment by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean. The International Scientific Committee also developed stock status conclusions and conservation advice based on the blue shark assessment, and endorsed a plan to conduct a shortfin mako shark stock assessment in 2014–2015. The Western and Central Pacific Fisheries Commission adopted a conservation and management measure prohibiting the retention of silky sharks. Oceanic whitetip sharks, three species of hammerhead sharks, porbeagle sharks, and manta rays were also added to Appendix 2 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora during 2013. Detailed information on international shark-related efforts during calendar year 2013 is provided in Section 3 of the online appendix.

References and internet sources used to compile this Report can be found in Section 6 of the appendix, available online at
http://www.nmfs.noaa.gov/sfa/laws_policies/sca/shark_finning_reports.html.

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2014 Shark Finning Report to Congress: Appendix

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Section 1: Management and Enforcement

1.1 Management Authority in the United States

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) forms the basis for fisheries conservation and management in Federal waters and requires NMFS and the eight regional fishery management councils to take specific actions. State agencies and interstate fishery management commissions are bound by State regulators and, in the Atlantic region, by the Atlantic Coast Fisheries Cooperative Management Act.

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 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 spiny dogfish) has been the responsibility of the Secretary of Commerce. Spiny dogfish in the Atlantic Ocean are managed by the New England Fishery Management Council (NEFMC) and 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 exclusive economic zone (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 the seaward boundary of each of the coastal States out to 200 nautical 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). While States set fishery regulations in their own waters, they are encouraged to adopt compatible regulations between State and Federal jurisdictions. Many coastal States promulgate regulations for shark fishing in State waters that complement or are more restrictive than Federal shark regulations for the U.S. 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). 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).NMFS is addressing the requirements of the Shark Conservation Act of 2010 through three separate rulemakings.

Rulemaking to Implement Domestic Provisions of the Shark Conservation Act of 2010

On May 2, 2013, NMFS published a proposed rule (78 FR 25685) to implement provisions of the SCA that prohibit any person from removing any of the fins of a shark at sea, possessing shark fins on board a fishing vessel unless they are naturally attached to the corresponding carcass, transferring or receiving fins from one vessel to another at sea unless the fins are naturally attached to the corresponding carcass, landing shark fins unless they are naturally attached to the corresponding carcass, or landing shark carcasses without their fins naturally attached. NMFS proposed this action to amend existing regulations and make them consistent with the SCA. The public comment period was open for 91 days, and over 180,000 comments were received. Twelve states and territories have passed laws that prohibit some combination of the possession, sale, offering for sale, trade, or distribution of shark fins. In the proposed rule, NMFS stated that federal preemption under the Magnuson-Stevens Act was possible if these state laws undermine the management of federal shark fisheries. Since the publication of the proposed rule, NMFS has been engaged in discussions with the affected states and territories to determine whether each state or territories's fin ban undermines federal shark management. These conversations are ongoing.

1.2 2013 Conservation and Management Actions in the Atlantic Ocean

Atlantic Highly Migratory Species Management

On October 2, 2006, the 1999 FMP for Sharks of the Atlantic Ocean 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 1.2.1). The 2007–2013 commercial shark landings and the 2013 preliminary commercial shark landings are shown in Tables 1.2.2 and 1.2.3, respectively. In 2013, catch of Porbeagle in the Atlantic and catch of species in the aggregated large coastal sharks complex in the Gulf of Mexico exceeded the annual catch limits set for the stocks.

Table 1.2.1 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*
		Gulf smoothhound	*Mustelus sinusmexicanus*
Prohibited Species			
Bignose	*Carcharhinus altimus*	Bigeye thresher	*Alopias superciliosus*
Galapagos	*Carcharhinus galapagensis*	Narrowtooth	*Carcharhinus brachyurus*
Dusky	*Carcharhinus obscurus*	Caribbean reef	*Carcharhinus perezii*
Night	*Carcharhinus signatus*	Smalltail	*Carcharhinus porosus*
Sand tiger	*Carcharias taurus*	Sevengill	*Heptranchias perlo*
White	*Carcharodon carcharias*	Sixgill	*Hexanchus griseus*
Basking	*Cetorhinus maximus*	Bigeye sixgill	*Hexanchus nakamurai*
Bigeye sand tiger	*Odontaspis noronhai*	Longfin mako	*Isurus paucus*
Whale	*Rhincodon typus*	Caribbean sharpnose	*Rhizoprionodon porosus*
		Atlantic angel	*Squatina dumeril*
Deepwater and Other Species (Data Collection Only)			
Iceland catshark	*Apristurus laurussoni*	Green lanternshark	*Etmopterus virens*
Smallfin catshark	*Apristurus parvipinnis*	Marbled catshark	*Galeus arae*
Deepwater catshark	*Apristurus profundorum*	Cookiecutter shark	*Isistius brasiliensis*
Broadgill catshark	*Apristurus riveri*	Bigtooth cookiecutter	*Isistius plutodus*
Japanese gulper shark	*Centrophorus acus*	American sawshark	*Pristiophorus schroederi*
Gulper shark	*Centrophorus granulosus*	Blotched catshark	*Scyliorhinus meadi*
Little gulper shark	*Centrophorus uyato*	Chain dogfish	*Scyliorhinus retifer*
Portuguese shark	*Centroscymnus coelolepis*	Dwarf catshark	*Scyliorhinus torrei*
Kitefin shark	*Dalatias licha*	Smallmouth velvet 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 1.2.2 Commercial landings for Atlantic large coastal, small coastal and pelagic sharks in metric tons dressed weight, 2007–2013.
Source: Cortés pers. comm. (2013) and HMS eDealer landings database.

Commercial Shark Landings (mt)							
Species Group	2007	2008	2009	2010	2011	2012	2013
Large Coastal Sharks	1,056	618	686	689	674	629	640
Small Coastal Sharks	280	283	303	162	265	281	215
Pelagic Sharks	118	106	91	141	141	142	118
Total	**1,454**	**1,007**	**1,080**	**992**	**1,080**	**1,052**	**973**

On July 3, 2013, NMFS published a final rule for Amendment 5a to the 2006 Consolidated HMS FMP (78 FR 40318) which maintained the rebuilding of sandbar sharks, implemented a rebuilding plan for scalloped hammerhead and Atlantic blacknose sharks, established total allowable catches (TAC) and commercial quotas for Gulf of Mexico blacknose and blacktip sharks, and established new recreational shark fishing management measures. To accomplish these goals, Amendment 5a established several new regional shark management groups and quotas. Hammerhead shark (great, smooth, and scalloped hammerhead sharks) were pulled out of the LCS management group and separate Atlantic and Gulf of Mexico quota were established. The remaining "aggregated LCS" complex was also divided into two regional quotas; one in the Atlantic for all LCS species except for the three hammerhead species, and one in the Gulf of Mexico for all LCS species except for the three hammerhead species and blacktip sharks. In the Gulf of Mexico, a separate Gulf of Mexico blacktip quota was established. Separate non-blacknose SCS and blacknose shark quotas were also established in the Atlantic and Gulf of Mexico regions. These adjustments help the U.S.to more effectively rebuild stocks of sharks that have been listed as overfished since.

Table 1.2.3 Preliminary landings estimates in metric tons (mt) and pounds (lb) dressed weight (dw) for the 2013 Atlantic shark commercial fisheries.
Landings are based on dealer data provided through the quota monitoring system.

2013 Landings Estimates				
Management Groups	Region	2013 Quota	Estimated Landings in 2013	% of 2013 Quota
Blacktip Sharks	Gulf of Mexico	256.6 mt dw (565,700 lb dw)	239.4 mt dw (527,861 lb dw)	93%
Aggregated Large Coastal Sharks[A]	Gulf of Mexico	157.5 mt dw (347,317 lb dw)	163.8 mt dw (361,214 lb dw)	104%
Hammerhead Sharks	Gulf of Mexico	25.3 mt dw (55,722 lb dw)	10.5 mt dw (23,212 lb dw)	42%
Aggregated Large Coastal Sharks[B]	Atlantic	168.9 mt dw (372,552 lb dw)	155.0 mt dw (341,669 lb dw)	92%

Hammerhead Sharks		27.1 mt dw (59,736 lb dw)	13.4 mt dw (29,454 lb dw)	49%
Shark Research Fishery (Aggregated LCS)	No Regional Quotas	50.0 mt dw (110,230 lb dw)	21.2 mt dw (46,716 lb dw)	42%
Shark Research Fishery (Sandbar only)		116.6 mt dw (257,056 lb dw)	37.0 mt dw (81,628 lb dw)	32%
Non-Blacknose Small Coastal Sharks[C]	Gulf of Mexico	135.7 mt dw (299,075 lb dw)	89.3 mt dw (196,783 lb dw)	66%
	Atlantic	193.5 mt dw (426,570 lb dw)	108.8 mt dw (239,807 lb dw)	56%
Blacknose Sharks	Gulf of Mexico	2.0 mt dw (4,513 lb dw)	1.5 mt dw (3,319 lb dw)	74%
	Atlantic	18.0 mt dw (39,749 lb dw)	15.1 mt dw (33,382 lb dw)	84%
Blue Sharks	No Regional Quotas	273.0 mt dw (601,856 lb dw)	4.4 mt dw (9,767 lb dw)	2%
Porbeagle Sharks		**Closed for 2013**	< 1 mt dw (54 lb dw)	< 1%
Pelagic Sharks Other Than Porbeagle or Blue[D]		488 mt dw (1,075,856 lb dw)	113.5 mt dw (250,138 lb dw)	23%

[A]Aggregated Large Coastal Sharks (LCS) in the Gulf of Mexico includes the following: silky, tiger, spinner, bull, lemon, and nurse.
[B]Aggregated Large Coastal Sharks (LCS) in the Atlantic include the following: silky, tiger, blacktip, spinner, bull, lemon, and nurse.
[C] Non-blacknose small coastal sharks (SCS) include the following: Atlantic sharpnose, finetooth, and bonnethead
[D] Pelagic sharks other than porbeagle and blues include the following: shortfin mako, thresher, and oceanic whitetip

Shark Stock Assessments and Overfishing/Overfished Status

In 2013, Atlantic sharpnose and bonnethead sharks were assessed under the 34th Southeast Data, Assessment, and Review (SEDAR 34) stock assessment. Information contained in the assessment for Atlantic sharpnose shark supported NMFS's determination to split into two separate Gulf of Mexico and Atlantic stocks, both of which are not overfished and not subject to overfishing. The assessment for bonnethead sharks strongly supported splitting into two separate stocks for the Atlantic and Gulf of Mexico. However the underlying models and supporting information in the assessment were not sufficient to determine the overfishing and overfished status of these separate stocks. The 2013 decision to split the stock into two will better help stock assessment scientists improve their estimates of biomass and fishing rate that inform accurate determinations about the status of these stocks.

Observer Coverage

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

Shark Management by the Regional Fishery Management Councils and States

The Mid-Atlantic Fishery Management Council and NMFS manage spiny dogfish (*Squalus acanthias),* the only shark species managed by the Regional Fishery Management Councils in Federal waters off the Atlantic. The Mid- Atlantic Council manages spiny dogfish under the 2000 Spiny Dogfish FMP in consultation with the New England Fishery Management Council. Amendment 2 to the Spiny Dogfish FMP went into effect in 2012 and established annual catch limits (ACL) and accountability measures. The 2014/2015 ACL for spiny dogfish grew to 49,037,000 pounds (previsously 41,784,000 pounds) in response to increases in the spawning stock biomass. Spiny dogfish are typically landed whole, with fins attached, and processed on shore. However, recently, some seafood dealers have expressed interest in buying spiny dogfish dressed at sea, but landed with fins naturally attached, consistent with the 2010 SCA. Current dock prices for whole spiny dogfish are around $0.20 per pound, which includes the value of fins. Spiny dogfish products landed in the United States are almost entirely exported to Europe (meat) and Asia (fins).

A significant decline in spiny dogfish landings and exports occurred during 2013. This was primarily due to the detection of unacceptably high concentrations of polychlorinated biphenyls (PCBs) in spiny dogfish meat at points of entry into the European Union (EU). The EU has much more stringent PCB tolerances for seafood than the U.S., which effectively eliminated large portions of the traditional markets for US caught spiny dogfish during 2013. In response, NMFS has been working with USDA and EU partners to better quantify the occurrence of PCBs in spiny dogfish and smoothhounds (*Mustelus canis),* including testing by Northwest Fisheries Science Center (see details in section 5 below). NMFS continues to work with the USDA, EU and the fishing industry to address the PCB concerns, and re-establish these spiny dogfish markets, and/or develop new markets if appropriate.

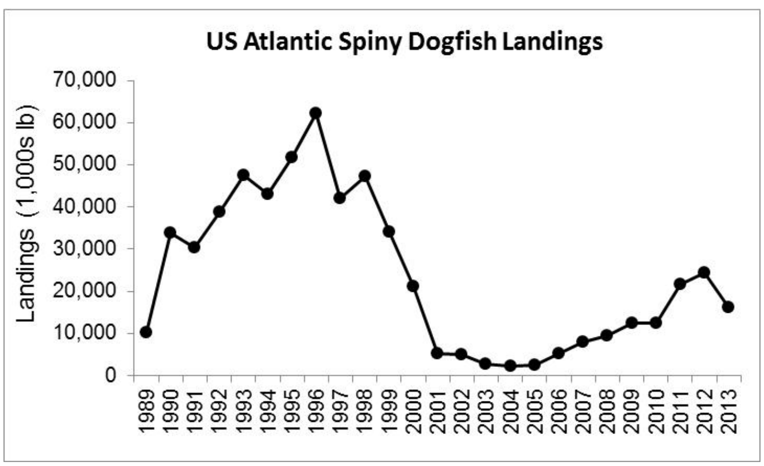

Figure 1.2.1. History of US Atlantic spiny dogfish landings from 1989 – 2013.

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 from 2010-2013. 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 addressed in Amendment 3 to the Spiny Dogfish FMP, which was approved by NMFS in 2014.

1.3 Current Management of Sharks in the Pacific Ocean

Pacific Fishery Management Council (PFMC)

The PFMC's area of jurisdiction is the EEZ off the coasts of California, Oregon, and Washington. The Pacific Fishery Management Council and NMFS manage 6 species of sharks under the 2004 U.S. West Coast Highly Migratory Species (HMS) Fisheries FMP and the Pacific Coast Groundfish FMP (approved in 1982 and most recently amended in 2010).Under the West Coast HMS FMP, these species include the common thresher and shortfin mako (sharks commercially valued but not primarily targeted in the West Coast–based fisheries), as well as blue sharks (Table 1.3.1). Amendment 2 to the West Coast HMS FMP and its supporting regulations (76 FR 56327) reclassified bigeye thresher and pelagic thresher sharks as ecosystem component species that do not require management. The West Coast HMS FMP also designates three shark species as prohibited (Table 1.3.1). If intercepted during HMS fishing operations, these species—great white, megamouth, and basking sharks—must be released immediately, unless other provisions for their disposition are established consistent with State and Federal regulations.

Table 1.3.1 Shark species in the West Coast Highly Migratory Species Fishery Management Plan.

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

Sharks within the West Coast HMS FMP are managed to achieve optimum yield (OY) set at a precautionary level of 75 percent of maximum sustainable yield (MSY). The precautionary approach is meant to prevent localized depletion of these vulnerable species. Blue, thresher and shortfin mako sharks are managed under the West Coast HMS FMP, and while blue sharks are not overfished, the status of thresher and shortfin mako sharks is unknown. The FMP proposed annual harvest guidelines for common thresher and shortfin mako sharks given the level of exploitation in HMS fisheries at the time the FMP was adopted (e.g., large mesh drift gillnet), and accounting for the uncertainty about catch in Mexico of these straddling stocks. High exploitation rates and their impact on HMS shark stocks, if not checked, could take decades to correct given the vulnerable life history characteristics of the species. In 2013, the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) produced its first assessment of blue sharks in the North Pacific Ocean (ISC 2013). The results of that assessment are being used to conduct further analyses and a revised assessment will be presented to the ISC Plenary and WCPFC SC in 2014.

The Pacific Coast Groundfish FMP (last amended in 2010) includes three shark species (leopard, soupfin, and spiny dogfish) in the groundfish management unit (Table 1.3.2). These shark species are mainly caught incidentally in groundfish fisheries and discarded at sea. In 2013, spiny dogfish were not overfished but the status was unknown for soupfin and leopard sharks. Since 2006, NMFS has 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.

Table 1.3.2 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 suckleyi*
Leopard shark	*Triakis semifasciata*

Shark catch data are obtained from commercial landings receipts, observer programs, and recreational fishery surveys. Landings data for the U.S. West Coast are submitted by the States to the Pacific Fisheries Information Network (PacFIN) and Recreational Fisheries Information Network (RecFIN) data repositories. Table 1.3.3 shows commercial shark landing for the West Coast from 2002 to 2012. Estimates of commercial discard, as well as catch in the at-sea hake 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 1.3.3 Commercial Shark landings (round weight equivalent in metric tons) for California, Oregon, and Washington, 2004–2013. Source: PacFIN Database, data for the Pacific Fishery Management Council area extracted using the "Explorer" tool on September 25, 2014[A].

	Commercial Shark Landings (mt) for California, Oregon, and Washington									
Species Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Bigeye thresher shark	5	10	4	5	6	7	1	1	--	<1
Blue shark	1	1	<1	10	<1	1	<1	<1	<1	<1
Brown catshark	--	--	--	--	--	--	11	4	17	1
Common thresher shark	115	179	160	204	147	107	96	75	70	66
Leopard shark	11	13	11	11	3	2	3	2	3	1
Pacific angel shark	13	12	15	8	12	12	9	10	10	11
Pelagic thresher shark	2	<1	<1	2	<1	<1	<1	--	--	--
Shortfin mako	53	33	45	44	35	29	20	17	27	30
Soupfin shark	27	26	30	17	8	5	3	3	2	1
Spiny dogfish	418	468	394	425	638	264	230	393	216	160
Other shark	3	5	4	2	2	2	3	1	2	1
Unspecified shark	6	5	5	5	2	2	20	4	3	2
Total	**654**	**752**	**668**	**733**	**853**	**431**	**396**	**510**	**350**	**273**

[A]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 and NMFS manage fisheries in Federal waters off Alaska. Eleven shark species are found in the Alaskan waters (Table 1.3.4; Goldman 2012). NMFS monitors shark catch in season by species for Pacific sleeper, salmon, and spiny dogfish sharks and the remaining species of sharks are grouped into the "other/unidentified sharks". Pacific sleeper, salmon, and spiny dogfish sharks are taken incidentally in Federal groundfish fisheries while the other eight species are very rarely taken in any sport or commercial fishery.

Table 1.3.4 North Pacific shark species.

North Pacific shark species	
Common name	Scientific name
Pacific sleeper shark	*Somniosus pacificus*
Salmon shark	*Lamna ditropis*
Spiny dogfish shark	*Squalus suckleyi*
Brown cat shark	*Apristurus brunneus*
Basking shark	*Cetorhinus maximus*

Sixgill shark	*Hexanchus griseus*
Blue shark	*Prionace glauca*
Pacific angel shark	*Squatina californica*
White shark	*Carcharodon carcharias*
Common thresher shark	*Alopias vulpinus*
Soupfin shark	*Galeorhinus glaeus*

In Federal waters sharks are currently in a "bycatch only" status, preventing directed fishing for the species. In the Bering Sea/ Aleutian Islands (BSAI), most of the shark incidental catch occurs in the midwater trawl pollock fishery and in the hook-and-line fisheries for sablefish, Greenland turbot, and Pacific cod along the outer continental shelf and upper slope areas. In the Gulf of Alaska (GOA), most of the shark incidental catch occurs in the midwater trawl pollock fishery, non-pelagic trawl fisheries, and hook-and-line Pacific cod, sablefish, and halibut fisheries. The most recent estimates of the incidental catch of sharks in the BSAI and GOA are from 2013. These data are included in Chapter 20 in the 2013 BSAI and GOA Stock Assessment and Fishery Evaluation (SAFE) reports and the NMFS catch accounting system. Estimates of the incidental catch of sharks in the groundfish fisheries from 2003 through 2012 have ranged from 522 to 2,166 mt in the GOA and from 60 to 689 mt in the BSAI (Table 1.3.5). Very few of the sharks incidentally taken in the groundfish fisheries in the GOA and BSAI are retained. Since 2006 there has been no effort targeting sharks in the BSAI or GOA.

Table 1.3.5 Incidental catch and utilization (in metric tons) of sharks in the Gulf of Alaska and Bering Sea/Aleutian Islands commercial groundfish fisheries, 2004-2013. (Values are rounded to nearest metric ton)
Source: NMFS Catch Accounting System Data

Incidental Catch of Sharks (mt) - Gulf of Alaska										
Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Spiny dogfish	183	443	1,188	797	533	1,653	404	484	458	2,061
Pacific sleeper shark	282	482	252	295	66	56	168	26	142	95
Salmon shark	41	60	34	141	7	9	107	7	50	4
Unidentified shark	39	69	83	107	12	24	9	5	10	6
Total	**545**	**1,054**	**1,557**	**1,340**	**618**	**1,742**	**688**	**522**	**660**	**2,166**
% Retained	2.1	3.3	4.2	3.4	6.8	3.3	5.7	2.9	2.6	0.6
Incidental Catch of Sharks (mt) - Bering Sea/Aleutian Islands										
Spiny dogfish	9	11	7	3	17	20	15	8	20	24
Pacific sleeper shark	420	333	313	257	127	51	28	48	47	69
Salmon shark	26	47	63	44	41	71	12	47	26	23

Unidentified shark	60	26	305	28	7	10	6	5	3	1
Total	**515**	**417**	**688**	**332**	**192**	**152**	**61**	**108**	**96**	**117**
% Retained	2.6	4.9	3.9	9.8	6.7	4.1	6.3	6.4	3.6	1.9

In October 2010 NMFS issued a final rule to implement Amendments 95 and 96 to the BASI FMP and Amendment 87 to the GOA FMP (75 FR 61639) in order to comply with statutory requirements for annual catch limits and accountability measures (under National Standard 1), and to rebuild overfished stocks. The NPFMC recommended and NMFS specified, overfishing levels (OFLs), acceptable biological catch (ABCs), and TAC amounts. Due to conservation concerns, the final rules to implement groundfish harvest specifications in the BSAI and GOA in 2012 and 2013 prohibited directed fishing for sharks in both management areas. In other groundfish fisheries open to directed fishing, the retention of sharks taken as incidental catch is limited to no more than 20 percent of the aggregated amount of sharks, skates, octopuses, and sculpins in the BSAI and sharks, octopuses, squids, and sculpins in the GOA.

At its December 2012 meeting, the NPFMC recommended OFLs, ABCs, and TACs for sharks in both the BSAI and GOA for the 2013 and 2014 fishing years. The GOA TAC was based in large part on the natural mortality and biomass estimates for spiny dogfish combined with an average historical catch (1997-2007) of other shark species, while the BSAI TAC was set at a value of 100 mt, substantially less than that recommended ABC which was based on historical maximum catch (1997-2007) of all the shark species. Table 1.3.4 lists the recent historical catch of sharks in the BSAI and GOA. In 2013 the 100 mt TAC for sharks in the BSAI was exceeded (catch was 116 mt). The 2013 GOA TAC was 6,028 t, and catch was 2,167 t. The most recent assessments for sharks are in Chapter 20 to the 2013 SAFE reports for the BSAI and GOA (available online at http://www.afsc.noaa.gov/refm/stocks/assessments.htm).

The shark complexes in the BSAI and GOA are assessed biennially (with update only assessments in the off years), to coincide with the availability of new survey data, thus, the most recent BSAI SAFE report was in 2012 and the most recent GOA SAFE report was in 2011 (a full assessment was not conducted in 2013 due to the government shutdown). 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 2014 in the BSAI and in 2013 in the GOA, with the results incorporated into the SAFE reports for sharks. The next NMFS surveys are scheduled for 2015 in the BSAI and GOA, respectively.

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

Recreational shark fisheries

The Alaska Department of Fish and Game (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.

About 207 sharks of all species were harvested by the sport fishery in State and Federal waters of Southeast and South central Alaska in 2012 (most recent estimate). The South Central Region accounted for 95 percent of the harvest. The catch typically consists almost entirely of spiny dogfish and salmon shark.

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 percent 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 percent 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. No permits have been issued for the Cook Inlet spiny dogfish fishery since 2006.

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 Western Pacific Fishery Management Council and NMFS conserve and manage sharks through five fishery ecosystem plans, The WPFMC's Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region identifies nine sharks as management unit species (Table 1.3.6). Five species of coastal sharks are listed in the fishery ecosystem plans for American Samoa, Hawaii, the Mariana Archipelago, and the Pacific Remote Islands Areas (Table 1.3.7) as currently harvested.

The longline fisheries in the western Pacific, mostly in Hawaii and American Samoa, landed the vast majority of the sharks. 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, which is now prohibited. A State of Hawaii law prohibiting landing shark fins without an associated carcass passed in mid-2000 (Hawaii Revised Statutes 188.40-5). Shark landings have since decreased by almost 50 percent to 1,450 mt in 2000. With the subsequent enactment of the Federal Shark Finning Prohibition Act, shark landings since 2001 have been less than 200 mt (Table 1.3.8). Landings in 2013 were approximately 48 mt, down from 100 mt in 2012, and were 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 1.3.6 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	*Alopias superciliosus*
Silky shark	*Carcharhinus falciformis*
Oceanic whitetip shark	*Carcharhinus longimanus*
Shortfin mako shark	*Isurus oxyrinchus*
Longfin mako shark	*Isurus paucus*
Salmon shark	*Lamna ditropis*
Blue shark	*Prionace glauca*

Table 1.3.7 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	*Carcharhinus albimarginatus*	X	-	X	X
Grey reef shark	*Carcharhinus amblyrhynchos*	X	X	X	X
Galapagos shark	*Carcharhinus galapagenis*	X	X	X	X
Blacktip reef shark	*Carcharhinus melanopterus*	X	X	X	X
Whitetip reef shark	*Triaenodon obesus*	X	X	X	X

The American Samoa longline fishery lands a small amount of sharks compared to Hawaii's longline fisheries (Table 1.3.8). The pattern of shark landings by the American Samoa longline fishery was similar to shark landings by the Hawaii-based longline fisheries and has remained low since 2011. The decline in shark landings by the American Samoa longline fishery is attributed to the Shark Finning Prohibition Act.

Table 1.3.8 Shark landings (in metric tons) from the Hawaii-based and American Samoa-based pelagic longline fisheries, 2003–2013.
Source: Pacific Islands Fisheries Science Center, Fisheries Research and Monitoring Division.

	Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Hawaii-based Longline Fisheries	Blue shark	18	59	30	11	6	8	10	9	16	18	0
	Mako shark	89	65	105	95	127	130	119	92	64	66	43
	Thresher shark	49	55	34	33	44	42	30	17	19	14	4
	Misc. shark	4.1	8.2	7.7	12	6	4	6	4	3	2	<1
	Total shark landings	**160**	**188**	**176**	**150**	**186**	**186**	**166**	**122**	**102**	**100**	**48**
American Samoa	Total shark landings	**4**	**1**	**<1**	**1**	**2**	**1**	**1**	**2**	**4**	**4**	**<2**[1]

[1] 2013 metric tons American Samoa sharks "estimated weight landed" (zero lbs registered/estimated as sold)

Pacific Islands Region Endangered Species Act Scalloped Hammerhead Shark Listing

In response to a petition from WildEarth Guardians to list the scalloped hammerhead shark (*Sphyrna lewini*) under the ESA, NMFS initiated a status review of the species (76 FR 72891; November 28, 2011). On April 5, 2013, NMFS announced a proposed rule (78 FR 20718) to list four of six identified distinct population segments (DPSs) of scalloped hammerhead sharks. The eastern Atlantic DPS and the eastern Pacific DPS were both proposed as endangered; the central and southwest Atlantic DPS and the Indo-West Pacific DPS (which includes the U.S. Pacific territories and the PRIAs [excluding Johnston Atoll]) were both proposed as threatened; and the central Pacific DPS (which includes the Hawaiian archipelago and Johnston Atoll) and the northwest Atlantic and Gulf of Mexico DPS were both found not warranted for listing.

1.4 NOAA Enforcement of the Shark Finning Prohibition Act

The NOAA Office of Law Enforcement (OLE) has responsibility for enforcing the Shark Finning Prohibition Act of 2000 and implementing regulations. During calendar year 2013, violations of the SFPA, and noncompliance with regulations designed to protect sharks, were detected, investigated, and referred for administrative prosecution in the Northeast, Southeast, and Pacific Islands Enforcement Divisions. Violations which were investigated included finning by U.S. domestic fishing vessels and possession of prohibited shark species.

- The NOAA Office of the General Counsel – Enforcement Section (GCES) charged the owner and operator of the commercial shrimp fishing vessel *F/V Whiskey Joe* in two (2) counts under the Magnuson-Stevens Act for possessing shark fins on board the vessel and for not having a valid Atlantic Highly Migratory Species (HMS) permit. In December of 2011, an inspection of the *F/V Whiskey Joe* conducted by U.S. Customs and Border Protection (CBP) officers, wardens from the Texas Parks and Wildlife Division (TPWD), and a special agent from the NOAA Office of Law Enforcement (OLE) lead to the discovery of a bag found to contain shark fins that was secreted in a hidden compartment under the stairs of the wheel house. Forty-eight (48) individual shark fins were recovered by the boarding team. A Notice of Violation and Assessment (NOVA) penalty in the amount of $13,000 was issued to the respondent.

- NOAA GCES charged the owner and operator of the commercial fishing vessel *F/V Kalije Belle* under the Magnuson Stevens Act for illegally using shark bycatch as bait while fishing with longline gear in the United States Exclusive Economic Zone (EEZ). This concludes a joint investigation by the NOAA OLE and the Florida Fish and Wildlife Conservation Commission (FWC) that was initiated in 2011. In September of that year, officers from the FWC, while operating under OLE's Joint Enforcement Agreement (JEA) program, conducted an at-sea boarding an inspection of the *F/V Kalije Belle*. The vessel was intercepted approximately forty-one (41) nautical miles from shore and was actively engaged in longline fishing at the time of the boarding. FWC officers located bait and baited hooks consisting of shark. At the time of the violation, the *F/V Kalije Belle* did not hold a directed or incidental shark permit. Federal regulations require sharks to be harvested under a permit, and to be maintained intact through the landing process dockside. The respondents were issued a civil penalty in the amount $25,723.14 by GCES.

- A boarding team from the U.S. Coast Guard Cutter Heron conducted an inspection of a commercial shrimp fishing vessel in December of 2013. During the boarding, USCG personnel located nine (9) shark fins and three (3) whole sharks. The violations were referred to OLE and the case is currently under advisement by the NOAA Office of the General Counsel - Enforcement Section.

- In 2013, *Bryant Products, Inc*. was charged under the Magnuson-Stevens Act by the NOAA GCES for possessing shark fins from prohibited shark species. During the execution of a civil administrative search warrant on Bryant Products by special agents from the OLE, six (6) shark fins were recovered. Subsequent DNA analysis conducted by NOAA's Marine Forensics Program confirmed that the fins were from dusky and sandbar sharks, which are prohibited species. GCES issued a Written Warning penalty to the respondent.

- The commercial fishing vessel *F/V Sir Martin E* was issued a Written Warning penalty by NOAA GCES for using pieces of shark as bait on pelagic longline gear that was deployed in Federal waters in the Gulf of Mexico. In November of 2008, the vessel was intercepted by officers from the Florida Fish and Wildlife Conservation Commission (FWC) that were conducting an at-sea patrol pursuant to OLE's JEA program. The *F/V*

Sir Martin E was conducting pelagic longline fishing operations approximately eighty-four (84) nautical miles from shore. During the boarding and inspection by FWC officers, pieces of shark were observed mixed into the bait pile on deck and were also documented as having been placed on fishing hooks. Federal regulations require shark in or from the Gulf of Mexico (GOM) U.S. Exclusive Economic Zone (EEZ) to be maintained intact through offloading ashore.

- In April of 2013, OLE special agents were notified by the U.S. Coast Guard (USCG) that a boarding team had discovered shark fins on a chemical tanker ship during an inspection. The captain of the tanker vessel assumed full responsibility and surrendered the fins to the OLE agents.

- Matthew Brian Case, a fishing boat captain formerly based in Hawaii, pled guilty on December 6, 2013 in federal court for attempting to sell shark fins to a Honolulu restaurant, a violation of the federal Lacey Act. Case, a resident of Mexico, voluntarily appeared in Honolulu to answer the criminal charge. Case entered the plea before United States Magistrate Judge Kevin S.C. Chang, who sentenced him to a $100 fine. According to information produced in court, Case was the captain of the *F/V Hokuao*, a longline fishing vessel which operated out of Honolulu. During a month-long fishing trip that began in February 2013, Case instructed his crew to engage in “shark finning,” which involved catching sharks, removing their fins aboard the vessel, and disposing of the carcasses in the ocean. Case concealed approximately 100 shark fins in a hidden compartment in the vessel, and transported them back to Honolulu. During court proceedings, Case admitted trying to sell the shark fins to a restaurant in the Ala Moana area on March 8, 2013. During arguments presented to the court, the government recommended a $100 fine, based on various factors, including Case’s immediate and continued cooperation with authorities, lack of profit, and willingness to return from Mexico to enter the plea. NOAA OLE was assisted by the U.S. Coast Guard, Immigration and Customs Enforcement - Homeland Security Investigations, and the State of Hawaii Department of Conservation and Resources Enforcement.

- A NOAA enforcement officer in the Pacific Islands Division responded to a complaint concerning a Hawaii-based longline fishing vessel wherein the crew reportedly cut the tail off from a thresher shark.

- An individual on board the *F/V Lady Kristie II* was charged in 2013 by NOAA GCES for possessing shark fins without corresponding carcasses. In September of 2009, officers from the Mississippi Department of Marine Resources boarded the shrimp vessel *F/V Lady Kristie II* inside state waters. During the boarding and inspection, state officers discovered four (4) shark fins without corresponding carcasses. A crewmember admitted to removing the fins from several sharks when questioned by law enforcement. NOAA GCES issued a Written Warning penalty.

- In November of 2013, a NOAA enforcement officer, with assistance from the Louisiana Department of Wildlife and Fisheries (LDWF), conducted a dockside inspection of a commercial fishing vessel. As the enforcement team approached the vessel, they observed the vessel captain and crew loading coolers into a nearby truck. An inspection of the coolers revealed ten (10) shark fins. During a boarding of the vessel, no corresponding carcasses were located.

- The owner-operator of the fishing vessel *F/V Diane* was charged by GCES in two (2) counts under the Magnuson-Stevens Act for fishing for Atlantic Highly Migratory Species (HMS) without the appropriate valid vessel permit, and for possessing a prohibited shark. An investigation by the NOAA OLE in June of 2010 determined that individuals on the *F/V Diane* harvested, possessed, and retained a white shark (Carcharias carcharodon), a prohibited species, while fishing in a tournament in Montauk, New York. At the time of landing, NMFS staff monitoring the tournament determined that the animal was a white shark, notified the vessel occupants that the shark was a prohibited species, and advised OLE of the apparent violation. NMFS staff observed that this was the only shark on board the *F/V Diane* at the time of landing. GCES issued an administrative penalty in the amount of $6,650 to the respondent.

- An Enforcement Officer from the Pacific Islands Division conducted an investigation involving Incident reports received from the NMFS Observer program relating to the removal and discard at sea of shark fins. These incidents include:
  - 4 fins from 1 mako shark
  - 8 fins from 2 big eye thresher sharks
  - Two incidents of 4 fins from 1 short fin mako shark
  - 16 fins from 4 short fin mako sharks
  - 12 fins from 3 short fin mako sharks

1.5 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, OLE, and other U.S. shark management entities have completed the following actions:

- NOAA OLE and enforcement personnel from the California Department of Fish and Wildlife (CDFW) participated in a community outreach meeting hosted by the China Town Neighborhood Association in San Francisco, CA. The recent ban under California state law on the possession, sale, and importation of shark fins was discussed. CDFW also reviewed records maintenance requirements for fish dealers per state law.

- In June of 2013, a NOAA enforcement officer monitored the South Jersey Marina's 33rd Annual Shark Tournament, regarded as the highest payout shark tournament in the state. Participating vessels were inspected for compliance with Highly Migratory Species (HMS) permitting requirements and other applicable fisheries regulations.

- The Greater Atlantic Regional Fisheries Office and the Northeast Fisheries Science Center work together to provide the public with information about shark and skate species found in the Northwest Atlantic Ocean. This includes collaborating and coordinating media interviews with shark experts to highlight recent research (i.e., what shark and basking shark papers), to pushing out information about shark related (i.e., spiny dogfish and skates) management actions.

- Staff from NMFS NEFSC attend Northeast U.S. recreational shark fishing tournaments, captains meetings, and local sport fishing shows to inform participants on current shark management regulations and discuss and answer questions on current research. Annually, the NEFSC tagging booklet is updated, detailing tagging and recapture instructions, catch and release guidelines, research results, length and weight information, management regulations, and contact websites and telephone numbers. This booklet along with tags and identification guides and placards are made available to the fishing public and is 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.

- Drs. Kohler and Natanson, staff at the Northeast Fisheries Science Center were featured in Shark Hunters and NBC Sports series that premiered in 2013. These interviews highlighted the research conducted at recreational shark fishing tournaments.

- Dr. Natanson, staff at the Northeast Fisheries Science Center participated in a Twitter question and answer session during 2013 Discovery shark week. This session gave the public the opportunity to interact with NMFS shark biologists in real time

- The NMFS Office of Communications coordinates a national Shark Week campaign that each Region and Science Center has the option of contributing too.

Section 2: 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 the U.S. Customs and Border Protection and to the U.S. Census Bureau as reported in the NMFS Trade database.

2.1 U.S. Imports of Shark Fins

During 2013, shark fins were imported through the following U.S. Customs and Border Protection districts: Los Angeles, Miami, and New York. In 2013, countries of origin (in order of importance based on quantity) were New Zealand, China and Hong Kong. Shark fins were also imported in smaller numbers from Spain, South Africa, and Indonesia (Table 2.1.1). The mean value of imports per metric ton has consistently declined since 2008 with a more pronounced drop between 2011 and 2013. The unit price of $12,000/mt in 2013 was well below the mean value in 2008 of $59,000/mt. 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.

2.2 U.S. Exports of Shark Fins

The majority of shark fins exported in 2013 were sent from the United States to Hong Kong, with smaller amounts going to China (Taipei), China, and Turkey (Table 2.2.1). The mean value of exports per metric ton has decreased from $56,000/mt in 2008 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 $93,000/mt. Values continue to fluctuate in recent years with the 2013 average at $66,000 mt.

2.3 International Trade of Shark Fins

The Food and Agriculture Organization of the United Nations (FAO) compiles data on the international trade of fish. The summaries of imports, exports, and production of shark fins in tables 2.3.1, 2.3.2, and 2.3.3 are based on 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. For 2010 and 2011 global imports of shark fins were approximately 17,000 mt, an increase from the 2008 and 2009 levels. In 2011, the average value of imports increased to $25,544, while the average value of exports increased to $16,022/mt. Hong Kong remains the largest importer and exporter (primarily, re-exports) of shark fins.

Table 2.1.1 Weight and value of dried shark fins imported into the United States, by country of origin.
Note: Weight is rounded to the nearest metric ton and value is rounded to thousands of dollars. (1) means that the weight was less than 500 kilograms.
Source: U.S. Census Bureau

Country	2009		2010		2011		2012		2013	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	0	0	0	0	7	85	0	0	0	0
Canada	1	2	0	0	0	0	0	0	0	0
China	6	200	21	422	12	732	16	131	10	75
China, Hong Kong	11	706	11	695	15	700	2	39	3	89
India	0	0	0	0	(1)	3	0	0	0	0
Indonesia	0	0	0	0	0	0	0	0	(1)	8
Japan	0	0	(1)	3	0	0	0	0	0	0
New Zealand	3	57	1	37	24	275	26	595	50	551
South Africa	0	0	0	0	0	0	0	0	(1)	3
Spain	0	0	(1)	3	0	0	(1)	8	(1)	12
Total	21	966	34	1800	58	1795	44	773	63	739
Mean value	$46,000/mt		$35,00/mt		$31,000/mt		$18,000/mt		$12,000/mt	

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

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

Source: U.S. Census Bureau

Country	2009		2010		2011		2012		2013	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Canada	2	277	1	206	1	199	0	0	0	0
China	3	495	2	335	5	895	(1)	60	1	71
China, Hong Kong	71	2,948	33	2785	29	1,738	51	2,790	7	572
China, Taipei	0	0	(1)	6	0	0	0	0	0	4
Egypt	(1)	3	0	0	0	0	0	0	0	0
Germany	(1)	3	0	0	1	(3)	0	0	0	0
Indonesia	(1)	5	0	0	0	0	0	0	0	0
Japan	0	0	0	0	(1)	4	0	0	0	0
Panama	(1)	21	0	0	0	0	0	0	0	0
Poland	1	15	(1)	22	3	86	0	0	0	0
Portugal	(1)	3	0	0	0	0	0	0	0	0
South Korea	(1)	6	0	0	0	0	0	0	0	0
Turkey	0	0	0	0	0	0	0	0	(1)	10
Total	77	3776	36	3354	38	2925	51	2850	12	788
Mean value	$49,000/mt		$93,000/mt		$77,000/mt		$56,000/mt		$66,000/mt	

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

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

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

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	11	1,182	7	1,351	7	902	6	1,128	16	915
Brunei Darussalam	1	2	0	0	0	0	2	26	0	0
Canada	94	4,994	118	6,508	184	6,217	107	6,487	104	6,351
Chile	(1)	15	0	0	0	0	0	0	0	0
China	2,545	12,052	2,012	10,994	732	4,490	183	968	160	1,065
China, Hong Kong	10,209	276,690	9,984	288,019	9,395	247,087	9,891	296,167	10,322	345,469
China, Macao	119	5,313	123	5,920	132	6,149	119	7,124	116	7,570
China, Taipei	572	6,268	796	8,761	988	7,400	1,157	10,315	1262	14,273
Indonesia	84	366	220	1,515	150	1,120	237	970	101	1,762
Laos	12	67	(1)	1	(1)	(1)	0	0	0	0
Malaysia	1,220	2,885	1,197	3,418	1,331	3,809	3,676	10,369	3,489	10,248
Myanmar	42	39	2	40	119	372	813	2,173	601	1,635
North Korea	25	1,154	1	579	(1)	24	69	267	(1)	8
Peru	2	12	28	141	54	246	77	546	71	688
Singapore	2,163	53,570	848	38,412	557	27,576	591	36,690	595	43,863
South Korea	2	82	4	167	2	119	3	223	6	602
Thailand	405	1,898	103	925	44	651	63	761	96	1,021
Timor-Leste	0	0	0	0	112	29	96	24	131	29
United Arab Emirates	0	0	0	0	0	0	0	0	26	1,209
Total	**17,506**	**366,559**	**15,443**	**366,751**	**13,807**	**306,191**	**17,090**	**374,238**	**17,096**	**436,708**
Mean value	**$20,939/mt**		**$23,749/mt**		**$22,177/mt**		**$21,898/mt**		**$25,544/mt**	

Table 2.3.2 Weight and value of shark fins exported by countries other than the United States.
Note: Data are for “total exports,” which is a combination of domestic exports (may include products of both domestic and foreign origin) and re-exports (commodities that have entered into a country as imports and not sold, which, at the time of re-export, are in substantially the same conditions as when imported). Weight is rounded to the nearest metric ton and value is rounded to thousands of dollars. (1) indicates that the weight < 500 kilograms.
Source: Food and Agriculture Organization of the United Nations, FishStat database, www.fao.org

Country	2007		2008		2009		2010		2011	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metri c ton	Value ($1000)
Angola	3	179	2	149	4	282	7	527	19	873
Argentina	11	503	79	2,051	84	3,371	62	2,697	70	2,312
Bangladesh	351	1,407	17	403	15	347	8	99	11	260
Benin	0	0	0	0	0	0	0	0	21	59
Brazil	131	2,313	113	2,825	85	2,338	49	1,376	59	2,109
Brunei Darussalam	4	21	0	0	0	0	0	0	2	184
Chile	4	158	0	0	5	194	1	46	3	167
China	552	12,138	394	7,501	382	8,474	314	6,971	489	12,218
China, Hong Kong	5,684	97,183	5,308	101,181	4,935	80,316	5,060	73,198	3,362	88,918
China, Macao	0	0	0	0	0	0	0	0	8	444
China, Taipei	1,016	8,964	916	8,551	974	8,756	1,14	12,078	106	13,664
Colombia	19	1,146	16	1,074	19	600	11	509	10	724
Congo, Dem. Rep. of the	0	0	(1)	10	0	0	0	0	5	287
Congo, Republic of	10	266	15	410	17	410	13	410	15	900
Costa Rica	10	69	0	0	75	282	66	251	112	628
Cuba	0	0	0	0	0	0	0	0	1	204
Ecuador	12	257	124	2,526	131	2,627	184	3,388	226	4,399
Gabon	0	0	0	0	0	0	3	189	3	322
Guinea	39	1,692	52	2,665	40	2,228	51	3,290	56	4,376
Guinea-Bissau	5	276	0	0	2	160	0	0	0	0
India	96	3,879	95	7,496	107	12,504	98	8,946	135	8,310
Indonesia	801	7,303	1,320	7,047	1,43	10,833	2,378	13,563	1,607	13,570
Japan	197	8,735	163	8,457	164	6,824	164	8,591	131	8,759
Kiribati	0	0	0	0	39	360	18	131	26	217

Table 2.3.2 Continued

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)
Kuwait	0	0	0	0	0	0	0	0	1	23
Liberia	6	384	4	310	4	415	8	679	3	317
Malaysia	447	1,409	460	2,233	347	1,349	260	1,614	417	1,981
Maldives	15	107	9	70	9	57	4	22	0	0
Marshall Islands	55	825	17	305	16	495	11	539	24	1,717
Panama	66	4,836	61	2,615	47	3,310	37	1,457	24	1,481
Papua New Guinea	17	1,412	17	1,526	2	388	17	1,220	25	2,200
Peru	245	10,648	134	7,127	155	6,945	202	10,990	206	13,648
Philippines	7	3	27	40	3	11	35	25	2	3
Saudi Arabia	0	0	6	145	6	133	4	140	11	644
Senegal	2	14	0	0	0	0	0	0	0	0
Seychelles	9	86	2	29	7	167	5	157	4	218
Sierra Leone	0	0	0	0	(1)	15	3	61	2	44
Singapore	1,690	44,274	677	27,382	296	15,901	390	23,088	238	20,295
Somalia	(1)	3	0	0	0	0	0	0	0	0
South Korea	7	224	16	610	34	1,063	80	3,137	93	4,491
Suriname	4	260	4	243	93	192	54	539	178	561
Thailand	13,188	48,424	4,724	26,279	5,005	24,795	7,141	32,545	7,723	40,245
Togo	23	2,100	21	1,900	31	2,900	38	4,100	33	3,600
Trinidad and Tobago	10	540	106	1,750	186	1,600	129	740	364	2,281
United Arab Emirates	496	14,609	515	16,228	460	13,242	501	17,912	479	14,823
Uruguay	21	332	22	335	16	269	12	188	10	87
Venezuela	2	21	8	53	7	113	13	46	16	74
Vietnam	157	476	693	3,157	347	1,540	98	504	223	1,105
Yemen	527	10,926	629	15,532	260	10,736	431	13,942	347	12,428
Total	**25,944**	**288,384**	**16,784**	**260,215**	**15,846**	**226,587**	**19,104**	**249,905**	**17,861**	**286,169**
Mean value	**$11,116/mt**		**$15,504/mt**		**$14,299/mt**		**$13,081/mt**		**$16,022/mt**	

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

Country	2007	2008	2009	2010	2011
Bangladesh	0	266	276	955	0
Brazil	131	113	85	50	60
China, Taipei	36	89	12	381	29
Ecuador	12	124	131	184	226
El Salvador	44	0	19	0	0
Guyana	125	131	132	126	75
India	172	1232	1624	933	425
Indonesia	1360	1320	1367	2320	1395
Maldives	11	9	9	4	0
Pakistan	69	78	80	83	91
Senegal	16	22	27	18	35
Singapore	170	260	218	192	210
South Korea	7	16	34	80	93
Sri Lanka	80	50	70	70	90
Uruguay	7	25	0	14	8
Yemen	527	629	260	431	347
TOTAL (mt)	**2767**	**4364**	**4344**	**5841**	**3084**

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

The key components of a comprehensive framework for international shark conservation and management have already been established in global and regional agreements, as well as through resolutions and measures adopted by international organizations. 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 Shark Finning Prohibition Act. Discussions have focused on possible bilateral, multilateral, and regional work with other nations. The Act 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. Please go to http://www.nmfs.noaa.gov/ia/species/sharks/shark.html to learn more about the United States' international shark conservation activities.

3.1 Bilateral Efforts

The United States continues to participate in bilateral discussions with a number of States and entities to address 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 shark fin landings, transshipping activities, and catch and trade data. 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, implementing and periodically updating their own National Plans of Action and to adopt a policy that requires all sharks to be landed with their fins naturally-attached.

For example, in an effort to better monitor shark product trade in light of new additions of several shark species to CITES Appendix II, NMFS and NGO partners have been working to build capacity in Central and South American countries. These efforts have been broad covering topics from chain of custody, species identification using several visual keys, and genetic tools for monitoring. A kickoff workshop was held in Brazil in December 2013 (see http://www.nmfs.noaa.gov/ia/slider_stories/2014/01/recife_workshop.html).   NOAA's Office of International Affairs also awarded a grant to WWF to establish 2 pilot project level genetic identification labs in Ecuador. Ecuador was chosen due to their already well-established fishery monitoring program allowing for more seamless implementation. Planning of the labs and training workshops is underway. .

In order to promote data collection in Mexico, the SWFSC and SWR are collaborating on multiyear efforts with 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, U.S. and IATTC scientists. Sampling has provided valuable data for international assessment efforts through the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), as well as for a USA-Mexico partnership to assess the status of common thresher sharks. As a result of the sampling program, fishery data for pelagic sharks now includes some size and sex sampling as well as several years of species specific catch information. In 2013, the Mexican scientists produced a time series of North Pacific blue shark catch that was used in the International Scientific Committee’s first North Pacific blue shark stock assessment.

3.2 Regional Efforts

The U.S. Government continues to place priority on shark conservation and management globally and work 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 3.2.1 lists RFMOs and regional/multilateral programs in which the United States has worked to address shark conservation and management. Of the list in Table 3.2.1, The United States is a party to ICCAT, NAFO, CCAMLR, 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 which the United States is a Party are discussed below as a supplement to last year’s Report to Congress.

Table 3.2.1   Regional Fishery Management Organizations and Programs.

Regional Fishery Management Organizations and Programs
• Northwest Atlantic Fisheries Organization (NAFO)
• Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)
• Inter-American Tropical Tuna Commission (IATTC)
• International 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)
- South Pacific Fisheries Commission (SPRFMO)

Northwest Atlantic Fisheries Organization (NAFO)

The NAFO Fisheries Commissions maintains a ban on shark finning in all NAFO-managed fisheries and mandated the collection of information on shark catches. The NAFO Fisheries Commission was the first regional fisheries management organization to establish a total allowable catch (TAC) for a directed elasmobranch fishery, but that TAC was too high. The United States successfully negotiated a series of reductions since 2010 and the TAC (at 7,000 metric tons) is now consistent with scientific advice.

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

In 2006, CCAMLR adopted a conservation measure prohibiting directed fishing on shark species in the Convention Area, other than for scientific research purposes. The conservation measure requires that any bycatch of shark, especially juveniles and gravid females, taken accidentally in other fisheries, shall, as far as possible, be released alive. Few sharks are caught in the Convention Area.

In 2011 and 2013, the United States tabled a proposal to require landing of sharks with fins naturally attached to discourage the finning of sharks incidentally caught and retained and improve the opportunities to collect data of such sharks. The proposal was not adopted in 2011 due to an early intervention by the EU indicating that they would not be able to take a position on the fins attached issue until their internal process to amend the EU Finning Regulation was concluded. In 2013, the proposal was met with strong support from many members. However consensus could not be reached. The United States intends to re-table the proposal at the 2014 annual meeting with co-sponsorship of some of members who expressed strong support.

Inter-American Tropical Tuna Commission (IATTC)

The IATTC adopted Resolution C-05-03 in 2005 on the conservation of sharks to require controls on shark finning using a five percent fin-to-carcass weight ratio requirement. In 2006, the IATTC Working Group on Stock Assessment presented information showing that the five percent fin-to-carcass weight ratio is difficult and inaccurate to apply due to the variation in weights by shark species, the type of cut used to remove the fins from the carcass, and variations in fleets drying fins on boards. The US has been consistently promoting a proposal to address those deficiencies by proposing a requirement that fins be naturally attached.

In 2013 and 2014, the European Union (EU) sponsored a proposal to require fins naturally attached that was supported by the United States and others; however, the Commission could not agree to adopt revisions to Resolution C-05-03 at that time

At the 2013 IATTC Annual Meeting, the U.S. also supported a proposal by the scientific staff of the IATTC to amend the measure for oceanic whitetip shark (Resolution C-11-10) to include silky shark. Although the United States supported this recommendation it was not adopted by the Commission.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

At its 2013 Annual Meeting, the U.S. supported ICCATs adoption of a proposal that will improve biological sampling of shark species that are currently prohibited from retention in ICCAT fisheries and that are dead at haulback, including oceanic whitetip, bigeye thresher, silky and scalloped, smooth and great hammerhead sharks.

Also at the 2013 meeting, the United States co-sponsored a proposal to require that all sharks be landed with their fins naturally attached. The text of this proposal was modified slightly from the version proposed by Belize, Brazil and the United States in the years 2009-2012. In addition, the following co-sponsors were added in 2013: Egypt, EU, Guatemala, Mexico, Panama, Senegal, and UK-Overseas Territories. As in past years, no consensus could be reached, but the increasing number of co-sponsors indicates growing support among some other ICCAT parties for a fins-attached approach. The issue is expected to be reconsidered at ICCAT's 2014 Annual Meeting. Proposals relating to shortfin mako and porbeagle sharks were also circulated at the 2013 Annual Meeting but were not adopted.

In 2013, the SCRS conducted an intersessionial meeting, the main product of which was the development of a Shark Research and Data Collection Program (SRDCP). The SRDCP focuses on the reduction of the major sources of uncertainty in the formulation of scientific advice, including the improvement of data collection and reporting procedures, and is included in the SCRS's strategic science plan envisaged for the period 2014-2020.

Western and Central Pacific Fisheries Commission (WCPFC)

At its 8th Regular Session of the Commission in March 2012, the Commission added whale shark to the list of key species. In 2011, based on a U.S proposal, the WCPFC adopted a conservation and management measure (CMM) for oceanic whitetip sharks, prohibiting retention on board, transshipment, and landing of the species. At its 9th Regular Session of the Commission in December 2012, the Commission adopted a CMM prohibiting intentional sets by purse seine vessels in the vicinity of whale sharks. In 2013, WCPFC adopted a CMM that prohibits retaining on board, transshipping, storing on a fishing vessel, or landing any silky shark caught in the Convention Area, in whole or in part, in the fisheries covered by the Convention. In addition, the measure requires the release of any silky shark as soon as possible after it is brought alongside the vessel, and to do so in a manner that results in as little harm to the shark as possible. The measure mimics a similar one adopted in 2012 for oceanic whitetip shark.

Stock assessments for oceanic whitetip sharks and on silky sharks were conducted in 2012 and 2013, and were reviewed by the Scientific Committee (SC) of the WCPFC. The SC8 (2012) and SC9 (2013) concluded that both oceanic whitetip and silky sharks are currently overfished and that both stocks are experiencing overfishing relative to commonly used MSY-based reference points. SC8 recommended management measures for mitigation to avoid capture of oceanic whitetip sharks. SC9 recommended measures directed at bycatch mitigation for silky sharks as well as measures directed at targeted catch, such as from shark lines.

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

The Thirteenth ISC Plenary, held in Busan, Korea from July 17–22, 2013, was attended by members from Canada, Chinese Taipei, Japan, Korea, Mexico, and the United States. The Plenary reviewed the progress of the Shark Working Group, reviewed the North Pacific blue shark stock assessment and endorsessed the conculsions that the stock is not overfished or experiencing overfihsing, developed conservation advice based on the blue shark assessment, and endorsed the SHARKWG's work plan to conduct a shortfin mako shark stock assessment in 2014/2015 and to sponsor the Second ISC Shark Age and Growth Workshop in early 2014. The SHARKWG held three working group meetings in 2013 to work on a North Pacific blue shark stock assessment and to advance shortfin mako fishery and life history data compilation. The final blue shark assessment data preparatory meeting was held in January 2013 in La Jolla, United States. The blue shark assessment meeting was held in April 2013 in Shizuoka, Japan. The blue shark assessment report was finalized and the SHARKWG began to examine shortfin mako shark fishery and life history data at a meeting in July 2013 in Busan, Korea. Active participants to the meetings have included Canada, Chinese Taipei, Japan, Korea, Mexico, USA, IATTC and the Secretariat of the Pacific Community (SPC).

3.3 Multilateral Efforts

The U.S. Government continues to work within other multilateral fora to facilitate shark research, data collection, monitoring, and management initiatives, as appropriate. Table 4.3.1 lists these multilateral fora. Of the list in Table 4.3.1, the recent activities for five organizations are discussed below as a supplement to last year's *Report to Congress.*

Table 3.3.1 Other multilateral fora.

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

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

CITES has taken a number of actions to address the international trade of sharks and rays and help ensure that it is sustainable. Most recently, at the Sixteenth Meeting of the Conference of the Parties (CoP16) to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which was held in Bangkok, Thailand in March 2013, several commercially harvested shark and ray species were listed in Appendix II of CITES. The newly listed shark species include: oceanic whitetip shark, three species of hammerhead sharks (scalloped, great, and smooth), porbeagle shark, and manta rays. The effective date for these listings is September 14, 2014. Shark species already listed in Appendix II of CITES include the basking shark, whale shark, and great white shark.

Prior to CoP16, all sawfishes (Pristidae) were listed in Appendix I of CITES, with the exception of *Pristis microdon*. At CoP16, CITES Parties adopted a proposal submitted by Australia to transfer this species from Appendix II to Appendix I. The proposal was put forward to provide the same protection to freshwater sawfish provided to other species of the Pristidae family and help facilitate enforcement due to look-alike issues.

World Customs Organization

Related to actions taken in CITES and RFMOs to increase protection for commercially-exploited shark species, the World Customs Organization's (WCO) Harmonized System Review Subcommittee considered a Food and Agriculture Organization (FAO) proposal supported by the United States that would assist countries in tracking international trade in shark fins of several commercially-important species, including porbeagle shark, oceanic whitetip shark, hammerhead sharks, and blue shark. The FAO proposal would establish global harmonized system tariff codes to permit the monitoring of trade in shark fins for these commercially significant shark species. However, the proposal for species-specific codes did not receive sufficient support among WCO members to advance during the current 2017 review cycle. Although the proposed species-specific codes were not adopted, aspects of the FAO proposal that were successful at the WCO will help improve the monitoring of shark products in trade by establishing separate codes for fresh, frozen, prepared, and preserved forms of shark fins, among other changes. The next opportunity for WCO consideration of this proposal may take place during the upcoming 2022 review cycle.

Food and Agriculture Organization of the United Nations (FAO)

The FAO maintains it's International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks), which is understood to include all species of sharks, skates, rays, and chimaeras (Class Chondrichthyes). The IPOA-Sharks 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. Twelve FAO members have developed national plans of action, including the United States, and a regional plan of action for the Mediterranean Sea has been developed.

United Nations (UN))

The United States continues to work within the United Nations system (UN) process to develop specific calls to States and RFMOs to strengthen conservation and management measures for sharks. The United States has 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 improving 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)

In February 2010, the United States, along with 10 other States signed a global Memorandum of Understanding (MOU) for Migratory Sharks under the auspices of the Convention on Migratory Species. There are currently 36 Signatories - 35 national governments, including the United States, and the European Union. 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.

Section 4: 2013 NOAA Research on Sharks

Large predators such as sharks are a valuable part of marine ecosystems. Many shark species are vulnerable to overfishing because they are long-lived, take many years to mature, and only have a few young at a time. To manage sharks sustainably, we need information about their biology and the numbers caught (either as target species, incidentally, or as bycatch) to make sure their populations are not depleted. 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 2013 is presented here, but more complete descriptions of ongoing research taking place in each region is found in Appendix 5.

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

Pacific Islands Fisheries Science Center (PIFSC)

Fishery Data Collection

Market data from the PIFSC shore side 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 (Lowe et al. 2013). 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. Federal logbooks were implemented for the American Samoa longline fishery in 1996, and the PIRO Observer Program began in 2006.

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 since 2000. These estimates include surveys of major shallow reefs in the Northwestern Hawaiian Islands, the main Hawaiian Islands, and the Pacific remote island areas, American Samoa, Guam and the Commonwealth of the Northern Marianas Islands, Johnston Atoll, and Wake Atoll.

Although 11 species of shark have been observed during Coral Reef Ecosystem Division surveys (Table A.1.1), only four species are typically recorded by towed divers in sufficient frequency to allow meaningful analyses: grey reef shark (*Carcharhinus amblyrhynchos*), Galapagos shark (*Carcharhinus galapagensis*), whitetip reef shark (*Triaenodon obesus*), and blacktip reef shark (*Carcharhinus melanopterus*).

Spatial analyses of data up to 2011 showed 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. Williams et al., 2011; Nadon et al., 2012). More recent data is entirely consistent with those findings. Analyses through time (~ 12 years) indicate downwards trends in reef shark densities in the Northwestern Hawaiian Islands and in the Northern Mariana Islands. In 2013, deployment of baited and un-baited remote underwater video cameras to measure fish and shark abundance levels may help add to the understanding of these population trends. Possible explanations for these patterns are currently being investigated.

Growth rates of Tiger Shark in Hawaii
PIFSC, in collaboration with the University of Hawai'i, Hawai'i Institute of Marine Biology, used mark/recapture data to estimate growth rates and maximum size for tiger sharks (Galeocerdo cuvier) in Hawai'i. Results found that tiger sharks in Hawaii grow twice as fast as previously thought, on average reaching 340 cm TL by age 5, and attaining a maximum size of 403 cm TL. The maximum likelihood growth model indicated that the fastest growing individuals attain 400 cm TL by age 5, and the largest reach a maximum size of 444 cm TL. The largest shark captured during the study was 464 cm TL but individuals >450 cm TL were extremely rare (0.005% of sharks captured). It was concluded that tiger shark growth rates and maximum sizes in Hawaii are generally consistent with those in other regions, and hypothesized that a broad diet may help them to achieve this rapid growth by maximizing prey consumption rates (Meyer et al., 2014).

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 the Southeast Fisheries Science Center) is currently involved in a project funded by the NMFS Office of Protected Resources through their Species of Concern Program to validate the age, growth, and longevity of sand tiger shark (*Carcharias taurus*) from the western North Atlantic (WNA) and southwestern Indian Oceans (SIO). 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. Visual counts of vertebral growth bands were used to assign age and estimate year of formation (YOF) for sampled growth bands in eight sharks from the WNA and two sharks from the SIO. Carbon-14 results were plotted relative to YOF for comparison with regional $\Delta^{14}C$ reference chronologies to assess accuracy of age estimates. Results from the WNA validated vertebral age estimates up to 12 years, but indicated ages of large adult sharks were underestimated by 11-12 years. Age was also underestimated in adult sharks from the SIO by 14-18 years. Overall, validated lifespan for *C. taurus* is at least 40 years for females and 34 years for males. Findings indicate the current age-reading methodology is not suitable for estimating the age of *C. taurus* beyond approximately 12 years. Future work should investigate whether vertebrae of *C. taurus* record growth throughout ontogeny, or cease to be reliable indicator at some point in time (Passerotti et al., in review).

White Shark in NE Pacific

Age validation studies of large shark species using bomb radiocarbon (14C) dating have revealed that the growth of vertebrae can cease in adults. In a previous study of white sharks (*Carcharodon carcharias*) of the northeastern Pacific Ocean the latest growth material (leading edge of the corpus calcareum) was assigned a known date of formation assumed to coincide with the individual's date of capture. This perspective prevented the assignment of older years of formation (a shift in age) to this material, leading to complicated results and no validated age estimates. A reanalysis of the bomb 14C data, in light of the recent findings for other species, has led to a validated lifespan estimate exceeding 30 years for white sharks of the northeastern Pacific Ocean (Andrews and Kerr, 2014).

Deep water dogfish finspines

Vertebrae of most deep-water sharks are too poorly calcified to record visible growth bands and therefore are not useful for age determination. Most dogfish species (Order: Squaliformes) possess dorsal finspines and several recent studies have shown that these structures offer potential for age determination. Age validation should be central to any age determination study, yet to date no age and growth study of deep-water sharks has included a complete validation of age estimates. In this study we sought to age two deep-water dogfish species by analyzing 210Pb and 226Ra incorporated into the internal dentin of the finspines. These radiometric age estimates were compared with counts of internal growth bands observed in the finspines. A pilot study indicated that dorsal finspines of Centroselachus crepidater are too small and thus offer insufficient mass for the radiometric techniques employed in this study. For ageing larger finspines of Centrophorus squamosus, the lead–radium disequilibria method (ingrowth of 210Pb from 226Ra) was found to be inapplicable due to exogenous uptake of 210Pb in the finspine. Therefore, to approximate age, we measured the decay of 210Pb within the dentin material at the tip of the finspine (formed in utero), relative to the terminal material at the base of the finspine. Results with this method proved to be inconsistent and did not yield reliable age estimates. Hence the use of 210Pb and 226Ra for radiometric age determination and validation using dorsal finspines from these deep-water dogfishes was deemed unsuccessful. This outcome was likely due to violations of the consistent, life-long isotopic uptake assumption as well as the provision that the finspine must function as a closed system for these radioisotopes. Future improvements in analytical precision will allow for smaller samples to be analyzed, potentially yielding a better understanding of the fate of these radioisotopes within finspine dentin throughout the life of the shark (Cotton et al., 2014).

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

Abundance Surveys

<u>Juvenile Shortfin Mako (*Isurus oxyrinchus*) and Blue Shark (*Prionace glauca*) Survey</u>

In 2013, the SWFSC conducted its twentieth juvenile shark survey for mako and blue sharks since 1994. The annual abundance survey was completed between July 3 and July 26, 2013. Working aboard F/V *Ventura II*, a team of scientists and volunteers fished a total of 5,946 hooks during 28 daytime sets within seven focal areas of the Southern California Bight. The survey catch totaled 257 shortfin makos, 14 blue sharks, 11 pelagic rays (*Pteroplatytrygon violacea*), 8 opah (*Lampris guttatus*), and 1 ocean sunfish (*Mola mola).* The preliminary data indicate that the nominal survey catch rate was 1.08 sharks per 100 hook-hours for shortfin mako and 0.06 sharks per 100 hook-hours for blue sharks. The mako shark nominal CPUE was higher than the previous year. However, there is a declining trend in nominal CPUE for both species over the time series of the survey.

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 2013, SWFSC scientists and volunteers conducted the survey aboard the F/V *Outer Banks*. Forty-nine longline sets were made in relatively shallow, nearshore waters and a total of 4,916 hooks were fished during the 18-day cruise. A total of 336 fish across a range of species were sampled during the survey. Two hundred and eighty-five thresher sharks were captured. Most of these sharks were injected with oxytetracycline and tagged with a combination of conventional tags for movement and stock structure, and plastic dorsal tags containing return information for the age and growth study. The preliminary survey data indicate that the average nominal catch rate by set was 2.49 thresher sharks per 100 hook-hours, equivalent to the CPUE from 2012. The overall average trend since the start of the survey is increasing.

Electronic Tagging Studies
Since 1999, SWFSC scientists have used data logging tags and satellite technology to characterize the essential habitats of large pelagic fish and subsequently to better understand how populations might shift in response to changes in environmental conditions on short or long time scales; sharks tagged are primarily blue sharks, shortfin mako, and common thresher sharks, while other species are tagged opportunistically. In recent years, the SWFSC has collaborated with Mexican colleagues at Centro de Investigación Científica y de Educación Superior de Ensenada, Canadian colleagues at the Department of Fisheries and Oceans Pacific Biological Station in Nanaimo, British Columbia, and the Tagging of Pacific Predators program (www.topp.org) on shark tagging.

In 2013, a number of sharks were released with electronic tags in support of several collaborative projects. Four shortfin mako and two blue sharks were tagged with satellite-linked radio position tags (SPOTs). Three shortfin mako and one common thresher were released with pop-off satellite archival tags (PSATs). SWFSC scientists have been synthesizing all the electronic tagging data for mako sharks. Data from 85 SPOTs with deployment durations of 3 to 1025 days and 56 PSATs with durations of 18 to 227 days, including data from 40 double tagged sharks, have been analyzed. The sharks ranged from the surface to more than 600 m depth, with the majority of time spent in the top 100 m. The range of horizontal movements of tagged sharks spanned along the coast of North America from the northern coast of Washington to just south of Puerto Vallarta, Mexico and out to the Hawaiian Islands. Two sharks travelled as far south as 4˚N but did not cross the equator.

The SWFSC has an ongoing basking shark research program and has deployed 4 satellite tags on basking sharks since 2010. Data from all sharks tagged with satellite tags in 2010 and 2011 have been analyzed. The sharks showed impressive plasticity in vertical behaviors depending upon the region and distance from shore, as has been shown in the Atlantic. Typically spotted near the surface in coastal waters, as one shark moved offshore, swimming depths increased and the shark completely avoided surface waters. While at depth, a distinct diel pattern was apparent with the shark remaining at shallower depths at night than during the day. These data support the hypothesis that when offshore, basking sharks forage on the deep scattering layer and not on aggregations of copepods in surface waters as seen near-shore

Age Validation Studies

Age and growth of shortfin mako (*Isurus oxyrinchus*), common thresher (*Alopias vulpinus*), and blue sharks (*Prionace glauca*) 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). Since the beginning of the program in 1997, 3,718 individuals have been injected with OTC. During the 2013 SWFSC shark surveys, 243 shortfin mako, 259 thresher, and 68 blue sharks were injected with OTC and released. A paper on the validation of ageing juvenile shaortfin makos was published in 2013(Wells et al., 2013). Analysis of recovered marked vertebrae for the other two species is in progress.

Record Shortfin Mako Shark Studied

Predatory sharks can be difficult to study, especially for the larger size classes which are infrequently encountered and rarely landed in commercial and recreational fisheries. In the Northeastern Pacific Ocean, shortfin mako sharks are important predators, and while data are increasing for smaller size classes, there is a paucity of data regarding large adults. On 3 June 2013, a record-breaking female shortfin mako shark (total length = 373 cm, mass = 600.1 kg) was captured by a recreational angler off Huntington Beach, California, and was subsequently donated to the SWFSC and California State University Long Beach for research. Samples of various tissue types were collected and analyzed to gain more information about the shark’s anatomy, physiology, ecology, and life history. This rare opportunity allowed for the collection of important data and contributes to our knowledge about the life history characteristics of large shortfin mako sharks.

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. Stomach content analysis work continued since the publication of Preti et al. 2012. Several stomachs from the 2012 and 2013 seasons have been processed. The predominant prey in shortfin mako stomachs was Pacific saury and several squid species. Blue shark stomachs contained Gonatus sp. squid, octopus squid, and paper nautilus. Common prey in thresher shark stomachs was market squid and Pacific saury.

Population Genetics Studies

An understanding of stock structure is important in order to make accurate assumptions for stock assessments and to develop effective management objectives that take the population range, distribution and life history into account. Various genetic analyses are useful to help identify differentiation between and within presumed stocks. During 2013, sample collection and processing continued to examine stock structure for a number of shark species including shortfin mako, common thresher, silky, and pelagic thresher sharks. In addition, samples of blue shark tissue have been sent to colleagues in Japan as part of a Pacific-wide collaboration. DNA samples were collected during research cruises in 2013 from 263 shortfin makos, 72 blue sharks, 262 common threshers, 6 leopard sharks and one brown smoothhound. Additional samples were obtained by fishery observers on commercial drift gillnet trips.

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 the past, the survey program 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.

Movement Research

Through 2012, the NWFSC 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 suggested 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.

Ongoing Sample Collection and Methods Development for Molecular Shark Species Identification

The Marine Forensics Laboratory, formerly of NOAA's National Ocean Service (NOS) Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) in Charleston, South Carolina, was administratively moved in December 2013 to the NOAA Fisheries Northwest Fisheries Science Center's Conservation Biology Division Forensic laboratory. The Laboratory conducts research on suitable molecular and morphological markers for identification of shark species in consignments of fins, whether fresh or dried. The Marine Forensics program currently uses mitochondrial DNA sequencing to identify the species of suspected sharks seized by agents of Federal and State law enforcement agencies, and is developing morphological methods to triage which fins need more costly genetic analysis. Sample collection and research to expand the number and range of shark species sequenced for a diagnostic DNA fragment is continuing. In 2013, several shark and ray species were added to the marine forensics archive of vouchers, and the NOAA Office of Law Enforcement submitted several shark fin cases to the NWFSC Forensics Laboratory for identifications.

Alaska Fisheries Science Center (AFSC, Auke Bay Laboratory)

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

Stock assessments are currently completed on the shark species most commonly encountered as incidental catch: Pacific sleeper sharks (*Somniosus pacificus*), spiny dogfish (*Squalus suckleyi*), and salmon sharks (*Lamna ditropis*). In both the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) fishery management plans, sharks are managed as a complex. Directed fishing for all sharks is prohibited. In the BSAI, the shark complex is managed with catch limits based on historical maximum catch. In the GOA, catch limits for the complex are the sum of individual species recommendations: spiny dogfish catch limits are based on survey biomass estimates and the remaining species are based on historical average catch. Stock assessments are summarized annually and are available online (see Tribuzio et al. 2013a and 2013b, or http://www.afsc.noaa.gov/REFM/stocks/assessments.htm for the most recent assessments).

Migration and Habitat Use of Spiny Dogfish

Spiny dogfish (*Squalus suckleyi*) are a small species of shark, common in coastal waters of the eastern North Pacific Ocean. Previous tagging studies have shown that they have the potential to undertake large scale migration and that there are seasonal patterns to movement. This study aims to investigate movement on an even finer scale. The miniaturization of pop-off satellite archival tags (PSATs) has enabled smaller species to be tagged. Since 2009 we have deployed 184 PSATs on spiny dogfish at locations across the Gulf of Alaska, British Columbia (Canada), and Puget Sound (Washington, USA) waters. To date, 145 tags have been recovered, with 31 still outstanding and the remainder failed to report. As well, 6 spiny dogfish were double tagged with acoustic tags and deployed in Puget Sound. Data analysis is ongoing; however, preliminary results, such as pop-off location are already elucidating surprising movement patterns. Many spiny dogfish tagged in the Gulf of Alaska remained in the Gulf of Alaska, but a surprising number of fish moved as far south as Southern California. Further, the fish that undertook the large scale migrations, tended to have a different daily movement pattern from those that remained. A great deal of analysis remains on this project, but early results are intriguing and suggest that spiny dogfish are more highly mobile than previously believed.

Age and Growth Methods

Scientists at Auke Bay Laboratory and AFSC's Resource Ecology and Fisheries Management Division age and growth lab are 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 deep water Squaloid sharks in the North Atlantic, and there is some suggestion that it will work for Pacific sleeper sharks.

Population Genetics of Pacific sleeper shark

Two species of the subgenus *Somniosus* are considered valid in the northern hemisphere: *S. microcephalus*, or Greenland shark, found in the North Atlantic and Arctic, and *S. pacificus*, or Pacific sleeper shark, found in the North Pacific and Bering Sea. The purpose of this study was to investigate the population structure of sleeper sharks in Alaskan waters. Tissue samples were opportunistically collected from 141 sharks from British Columbia, the Gulf of Alaska, and the Bering Sea. Sequences from three regions of the mitochondrial DNA, cytochrome oxidase c-subunit 1 (CO1), control region (CR), and cytochrome b (cytb), were evaluated. A minimum spanning haplotype network separated the sleeper sharks into two divergent groups, at all three mtDNA regions. Percent divergence between the two North Pacific sleeper shark groups at CO1, cytb, and CR, respectively were all approximately 0.5%. Greenland sharks were found to diverge from the two groups by 0.6% and 0.8% at CO1, and 1.5% and 1.8% at cytb. No Greenland shark data was available for CR. The consistent divergence from multiple sites within the mtDNA between the two groups of Pacific sleeper sharks indicates a historical physical separation. There appears to be no phylogeographic pattern, as both types were found throughout the North Pacific and Bering Sea. Development of nuclear markers (microsatellites) is currently underway and will allow for a better understanding of the level of introgression, if any, between these two ‘populations’ of sharks.

Managing large sharks by species instead of numbers, when observers cannot sample large fish

The Pacific sleeper shark (*Somniosus pacificus*) is a common bycatch species in the Gulf of Alaska and Bering Sea. This species is uniquely difficult to manage due to its biology which makes at-sea monitoring of discards and estimating total catch difficult. Sleeper sharks are currently managed as part of the “Shark Complex” that includes spiny dogfish, salmon sharks, and other less common species. Harvest limits for this group are specified in tons and management of the species is reliant on using estimates of total catch weight that are dependent on at-sea observer data. Sleeper sharks are especially difficult to handle onboard most vessels; they get tangled in fishing gear, their large size either precludes bringing them onboard or poses safety hazards to crew and observers, and they are difficult to weigh or incorporate into random catch sampling plans. Conversely, at-sea observers are generally able to obtain accurate counts of sleeper sharks, either because the species is often pre-sorted by vessel crew and set aside for sampling or they are tallied at the rail as gear is brought onboard. In either situation, count data may provide a better estimate of total sleeper shark catch then currently used weight estimates. In this study, we compared total catch trends between weights and counts using at-sea information to investigate differences between methods. We discuss how counts could be incorporated into the existing harvest specification process and associated issues with a change in management methods.

Northeast Fisheries Science Center (NEFSC)

Recreational Shark Fishing Data and Samples

Sampling for the NEFSC historic recreational shark fishing tournament database (1961-present) was ongoing in 2013 with the addition of biological samples and catch data for >120 pelagic sharks at 8 tournaments in the northeastern U.S. Staff also worked with a variety of partners to help stage an all-release, satellite tag shark tournament in NY with four electronic SPOT tags and numerous conventional tags placed on shortfin makos and blue sharks.

SEDAR Process

Staff participated in the Southeast Data, Assessment, and Review 34 Data Workshop for the assessment of the US Atlantic and Gulf of Mexico Atlantic sharpnose and bonnethead shark populations (Frazier and McCandless 2013, McCandless and Belcher 2013, McCandless and Frazier 2013, Kohler et al. 2013a, Kohler et al. 2013b, McCandless et al. 2013a, McCandless et al. 2013b, Schwartz et al. 2013).

Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program

Comprehensive and standardized investigations of coastal shark nursery habitat are conducted in Atlantic coastal waters from Florida to Massachusetts and in the USVI. In 2013, over 5,000 sharks of 16 species were caught during COASTSPAN surveys. In addition to SEDAR 34 documents, Kneebone et al. 2013 detailed the physiological effects of capture and post-release survivorship of juvenile sand tigers caught by rod and reel.

Spiny Dogfish (Squalus acanthias)

The NEFSC spiny dogfish tagging initiative in the Gulf of Maine, Southern New England, and Georges Bank regions continued with an additional 756 fish recaptured through 2013 with 125 fish that were OTC injected recaptured for age validation. In 2013, a new initiative was launched to determine the seasonality of pupping and gestation period of females in Southern New England.

Dusky Shark (Carcharhinus obscurus)

A revision of the age and growth of the dusky shark in the Northwestern Atlantic Ocean was completed (Natanson et al. 2013) where growth was compared pre- and post- population depletion and pre- and post- management for possible density-mediated shifts in age and growth parameters over time. Bomb radiocarbon dating was also used to determine the periodicity of band pair formation.

Movement Patterns for Atlantic Sharpnose Shark (Rhizoprionodon terranovae), Bonnethead (Sphyrna tiburo), and Blacktip Shark (Carcharhinus limbatus)

Mark/recapture data from the NMFS Cooperative Shark Tagging Program were summarized for these three species (Kohler et al. 2013a, Kohler et al. 2013b, Swinsburg 2013). In addition, survival estimates based on age, sex, and geographic grouping were generated for the blacktip shark using the program MARK (Swinsburg 2013).

Biology of the Thresher Shark (Alopias vulpinus)

Life history studies of the thresher shark in the western North Atlantic continued with published accounts of reproductive (Natanson and Gervelis 2013) and age parameters (Gervelis and Natanson 2013). In addition, a study on bomb carbon validation was initiated.

Southeast Fisheries Science Center (SEFSC)

Observer Programs

The shark longline observer program was created to obtain better data on catch, bycatch, and discards in the shark bottom longline fishery. 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 (5 in 2012) 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 percent. In 2013, a total of 61 trips with a total of 113 bottom longline hauls were observed. Sharks comprised about 95% of the catch, and teleost about 5%. Sandbar and blacktip shark comprised most of the shark catch. Small coastal shark species (e.g. Atlantic sharpnose shark) were also caught. Prohibited shark species (e.g. sand tiger shark, dusky shark, Caribbean reef shark) were also captured but in very low numbers (<1.0%). 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 225 sets comprising various gillnet fisheries were observed in 2013. Set locations ranged from North Carolina to the Florida Keys in the Atlantic Ocean and the Gulf of Mexico.

Distribution, Community Structure and Characterizing and Predicting Essential Habitat Features for Juvenile Coastal Sharks

The successful management of shark populations requires juvenile recruitment success. Thus, conservation initiatives now strive to include the protection of areas used by pre-adult sharks in order to promote juvenile survivorship. Many shark species use inshore areas for early life stages; however, species often seg- regate within sites to reduce competition. Using a fisheries-independent gillnet survey from the Northern Gulf of Mexico (2000–2010) we describe distribution patterns and preferred habitat features of the juveniles of six shark species. Our results suggest that multiple shark species concurrently use the area for early life stages and although they overlap, they exhibit distinct habitat preferences characterized by physical variables. Habitat suitability models suggest that temperature, depth, and salinity are the important factors driving juvenile shark occurrence. Within each site, across the sampled range of physical characteristics, blacktip shark preferred higher temperature (>30 °C) and mid-depth (~5.5 m); bonnethead shark preferred higher temperature (>30 °C) and mid-salinity (30–35 PSU), finetooth shark preferred low salinity (<20 PSU) with mid-depth (~4 m), scalloped hammerhead shark preferred high temperature (>30 °C) and salinity (>35 PSU), Atlantic sharpnose shark preferred high temperature (>30 °C) and deep water (>6 m), and spinner shark preferred deep water (>8 m) and high temperature (>30 °C). The other investigated factors, including year, month, latitude, longitude, bottom type, inlet distance, coastline and human coast were not influential for any species. Combining habitat preferences with the sampled environmental characteristics, we predicted habitat suitability throughout the four sites for which physical characteristics were sampled. Habitat suitability surfaces highlight the differences in habitat use between and within sites. This work provides important insight into the habitat ecology of juvenile shark populations, which can be used to better manage these species and protect critical habitat (Ward-Paige et al., 2014).

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 Atlantic sharpnose (*Rhizoprionodon terraenovae)*, 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. Additional data are being collected during SEFSC bottom longline surveys to examine spatial variability in the diets and feeding behaviors of various shark species.

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

The SEFSC Shark Population Assessment Group manages and coordinates a survey of coastal bays and estuaries from Florida to Louisiana. Surveys identify the presence or absence of neonate (newborn) and juvenile sharks and attempt to quantify the relative importance of each area as it pertains to essential fish habitat. A database currently includes 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 2015.

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). Smalltooth sawfish has been listed under the ESA since 2005, and the completion of the Smalltooth Sawfish Recovery Plan in early 2009 identified new research and monitoring priorities that are currently being implemented**.** Surveys identify the presence or absence of neonates, young-of-the-year, and juveniles in southwest Florida and research in the Florida Keys and Florida examines the distribution and abundance of adult animals.

Life History Studies of Elasmobranchs

In collaboration with the University of Southern Mississippi, age, growth, and reproduction for the finetooth shark (*C. isodon*) in the Gulf of Mexico are being examined. In addition, scientists from these groups are also examining age, growth, and reproduction of Cuban dogfish. Research with PIFSC and the NEFSC to validate age in sand tiger shark (*Carcharias taurus*) using bomb radiocarbon analysis was begun in 2011 and published in 2014 (Passerrotti et al. 2014). Research is also being conducted on the life history of Atlantic blacktip shark, lemon shark, blacknose shark, smoothhound sharks, and various species of deepwater sharks, including gulper and lantern sharks.

Taxonomic studies

Efforts are being made by biologists within the SEFSC to gain greater understanding concerning the number of shark species that occur in US waters off the east coast and throughout the northern Gulf of Mexico. In recent years, these efforts have led to the identification of a new species of hammerhead shark, documentation of a resident population of Caribbean reef sharks off the coast of Texas, presence of basking and sleeper sharks in the northern Gulf of Mexico, and additional records of exceptionally rare specimens, such as goblin and spined pygmy sharks. Additionally, in collaboration with NMFS HMS and ICCAT, SEFSC scientists have developed a Shark Identification Guide for use by the public to aid in the proper identification of sharks caught in commercial and recreational fisheries. Additional studies are being conducted in collaboration with Texas A&M University and Florida State University to resolve issues regarding identification of smoothhound and gulper sharks.

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. Ten satellite tags have been deployed on blue sharks to date. Five tags are currently providing real time data, which along with data for Ecological Risk Assessments are used as outreach to promote the collaboration between NOAA and DINARA (http://cicmar.org/en/projects-developed-by-cicmar/tiburuy-project-research-and-conservation-of-sharks-in-uruguay/blue-shark-satellite-tracking). An identification guide for carcharhinid sharks of the Atlantic Ocean was created in 2011 (ICCAT 2012).

Shark Assessment Research Surveys
The SEFSC has conducted annual bottom longline surveys in the northern Gulf of Mexico and off the east coast of the United States since 1995 (31 surveys have been completed through 2013). The primary objective is to utilize standardized gear to assess the distribution and abundance of large and small coastal sharks across their known ranges to provide fisheries-independent time series data for trend analysis. The survey is the largest of its kind anywhere globally and is considered essential for accurate stock assessments of sharks occurring off the east coast of the United States and throughout the northern Gulf of Mexico. This survey also provides a platform for other shark research activities including identification of essential habitats, reproductive biology, feeding behavior, gear selectivity, movement patterns, and effects of deleterious anthropogenic impacts. To date, over 38,000 fishes have been collected during the survey of which approximately 85% were sharks.

4.2 Incidental Catch Reduction

Pacific Islands Fisheries Science Center (PIFSC)

Redistribution of longline hooks to reduce shark bycatch – The interspecific preferences of fishes for different depths and habitats suggest fishers could avoid unwanted catches of some species while still effectively targeting other species. In pelagic longline fisheries, albacore (*Thunnus alalunga*) are often caught in relatively cooler, deeper water (>100 m) than many species of conservation concern (e.g., sea turtles, billfishes, and some sharks) that are caught in shallower water (<100 m). From 2007 to 2011, this study examined the depth distributions of hooks for 1154 longline sets (3,406,946 hooks) and recorded captures by hook position on 2642 sets (7,829,498 hooks) in the American Samoa longline fishery (Watson and Bigelow, 2014). Twenty-three percent of hooks had a settled depth <100 m. Individuals captured in the 3 shallowest hook positions accounted for 18.3% of all bycatch. The study analyzed hypothetical impacts for 25 of the most abundant species caught in the fishery by eliminating the 3 shallowest hook positions under scenarios with and without redistribution of these hooks to deeper depths.

Distributions varied by species: 45.5% (n = 10) of green sea turtle (*Chelonia mydas*), 59.5% (n = 626) of shortbill spearfish (*Tetrapturus angustirostris*), 37.3% (n = 435) of silky shark (*Carcharhinus falciformis*), and 42.6% (n = 150) of oceanic whitetip shark (*C. longimanus*) were caught on the 3 shallowest hooks. Eleven percent (n = 20,435) of all tuna and 8.5% (n = 10,374) of albacore were caught on the 3 shallowest hooks. Hook elimination reduced landed value by 1.6–9.2% and redistribution of hooks increased average annual landed value relative to the status quo by 5–11.7%. Based on these scenarios, redistribution of hooks to deeper depths may provide an economically feasible modification to longline gear that could substantially reduce bycatch for a suite of vulnerable species. The results suggest that this method may be applicable to deep-set pelagic longline fisheries worldwide (Watson and Bigelow, 2014).

Electromagnetic Deterrents to Bycatch (additional details provided in Appendix 1, PIFSC)
While electropositive metal deterrents have been tested experimentally as a potential bycatch solution on pelagic longline fisheries (Hutchinson et al., 2012), trials conducted in commercial fishing conditions are still needed. PIFSC in collaboration with Dalhousie University completed a study in the northwest Atlantic with the Canadian pelagic longline swordfish fishery where blue sharks comprise a significant proportion of unwanted bycatch. 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 off a commercial longliner 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 (Godin et al., 2013).

Figure 5.2.1: Orange LEDs attached to experimental gillnet.

In addition, PIFSC have been involved in the development of shark bycatch reduction technologies for other fisheries, in particular, coastal gillnet fisheries. Net illumination through the use of LED lights have been tested in small scale coastal gillnet fishery based in Baja California, MX. Experiments using short wavelength (UV range), mid length (green wavelengths) and long wavelengths (orange/red) have been conducted to understand the effects on catch composition. Results show that UV illumination of gillnets significantly reduces the catch rates of elasmobranchs, in particular guitarfish and scalloped hammerhead sharks (S. lewini). In addition, experiments with orange (605nm wavelength) net illumination suggest that elasmobranch interaction rates can also be reduced. Both types of net illumination do not affect the target catch rates or significantly change the market value. This suggests that net illumination may be a useful strategy to reduce shark interactions in coastal gillnet fisheries.

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 (approximately 63 percent) of the blue sharks entangled are discarded dead. To reduce the bycatch and/or post-release mortality of

multiple species, the SWFSC has been conducting tests since 2011 to target swordfish using deep-set longline gear (DSLL) off California at depths below 200 meters. These deeper depths coincide with the daytime distribution of swordfish, putting hooks below the epipelagic waters inhabited by sea turtles and shortfin mako sharks. On three cruises from 2011-2013, SWFSC collaborated with longline fishers aboard the chartered F/V *Ventura II* off central and southern California to target swordfish during the day. During 47 sets, with average hook depths of 230-247 m and soak times 2.7-4 hours, 111 marketable fish (including 8 swordfish, 67 opah and 23 pomfret) and 352 non-marketable fish (including 328 blue sharks and 17 king of the salmon) were caught. Short soak times were used to maximize fish condition for tagging; two swordfish, five opah and five blue sharks were released with satellite tags and the majority of the remaining blue sharks were tagged with conventional tags and released. Based on previous research on blue shark post-release mortality, 81%-91% of blue sharks would be expected to survive after release. This study concluded that it is possible to catch swordfish and other marketable species below turtle and shortfin mako habitat with a DSLL however, swordfish catch was low. Fishing conditions during these cruises were probably impacted by anomalous oceanographic conditions; swordfish catch for the drift gillnet fleet was very low over the same time periods. Given the experimental and small-scale nature of this research, these results are promising, but should not be projected beyond the study and warrant more research. Some funding has been received to continue the experiment during 2014 including funds to conduct a post-release survivorship study on blue sharks released.

West Coast Region (WCR) and PIER Testing Swordfish Deep-set Buoy Gear

The Pfleger Institute of Environmental Research (PIER), in collaboration with NMFS WCR, is conducting research into use of novel deep-set buoy gear (DSBG) to test the efficacy of capturing swordfish at depth (300 meters and deeper) during the day while avoiding bycatch species of concern. As with the deep-set longline research being conducted by the SWFSC (see above), targeting deeper depths coincides with known day time habitat preference of swordfish and puts hooks below the upper water column habitat preferred by leatherback turtles and several shark species. Gear trials during 2011 and 2012 off the coast of southern California produced promising results. There were no interactions with species of concern, minimal interaction with non-target species (i.e., sharks) and swordfish were the primary catch. DSBG field experiments in 2013 focused on improving the test configuration, enhancing deployment and retrieval efficiency and preparing for cooperative trials in 2014. The trial data will be used in 2014 to further expand DSBG research on cooperative fisher platforms and to assess the domestic market niche for buoy caught swordfish.

4.3 Post-Release Survival

Southwest Fisheries Science Center (SWFSC)

Common thresher, shortfin mako, and blue sharks are captured in both commercial and recreational fisheries in the California Current. The California drift gillnet fishery is the commercial fishery that catches the greatest number of each of these species. While thresher and mako sharks are landed, almost all blue sharks are discarded. For thresher and mako sharks, regional recreational fisheries are growing in popularity. Recreational 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 California drift gillnet 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.

Blue Sharks Released from the California Drift Gillnet Fishery

The California drift gillnet fishery targets swordfish in the California Current. With the exception of ocean sunfish (*Mola mola*), blue sharks are caught in greater numbers than any other fish species taken in this fishery. Nearly all blue shark are discarded at sea due to lack of market value. A 2009 analysis of the 1990-2008 observer data reveals that 32 percent of blue sharks captured were released alive, and an additional 5 percent were discarded with their disposition unknown. The remaining 63 percent were discarded dead. In 2007, the SWFSC and the WCR began deploying PSAT tags on sharks released from the California drift gillnet fishery to assess survivorship in order to determine more accurate estimates of fishery mortality for use in a blue shark stock assessment.

To date 15 blue sharks have been tagged with PSATs for the study. The results show that sharks that are released in "good" condition are likely to survive, whereas those released in "poor" condition are likely to die. The availability of candidate sharks for tagging has been low on observed trips in recent years; however, we hope to complete the study during the 2014 season.

Thresher Sharks Released from the Recreational Fishery

The SWFSC, SWR, and PIER have completed a three phase study to assess the post-release survival of thresher sharks caught by recreational anglers. The first phase of the study, involved releasing sharks which had been captured using tail-hooking techniques (common practice in the southern California fishery). The results from this work revealed that survivorship is low for large sharks (>185 cm FL) that endure fight times that exceed 85 minutes (Heberer et al. 2010). The second and third phases of the research effort focused on assessing post-release survival in two modes of capture routinely observed in the southern California recreational fishery: (1) sharks that are caught using caudal-based angling techniques and unintentionally released with trailing gear left embedded, and (2) sharks that are caught and released using mouth-based angling techniques. For the trailing gear investigation, six sharks died shortly after release, one died after several weeks, and two sharks survived the deployment period for an overall survivorship rate of 22%. For the mouth-based trials, all common thresher sharks survived the acute effects of capture (100% survivorship). These results indicate that trailing gear left embedded in sharks can negatively affect post-release survivorship, while mouth-based angling, when performed properly, can result in high survivorship of released sharks. The second publication for this project, based on results from phases two and three, is in press in *Fisheries Research*[1]

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

Post-release Recovery and Survivorship Studies in Sharks: Physiological Effects of Capture Stress

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[1] Sepulveda, C. A., Heberer, C., Aalbers, S. A., Spear, N., Kinney, M., Bernal, D., and Kohin, S. 2015. Post-release survivorship studies on common thresher sharks *(Alopias vulpinus)* captured in the southern California recreational fishery. Fisheries Research, 161, 102-108.

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 pop-up satellite archival tags (PSAT) data to quantify the magnitude and impacts of capture stress. The primary objectives of the new technology tag studies are to examine shark migratory routes, potential nursery areas, swimming behavior, and environmental associations. Secondarily, these studies can assess the physiological effects of capture stress and post-release recovery in commercially- and recreationally-captured sharks. These electronic tagging studies include: 1) acoustic tagging and bottom monitoring studies for coastal shark species in Delaware Bay and the USVI as part of COASTSPAN; 2) tracking of porbeagle sharks with acoustic and PSATs in conjunction with the MDMF; 3) placing real-time satellite (SPOT) and PSAT tags on shortfin makos and blue sharks in the Northeast U.S. and on their pelagic nursery grounds; 4) placing PSAT tags on sand tigers in Delaware Bay and Plymouth Bay (MA) as part of a fishery independent survey and habitat study; and 5) placing PSAT and SPOT tags on dusky and tiger sharks in conjunction with Monterey Bay Aquarium, University of California Long Beach, and MDMF. Integration of data from new-technology tags and conventional tags from the CSTP is necessary to provide a comprehensive picture of the movements and migrations of sharks along with possible reasons for the use of particular migratory routes, swimming behavior, and environmental associations. In addition, the results of this research will be critical to evaluate the extensive current catch-and-release management strategies for sharks.

Southeast Fisheries Science Center (SEFSC)

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

SEFSC 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. Pop-off archival satellite tags have also been deployed on select individuals to aid in determining the efficacy of closed areas for dusky shark. 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

Hooking mortality of scalloped hammerhead, Sphyrna lewini, and great hammerhead, Sphyrna mokarran, sharks caught on bottom longlines

The scalloped hammerhead and great hammerhead are typically caught as bycatch in a variety of fisheries and listed as Endangered Globally by the International Union for the Conservation of Nature (IUCN). Due to very high at-vessel mortality for these species, research is needed on fishing methods to reduce mortality for longline captured sharks. A series of fishing experiments were conducted employing hook timers and time-depth recorders on contracted commercial vessels fishing with bottom longline gear to assess factors related to mortality. Scalloped and great hammerhead sharks had at-vessel mortality rates of 62.9 % and 56.0%, respectively. Median hooking time was 3.5 hours and 3.4 hours and 50% mortality was predicted at 3.5 hours and 3.8 hours for scalloped and great hammerhead shark, respectively. When these data are considered for potential management strategies to reduce the mortality of hammerhead sharks, a limitation on gear soak time may well improve hammerhead shark survivorship. However, it may prove to be difficult for a fishery to remain economically viable if the soak time is limited to less than the median hooking time for the target species. Additional management options, such as time/area closures, may need to be explored to reduce bycatch mortality of great and scalloped hammerhead sharks (Gulak et al. in press).

The effect of circle hooks on shark catchability, at-vessel mortality and post-release survival rates in bottom longline fisheries

Over the last few years, a growing number of studies have investigated the use of circle hooks and their effects on a range of species, including sharks. However, for sharks, managers and scientists are confronted with multiple studies of small sample sizes with either conflicting results or no statistical significance and no clear conclusions. To assess the potential effect of a change from J hooks to circle hooks in the shark bottom longline fishery, commercial shark bottom longline vessels are being chartered to perform controlled experiments testing the catchability and mortality rates of sharks caught on J versus circle hooks. Post-release survivorship, will be assessed tagging sharks with a satellite pop-up archival transmitting (PAT) tag. Survival of post-captured PAT tagged animals will be inferred data provided by the PAT tag. The project is currently 66.3 percent complete. Ten PAT tags have been deployed and four made the full deployment of 34 days. Of the remaining six tags, four pulled early with two showing indications of mortality and one tag is still due to report. The current 90 percent report rate is higher than other PAT tag studies to date.

Section 5: Additional Information About Ongoing NOAA Shark Research

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.
- 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. 2013a and 2013b).

Catch of sharks in unobserved fisheries

The fishing fleet targeting Pacific halibut (*Hippoglossus stenelopus*) was unobserved until 2013. Prior to that, catches of non-halibut species (bycatch) were not accounted for unless the was landed. State of Alaska and Federal fishery managers and scientists have long recognized the need for bycatch estimation in this fishery. At-sea data collection (i.e. observers) was not authorized until 2013 with the implementation of the Amendment 76 to the Fishery Management Plan for Groundfish Fisheries in the Gulf of Alaska and Amendment 86 to the Fishery Management Plan for Groundfish Fisheries in the Bering Sea/Aleutian Island Area. Accounting for bycatch in the Pacific halibut fishery is also a requirement under the guidelines to National Standard 1 of the Magnuson-Steven Fishery Management and Conservation Act. An effort was made to estimate catch from the Pacific halibut Individual Fishing Quota fishery using survey data (Tribuzio et al. *submitted*), however, the authors point out a number of significant caveats or concerns about using the catch estimates in stock assessments. Beginning in 2013, the restructured North Pacific Observer Program provided data from previously unobserved Pacific halibut IFQ vessels and vessels under 60 feet.

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

Stable isotope ratios of nitrogen (δ^{15}N) and lipid normalized carbon (δ^{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 δ^{13}C' values of Pacific sleeper sharks differed significantly among geographic regions of the eastern North Pacific. Linear models identified significant ontogenetic and geographic variability in muscle tissue δ^{15}N values. The trophic position of Pacific sleeper sharks in the eastern North Pacific estimated from previously published stomach content data was within the range of Pacific sleeper shark trophic position predicted from a linear model of muscle tissue δ^{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 percent prediction intervals ranged from 2.9–6.4). The relative trophic position of Pacific sleeper sharks determined from a literature review of δ^{15}N by taxa in the eastern North Pacific was lower than would be expected based on stomach content data alone when compared to fish, squid, and filter feeding whales. Stable isotope analysis revealed wider variability in the feeding ecology of Pacific sleeper sharks in 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 17 electronic satellite popup tags on Pacific sleeper sharks in the upper Chatham Strait region of Southeast Alaska (Courtney and Hulbert 2007). Two numerical tags and 10 satellite tags have been recovered. The recovery of temperature, depth, and movement data from the electronic archival and acoustic tags will aid in the identification of Pacific sleeper shark habitat utilization and distribution in Southeast Alaska, and identify the potential for interactions between Pacific sleeper sharks and other species in this region. Analysis of tagging data is ongoing.

Migration and Habitat Use of Spiny Dogfish in the Gulf of Alaska

Since 2009 scientists from Auke Bay Laboratory have deployed 180 pop-off archival tags on spiny dogfish in the GOA, inside waters of Southeast Alaska, along the west coast of Vancouver Island (British Columbia) and in Puget Sound (Washington). Six tagged fish from Washington station were also double tagged with acoustic transmitting tags for a secondary project to validate the geolocation of the pop-off archival tags. Data have been successfully recovered from 140 tags to date. Results will indicate habitat preference with respect to depth and temperature, which may play a role in examining the effects of climate changes in the North Pacific. Further, the geolocation data will elucidate the degree to which 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 different daily behavior patterns depending on the migration path (i.e. those animals that stayed within the GOA or those that undertook larger migrations).

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.

Reproduction in salmon shark

Little is known about the reproductive biology of the salmon shark, *Lamna ditropis*, from the eastern North Pacific Ocean. Female salmon shark specimens were collected from Alaska waters in the summer, autumn, and winter to examine reproductive timing, periodicity, and fecundity. Results suggest that female salmon sharks ovulate during the autumn months of September and October. Further, those animals captured in July were either in a resting or post-partum state indicating a short gestation time of nine to 10 months. The presence of two maturity stages in both the summer and autumn months indicates a resting period of at least 14 months between parturition and ovulation. This study found mean fecundity was 3.88 (n = 8, SE = 0.13) with the majority of pregnant salmon sharks having a fecundity of four sharks per litter. These results provide new information on the reproductive biology of salmon sharks and will aid in the development of stock assessments for this species.

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.

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 last conducted an assessment of spiny dogfish along the Pacific coast of the United States in 2011 (see section 2.3 of the 2014 Shark Finning Report to Congress).

Southwest Fisheries Science Center (SWFSC)

Shark research

The NOAA Fisheries Southwest Fisheries Science Center (SWFSC) shark research program focuses on pelagic sharks that occur along the U.S. Pacific Coast, including blue sharks (*Prionace glauca*), basking sharks (*Cetorhinus maximus*), shortfin mako (*Isurus oxyrinchus*), and three species of thresher sharks: bigeye, common, and pelagic threshers (*Alopias superciliosus*, *A. vulpinus*, and *A. pelagicus*, respectively). 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 fishers, especially off Southern California. Although the blue shark is targeted in Mexico, it has little market importance in the U.S. but is a leading bycatch species in the California drift gillnet (CADGN) 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, as well as neonate (0-1 year old) common thresher sharks, surveys are carried out in the Southern California Bight (SCB) each summer. 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. Surveys for neonate thresher sharks are conducted using a small commercial longline vessel in near shore waters.

Juvenile Mako and Blue Shark Survey

In 2013, the SWFSC conducted its twentieth juvenile shark survey for mako and blue sharks since 1994. The annual abundance survey was completed between July 3 and July 26. Working aboard F/V *Ventura II*, a team of scientists and volunteers fished a total of 5,946 hooks during 28 daytime sets within seven focal areas of the SCB. The survey catch totaled 257 shortfin makos, 14 blue sharks, 11 pelagic rays (*Pteroplatytrygon violacea*), 8 opah (*Lampris guttatus*), and 1 ocean sunfish (*Mola mola)*. The preliminary data indicate that the nominal survey catch rate was 1.08 sharks per 100 hook-hours for shortfin mako and 0.06 sharks per 100 hook-hours for blue sharks. The mako shark nominal CPUE was higher than the previous year. However, there is a declining trend in nominal CPUE for both species over the time series of the survey.

In addition to survey longline sets, other fishing methods were used to maximize time on the water and increase the opportunity for catching other highly migratory large pelagic species (HMS). Longline gear was modified for ancillary sets in an effort to cover a greater vertical distribution of the water column by using longer branchlines and more hooks per basket.

In all, 35 longline sets were completed. A total of 317 animals were caught. Most animals were brought onboard, measured, tagged, and sampled for DNA biopsies before they were released. Conventional spaghetti tags were released on 267 sharks to allow for movement and stock structure data collection. In addition, sharks tagged with conventional tags were also injected with oxytetracycline and tagged with plastic dorsal tags containing information for fishers upon recapture of the animal to retain a portion of the vertebrae for ongoing age and growth studies. Biological collections included DNA samples from most sharks captured, as well as stomachs, digestive tracts, and blood from a small number of sharks that did not survive.

Neonate Common Thresher Shark Survey

In 2013, SWFSC scientists and volunteers conducted the survey aboard the F/V *Outer Banks*. Forty-nine longline sets were made in relatively shallow, nearshore waters and a total of 4,916 hooks were fished during the 18-day cruise. A total of 336 fish across a range of species were sampled during the survey. Two hundred and eighty-five thresher sharks were captured. Most of these sharks were injected with oxytetracycline and tagged with a combination of conventional tags for movement and stock structure, and plastic dorsal tags containing return information for the age and growth study.

The preliminary survey data indicate that the average nominal catch rate by set was 2.49 thresher sharks per 100 hook-hours, equivalent to the CPUE from 2012. The overall average trend since the start of the survey is increasing. However, 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 the SWFSC, including age and growth, feeding, and habitat utilization studies.

Electronic Tagging Studies

Since 1999, SWFSC scientists have been using satellite technology to study the movements and behaviors of large pelagic sharks, primarily blue, shortfin mako, and common thresher sharks, while other species are tagged opportunistically. Shark tag deployments have been carried out in collaboration with a number of partners in the U.S., Mexico and Canada. 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 characterization of the essential habitats of sharks and a better understanding of how populations might shift in response to changes in environmental conditions over short or long time scales. SWFSC scientists have been collecting data on shortfin mako and blue sharks for over a decade and continue to look at horizontal and vertical movement patterns on many different time scales. In 2013, a number of sharks were released with electronic tags in support of several collaborative projects. Four shortfin mako and two blue sharks were tagged with satellite-linked radio position tags (SPOTs). Three shortfin mako and one common thresher were released with pop-off satellite archival tags (PSATs).

Shortfin Mako Shark

In 2012 the SWFSC began a collaboration with Fishtrack to deploy SPOT tags on larger makos during the longline survey. Four makos have been released with tags sponsored by Fishtrack. The tracking data are posted in near-real-time on their website (http://www.fishtrack.com/live-track/). Tags of two sharks tagged in 2012 and one tagged in 2013 were still reporting as of April 2014 (Figure 6.1).

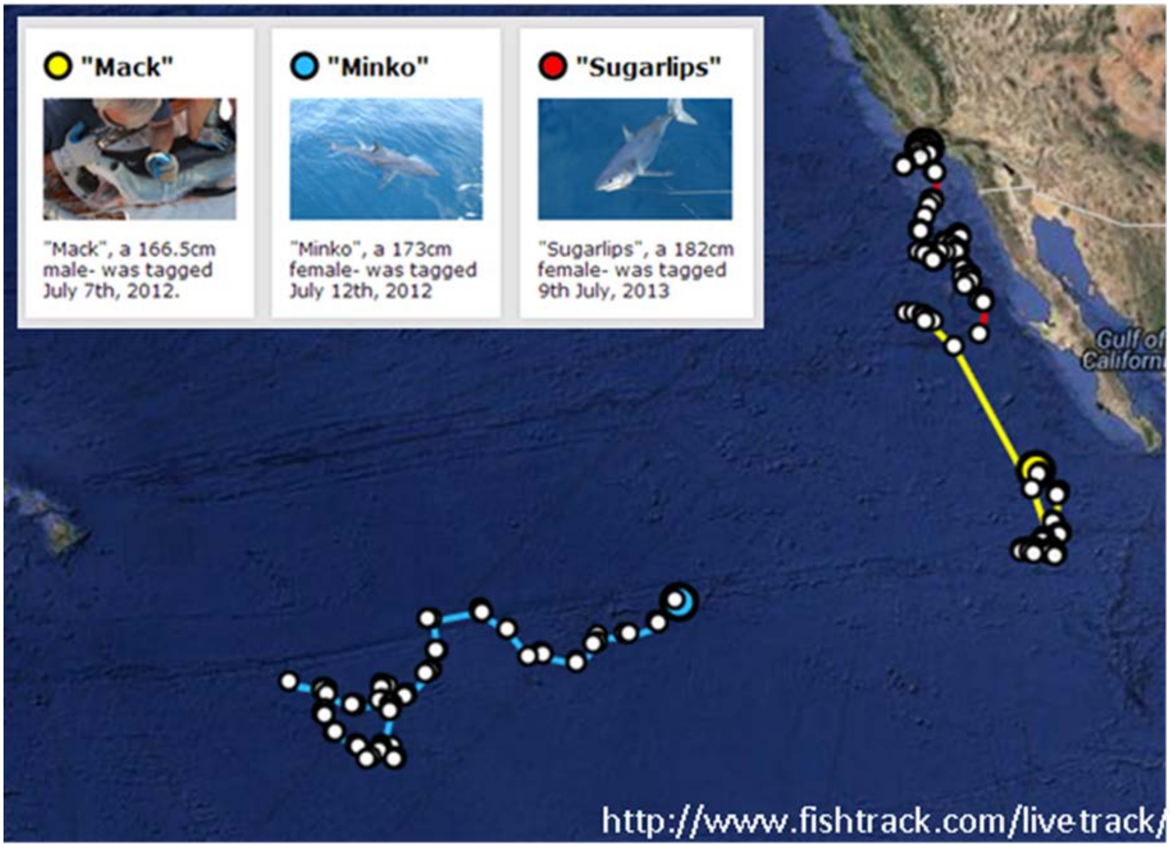

Figure 6.1: Tracks of three shortfin mako sharks tagged in collaboration with Fishtrack in 2012 and 2013. The tracks show the most recent 2 months of data representing movements during March and April, 2014.

In 2013, the SWFSC began a collaboration with recreational anglers to deploy PSATs on very large shortfin mako sharks that are typically not caught in commercial fisheries or on the SWFSC fishery-independent shark survey. Three makos estimated at 250 kg or larger were tagged with PSATs in September and October 2013. We are hoping to hear from the tags in May 2014.

SWFSC scientists have been synthesizing all the electronic tagging data for mako sharks. Tracking success has been very good for makos as they generally provide long duration tracks allowing an incredible opportunity to examine seasonal movement patterns and regional fidelity. Data from 85 SPOTs with deployment durations of 3 to 1025 days and 56 PSATs with durations of 18 to 227 days, including data from 40 double tagged sharks, have been analyzed. The sharks ranged from the surface to more than 600 m depth, with the majority of time spent in the top 100 m. The range of horizontal movements of tagged sharks spanned along the coast of North America from the northern coast of Washington to just south of Puerto Vallarta, Mexico and out to the Hawaiian Islands. Two sharks travelled as far south as 4˚N but did not cross the equator.

Sharks showed seasonal movements travelling out of the Bight in the fall and winter and returning in the spring and summer. A manuscript is currently being drafted.

Basking Shark

The eastern North Pacific basking shark population appears to have declined dramatically in the last 50 years with no evidence of recovery. Where hundreds to thousands of individuals were observed off the U.S. West Coast in the early to mid-1900s, sighting even a few individuals is now rare. Due to concern over 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 in the U.S. in 2010. Given severe data gaps for this population, the SWFSC initiated a basking shark research program in 2010 that includes an electronic tagging study.

During 2013, data from the three sharks tagged with satellite tags in 2010 and 2011 were analyzed and the results are being prepared for publication. The 3 sharks showed impressive plasticity in vertical behaviors depending upon the region and distance from shore, as has been shown in the Atlantic. Figure 6.2 shows the track and vertical movements from one shark that moved to just north of Hawaii after 240 days. As it moved offshore, swimming depths increased and the shark avoided surface waters. While at depth, a distinct diel pattern was apparent with the shark remaining at shallower depths at night than during the day. These data support the hypothesis that when offshore, basking sharks forage on the deep scattering layer and not on aggregations of copepods in surface waters as seen near-shore.

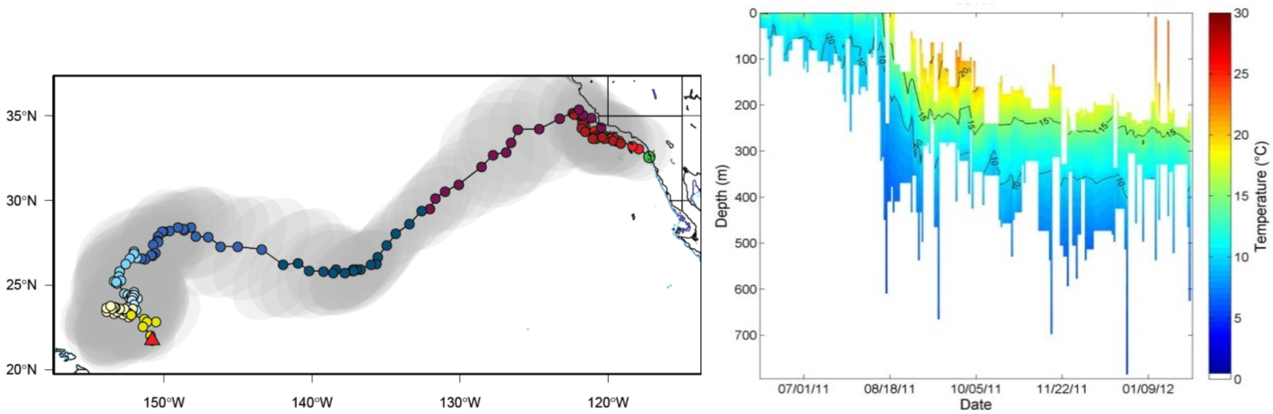

Figure 6.2: (Left) The track of a basking shark tagged on 6/7/2011 off San Diego. The tag released as programmed on 2/2/2012. (Right) The vertical movements of the same shark showing the shift in habitat use as it moved offshore.

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). 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, 3,718 individuals have been injected with OTC. During the 2013 SWFSC shark surveys, 243 shortfin mako, 259 thresher, and 68 blue sharks were injected with OTC and released.

The Shark Working Group (SHARKWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) has developed a collaborative research plan to address uncertainties about age and growth of pelagic sharks. As part of the plan, participating national scientists are collecting samples from blue and shortfin mako sharks for a reference collection. Band enhancement methods vary between labs and the reference collection will be used to corroborate age reading across labs and ultimately develop improved growth models for these two species. The SWFSC collected samples during research cruises and through the fishery observer program during 2013 and has contributed those samples to the ISC SHARKWG age and growth specialists. In January 2014, the ISC convened its second Shark Age and Growth Workshop during which participants progressed on their work plan. The group hopes to provide the SHARKWG updated information on shortfin mako shark growth for use in their upcoming stock assessment.

Oxytetracycline Age Validation of Juvenile Shortfin Makos

The results of OTC age validation of 29 juvenile shortfin mako sharks tagged in the Southern California Bight showed vertebral band pair deposition rates of two per year for sharks up to about 4-5 years old in the northeast Pacific (Wells et al. 2013).

Oxytetracycline Age Validation of Blue Sharks

Vertebrae of 26 blue sharks marked with OTC were obtained from tag-recapture activities to determine timing of centrum growth band deposition. Length-frequency modal analysis was also used to obtain growth estimates from a 22-year data set of research and commercial catch data. Tagging occurred off southern California with time at liberty ranging from 22 days to 1.61 years including six returns at liberty over one year (390-587 days). For recaptured blue sharks used for age validation, shark size at initial capture ranged from 73 to 231 cm fork length (FL) consisting of nine females and 17 males. Results from band counts distal to the OTC mark on each vertebrae indicate a single band pair (1 translucent and 1 opaque) is formed per year for blue sharks ranging from one to eight years of age. Length-frequency analysis identified three age-class modes at 79, 108, and 133 cm FL with estimated growth rates of 29 and 25 cm FL for the first two years, respectively. Results provide support for annual vertebral band pair deposition in blue sharks in the northeast Pacific Ocean.

Oxytetracycline Age Validation of Common Thresher Sharks

A total of 1,454 common thresher sharks ranging in size from 45 to 230 cm FL have been injected with OTC. Vertebrae from 54 of these sharks (size range at tagging: 63-145 cm FL) have been returned with an average time-at-liberty of 342 days. Sample processing is underway and the preliminary results suggest an annual deposition rate for the size classes studied.

Record Shortfin Mako Shark Studied

Predatory sharks can be difficult to study, especially for the larger size classes which are infrequently encountered and rarely landed in commercial and recreational fisheries. In the Northeastern Pacific Ocean, shortfin mako sharks are important predators, and while data are increasing for smaller size classes, there is a paucity of data regarding large adults. On 3 June 2013, a record-breaking female shortfin mako shark (total length = 373 cm, mass = 600.1 kg) was captured by a recreational angler off Huntington Beach, California, and was subsequently donated to the SWFSC and California State University Long Beach for research. Samples of various tissue types were collected and analyzed to gain more information about the shark's anatomy, physiology, ecology, and life history. The shark was found to have an approximately three-year old female sea lion carcass in its stomach. This confirms the presence of pinnipeds in the diet of larger shortfin makos, which are available prey items year round in southern California. The spiral valve contents included two species of cestode parasite including 20 specimens of a tetraphyllidea tapeworm and two of a trypanorhyncha tapeworm. Two damaged specimens of a capillaria nematode were also found, but as the genus is not known to parasitize sharks, it is likely that they were ingested along with their teleost hosts. Two ageing methods, thin sectioning with microscopy and x-ray imaging, were used to age the vertebrae of this mako, producing counts of 26 and 27 band pairs, respectively. Given that shortfin mako sharks in the northeast Pacific deposit two band pairs in vertebrae per year through age 5 (Wells et al. 2013) and the uncertainty regarding band pair deposition rates in older specimens, the estimated age range of this shark was 13-22 years old. Organic contaminants and total mercury were measured in the liver and muscle tissue of the shark and were found to be substantially greater than most animals previously measured in southern California (total DDTs: 0.2 mg/g wet weight; total PCBs: 0.03 mg/g wet weight); however, the potential implications of this contaminant burden are unknown. Mercury levels were much higher than FDA recommendations for human consumption. This rare opportunity allowed for the collection of important data and contributes to our knowledge about the life history characteristics of large shortfin mako sharks.

Foraging Ecology of Pelagic Sharks

The California Current is a productive eastern boundary current that is an important nursery and foraging ground for a number of highly migratory predator species. To better understand niche separation and the ecological role of spatially overlapping species, stomach content analyses have been ongoing at the SWFSC since 1999. Stomachs are obtained primarily from the CADGN observer program. Stomach content analysis work has continued since the publication of Preti et al. 2012.

The stomachs of several species of pelagic sharks caught during the 2012 and 2013 fishing seasons have been analyzed. Current levels of analysis have allowed us to identify some of the most frequently encountered prey species. For the 2012 and 2013 seasons, shortfin mako stomachs (n=39) contained Pacific saury (F=23; F=Frequency of prey occurrence), jumbo squid (F=7), market squid (F=6), and octopus squid (F=4). Blue shark stomachs (n=13) contained Gonatus sp. squid (F=11), octopus squid (F=5), and paper nautilus. Common prey in thresher shark stomachs (n=12) was market squid (F=6) and Pacific saury (F=4). Jumbo squid was found in mako stomachs for the 2012 season only. Not all stomachs for the 2013 season have been analyzed, however, and the absence of jumbo squid in mako stomachs is preliminary pending completion of all the analyses.

Survival after Capture and Release

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

Blue Sharks Released from the California Drift Gillnet Fishery

The CADGN fishery targets swordfish in the California Current. With the exception of ocean sunfish, blue sharks are caught in greater numbers than any other fish species taken in this fishery. Nearly all blue shark are discarded at sea due to lack of market value. A 2009 analysis of the 1990-2008 observer data reveals that 32% 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 CADGN fishery to assess survivorship in order to determine more accurate estimates of fishery mortality for use in a blue shark stock assessment. As part of the study, a set of criteria was developed to document the condition of all live blue sharks released: “good”, “fair” or “poor”.

Prior to the 2012-2013 season, 15 blue sharks (100 to 200 cm FL) had been tagged by fishery observers. Three of the 15 sharks were released in “good” condition, 10 were released in “fair” condition, and 2 in “poor” condition. The two sharks that were released in “poor” condition as well as one released in “fair” condition did not survive the acute effects of capture in the CADGN fishery. These results, suggest that sharks that are released in “good” condition are likely to survive, whereas those released in “poor” condition are likely to die. No tags were released during the 2013-2014 season due to low effort and few blue sharks caught during the time the tags were available to observers, but we hope to complete the study during the 2014-2015 season.

Thresher Sharks Released from the Recreational Fishery

The SWFSC, SWR, and Pfleger Institute of Environmental Research (PIER) have conducted a three phase study to assess the post-release survival of thresher sharks caught by recreational anglers. The first phase of the study, which was completed in 2010, involved releasing sharks which had been captured using tail-hooking techniques (common practice in the southern California fishery). The results from this work revealed that survivorship is low for large sharks (>185 cm FL) that endure fight times that exceed 85 minutes (Heberer et al. 2010). The second and third phases of the research effort focused on assessing post-release survival in two modes of capture routinely observed in the southern California recreational fishery: (1) sharks that are caught using caudal-based angling techniques and unintentionally released with trailing gear left embedded, and (2) sharks that are caught and released using mouth-based angling techniques. Post-release survivorship was assessed using PSATs. For the trailing gear investigation, six sharks died shortly after release, one died after several weeks, and two sharks survived the deployment period for an overall survivorship rate of 22%. For the mouth-based trials, all common thresher sharks survived the acute effects of capture. These results indicate that trailing gear left embedded in sharks can negatively affect post-release survivorship, while mouth-based angling, when performed properly, can result in high survivorship of released sharks. The second publication for this project, based on results from phases two and three, is in press in the journal *Fisheries Research (*Sepulveda *et al. in press).* Overall, the results from all phases of this study indicate that methods that maximize mouth-based capture and reduced fight times increase the survivability of released thresher sharks.

A major component of this project is to promote fishing practices that enhance thresher shark catch and release survival by developing education and outreach tools for the recreational fishing community. An outreach video highlighting phase one of the research was produced by the Ocean Media Center (OMC) and posted on the NOAA Fisheries Home Page under the Video Gallery (http://www.nmfs.noaa.gov/gallery/videos/) in 2012. A second video, highlighting phases two and three of the research effort, is still under development by OMC.

Genetic Analysis of Pelagic Sharks

An understanding of stock structure is important in order to make accurate assumptions for stock assessments and to develop effective management objectives that take the population range, distribution and life history into account. Various genetic analyses are useful to help identify differentiation between and within presumed stocks. During 2013, sample collection and processing continued to examine stock structure for a number of shark species including shortfin mako, common thresher, silky, and pelagic thresher sharks. In addition, samples of blue shark tissue have been sent to colleagues in Japan as part of a Pacific-wide collaboration. DNA samples were collected during research cruises in 2013 from 263 shortfin makos, 72 blue sharks, 262 common threshers, 6 leopard sharks and one brown smoothhound. Additional samples were obtained by fishery observers on commercial drift gillnet trips.

Shark Stock Assessments

The SWSFC provides scientific advice on stock status of pelagic sharks to international and domestic regional fishery management organizations. Collaborative stock assessment research has been ongoing on pelagic sharks through the SHARKWG of the ISC, chaired by SWFSC scientist Dr. Suzanne Kohin, and through other multinational efforts. Starting in 2010, the SWFSC began working with member nations of the ISC, as well as scientific partners in Mexico, of the IATTC, and the Secretariat of the Pacific Community (SPC) to begin the first formal assessments of common thresher, blue and shortfin mako sharks in the eastern Pacific and north Pacific basins. These sharks are both fishing targets and incidental bycatch in numerous fisheries throughout their range and their status requires long-term monitoring.
In order to promote data collection in Mexico, the SWFSC and SWR are collaborating on multiyear efforts with Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), led by Dr. Oscar Sosa-Nishizaki, to coordinate artisanal fish camp monitoring and sampling in Baja California, Mexico and help advance cooperative stock assessment efforts with Mexico, U.S. and IATTC scientists. Sampling has provided valuable data for international assessment efforts through the ISC as well as for a USA-Mexico partnership to assess the status of common thresher sharks. As a result of the sampling program, fishery data for pelagic sharks now includes some size and sex sampling as well as several years of species specific catch information.

In 2013, the ISC produced its first assessment of blue sharks in the North Pacific Ocean. Two assessment models including a surplus production model as well as an age-structured model were used to investigate stock status. The ISC accepted the assessments at its July 2013 Plenary meeting in Busan, South Korea. The assessments were subsequently submitted to the Scientific Committee (SC) of the WCPFC. The SC recognized these efforts, but requested that further analyses to explore key aspects of uncertainty, including changes in targeting practices through time and the effect on estimated abundance indices, as well as additional exploration of model process be undertaken. The ISC SHARKWG is working to reassess the stock for a resubmission to the 2014 ISC Plenary and WCPFC SC.

Deep-set Longline Survey to Investigate Swordfish-Sea Turtle Habitat Separation

Heightened focus on minimizing bycatch of protected species has lead U.S. fisheries managers to implement combinations of gear restrictions and time-area closures. For example in 2001, to reduce sea turtle bycatch is swordfish fisheries, shallow-set longline (SSLL) fisheries were closed in the Atlantic and Central Pacific and a time-area closure was imposed on California pelagic drift gillnet (CADGN) fisheries. In response to the SSLL closures, fishers and scientists collaborated to develop gear modifications that reduced loggerhead and leatherback bycatch by 90% and 65%, respectively, leading to MSC certification of the Atlantic SSLL fishery. In contrast, the CADGN fishery has declined dramatically since implementing a large time area closure in 2001. The goal of this project was to explore potential gear alternatives for targeting swordfish off California building on previous efforts to reduce turtle bycatch in LL fisheries. The idea was to shift the longline gear to deeper water to capitalize on the difference is daytime depths; swordfish typically spend the daylight hours in waters deeper than 200 m whereas leatherbacks remain above 120 m.

On three cruises from 2011-2013, NOAA collaborated with longline fishers aboard the chartered F/V *Ventura II* off central and southern California to investigate the efficacy of targeting swordfish during the day using a deep-set longline (DSLL). During 47 sets, with average hook depths of 230-247 m and soak times 2.7-4 hours, 111 marketable fish (including 8 swordfish, 67 opah and 23 pomfret) and 352 non-marketable fish (including 328 blue sharks and 17 king of the salmon) were caught. Short soak times were used to maximize fish condition for tagging; two swordfish, five opah and five blue sharks were released with satellite tags and the majority of the remaining blue sharks were tagged with conventional tags and released. Based on previous research on blue shark post-release mortality, 81%-91% of blue sharks would be expected to survive after release. This study concluded that it is possible to catch swordfish and other marketable species below turtle habitat with a DSLL however, swordfish catch was low. Fishing conditions during these cruises were probably impacted by anomalous oceanographic conditions; swordfish catch for the CADGN fleet was very low over the same time periods. Efforts to collect additional data under more realistic fishing operations (i.e. fishing when and where conditions are best, over longer time periods) would provide a further test of the gear's potential. Given the experimental and small-scale nature of this research, these results are promising, but should not be projected beyond the study and warrant more research.

Swordfish Deep-Set Buoy Gear (DSBG) Research

The West Coast Region (WCR) Long Beach Sustainable Fisheries Division and the Pfleger Institute of Environmental Research (PIER) are conducting research using a deep-set vertical hook and line configuration (buoy gear) to target swordfish within the exclusive economic zone off the coast of California. To minimize interactions with species of concern, the deep-set gear was designed to fish below the thermocline (270 to 350m) during daylight hours. Gear trials were conducted during the 2011 and 2012 swordfish seasons off the coast of southern California using both research and cooperative fisher vessels. There were no interactions with species of concern, minimal interaction with non-target species (i.e., sharks) and swordfish were the primary catch. This work has been submitted for publication in 2013. Additional DSBG field experiments in 2013 focused on improving the test configuration, enhancing deployment and retrieval efficiency and preparing for cooperative trials in 2014. These data will be used in 2014 to trial DSBG from cooperative fisher platforms and to assess the domestic market niche for buoy caught swordfish. Additional collaborative efforts in 2013 with the WCR, SWFSC and PIER focused on documenting depth distribution for swordfish in the Pacific Leatherback Conservation Area. This work deployed 13 pop-off satellite archival tags and provided the first movement data for this species within the study region. These data will be analyzed and submitted for publication in 2014. Preliminary research results were presented at the March 2014 meeting of the Pacific Fishery Management Council.

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, and sharing, fisheries data on sharks and other species from U.S. island territories and states in the Central and Western Pacific(Hamm et al. 2011). The WPacFIN program has assisted other U.S. islands' fisheries agencies in American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands in modifying their data-collection procedures to include bycatch information. These modifications have improved the documentation of shark interactions with fishing gear. Shark catches in the Hawaii-based longline fishery have been monitored by a logbook program since 1990 and by an observer program since 1994. American Samoa has had a federal logbook program since 1996, and an observer program since 2006.

Biometrics Research on Catch Statistics

Biometrics 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 Office (PIRO) 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 historically has comprised approximately 85 percent of the shark bycatch from the Hawaii longline fishery, exhibits a high rate of survival (about 95 percent) to the time of release. On the basis of these very low mortality estimates if released, 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.

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

NMFS 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 (Table 6.1) 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 6.1 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 6.1), only four species are typically recorded in sufficient frequency by towed divers to allow meaningful statistical analyses: grey reef shark (*Carcharhinus amblyrhynchos*), Galapagos shark (*Carcharhinus galapagensis*), whitetip reef shark (*Triaenodon obesus*), and blacktip reef shark(*Carcharhinus melanopterus*). Analyses show a highly significant negative relationship between grey reef and Galapagos shark densities and proximity to human population centers (e.g., proxy for potential fishing pressure and other human impacts). Average combined numerical density for these two species near population centers is less than 1 percent of densities recorded at the most isolated islands (e.g., no human population, very low present or historical fishing pressure or other human activity). Even around islands with no human habitation but within reach of populated areas, grey reef and Galapagos shark densities are only between 15 percent and 40 percent of the population densities around the most isolated near-pristine reefs. Trends in whitetip and blacktip reef shark numbers are similar but less dramatic.

Recent analysis of data from 2008 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.

Insular Shark Population Model

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

The shark count data were used to build a computer model capable of explaining observed reef shark abundances at various reefs by examining the effects of variables related to human impacts, oceanic productivity, sea surface temperature, and reef habitat physical complexity. This model was used to predict reef shark densities in the absence of humans (i.e., baseline or pristine abundance) and found that current reef shark numbers around populated islands in Hawaii, the Mariana Archipelago, and American Samoa are down to about 3 to 10 percent of their baseline values (Figure 6.3). 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 percent lower than on pristine reefs) and direct removal through fishing (bycatch, recreational, or targeted) (Nadon et al. 2012).

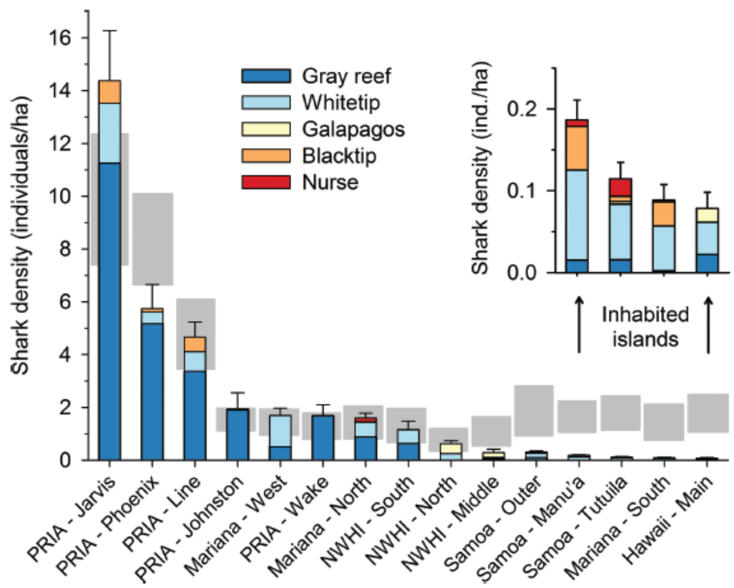

Figure 6.3: Mean (SE) observed densities of reef sharks in the U.S. Pacific. Colors represent actual densities; gray rectangles represent model predictions in the absence of humans.

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

Shark predation on Hawaiian monk seal pups (*Monachus schauinslandi*) has become unusually common at one breeding site, French Frigate Shoals (FFS) in the Northwestern Hawaiian Islands (NWHI). Since 1997, NMFS has frequently observed Galapagos sharks (*Carcharhinus galapagensis*) patrolling and attacking monk seal pups. Tiger sharks (*Galeorcerdo cuvier*) also prey on monk seals and are abundant at FFS; however, Tiger sharks have not been observed to attack pups (Gobush 2010; unpublished data). For these reasons, monitoring and mitigation efforts at FFS continue to be focused on Galapagos sharks. Shark tagging studies at FFS indicate that, although Galapagos sharks are the most 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 highly selective shark removal project to mitigate predation on monk seal pups from 2000-2013, 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 been lethally removed to date. In 2009, the number of shark sightings and predation incidents at two pupping islets did not differ significantly between the control and two experimental treatments: (1) acoustic playback and a moored boat, and (2) continuous human presence, versus a control (Gobush and Farry 2012). No sharks were removed at French Frigate Shoals in 2013.

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's Fisheries Research Agency, to update the blue shark assessment with the latest data from Japanese and Hawaii based longline fisheries, 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 same pattern of stock decline in the 1980s followed by recovery to a biomass that was greater than that at the start of the time series. One of the several alternate analyses indicated some probability (around 30 percent) 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-specific depth and temperature ranges, although with significant individual temporal and spatial variability in vertical movement patterns, which were also punctuated by stochastic events (e.g., El Niño-Southern Oscillation [ENSO]). Pelagic species, including some other species that have been PSAT tagged (swordfish, bigeye tuna, and marlins) can be separated into three broad groups (figure 6.4) based on daytime temperatures occupied using a clustering algorithm. These groups and the temperatures occupied by the sharks are characterized as: (1) epipelagic species (including silky and oceanic whitetip sharks) which spent more than 95 percent 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 percent 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 percent 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).

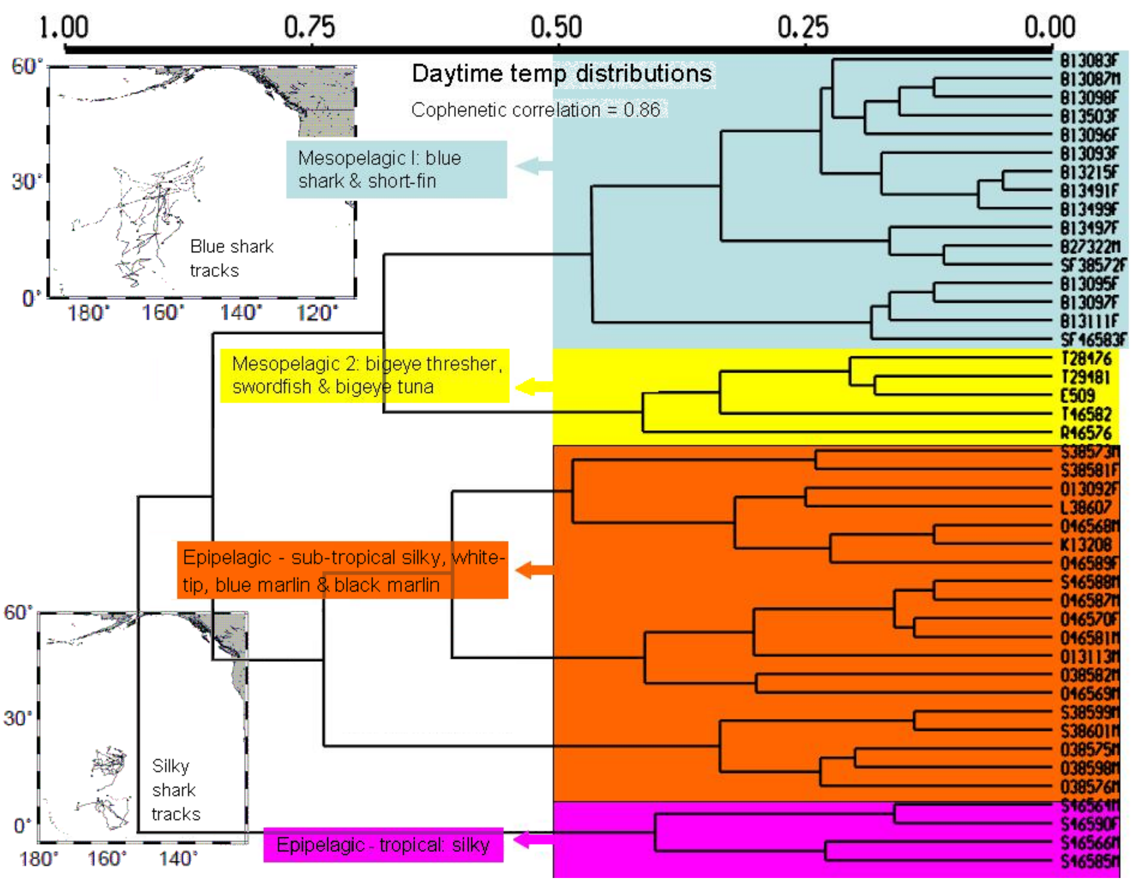

Figure 6.4: Clustered relationships among pelagic animals using daytime temperature preferences from pop-up satellite archival tags (PSATs). B = blue shark, SF = shortfin mako, T = bigeye thresher, E = bigeye tuna, R = swordfish, S = silky shark, O = oceanic whitetip shark, K = black marlin, L = blue 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 Shark Defense 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 of a 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 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 field trials in Kaneohe Bay, Hawaii, suggest that catch rates of juvenile scalloped hammerhead sharks are reduced by 63 percent on branch lines with the Nd/Pr alloy attached as compared to lead weight controls (Figure 6.5). Initial behavioral experiments examining effects on swimming behavior have been initiated (Wang et al. 2009, Brill et al. 2009).

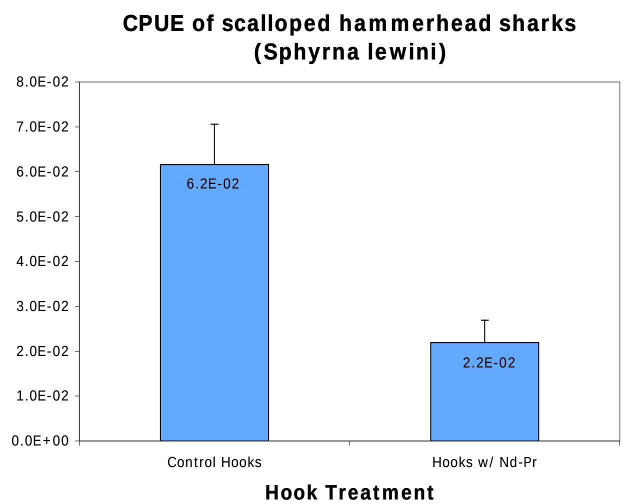

Figure 6.5: Catch per unit effort of scalloped hammerhead sharks on longlines with Nd/Pr alloy attached versus control hooks.

In addition, field trials on pelagic sharks were initiated via collaboration with the Southwest Fisheries Science Center (SWFSC). 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.

A collaborative pilot study in the Ecuadorian mahi-mahi longline fisheries was also conducted. Branch lines with lead weight were alternated with branch lines 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 branch lines and branch lines 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 percent of the total catch by number. Catch rates on large 18/0 circle hooks were significantly reduced—by 17 percent for blue shark, 27 percent for bigeye thresher shark, and 69 percent for pelagic stingray. Bycatch rates for other incidental species such as billfish, opah (*Lampris guttatus*), and mahimahi (*Coryphaena hippurus*) were also reduced compared to traditional tuna hooks. There was no significant difference in the catch rate of the target species, bigeye tuna, by hook type. In contrast to tuna hooks, large circle hooks have conservation potential for use in the world's pelagic tuna longline fleets for some highly migratory species based on demonstrated catch rate reductions (Curran and Bigelow 2010, 2011).

Testing Deeper Sets

An experiment with deeper set longline gear conducted in 2006 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, is required to carry and use dehookers for removing hooks from sea turtles. These dehookers can also be used to remove external hooks and ingested hooks from the mouth and upper digestive tract of fish, and could improve post-release survival and condition of released sharks. Sharks are generally released from the gear by one of the following methods: (1) severing the branch line,(2) hauling the shark to the vessel to slice the hook free, or (3) dragging the shark from the stern until the hook pulls free. Fishermen are encouraged to use dehooking devices to minimize trauma and stress of bycatch by reducing handling time and to mitigate post-hooking mortality.

Testing of the dehookers on sharks during research cruises has indicated that removal of circle hooks from shark jaws with the dehookers can be quite difficult. PIFSC is looking into the feasibility of barbless circle hooks for use on longlines, which would make it easier to dehook unwanted catch with less harm. Preliminary research in the 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 percent success rate in dehooking and releasing live sharks on barbless hooks, compared to a 0 percent success rate when used with sharks caught on barbed hooks. In 2007, PIFSC and 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 percent with barbed hooks and 72 percent with barbless hooks. During the study a new dehooker was developed and tested. Preliminary results were more than 90 percent 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 survival is typically estimated using tagging programs. Historically, large-scale conventional tagging programs were used. These programs yielded low return rates, consistent with a high post-release mortality. For example, in a 30-year study of Atlantic blue sharks, only 5 percent of tags were recovered. Short-duration studies using ultrasonic telemetry have shown that large pelagic fish usually survive for at least 24 to 48 hours following release from sport fishing or longline gear. PIFSC researchers and collaborators from other agencies, academia, and industry have been developing alternative tools to study longer-term post-release mortality. Whereas tagging studies assess how many fish survive, new approaches are being used to understand why fish die. A set of diagnostic tools is being developed to assess the biochemical and physiological status of fish captured on various gear. These diagnostics are being examined in relation to survival data obtained from a comprehensive PSAT program. Once established as an indicator of survival probability, such biochemical and physiological profiling could provide an alternative means of assessing consequences of fishery release practices.

PIFSC scientists have been developing biochemical and physiological profiling techniques for use in estimating post-release survival of blue sharks, which are frequently caught as bycatch 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 Mg^{2+}, plasma lactate, erythrocyte Hsp70 mRNA, plasma Ca^{2+}, and plasma K^+. A logistic regression model incorporating a combination of Mg^{2+} and lactate successfully categorized 19 of 20 (95 percent) fish of known fate and predicted that 21 of 22 (96 percent) sharks of unknown fate would have survived upon release. These data suggest that a shark captured without obvious physical damage or physiological stress (the condition of 95 percent of the sharks they captured) would have a high probability of surviving upon release (Moyes et al. 2006).

In the second approach PIFSC and colleagues deployed 71 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 that succumbed seven days post-release. The depth and temperature data suggest that this one mortality was due to injuries sustained during capture and handling, rather than predation. Meta-analysis on blue shark mortality from published and ongoing research (n=78 reporting PSATs) indicated the summary effect for post-release mortality from longline gear was 15 percent (95% CI, 9 – 25%).

Antecedent stress variables to explain mortality have been examined (i.e., capture temperature, soak time, etc.) but 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 percent 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) Studies on Horizontal and Vertical Movement Patterns
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) 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-specific depth 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 percent of their time at temperatures within 2°C of sea surface temperature; (2) mesopelagic-I species (blue sharks and shortfin makos), which spent 95 percent 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 percent of their time at temperatures from 6.7° to 21.2°C (Musyl et al. 2011a). This 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).

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 percent) reported data. Of the tags that recorded data, 106 (18 percent) hit their programmed pop-off date and 471 tags popped off earlier than their program date. The 154 (21 percent) 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 percent reported and 65 percent detached before the programmed pop-up date. Shark PSAT reporting rates were highest in species such as oceanic whitetip (81 percent), 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 percent) and shortfin mako (40 percent). 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).

Pop-up Satellite Archival Tags (PSAT) and Post-release Survival

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 percent) that 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 percent) and shortfin mako (40 percent). 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 percent (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.

Reducing Longline Shark Bycatch

The resumption of the previously closed Hawaii shallow-set longline fishery for swordfish in late 2004 and continuing through 2007 was anticipated to increase blue shark catches, as in the past blue sharks made up about 50 percent of the total catch in this fishery. With the ban on shark finning, these sharks are not retained and are categorized as regulatory bycatch. Although the anticipated increase in shark bycatch has been less than expected (perhaps due to the requirement to use fish bait instead of squid, or because of a shift toward an earlier fishing season in the reopened swordfish fishery), researchers at PIFSC have undertaken several projects to address shark bycatch on longlines (Huang et al., 2013; Hutchinson et al., 2012; Swimmer et al. 2008, 2011).The use of large circle hooks instead of conventional tuna hooks in the world’s pelagic tuna longline fleets has displayed conservation potential for some highly migratory species (Curran and Bigelow 2010, 2011). However, recent collaborative research on capture rates of species caught on Japanese tuna hooks vs. relatively large circle hooks conducted on a Taiwanese commercial longline vessel indicated significantly higher catch rates of blue sharks caught on circle hooks (Huang et al., 2013). Additionally, research in the South Atlantic Ocean conducted on a Uruguayan longline vessel found higher rates of capture of shortfin mako sharks on circle hooks compared to J hooks (Domingos et al., 2012).

Electromagnetic Deterrents to Bycatch

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

Southeast Fisheries Science Center (SEFSC)

Shark Longline Program

This program is designed to meet the intent of the ESA 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 36 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, and six in 2012 and 2013. These vessels carried observers on 100 percent of trips. Outside the research fishery, vessels targeting shark and possessing current valid directed shark fishing permits were randomly selected for coverage with a target coverage level of 4 to 6 percent.

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 ESA, and the 1999 revised FMP for HMS. It was also created to obtain better data on catch, bycatch, and discards in the shark fishery. Historically, the Atlantic Large Whale Take Reduction Plan and the Biological Opinion issued under Section 7 of the Endangered Species Act mandated 100 percent observer coverage during the right whale calving season (November 15 to April 1). Outside the right whale calving season, observer coverage equivalent to 38 percent of all trips was maintained. In 2007, the regulations implementing the Atlantic Large Whale Take Reduction Plan were amended and included the removal of the mandatory 100 percent observer coverage for drift gillnet vessels during the right whale calving season, but now prohibit all gillnets in an expanded southeast 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 strike net fishing[2] during this same period, and for Spanish mackerel gillnet fishing in December and March. Based on these regulations and on current funding levels, the shark gillnet observer program now covers a portion of all anchored (sink, stab, set), strike, or drift gillnet fishing by vessels that fish from Florida to the North Carolina year-round. All observers must record information on all gear characteristics, species caught, condition of the catch, and the final disposition of the catch. A total of 225 sets comprising various gillnet fisheries were observed in 2013. Set locations ranged from North Carolina to the Florida Keys in the Altantic Ocean and the Gulf of Mexico. Trips were made targeting one or more of the following: mixed shark species, king mackerel (*Scomberomorus cavalla)*, smooth dogfish (*Mustelus canis)*, Spanish mackerel (*Scomberomorus maculates)*, southern kingfish (*Menticirrhus americanus)*, and mixed teleosts (including Atlantic croaker (*Micropogonias undulates)*, bluefish (*Pomatomus saltatrix)*, and mixed teleost species).

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 PSATs. 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. A second shark also tagged off Key Largo in March traveled south toward Cuba. The third shark, tagged off North Carolina in March, moved little from where it was initially tagged but problems with estimating the geolocation precluded fully

[2] When a vessel fishes for sharks with strike nets, 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.

determining its movement patterns in and around the closed area. Three dusky sharks were tagged in 2012; one animal died, one tag did not report, and the third animal traveled 723 km north of where it was initially tagged.

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.

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

The SEFSC Shark Population Assessment Group manages and coordinates a survey of coastal bays and estuaries from Cedar Key, Florida, to Terrebonne Bay, Louisiana. Surveys identify the presence or absence of neonate (newborn) and juvenile sharks and attempt to quantify the relative importance of each area as it pertains to EFH. The Group initiated a juvenile shark abundance index survey in 1996. The index is based on random, depth-stratified gillnet sets conducted throughout coastal bays and estuaries in coastal areas of the Gulf of Mexico from April to October. The species targeted in the index of abundance survey are juvenile sharks in the large and small coastal management groups. This index has been used as an input to various stock assessment models. A database containing tag and recapture information on elasmobranchs tagged by GULFSPAN participants currently includes 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 2013 with hopes to have it online and searchable by all participants in FY 2015.

Monitoring the Recovery of Smalltooth Sawfish (Pristis pectinata)

The smalltooth sawfish was listed as endangered under the ESA in 2003. Smalltooth sawfish are the first marine fish and first elasmobranch listed under the ESA. Smalltooth sawfish were once common in the Gulf of Mexico and off the southeast coast of the United States. Decades of fishing pressure, both commercial and recreational, and habitat loss caused the population to decline by up to 95 percent during the second half of the twentieth century. Today they exist mostly in southern Florida.

The completion of the Smalltooth Sawfish Recovery Plan in early 2009 brought about a new phase of research and management for the U.S. population of smalltooth sawfish. Research and monitoring priorities identified in the Recovery Plan are now being implemented. Field work is underway to gather information on determining critical habitat and monitoring the population.

This information will evaluate the effectiveness of protective and recovery measures and help determine if the population is rebounding or, at the very least, stabilizing.

One of the high-priority research areas is monitoring of the number of juvenile sawfish in various regions throughout Florida to provide a baseline and time series of abundance. One of the more important regions for smalltooth sawfish identified in previous research is the section of coast from Marco Island to Florida Bay, Florida. This region encompasses the coast of the Ten Thousand Islands National Wildlife Refuge and Everglades National Park. Scientists from the SEFSC conduct monthly surveys in southwest Florida to capture, collect biological information, tag, and then release smalltooth sawfish. Preliminary results indicate that juvenile sawfish exhibit a high degree of site fidelity. 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.

Successful recovery of sawfish populations requires juvenile recruitment success and initiatives now strive to include the protection of areas used by juveniles in order to promote survivorship. Initial studies have identified sheltered, shallow, mangrove areas as nursery habitat with subsequent studies finding warmer water temperatures and variable salinity associated with the capture of juvenile sawfish. However, further refinement is required to fully predict the essential features smalltooth sawfish require as juveniles. Since 2009, a fisheries-independent gillnet survey of smalltooth sawfish abundance has occurred in Everglades National Park, US.

Variables collected with each sample include environmental characters such as temperature, salinity, and dissolved oxygen and in later years specific habitat features such as mangrove prop root density. Using a bivariate generalized linear mixed modeling approach, we conducted exhaustive screening of all possible variable combinations including two-way interactions to construct habitat suitability models for young-of-the year and juvenile smalltooth sawfish. Variable selection was determined using a combination of Chi-square tests of significance and minimizing the Bayesian information criterion. Regardless of life stage, habitat suitability models suggest that salinity, red mangrove prop root and number of pneumatophores on black mangroves are the most important factors driving smalltooth sawfish occurrence. Coastal development and urbanization have caused mangrove habitats globally to be removed from many areas throughout the species' current range. Given the importance of mangroves to the recruitment of juvenile sawfish, adequate protection of remaining areas will be essential for recovery of the species.

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.

Maximum Age and Missing Time in the Vertebrae of Sand Tiger Sharks (Carcharias taurus): Validated Lifespan From Bomb Radiocarbon Dating in the Western North Atlantic and Southwestern Indian Oceans

Bomb radiocarbon analysis of vertebral growth bands was used to validate lifespan for sand tiger sharks, *Carcharias taurus*, from the western North Atlantic and southwestern Indian Oceans. Visual counts of vertebral growth bands were used to assign age and estimate year of formation for sampled growth bands in eight sharks from the western North Atlantic and two sharks from the southwestern Indian Ocean. Carbon-14 results were plotted relative to year of formation for comparison with regional Δ14C reference chronologies to assess accuracy of age estimates. Results from the western North Atlantic validated vertebral age estimates up to 12 years, but indicated ages of large adult sharks were underestimated by 11-12 years. Age was also underestimated in adult sharks from the southwestern Indian Ocean by 14-18 years. Validated lifespan for *C. taurus* individuals in this study reached at least 40 years for females and 34 years for males. Findings indicate the current age-reading methodology is not suitable for estimating the age of *C. taurus* beyond approximately 12 years. Future work should investigate whether vertebrae of *C. taurus* record age throughout ontogeny, or cease to be a reliable indicator at some point in time.

Demography of manta rays

The directed harvest and global trade in the gill plates of mantas, and devil rays, has led to increased fishing pressure and steep population declines in some locations. The slow life history, particularly of the manta rays, is cited as a key reason why such species have little capacity to withstand directed fisheries. Despite the limited availability of data, we use life history theory and comparative analysis to estimate the intrinsic risk of extinction (as indexed by the maximum intrinsic rate of population increase rmax) for a typical generic manta ray using a variant of the classic Euler–Lotka demographic model. This model requires only three traits to calculate the maximum intrinsic population growth rate rmax: von Bertalanffy growth rate, annual pup production and age at maturity. To account for the uncertainty in life history parameters, we created plausible parameter ranges and propagate these uncertainties through the model to calculate a distribution of the plausible range of rmax values.The maximum population growth rate rmax of manta ray is most sensitive to the length of the reproductive cycle, and the median rmax of 0.116 year−1 CI [0.089–0.139] is one of the lowest known of the 106 sharks and rays for which we have comparable demographic information. In common with other unprotected, unmanaged, high-value large- bodied sharks and rays this combination of very low population growth rates of manta rays, combined with the high value of their gill rakers and the international nature of trade, is highly likely to lead to rapid depletion and local extinction unless a rapid conservation management response occurs worldwide. Furthermore, we show that it is possible to derive important insights into the demography extinction risk of data-poor species using well-established life history theory.

Bonnethead (Sphyrna tiburo) site fidelity

To examine the migratory patterns, habitat utilization and residency of bonnethead sharks (*Sphyrna tiburo*) in estuarine systems within coastal South Carolina, a tag-recapture experiment was conducted from 1998 to 2012 during which 2300 individuals were tagged. To assess the intra and inter-annual movements of tagged sharks, six estuaries within state waters were monitored using multiple gear types in addition to the cooperative efforts of recreational anglers throughout the southeastern United States. Over the course of the experiment 177 bonnetheads were recaptured after 3 days to 8.9 years at liberty, representing a recapture rate of approximately 8%. All bonnetheads were recaptured within the same estuary where they were originally tagged on intra and/or inter-annual scales, with the exception of six individuals, which were recaptured during migratory periods (i.e. late fall,winter and spring) in coastalwaters off Florida,Georgia,North Carolina, and South Carolina. On 23 occasions cohesion was demonstrated by groups ranging in size from2 to 5 individuals that were tagged together and recaptured together, with times at liberty ranging from12 days to 3.6 years. Additionally, 13 Individuals were recapturedmultiple times with times at liberty ranging from12 days to 8.9 years; all individuals were recaptured in the same estuary where they were initially tagged. We hypothesize that bonnetheads are using South Carolina's estuaries as summer feeding grounds due to the relatively high abundance of blue crabs (*Callinectes sapidus*), including ovigerous females during spring and summer months, and the location of these ephemeral yet predictable feeding areas is socially transmitted to relatively young, naïve sharks by experienced,

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

Brazil (Universidade Federal Rural de Pernambuco) and the United States (NMFS SEFSC 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 and temperature and depth recorders) 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.

Catches in longlines employing circle hooks (15/0 and 17/0) and 10/0 "J"- hooks were compared with the use of hook timers to measure differences in fishing mortality associated with 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 hook timers 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.

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, 11 satellite tags have been deployed on blue sharks to date. Tags that are providing real time data, along with data for Ecological Risk Assessments are used as outreach to promote the collaboration between NOAA and DINARA. Staff from DINARA and the SEFSC also worked cooperatively on the creation of identification guides for carcharhinid and pelagic sharks of the Atlantic Ocean for ICCAT (ICCAT 2012).

Shark Assessment Research Surveys

The SEFSC has conducted bottom longline surveys in the Gulf of Mexico (see Figure 6.6), Caribbean, and Southern North Atlantic since 1995 (31 surveys have been completed through 2013). 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: stock wide 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.

Figure 6.6: Scalloped hammerhead captured in the Gulf of Mexico during a bottom longline survey.
Source: NMFS SEFSC

Northeast Fisheries Science Center (NEFSC)

Fishery Independent Coastal Shark Bottom Longline Survey

The fishery independent survey of Atlantic large and small coastal sharks is conducted bi-annually in U.S. waters, depending on funding. Its primary objective is to conduct a standardized, systematic survey of the shark populations off the U.S. Atlantic coast to provide unbiased indices of relative abundance for species inhabiting the waters from Florida to the Mid-Atlantic (see Figure 6.7). This survey also provides an opportunity to tag sharks with conventional and electronic tags as part of the NEFSC Cooperative Shark Tagging

Figure 6.7: Releasing a sandbar shark during the NEFSC Coastal Shark Bottom Longline Survey. .Source: L.J. Natanson / NMFS photo.

Program, to inject with oxytetracycline for age validation studies, and to 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 are critical to the evaluation of coastal Atlantic shark species. Results from the 2012 survey included 1,845 fish (1,831 sharks) representing 16 species. Sharks represented 99% of the total catch of which sandbar sharks were the most common, followed by dusky and tiger sharks. As part of this survey, bottom longline sets were conducted in the closed area off North Carolina. These results represent the highest catches of sharks from any previous survey to date. Standardized indices of abundance from this survey for sandbar and dusky sharks were used in the 2012 Southeast Data Assessment and Review (SEDAR) process (McCandless and Natanson 2012). The next survey is scheduled for spring of 2015.

Fishery Independent Pelagic Shark Longline Survey

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

Juvenile Shark Survey for Monitoring and Assessing Delaware Bay Sandbar Sharks (Carcharhinus plumbeus)

The juvenile sandbar shark population in Delaware Bay is surveyed by NEFSC staff as part of the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) program. A random stratified longline sampling plan, based on depth and geographic location, was developed in 2001 to assess and monitor the juvenile sandbar shark population during the nursery season. In 2013, a total of 219 sandbar sharks were caught with 93% of these sharks 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. During the most recent SEDAR for sandbar sharks, 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 (McCandless, 2010). All three juvenile sandbar shark time series showed stability in relative abundance from 2001 to 2005 with only a brief decrease in abundance in 2002, which may be attributed to a large storm (associated with a hurricane offshore) that passed through the Bay that year. There was a subsequent decreasing trend from 2005 to 2008 that ends with an increase in relative abundance in 2009.

Delaware Bay Sand Tiger (Carcharias taurus) Survey

A survey, initiated in 2006 targeting the sand tiger shark for identifying Essential Fish Habitat (EFH) and for future stock assessment purposes, continued in 2013 (see Figure 6.8). 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 2013, a total of 37 sand tigers were caught and released and 86% of these sharks were tagged with conventional tags bringing the total since the beginning of the survey to 238 sand tigers.

Figure 6.8: Measuring a sand tiger during the NEFSC Delaware Bay Sand Tiger Survey. Source: Corey Eddy / NMFS photo.

Collection of Recreational Shark Fishing Data and Samples

Historically, species-specific landings data from recreational fisheries is lacking for sharks. In an effort to augment these data, the NEFSC has been attending recreational shark tournaments continuously since 1961 collecting data on species, sex, and size composition from individual events; in some cases, for nearly 50 years. In addition, these tournaments provide a source of samples for pelagic and some coastal sharks to aid in our biological research. Analysis of these tournament landings data was initiated by creating a database of historic information (1961-2013) 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 2013, biological samples for life history studies and catch and morphometric data for more than 120 pelagic sharks were collected at 8 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 finally, to provide additional information on movements that complement the NMFS Cooperative Shark Tagging Program (CSTP).

In 2013, NOAA Fisheries staff worked with a variety of partners (Concerned Citizens of Montauk, Montauk Chamber of Commerce, researchers from MADMF, Mote, OCEARCH, recreational sport fishermen, charter boat captains, marina owner, and the Guy Harvey Ocean Foundation) to help stage an all-release, satellite tag shark tournament in Montauk, LI, NY called ‘Shark’s Eye’. This is the first and only satellite tag, all-release shark tournament, to be held in the Northeast US; rules required the mandatory use of circle hooks, heavy tackle and safe handling practices. Results from the first year included four electronic SPOT tags and numerous conventional tags that were put on shortfin makos and blue sharks. Location data from the spot tags were made available on the OCEARCH website. Additionally, there was a 2-day public outreach event where much information was given out on NOAA Fisheries research.

NEFSC Historical Longline Survey Database
The NEFSC recovered the shark species catch per set data from the exploratory shark longline surveys conducted by the Sandy Hook and Narragansett Laboratories from 1961 to 1991. In addition to the fishery-independent surveys conducted by the NEFSC, scientific staff has been working with the University of North Carolina (UNC) to electronically recover the data from an ongoing coastal shark survey in Onslow Bay that began in 1972. These surveys provide a valuable historical perspective for evaluating the stock status of Atlantic sharks. This data recovery process is part of a larger, systematic effort to electronically recover and archive historical longline surveys and biological observations of large marine predators (swordfish, sharks, tunas, and billfishes) in the North Atlantic. When completed, these efforts will include reconstructing the historic catch, size composition, and biological sampling data into a standardized format for time series analysis of CPUE and size. Standardized indices of abundance developed for sharks caught during these longline surveys have been and will continue to be used in stock assessments as part of the SEDAR process. Abundance indices were summarized for sandbar and dusky sharks caught during the NEFSC exploratory longline surveys (McCandless and Hoey 2010) and for Atlantic sharpnose, blacknose, sandbar, and dusky sharks caught during the UNC shark survey (Schwartz et al. 2010, Schwartz et al. 2013). Work on the recovery of environmental data for both the NEFSC and the UNC time series, as well as the associated individual shark data, is ongoing to further refine these indices and to develop indices of abundance for other shark species, and for future use in shark EFH designations. Analyzing catch rates according to differences in time, space, or methods provide an opportunity to better understand seasonal distribution patterns and relative vulnerability of various species to different fishing practices.

South East Data, Assessment, and Review (SEDAR) Process
Staff participated in the Southeast Data, Assessment, and Review (SEDAR) 34 Data Workshop for the assessment of the US Atlantic and Gulf of Mexico Atlantic sharpnose and bonnethead shark populations. Working papers were presented summarizing standardized indices of abundance for these species (Frazier and McCandless 2013, McCandless and Belcher 2013, McCandless and Frazier 2013, McCandless et al. 2013a, McCandless et al. 2013b, Schwartz et

al. 2013) and mark/recapture data for these species from the Cooperative Shark Tagging Program (Kohler et al. 2013a, Kohler et al. 2013b).

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 2013 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 3). 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 2 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 2013, an additional 354 sharks were tagged bringing the total to over 3,300 with over 200 recaptured. These fish were primarily blue sharks that were recovered by commercial fishermen working in the mid-Atlantic Ocean. This research was featured as part of the Discovery Channels ‘Swords: Life on the Line’ which is a series documenting the lives of commercial longline fishermen.

Figure 6.9: Shortfin mako brought aboard during the NEFSC Pelagic Nursery Ground cruise. Source: Lisa Natanson / NMFS photo.

Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program

The NEFSC manages and coordinates this program, which surveys Atlantic coastal waters from Florida to Massachusetts and in the U.S. Virgin Islands (USVI) by conducting cooperative, comprehensive, and standardized investigations of coastal shark nursery habitat. COASTSPAN surveys are used to describe habitat preferences, and to determine the relative abundance, distribution, and migration of shark species through longline and gillnet sampling and mark-recapture data (see Figure 6.10). In 2013, COASTSPAN participants were the University of North Florida, Georgia Department of Natural Resources, South Carolina Department of Natural Resources, North Carolina Division of Marine Fisheries, Virginia Institute of Marine Science and Stony Brook University. 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. In 2013, a total of over 5,000 sharks of 16 species were caught during COASTSPAN surveys and 1724 (40%) of these sharks were tagged for migration studies. Three COASTSPAN documents were presented during the SEDAR 34 Data Workshop summarizing abundance indices for Atlantic sharpnose sharks and bonnetheads in the southern US Atlantic estuarine and coastal waters (McCandless and Belcher 2013, McCandless and Frazier, McCandless et al. 2013a). A Ph.D. dissertation from the University of Massachusetts School for Marine Science and Technology was completed using COASTSPAN supported research with passive acoustic telemetry in Massachusetts waters to study the habitat utilization and essential fish habitat of juvenile sand tigers (Kneebone et. al 2012). Additionally, work conducted by our Massachusetts COASTSPAN participant on the physiological effects of capture and post-release survivorship of juvenile sand tigers caught by rod and reel (Kneebone et al. 2013) indicated that the current state and federal management regulations requiring the mandatory release of recreationally caught sand tigers is a viable management strategy for juvenile sand tigers caught by rod and reel.

Figure 6.10: Tagging a juvenile sandbar shark during the NEFSC COASTSPAN Program Survey. Source: W. David McElroy / NMFS photo.

In collaboration with MDMF and NMFS (Galveston, TX; Silver Spring, MD), 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, United States 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 (5 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 NOAA Living Marine Resources Cooperative Science Center to support a multi-year cooperative research project with staff from Delaware State University and the University of Rhode Island on habitat use, depth selection, and the timing of residency for sand tigers in Delaware Bay. Sand tigers were implanted with standard acoustic or depth-sensing transmitters to monitor their movements and habitat use of Delaware Bay during the summer months. Sand tiger movements continue to be monitored using passive acoustic telemetry.

Funding was received through the NOAA NMFS Species of Concern Internal Grant Program to study the regional movements, habitat use, and site fidelity of sand tigers off the US east coast using satellite telemetry. PSATs were deployed on seven sand tigers; five 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 participates on a working group with others from the NMFS HMS Division and SEFSC to update and refine the EFH designations for managed shark species. This process was ongoing in 2013 and entailed providing summaries from COASTSPAN surveys and the CSTP databases 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 and shortfin mako in the North Atlantic are ongoing. Fisheries-independent published research on blue shark demographics has allowed for the construction of an age-structured population model. This model confirms the importance of juvenile survival for population growth. In addition, a risk analysis is proposed as a supplement to the data-limited stock assessment to better evaluate the probability that a given management strategy will put the population at risk of decline.

Figure 6.11: Blue shark ready to be tagged and released. Source: Lisa J. Natanson / NMFS photo.

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

From samples 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 1962-2000. 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, life-history strategies, and population structure is needed to develop informed management of this open ocean species.

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

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

Biology of the Spiny Dogfish (*Squalus acanthias*)

The NEFSC Cooperative Research and Apex Predators Programs began tagging spiny dogfish in the Gulf of Maine, Southern New England, and Georges Bank regions in 2011. This project aims to answer long-standing questions about stock structure, movement patterns, and life history to update and improve spiny dogfish stock assessments. Over a two-year period, dogfish were tagged during winter and summer using three commercial vessels. In 2012, an additional 18,570 spiny dogfish were tagged bringing the total tagged to 34,604 for the two year project. Of the total tagged, 756 have been recaptured through 2013. Some tagged dogfish were injected with oxytetracycline (OTC) for an age validation study. As of 2013 125 fish that were OTC injected have been recaptured and returned to the APP for age validation.

In 2013, a new initiative was launched to determine the seasonality of pupping and gestation period of female spiny dogfish in Southern New England. Many populations of spiny dogfish are known to have a two-year gestation period, however, this has never been comprehensively studied in the western North Atlantic. The primary purpose of this study is to determine the gestation period. Additional information on seasonality of mating and pupping and size at birth will also be obtained. Thirty samples of mature females were obtained and dissected each month with the exception of October. Sampling will continue for two years.

Biology of the White Shark (*Carcharodon carcharias*)

The white shark is well documented in the western North Atlantic (WNA) from Newfoundland to the Gulf of Mexico, including the Bahamas and parts of the Caribbean. However, the species is relatively elusive in the WNA and efforts to study its life history and ecology have been hampered by the inability of researchers to predictably encounter these sharks. An update to a NEFSC western North Atlantic white shark distribution paper is being finalized for publication. This study is a joint effort with NOAA Fisheries staff from the NEFSC, SEFSC, and 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 649 confirmed white shark records compiled over a 210-year period (1800-2010) 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. 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. In 2013, sightings records were analyzed using multiple time frames to look at extinction risk through annual changes in magnitude in a generalized linear model framework and the remaining indices of abundance were combined using a hierarchical framework to develop an overall trend in relative abundance for WNA white sharks.

Researchers from Stony Brook University, Field Museum of Chicago, Nova Southeastern University, and NEFSC are currently employing a multi-analytical approach to test the hypothesis that northwest Atlantic white sharks have experienced a recent loss of genetic diversity due to a population bottleneck. Results show that contemporary northwest Atlantic white sharks are genetically distinct from other populations and comprise a demographically distinct unit. Ongoing work includes attempting to reconstruct the genetic diversity of white sharks in the 1960s and 1970s using DNA recovered from archived vertebrae. Historical genetic diversity will be directly compared to contemporary genetic diversity in this study, which could serve as a model for similar studies of other elasmobranchs. A manuscript for this study was revised in 2013.

Vertebrae for age and growth have been collected by members of the Apex Predators Program since 1963. Since they are a prohibited species, new samples are not likely to be obtained in sufficient quantity and thus 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. In 2013, final results were obtained for the bomb carbon analysis and two manuscripts were submitted; one describing the bomb carbon results was accepted for publication in PlosOne and one using the validated data to age the white shark returned pending publication of the previous manuscript.

Biology of the Thresher Shark (*Alopias vulpinus*)
Life history studies of the thresher shark in the western North Atlantic continued with published accounts of reproductive and age parameters. Reproductive organs from 130 males and 256 females were examined to describe the reproductive characteristics and determine size at maturity and reproductive seasonality for the species in the western North Atlantic Ocean (Natanson and Gervelis 2013). Males ranged in size from 78 to 237 cm FL and females ranged from 62 to 263 cm FL. The onset of maturity in males was best described by an inflection in the relationship of clasper length to FL in combination with the degree of clasper calcification. Males matured between 181 and 198 cm FL, and estimated median size at maturity was 188 cm FL. In females, changes in the relationship between ovary and uterus length and width with FL were used to estimate the size at maturity. Females matured between 208 and 224 cm FL; the estimated median size at maturity was 216 cm FL. Litter sizes averaged 3.7 young. The period of parturition is protracted, spanning late spring to late summer (May–August). As in other Lamniformes, young are nourished through oophagy. The proportion of mature females in the resting, pregnant, and postpartum stages provides evidence that indicates that the Common Thresher Shark does not reproduce annually.

Age and growth estimates were generated using vertebral centra from 173 females, 135 males, ranging in size from 56 to 264 centimeters fork length (Gervelis and Natanson 2013). Assuming that vertebral band pairs were deposited annually, ages were estimated up to 22 years (228 cm FL) for males and 24 years (244 cm FL) for females. The growth of both sexes was similar until approximately age 8 (185 cm FL), after which male growth slowed. The growth of females slowed at a later age (~age 12) than that of males. Relative goodness of fit for all candidate models supported the separate modeling of sexes. For males, von Bertalanffy growth parameters generated from the vertebral data using a set size at birth (81 cm FL) provided the best fit for the band counts (asymptotic length [L_∞] = 225.4 cm FL; growth coefficient [k] = 0.17). For females, the standard three-parameter von Bertalanffy growth model provided the best fit to the band counts (L_∞ = 274.5 cm FL; k =0.09; theoretical age at a length of zero [t_0] = −4.82). These are the first growth parameters generated for Common Thresher Sharks in the WNA and can be used to make informed decisions for the management of this species. In addition in 2013, a study on bomb carbon validation was initiated. Samples from two specimens were processed for bomb carbon analysis in conjunction with researchers at WHOI.

Biology of the Galapagos Shark (*Carcharhinus galapagensis*)

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. 2011) 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). *The Life History of Torpedo cf. nobiliana Caught off the Coast of Southern New England* will be the basis for a future publication. This research is ongoing due to a lack of large females for reproductive analysis. Samples for age and growth, reproduction, and food habits were obtained from the bycatch of bottom trawl, trap net and gillnet fisheries operating primarily out of Pt. Judith, Rhode Island, USA. 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 due to it being 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; and thus, ageing has not been completed due to the inability to define a working criterion for the identification of band pairs. Work with researchers at other institutions is ongoing to determine if it is possible to develop a criterion for band identification. There are approximately 21 validated species in the genus *Torpedo*, of which only the Atlantic torpedo, *Torpedo nobiliana*, is believed to be found in the Northwest Atlantic Ocean. The torpedo rays caught off New England were originally named *T. occidentalis* and were later synonymized as a junior synonymy of a Mediterranean species, *Torpedo nobiliana*. As a result of this study, the population of torpedo rays off the coast of Rhode Island is being more closely examined to determine if the species is actually distinct and should revert to the name *T. occidentalis*. Currently, an effort is being made to obtain samples from the eastern North Atlantic to compare with the samples from this study to validate the species.

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 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_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_T for males, and occurs at age 9 years and 540 mm L_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 FMP objectives to collect information critical for improving knowledge of the identification of these species, monitoring their status and improving management approaches. Data including date, catch location, species name, total length, disk width, and weight were collected from 2213 skates from boats out of Point Judith and Little Compton, Rhode Island. Of the skates sampled, 2024 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.

Angel Shark (*Squatina spp.*)

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

Observations of growth and demography in captive-born Pacific Angel Sharks (*Squatina californica*), at Aquarium of the Bay in San Francisco, California were summarized for a presentation at the 2012 American Elasmobranch Society Meeting (Grassmann et al. 2012). The data collected on these specimens offer a unique opportunity to closely observe the early stages of age-related growth in Pacific angel sharks using over two and a half years of regularly collected data on each shark's length, weight, average consumption, and the percentage body weight consumed. Initial analysis using standard growth curves did not adequately represent these data and the manuscript is currently under revision using other techniques.

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* by analyzing part of the mitochondrial control region in 255 individuals sampled from 8 geographically dispersed locations These analyses suggest that replenishment of the collapsed US Atlantic management unit via immigration of females from elsewhere is unlikely. In addition, these mtCR sequences can be used to reconstruct the relative contributions of US Atlantic, South Africa, and Australia management units to the Asian fin trade.

Age and Growth of Elasmobranchs

Accurate age estimation is critical to population assessment and conservation strategies for sharks and rays as it allows for the calculation of important demographic information including longevity, growth rate, and age at sexual maturity; management decisions based on under ageing can inadvertently lead to overexploitation. The primary method for estimating age of sharks relies on counting band pairs that are assumed to be annual in vertebrae. While it is widely acknowledged that the assumption of annual deposition should be tested by an independent method, most shark species lack this validation. Determining metabolic stability is also critical if vertebrae are to be used as lifetime chemical records. White sharks *(Carcharodon carcharias)*, basking sharks (*Cetorhinus maximus*), and dusky sharks (*Carcharhinus obscurus*) are listed as vulnerable on the IUCN Red List of Threatened Species due to a history of overfishing, and all three currently lack age validation. Presentations were given in 2012 (Hamady et al. 2012) summarizing the results of new bomb radiocarbon validation data and determination of metabolic stability from vertebrae taken from white, basking, and dusky shark vertebrae. A review chapter assessing the age and growth of Chondrichthyan fishes was published in 2012 (Goldman et al. 2012). This reported overviews on ageing structures, sampling and processing specimens, and methodologies of age determination and verification/validation. Implications of growth, longevity, and demography, as well as the use of various growth models were also discussed.

Tiger Shark (*Galeocerdo cuvier*)

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

Age validation in sand tiger shark, *Carcharias taurus*, using bomb radiocarbon analysis

There is a great deal of ambiguity in the age and growth data of sand tiger shark. Of particular concern is the observed maximum age based on vertebral band counts. To address this uncertainty, archival vertebrae of sand tiger sharks from both the north Atlantic and south Indian Oceans will be processed for bomb radiocarbon analysis in an effort to validate growth band periodicity and longevity in the species. Age estimates for each shark will be obtained by counting growth band-pairs assuming annual band-pair deposition, and will be used in conjunction with date of capture to assign a year of formation for each band-pair. These results will either validate age estimates or will provide evidence for discrepancies in age from growth band counting. New estimates of age at maturity and longevity will be used to update the productivity for this species, which current data estimates to be strikingly low (i.e. population growth rates are negative) even in the absence of fishing pressure. A presentation summarizing some results was given at the 2012 American Elasmobranch Society Meeting (Passerotti et al. 2012). In 2013, a manuscript was accepted for publication in Marine and Freshwater Research.

Basking Shark (*Cetorhinus maximus*)

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

Dusky Shark (*Carcharhinus obscurus*)

A revision of the age and growth of the dusky shark in the Northwestern Atlantic Ocean was completed (Natanson et al. 2013) where sample collection spanned the years prior to and following the implementation of management measures (1963– 2010). Growth was compared pre- and post- population depletion and pre- and post- management to investigate the possibility of density-mediated shifts in age and growth parameters over time. There was no evidence of difference between periods for either sex. Additionally, bomb radiocarbon dating was used to determine the periodicity of band pair formation. Results support the traditional interpretation of annual band pairs up to approximately 11 years of age. After this time, vertebral counts considerably underestimate true age. Maximum validated ages were estimated to be between 38 and 42 years of age (an increase of 15 to 19 years over the band count estimates), confirming longevity to at least 42 years of age. Growth curves estimated using only validated data were compared to those generated using band pair counts. Logistic growth parameters derived from validated vertebral length-at-age data were $L\infty$= 261.5 cm FL, Lo=85.5 cm, to=4.89 year and g= 0.15 $year^{-1}$ for the sexes combined. Revised estimates of age at maturity were 17.4 years for males and 17.6 years for females.

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 U.S. 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. The manuscript was finalized and submitted to Transactions of the American Fisheries Society.

Sandbar Shark (*Carcharhinus plumbeus*)

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.

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 1972–83 and 2001–02 diets, accounting for 92.6% of the current diet by weight and 86.9% of the historical diet by volume. From the 2001– 02 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 4909 KJ/kg. Based on the proportional energy of bluefish in the diet by weight, an average shortfin mako could consume roughly 500 kg of bluefish per year off the northeast coast of the United States.

Figure 6.12: Juvenile sandbar shark on NEFSC COASTSPAN Survey bottom longline. Source: NMFS photo.

Sandbar Shark (*Carcharhinus plumbeus*)

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

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. Additionally, sharks kept in tanks for feeding experiments survived multiple eversions.

<u>Smooth Dogfish (*Mustelus canis*)</u>

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 predominately benthic macro-invertebrates, including most common large crab species, several gastropods, and a few teleosts. Differences in meal size, diet diversity, prey number, and total biomass among size classes were limited, indicating limited ontogenetic changes in foraging patterns. Some changes in diet composition between months occurred but likely reflected shifts in prey availability or habitat usage. The continuous feeding pattern of this species may help compensate for the lower energetic value of many of the prey. The large number and mass of prey items per stomach, as well as the abundance of this species, indicate that this species plays an important role in the trophic relationships of the macro-invertebrate community in the bay.

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

Resource Partitioning Between 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 four-decade period, some prey categories showed dramatic increases in the diet (spiny dogfish, marine mammals), others declined (cephalopods, flatfishes, hakes), and others fluctuated (bluefish, herrings, mackerels). The shortfin mako is more specialized, consuming mainly bluefish, and appears resistant to dietary change when its preferred prey becomes less abundant. A presentation summarizing some results was given at the 2010 American Elasmobranch Society Meeting.

Basking Shark Isotope Analysis

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

Sable Island Seal Predation

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

Movements and Migrations using conventional and electronic tag technology

Cooperative Shark Tagging Program (CSTP)

The 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 2013, information was received on 3,200 tagged and 595 recaptured fish bringing the total numbers tagged to 244,000 sharks of more than 50 species and 14,875 sharks recaptured of 33 species. To improve the quality of data collected through the CSTP, the Guide to Sharks, Tunas, & Billfishes of the US Atlantic and Gulf of Mexico has been reprinted and made available to recreational and commercial fishermen through the Rhode Island Sea Grant. In addition, identification placards for coastal and pelagic shark species were distributed. A toll-free number has been established as well as online reporting to collect information on recaptures for all species.

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

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

The NEFSC Integrated Mark-Recapture Database System (I-MARK) provides a platform to keep multi-species tagging program data in a common format for management and analysis. Initiated by the Cooperative Research Program, the database design and application were developed collaboratively by the shark, yellowtail flounder, black sea bass, and scup tagging programs, and Data Management Systems. A web application is used for data input and quality control. I-MARK was designed to track fish and tags independently. It consists of several web application modules including inventory of tags, initial release events, subsequent recapture events, bulk data entry of cruise releases, contact name and address information, map display, reports and statistical queries. Fate of animal, fate of tag, double tags, and multiple recaptures can be accommodated within the database. Extensive quality control is achieved using the web application to enter and maintain the I-MARK data. These audits can be applied to data for all fisheries or a specific fishery and encompass standard audits such as checking data type, land locations, and allowable values as well as more complex validations which check relationships between the fate of animal, fate of tag and event type. A constituent release recapture letter is generated by the web application with a map, size, location, time at liberty and distance traveled information. To date, all scanned tag card images from the CSTP have been 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 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 seasonally-dependent horizontal (77-870 km) and vertical (surface to 1300 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 (200-1000 m). Temperature records indicate that these fish were likely associated with the Gulf Stream. Additional analyses, which include the integration of these data with those from the long-term conventional tag-recapture database, are ongoing. Since none of these fish moved to the NE Atlantic, this work also supports the two stock hypotheses for the North Atlantic.

Atlantic Sharpnose Shark (*Rhizoprionodon terranovae*) Movement Patterns

A total of 4,653 Atlantic sharpnose sharks were released with tags along the U.S. east coast and the Gulf of Mexico between 1969 and 2012 (Kohler et al. 2013a). Of the 4,370 fish of known sex, 2,612 (60%) were males and 1,758 (40%) were females resulting in a 1:0.67 male: female sex ratio. The largest measured male and female fish were 109.2cm and 114cm FL, respectively. The mean fork length for both males and females and overall was 71 cm. A total of 77 sharks were recaptured from 1969 through 2012 with an overall recapture rate of 1.7% and mean distance traveled of 103nm. Young of the year had the highest displacement (187nm) relative to the other life-stages (juvenile, 140 nm; mature, 83nm). The Atlantic sharpnose shark at liberty the longest was 7.3 years and was recaptured 70nm from its original tagging location. The longest distance traveled was 570nm from a fish that was originally tagged off Texas and recaptured in Mexican waters 4.8 months later. There was no movement between the Atlantic and Gulf of Mexico. The majority of the recaptured fish showed Atlantic coastal movements with some exchange between US Gulf and Mexican waters. Eight Atlantic sharpnose sharks that were tagged off Texas were recaptured off Mexico; this represents 0.2% of the total numbers tagged.

Figure 7: Tagged blacktip shark on NEFSC Coastal Shark Bottom Longline Survey. Source: NMFS photo.

Bonnethead (*Sphyrna tiburo*) Movement Patterns

A total of 4,123 bonnetheads were released with tags along the U.S. east coast and the Gulf of Mexico between 1965 and 2012 (Kohler et al. 2013b). Of the 3,938 fish of known sex, 934 (24%) were males and 3,004 (76%) were females resulting in a 1:3.22 male: female sex ratio. The largest measured male and female bonnetheads were 122cm FL and 135cm FL, respectively. The mean fork length for both males and females was 60.4 and 77.3cm FL, respectively and overall was 73.2cm FL (Table 3). A total of 172 sharks were recaptured from 1972 through

2012 with an overall recapture rate of 4.2% and mean distance traveled of 10.0nm. Young of the year had the highest mean displacement (32nm) relative to the juvenile and mature sharks (11nm and 6nm, respectively). The bonnethead at liberty the longest was 7.0 years (2,572 days) and was recaptured 1 nm from its original tagging location off the coast of South Carolina. The longest distance traveled was 301nm from a fish that was originally tagged off Bulls Bay, South Carolina and recaptured off Melbourne Beach, FL, 7.9 months later. Both fish were released again after recapture. There was no movement between the Atlantic and Gulf of Mexico. The majority of the recaptured fish showed small Atlantic and Gulf coastal movements with only one bonnethead recovered just into Mexican waters.

Blacktip Shark (*Carcharhinus limbatus*) Movement Patterns

Mark/recapture data from the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP) were summarized for the blacktip shark in the Gulf of Mexico from 1964 through 2011 (Swinsburg et al. 2012, Swinsburg 2013). Survival estimates based on age, sex, and geographic grouping were generated using the program MARK. Data on fork length, life stage, movement, time at large, and displacement were also provided. No blacktip sharks in this study moved between the Gulf of Mexico and the Atlantic or Caribbean. Similarly, there was no evidence of exchange between the eastern and western Gulf of Mexico. Blacktip sharks were distributed strictly within the 200 m depth contour. Some (n=33) of these sharks migrated from the United States to Mexican waters within a time period of less than one year. These data were pivotal in determining the need for multiple (Gulf of Mexico and U.S. Atlantic) stock assessments for this species.

Scalloped Hammerhead Shark (*Sphyrna lewini*) Movement Patterns

The scalloped hammerhead shark is found circumglobally in temperate to tropical seas and 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 encounters with 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, 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. 2011) was given at the 2011 American Elasmobranch Society Meeting.

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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

The Office of Sustainable Fisheries
http://www.nmfs.noaa.gov/sfa/

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 Appendix 1, Table 1.3.3 (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/fishery-plans-policies-reports/.

Data reported in Appendix 1, Table 1.3.8 (Shark landings (mt) from the Hawaii-based longline fishery and the American Samoa longline fishery, 2003-2013) was partially obtained from the Western Pacific Fisheries Information Network (WPacFIN). http://www.pifsc.noaa.gov/wpacfin/.

The Bering Sea/Aleutian Islands Groundfish FMP and the Groundfish of the Gulf of Alaska FMP are available on the North Pacific Fishery Management Council's (NPFMC) website: http://www.npfmc.org/bering-seaaleutian-islands-groundfish/.

Stock assessments and other scientific information for sharks are summarized annually in the NPFMC SAFE Reports that are available online: http://www.afsc.noaa.gov/REFM/stocks/assessments.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/Final%20NPOA.February.2001.htm

NAFO Conservation and Enforcement Measures
http://www.nafo.int/fisheries/frames/cem.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: https://www.wcpfc.int/

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

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

U.S. Imports and Exports of Shark Fins

Summaries of U.S. imports and exports of shark fins are based on information submitted by importers and exporters to 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.noaa.gov/commercial-fisheries/foreign-trade/index