NOAA FISHERIES

2015 Shark Finning Report to Congress
Appendix

Pursuant to the

Shark Finning Prohibition Act

(Public Law 106-557)

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

Prepared by the
National Marine Fisheries Service

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Section 1: Management and Enforcement

1.1 Management Authority in the United States

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) provides the legal authority 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, established under the MSA, as well as, 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, though 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 (SCA) of 2010 through three separate rulemakings. Two of these address domestic provisions of the SCA. A third rule, finalized in 2013, amended the identification and certification procedures under the High Seas Driftnet Fishing Moratorium Protection Act and amended the definition of illegal, unreported, and unregulated fishing.

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 to 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 noted that state or territorial shark fin laws may be preempted if they are inconsistent with the Magnuson-Stevens Act, as amended by the Shark Conservation Act. Since the publication of the proposed rule, NMFS has been engaged in discussions with states and territories with shark fin laws to determine whether the state's or territory's fin ban undermines federal shark management. These conversations are ongoing, and NMFS is working to finalize that rulemaking.

The SCA included a provision that allowed for limited at-sea fin removal of smooth dogfish caught in the Atlantic within 50 nautical miles of shore. On August 7, 2014, NMFS published a proposed rule (79 FR 46217) to, among other things, implement this limited smooth dogfish exception. The comment period closed on November 14, 2014, and over 500 comments were received.

1.2 2014 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 Highly Migratory Species (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 2007–2014 commercial shark landings and the 2014 preliminary commercial shark landings are shown in Tables 1.2.2 and 1.2.3, respectively. In 2014, 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, 2007–2014.
Source: Cortés pers. comm. (2014) and HMS eDealer database.

Commercial Shark Landings (mt)								
Species Group	2007	2008	2009	2010	2011	2012	2013	2014
Large Coastal Sharks	1,056	618	686	689	674	629	640	619
Small Coastal Sharks	280	283	303	162	265	281	215	197
Pelagic Sharks	118	106	91	141	141	142	118	163
Total	**1,454**	**1,007**	**1,080**	**992**	**1,080**	**1,052**	**973**	**979**

Table 1.2.3 Preliminary landings estimates in metric tons (mt) and pounds (lb) dressed weight (dw) for the 2014 Atlantic shark commercial fisheries.
Landings are based on dealer data provided through the MHS eDealer databse.

2014 Landings Estimates				
Management Groups	Region	2014 Quota	Estimated Landings in 2014	% of 2014 Quota
Blacktip Sharks	Gulf of Mexico	274.3 mt dw (604,626 lb dw)	200.9 mt dw (442,882 lb dw)	73%
Aggregated Large Coastal Sharks[A]		151.2 mt dw (333,828 lb dw)	152.7 mt dw (336,631 lb dw)	101%
Hammerhead Sharks		25.3 mt dw (55,722 lb dw)	13.8 mt dw (30,447 lb dw)	55%
Non-Blacknose Small Coastal Sharks[B]		68.3 mt dw (150,476 lb dw)	73.5 mt dw (162,088 lb dw)	108%
Blacknose sharks		1.8 mt dw (4,076 lb dw)	1.4 mt dw (3,160 lb dw)	78%
Aggregated Large Coastal Sharks[C]	Atlantic	168.9 mt dw (372,552 lb dw)	158.2 mt dw (348,733 lb dw)	94%
Hammerhead Sharks		27.1 mt dw (59,736 lb dw)	12.5 mt dw (27,586 lb dw)	46%
Non-Blacknose Small Coastal Sharks[B]		264.1 mt dw (582,333 lb dw)	104.7 mt dw (230,815 lb dw)	40%
Blacknose sharks		17.5 mt dw (38,638 lb dw)	17.4 mt dw (38,437 lb dw)	99%
Shark Research Fishery (Aggregated LCS)	No Regional Quotas	50.0 mt dw (110,230 lb dw)	26.5 mt dw (58,367 lb dw)	53%
Shark Research Fishery (Sandbar only)		116.6 mt dw (257,056 lb dw)	54.2 mt dw (119,527 lb dw)	46%
Blue Sharks	No	273.0 mt dw	8.1 mt dw	3%

	Regional Quotas	(601,856 lb dw)	(17,806 lb dw)	
Porbeagle Sharks		1.2 mt dw (2,820 lb dw)	2.9 mt dw (6,414 lb dw)	227%
Pelagic Sharks Other Than Porbeagle or Blue[D]		488 mt dw (1,075,856 lb dw)	151.7 mt dw (334,329 lb dw)	31%

[A]Aggregated Large Coastal Sharks (LCS) in the Gulf of Mexico includes the following: silky, tiger, spinner, bull, lemon, and nurse.
[B] Non-blacknose small coastal sharks (SCS) include the following: Atlantic sharpnose, finetooth, and bonnethead
[C] Aggregated Large Coastal Sharks (LCS) in the Atlantic includes the following: silky, tiger, blacktip, spinner, bull, lemon, and nurse.[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 2014, stock assessments for Atlantic and Gulf of Mexico smoothhound sharks were begun under the 39th Southeast Data, Assessment, and Review (SEDAR 34) stock assessment. These stock assessments were not finalized until 2015.

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 Finning Prohibition Act and requirements under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). The data collected through the observer program is critical for monitoring takes and estimating mortality of protected sea turtles, seabirds, marine mammals, Atlantic sturgeon, and smalltooth sawfish. Data obtained through the observer program are also vital for conducting stock assessments of sharks and for use in the development of fishery management measures for Atlantic sharks. Gillnet observer coverage is also necessary to comply with the requirements of the 2007 Atlantic Large Whale Take Reduction Plan (ALWTRP) (72 FR 34632, 72 FR 57104).

Atlantic Shark Endangered Species Act Updates

In response to petitions from WildEarth Guardians (WEG) and the Natural Resources Defense Council (NRDC) to list the entire population of great hammerhead sharks (*Sphyrna mokarran*), the northwest Atlantic population, or any distinct population segments (DPSs) of great hammerhead sharks, as threatened or endangered under the ESA, NMFS published a positive 90-day finding (78 FR 24701) on April 26, 2013, announcing that listing the species may be warranted. On June 11, 2014, NMFS announced a 12-month finding (79 FR 33509) and determined that the species is not comprised of DPSs and does not warrant listing at this time. NMFS concluded that the great hammerhead shark is not currently in danger of extinction throughout all or a significant portion of its range and is not likely to become so within the foreseeable future.

On July 3, 2014, in response to a petition submitted by WEG and Friends of Animals, NMFS issued a final determination (79 FR 38213) to list the Central and Southwest (SW) Atlantic DPS and the Indo-West Pacific DPS of scalloped hammerhead shark (*Sphyrna lewini*) as threatened species under the Endangered Species Act (ESA). The determination also listed the Eastern Atlantic DPS and Eastern Pacific DPS of scalloped hammerhead sharks as endangered under the ESA.

NMFS received a petition from Wild Earth Guardians (WEG) dated January 20, 2010, requesting that we list porbeagle sharks (Lamna nasus) throughout their entire range, or as Northwest Atlantic, Northeast Atlantic, and Mediterranean Distinct Population Segments (DPS) under the ESA, as well as designate critical habitat for the species. NMFS also received a petition from the Humane Society of the United States (HSUS), dated January 21, 2010, requesting that we list a Northwest Atlantic DPS of porbeagle sharks as endangered in the North Atlantic under the ESA. Information contained in the petitions focused on the species' imperilment due to historical and continued overfishing; modification of habitat through pollution, climate change, and ocean acidification; failure of regulatory mechanisms; and low productivity of the species. On July 12, 2010, we published a 90-day finding in the Federal Register (75 FR 39656) stating that neither petition presented substantial information indicating that listing porbeagle sharks may be warranted. Accordingly, a status review of the species was not initiated. In August 2011, the petitioners filed complaints in the U.S. District Court for the District of Columbia challenging our denial of the petitions (Case 1:11–cv–01414–BJR HUMANE SOCIETY OF THE UNITED STATES v. BLANK et al.). On November 14, 2014, the court published a Memorandum Opinion vacating the 2010 90-day finding for porbeagle shark, and ordering NMFS to prepare a new 90-day finding. The court entered final judgment on December 12, 2014.

On December 15, 2014, in response to petitions from WEG and NRDC, NMFS determined that the Northwest Atlantic and Gulf of Mexico population of dusky shark constitutes a DPS, but does not warrant listing at this time (79 FR 74684). The finding concluded that the Northwest Atlantic and Gulf of Mexico DPS is not currently in danger of extinction throughout all or a significant portion of its range and is not likely to become so within the foreseeable future.

Shark Management by the Regional Fishery Management Councils and States

The Mid-Atlantic and New England Fishery Management Councils and NMFS manage spiny dogfish (*Squalus acanthias),* the only shark species managed by the Regional Fishery Management Councils in Federal waters off the Atlantic. These Councils manage spiny dogfish fisheries under the 2000 Spiny Dogfish FMP. Spiny dogfish products landed in the United States are almost entirely exported to Europe (meat) and Asia (fins). Most product is landed whole with fins attached, and dock prices average $0.20 per pound. The commercial quota for the 2014 fishing year was 49 million pounds, but only about 23 million pounds were landed due to demand limitations. Spiny dogfish is not overfished or experiencing overfishing and was above its biomass target in 2014.

A significant decline in spiny dogfish landings and exports occurred during 2013 (Figure 1.2.1), due to the detection of high concentrations of polychlorinated biphenyls (PCBs) in spiny dogfish meat at points of entry into the European Union (EU). The EU subsequently adjusted its PCB tolerances for US dogfish, and landings rebounded during the 2014 fishing year.

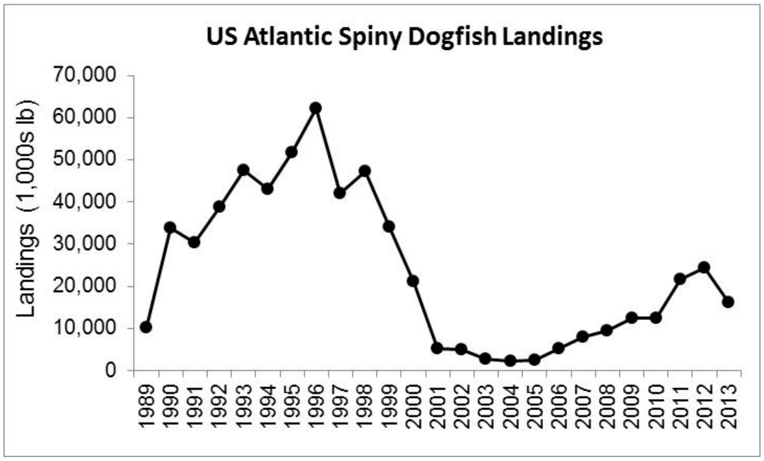


Figure 1.2.1. History of US Atlantic spiny dogfish landings from 1989 – 2013.

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 2010-2014. Amendment 3 to the Spiny Dogfish FMP, which was implemented by NMFS in 2014, made further improvements in consistency by removing the seasonal allocation of the commercial quota, which effectively allows the states to take the lead on quota allocation. Amendment 3 also updated EFH for spiny dogfish, and made other administrative improvements to the FMP.

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 sharks under the 2004 U.S. West Coast HMS Fisheries FMP and the Pacific Coast Groundfish FMP which was approved in 1982 and most recently amended in 2010. Species included under the West Coast HMS FMP, are the common thresher and shortfin mako (sharks commercially valued but not primarily targeted in the West Coast–based fisheries), as well as blue sharks (Table 1.3.1). 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 and common thresher sharks are not overfished, the status of the 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 2014, the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) produced a reassessment of blue sharks in the North Pacific Ocean (ISC 2014). The main differences between the 2014 assessment and the 2013 assessment were: 1) inclusion of revised CPUE series; 2) some time-series data was updated through 2012; 3) further examination of the effect of the Bayesian priors on the BSP model outcomes; and 4) use of the SS model to provide an alternative approach that could be compared to the production modeling. While uncertainties remain, results indicate that stock biomass and spawning biomass in 2011 (B_{2011} and SSB_{2011}) were 65% and 62% higher than at *MSY*, respectively, and the annual fishing mortality in 2011 (F_{2011}) was estimated to be well below F_{MSY}.

In 2014, the ISC SHARKWG also began an assessment of the stock status of shortfin mako sharks for review at the 2015 ISC Plenary and the Western and Central Pacific Fisheries Commission (WCPFC) Science Committee (SC) meetings. The SHARKWG met in late 2014 and early 2015 to compile data, and developed a fishery indicator analysis approach to use for the first assessment of this species in the North Pacific. The SWFSC is also involved in shark assessments outside of the ISC. In order to promote data collection for shark research in Mexico, the SWFSC and WCR are collaborating on multiyear efforts with Centro de Investigación

Científica y de Educación Superior de Ensenada (CICESE), led by Dr. Oscar Sosa-Nishizaki. This collaboration is intended to coordinate artisanal fishing camp monitoring and sampling in Baja California, Mexico, and help advance cooperative stock assessment efforts with Mexico, U.S., and IATTC scientists. 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. Fishery data for common thresher sharks have been compiled and the first joint U.S.-Mexico stock assessment will be completed by SWFSC and Mexico scientists in 2015.

The Pacific Coast Groundfish FMP, last amended in 2015, 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. As part of the PFMC's biennial specifications process for 2015-16, soupfin shark was reclassified as an Ecosystem Component species, as it is not targeted, is not subject to overfishing or being overfished in the absence of conservation measures, and is not generally retained for sale or personal use. A separate OFL and ACL were also established for spiny dogfish, beginning in 2015. From 2006 through 2010, NMFS managed spiny dogfish using two-month cumulative trip limits for both open access and limited entry fisheries. Since 2011, most of the limited-entry trawl fishery for groundfish has been managed under an individual quota program, in which vessels are held accountable for their total catch of all species managed with quota shares. However, landings of spiny dogfish by trawlers continue to be managed through a cumulative trip limit, now of 1-month duration. Landing limits for non-trawl vessels remain at two months.

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 landings for the West Coast from 2005 to 2014. Estimates of commercial discards, as well as catch in the at-sea hake fishery, are developed by the West Coast Groundfish Observer Program, at the 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 through 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, 2005–2014. Source: PacFIN Database, data for the Pacific Fishery Management Council area extracted using the "Explorer" tool on August 26, 2015.

	Commercial Shark Landings (mt) for California, Oregon, and Washington									
Species Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Bigeye thresher shark	10	4	5	6	7	1	1	<1	1	1
Blue shark	1	<1	10	<1	1	<1	<1	<1	<1	0
Brown catshark	--	--	--	--	--	11	4	14	1	1
Common thresher shark	179	160	204	147	107	96	76	68	66	40
Leopard shark	13	11	11	3	2	3	2	3	1	3
Pacific angel shark	12	15	8	12	12	9	10	10	11	8
Pelagic thresher shark	<1	<1	2	<1	<1	<1	--	1	6	6
Shortfin mako	33	45	44	35	29	20	17	22	29	18
Soupfin shark	26	30	17	8	5	3	3	2	1	2
Spiny dogfish	468	394	425	638	264	230	393	215	160	150
Other shark	5	4	2	2	2	3	1	2	1	2
Unspecified shark	5	5	5	2	2	20	4	3	2	4
Total	**752**	**668**	**733**	**853**	**431**	**396**	**510**	**350**	**273**	**235**

[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 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, which prohibits directed fishing for the species. In the Bering Sea/ Aleutian Islands (BSAI), most of the shark incidental catch occurs in the midwater trawl pollock fishery and in the hook-and-line fisheries for sablefish, Greenland turbot, and Pacific cod along the outer continental shelf and upper slope areas. In the Gulf of Alaska (GOA), most of the shark incidental catch occurs in the midwater trawl pollock fishery, non-pelagic trawl fisheries, and hook-and-line Pacific cod, sablefish, and halibut fisheries. The most recent estimates of the incidental catch of sharks in the BSAI and GOA are from 2014. These data are included in Chapter 20 in the 2014 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 2004 through 2014 have ranged from 522 to 2,169 mt in the GOA and from 61 to 689 mt in the BSAI (Table 1.3.5). Very few sharks incidentally taken in the groundfish fisheries in the GOA and BSAI are retained. There has been no effort targeting sharks in the BSAI or GOA since 2006.

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, 2004-2014.
(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	2014
Spiny dogfish	183	443	1,188	797	533	1,653	404	484	458	2,066	1,330
Pacific sleeper shark	282	482	252	295	66	56	168	26	142	95	71
Salmon shark	41	60	34	141	7	9	107	7	50	3	145
Unidentified shark	39	69	83	107	12	24	9	5	10	6	6
Total	**545**	**1,054**	**1,557**	**1,340**	**618**	**1,742**	**688**	**522**	**660**	**2,169**	**1552**
% Retained	2.1	3.3	4.2	3.4	6.8	3.3	5.7	2.9	2.6	0.6	0.9
Incidental Catch of Sharks (mt) - Bering Sea/Aleutian Islands											
Spiny dogfish	9	11	7	3	17	20	15	8	20	24	19
Pacific sleeper shark	420	333	313	257	127	51	28	48	47	69	63
Salmon shark	26	47	63	44	41	71	12	47	26	23	52

Unidentified shark	60	26	305	28	7	10	6	5	3	1	2
Total	**515**	**417**	**688**	**332**	**192**	**152**	**61**	**108**	**96**	**117**	**136**
% Retained	2.6	4.9	3.9	9.8	6.7	4.1	6.3	6.4	3.6	1.9	2.9

In October 2010, NMFS issued a final rule to implement Amendments 95 and 96 to the BSAI FMP and Amendment 87 to the GOA FMP (75 FR 61639) to comply with statutory requirements for annual catch limits and accountability measures (under National Standard 1), and to rebuild overfished stocks. NMFS specified the NPFMC recommended overfishing levels (OFLs), acceptable biological catch (ABCs), and total allowable catch (TAC) amounts. Due to conservation concerns, the final rules to implement groundfish harvest specifications in the BSAI and GOA in 2014 and 2015 prohibited directed fishing for sharks in both management areas. In other groundfish fisheries open to directed fishing, the retention of sharks taken as incidental catch is limited to no more than 20 percent of the aggregated amount of sharks, skates, octopuses, and sculpins in the BSAI, and 20 percent of the aggregated amount of sharks, octopuses, squids, and sculpins in the GOA.

At its December 2013 meeting, the NPFMC recommended OFLs, ABCs, and TACs for sharks in both the BSAI and GOA for the 2014 and 2015 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 1.3.5 lists the recent historical catch of sharks in the BSAI and GOA. In 2014 the BSAI TAC was 225 t, and catch was 136 t. The 2014 GOA TAC was 5,989 t, and catch was 1,552 t. The most recent assessments for sharks are in Chapter 20 to the 2014 SAFE reports for the BSAI and GOA, which is currently available online.

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 completed in 2013 and the most recent GOA SAFE report was completed 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.

The North Pacific Observer Program was restructured in 2013. As a result, observers are now deployed on smaller vessels and vessels fishing in the Pacific halibut Individual Fishing Quota fishery, which were previously unobserved. Details of the restructuring are provided in Faunce et al. (2014). The restructuring in 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.

Recreational harvest of all shark species combined is estimated through a mail survey of sport fishing license holders. In 2014, an estimated 2,101 sharks of all species were harvested by the sport fishery in state and federal waters of Alaska (most recent estimate). The estimate is quite imprecise, with a coefficient of variation of about 35 percent. The Southcentral Region accounted for 64 percent of the harvest. The catch typically consists almost entirely of spiny dogfish and salmon shark. Although the vast majority of spiny dogfish are released, they are believed to be the primary species harvested. Salmon sharks are also taken occasionally by anglers targeting halibut. Catches of all other shark species are rare.

Commercial shark fishing in State waters

State of Alaska 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 includes 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, largely due to the finning of blue sharks, which is now prohibited. A State of Hawaii law prohibiting landing shark fins without an associated carcass was 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 2015 were approximately 58 mt, down from 105 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, 2003–2014.
Source: Pacific Islands Fisheries Science Center, Fisheries Research and Monitoring Division.

	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hawaii-based Longline Fisheries	Blue shark	59	30	11	6	8	10	9	16	19	1	0
	Mako shark	66	106	95	127	130	119	92	65	66	51	50
	Thresher shark	56	34	33	44	42	31	17	19	14	5	6
	Misc. shark	7	7	11	8	5	6	4	3	2	0	0
	Total shark landings	**188**	**177**	**151**	**186**	**186**	**166**	**122**	**102**	**101**	**57**	**56**
American Samoa	Total shark landings	**1**	**<1**	**1**	**2**	**1**	**1**	**2**	**4**	**4**	**4**	**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
On July 3, 2014, NMFS listed the Central and Southwest Atlantic DPS and the Indo-West Pacific DPS of scalloped hammered shark as threatened, and the Eastern Atlantic DPS and Eastern Pacific DPS of scalloped hammerhead sharks as endangered under the ESA (7 FR 38214).

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 2014, violations of the SFPA, and noncompliance with regulations designed to protect sharks, were detected, investigated, and referred for administrative prosecution in the Southeast and West Coast Enforcement Divisions. Violations which were investigated included finning by U.S. domestic fishing vessels and illegal use of shark as bait.

- In 2014, the owner and operator of the *F/V Honey Bee* were charged under the Magnuson-Stevens Act for failing to maintain sharks intact through offloading ashore.

During a federal fisheries patrol in November of 2012, officers from the Florida Fish and Wildlife Conservation Commission (FWC) conducted an inspection of the *F/V Honey Bee* after it was located actively retrieving longline fishing gear from the water, approximately 100 miles from shore in the U.S. Exclusive Economic Zone (EEZ). FWC officers boarded the *F/V Honey Bee* and determined that the longline gear had been illegally baited with federally regulated species, including finfish and shark, which are required to be maintained intact through offloading ashore. The NOAA Office of the General Counsel – Enforcement Section (GCES) issued a Notice of Violation and Assessment (NOVA) penalty in the amount of $8,000.00 to the respondents.

- A boarding team from the U.S. Coast Guard Cutter Staten Island conducted an inspection of a commercial fishing vessel in January of 2014. The vessel was located in the EEZ approximately thirty miles offshore of Oregon Inlet, NC. The USCG boarding team located three (3) pelagic sharks that had been harvested; one (1) thresher, and two (2) mako sharks. The thresher shark had been finned and all five fins were present, as well as the carcass. The vessel did not possess either a directed or incidental shark permit. In addition, numerous safety violations were discovered and the vessel's voyage was terminated by the USCG. After consulting with GCES, the NOAA OLE issued a Written Warning to the vessel operator. A Written Warning is a citation that serves as official notice to the respondent, and affirms the violation. It does not assess a monetary penalty, but may be viewed by the GCES as a prior offense when prosecuting future violations.

- NOAA GCES charged the owner and operator of the *F/V Watersport* under the Magnuson-Stevens Act for failing to maintain a shark in its proper form through offloading, by removing shark fins from the shark carcasses at sea. This investigation was initiated in December of 2011 after OLE had received a complaint through the NOAA Enforcement Hotline concerning a photograph that was found on the internet. The image detailed an individual aboard a commercial fishing vessel that was holding the tail section of a large swordfish that was positioned on the deck. Also on the deck, were what appeared to be, and later confirmed as mako shark fins that were harvested from several animals. A Notice of Violation and Assessment (NOVA) civil penalty in the amount of $5,015.00 was issued to the respondent.

- The NOAA Office of the General Counsel – Enforcement Section (GCES) charged the owner and operator of the *F/V Lucky Diamond*, a commercial shrimp fishing vessel, for catching sharks, removing their fins, and returning the illegally finned carcasses to the sea. This violation was detected in August of 2011 when officers from the Louisiana Department of Wildlife and Fisheries (LDWF) were on a federal fisheries compliance patrol under OLE's Joint Enforcement Agreement (JEA) program, and conducted a boarding of the *F/V Lucky Diamond* in the U.S. Exclusive Economic Zone (EEZ). During the course of the inspection, 146 individual shark fins were located onboard. There were no corresponding shark carcasses. In addition, the vessel operator did not possess a Highly Migratory Species (HMS) shark angling permit. The shark fins were seized as evidence and the vessel operator was cited by LDWF officers for illegally finning sharks and for failing to possess a required federal permit. A Notice of Violation and Assessment (NOVA) penalty in the amount of $15,000.00 was issued by NOAA GCES to the respondents for violating the Magnuson-Stevens Act.

- A NOAA OLE special agent assisted officers from the California Department of Fish and Wildlife (CDFW) with the seizure of over 2,000 pounds of shark fins. On January 29, 2014, wildlife officers from CDFW conducted a fish business inspection in San Francisco, and found shark fins for sale on the premises. The fins were possessed and also offered for sale in violation of California law. As part of the investigation, CDFW wildlife officers seized 2,138pounds of product and cited the owner for the violation. The California law that prohibits possession of shark fin for sale, went into effect in 2011, but included a phase-in period to allow restaurants and other businesses to sell off remaining stock. As of July 1, 2013, no person may possess shark fins for sale in California. Wildlife officers from the CDFW are federally deputized under NOAA OLE's Joint Enforcement Agreement (JEA) program in order to enforce federal fisheries laws.

- NOAA GCES charged the owner and operator of the commercial fishing vessel *F/V No Bull* under the Magnuson-Stevens Act for illegally using shark bycatch as bait while fishing with longline gear in the EEZ. This concludes a joint investigation by the NOAA OLE and the Florida Fish and Wildlife Conservation Commission (FWC) that was initiated in 2010. In December of that year, officers from the FWC, while operating under OLE's Joint Enforcement Agreement (JEA) Program, conducted an at-sea boarding and inspection of the *F/V No Bull*. The fishing vessel was observed hauling longline gear approximately 40 nautical miles offshore. During the inspection, FWC officers observed hooks baited with red grouper and shark. Numerous pieces of identifiable bait were seized as evidence. Federal regulations require finfish and shark in or from the Gulf Exclusive Economic Zone to be maintained intact through offloading ashore. The NOAA GCES issued a Notice of Violation and Assessment (NOVA) penalty in the amount of $8,000 to the respondents. This violation was eventually settled in the final amount of $7,200.

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:

- In March of 2014, a NOAA enforcement officer traveled to Venice, LA to conduct education and outreach with area shark dealers. This was in response to a U.S. Coast Guard boarding and inspection of a bottom longline shark fishing vessel wherein multiple gear violations and sea turtle disentangling equipment deficiencies were documented. OLE provided guidance to industry members concerning specific regulations pertaining to sharks, as well as legal requirements for fishing gear, protected resources mitigation equipment, and permitting.

- In October of 2014, a NOAA enforcement officer conducted education and outreach at a fishing tournament that was held in Destin, FL, with shark conservation highlighted. In addition, OLE worked with officers from the Florida Fish and Wildlife Conservation Commission (FWCC) to address a tournament complaint alleging that a tiger shark had been illegally caught in state waters. Further investigation disclosed that the tiger shark was legally harvested by a federally permitted vessel in the U.S. EEZ and eligible for entry in the Destin tournament.

- To facilitate identification of Atlantic sharks, the HMS Management Division requires that all Federal Atlantic shark dealers attend a mandatory Atlantic Shark Identification Workshop at least once every three years. These free, monthly workshops provide hands-on training to help identify both processed and whole sharks to the species level. State and Federal fish and wildlife law enforcement officers also frequently attend these workshops, which are conducted throughout the entire Atlantic and Gulf of Mexico coasts. A total of 12 Atlantic Shark Identification Workshops were held in 2014.

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

- In June 2014, the results of the collaborative GARFO, NEFSC, SEFSC, Massachusetts Division of Marine Fisheries, and University of Florida study on the distribution and increasing relative abundance of northwest Atlantic white sharks was published (Curtis et al. 2014) and received intense popular media coverage. The results were featured by over 200 news outlets worldwide, and the contributing NMFS scientists were interviewed on national and regional television programs and numerous newspapers and internet news sites.

- Staff from NMFS NEFSC regularly 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.

- In 2014, NEFSC 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) for an all-release, satellite tag shark tournament in Montauk, LI, NY called ‘Shark’s Eye’. Additionally, there was a 2-day public outreach event where much information was given out on NOAA Fisheries research.

- Toby Curtis, staff at GARFO participated in a Twitter question and answer session during 2014 Discovery shark week. This session gave the public the opportunity to interact with NMFS shark biologists in real time.

- Drs. McCandless and Natanson, staff at NMFS NEFSC participated in a live online segment of io9’s “Ask the Expert” series in August 2014 regarding shark biology and behavior. This session gave the public an opportunity to interact with NMFS shark biologists in real time.

- Dr. John Carlson participated in an informational video regarding shark attacks and sharks and their interactions with people. The video was posted on NOAA Fisheries Service YouTube channel.

- Drs. Enric Cortés, John Carlson, and Simon Gulak participated in an informational video regarding the Northwest Atlantic Shark Cooperative Research Fishery. The video was posted on NOAA Fisheries Service YouTube channel.

- The NMFS Office of Communications coordinates a national Shark Week campaign to which each Region and Science Center can contribute.

Section 2: Imports and Exports of Shark Fins

The summaries of annual U.S. imports and exports of shark fins in Tables 2.1.1 and 2.2.1 are based on information submitted by importers and exporters to 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 2014, shark fins were imported through the following U.S. Customs and Border Protection districts: Los Angeles, Miami, and New York. In 2014, countries of origin (in order of importance based on quantity) were New Zealand and Hong Kong (Table 2.1.1). The mean value of imports per metric ton has consistently declined since 2010, with a more pronounced drop between 2011 and 2012. The unit price of $13,000.00 per metric ton in 2014 was well below the mean value in 2008 of $59,000.00 per metric ton. 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 like 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 2014 were sent from the United States to Hong Kong, with smaller amounts going to China, and Thailand (Table 2.2.1). The mean value of exports per metric ton has decreased from $80,000/mt in 2010 to $52,000/mt in 2014, the lowest value since 2012 with the largest weight of 51 mt. Values continue to fluctuate in recent years with the 2014 average at $52,000 mt compared to the 2013 average of $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 2013, global imports of shark fins were approximately 27,000 metric tons, the largest volume since 2009. In 2013, the average value of imports decreased to $7,230.00 per metric ton, while the average value of exports decreased to $12,637.00 per metric ton. Malaysia is the largest importer and Thailand is the largest exporter of shark fins for 2013.

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	2010		2011		2012		2013		2014	
	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)
Australia	0	0	7	85	0	0	0	0	0	0
Canada	0	0	0	0	0	0	0	0	0	0
China	21	422	12	732	16	131	10	75	0	0
China, Hong Kong	11	695	15	700	2	39	3	89	1	43
India	0	0	(1)	3	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	(1)	8	0	0
Japan	(1)	3	0	0	0	0	0	0	0	0
New Zealand	1	37	24	275	26	595	50	551	34	406
South Africa	0	0	0	0	0	0	(1)	3	0	0
Spain	(1)	3	0	0	(1)	8	(1)	12	0	0
Total	34	1800	58	1795	44	773	63	739	35	449
Mean value	$35,00/mt		$31,000/mt		$18,000/mt		$12,000/mt		$13,000/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

	2010		2011		2012		2013		2014	
Country	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric ton	Value ($1000)	Metric Ton	Value ($1000)
Canada	1	206	1	199	0	0	0	0	0	0
China	2	335	5	895	(1)	60	1	71	1	130
China, Hong Kong	39	2785	29	1,738	51	2,790	7	572	10	565
China, Taipei	(1)	6	0	0	0	0	4	135	7	193
Egypt	0	0	0	0	0	0	0	0	0	0
Germany	0	0	(1)	3	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0	0	0	0
Japan	0	0	(1)	4	0	0	0	0	0	0
Panama	0	0	0	0	0	0	0	0	0	0
Poland	(1)	22	3	86	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0
Thailand	0	0	0	0	0	0	0	0	0	0
South Korea	0	0	0	0	0	0	0	0	1	91
Turkey	0	0	0	0	0	0	(1)	10	0	0
Total	42	3354	38	2925	51	2850	12	788	19	979
Mean value	$93,000/mt		$77,000/mt		$56,000/mt		$66,000/mt		$52,000/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	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	7	902	6	1,128	16	915	27	1,074	23	947
Brunei Darussalam	0	0	2	26	0	0	0	0	0	
Canada	184	6,217	107	6,487	104	6,351	275	3,347	243	3,541
Chile	0	0	0	0	0	0	0	0	0	0
China	732	4,490	183	968	160	1,065	113	1,434	39	339
China, Hong Kong	9,395	247,087	9,891	296,167	10,332	345,469	8.283	219.391	5,408	121,136
China, Macao	132	6,149	119	7,124	116	7,570	120	6,998	103	6,047
China, Taipei	988	7,400	1,157	10,315	1262	-	-	-	-	-
Indonesia	150	1,120	237	970	101	1,762	53	1,029	41	349
Laos	(1)	(1)	0	0	0	0	0	0	0	0
Malaysia	1,331	3,809	3,676	10,369	3,489	10,248	3,013	9,833	18,048	17,612
Myanmar	119	372	813	2,173	601	1,635	0	2	0	0
North Korea	(1)	24	69	267	(1)	8	-	0	0	2
Peru	54	246	77	546	71	688	30	680	94	967
Singapore	557	27,576	591	36,690	595	43,863	2,708	61,195	2,695	41,580
South Korea	2	119	3	233	6	602	8	570	2	391
Thailand	44	651	63	761	96	1,021	105	1,047	51	469
Timor-Leste	112	29	96	24	131	29	0	0	0	0
United Arab Emirates	-	-	-	-	26	1,209	16	330	16	113
Total	13,807	306,191	17,090	374,238	17,096	422,435	14,751	306,930	26,763	193,493
Mean value	$22,171/mt		$21,898/mt		$24,710/mt		$20,807/mt		$7,230/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	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)
Angola	4	282	7	527	19	873	15	797	6	439
Argentina	84	3,376	63	2,766	70	2,312	3	87	6	49
Bangladesh	-	-	-	-	-	-	24	196	6	41
Brazil	85	2,338	49	1,376	59	2,109	39	1,777	31	1,294
Brunei Darussalam	-	-	-	-	1	14	0	0	0	0
Chile	5	194	1	46	3	167	4	223	3	115
China	382	8,474	314	6,971	489	12,218	339	11,731	350	15,464
China, Hong Kong	4,93	80,316	5,06	73,198	3,362	88,918	2,427	58,942	2,004	31,412
China, Macao	-	-	-	-	8	444	31	1480	5	315
Colombia	19	600	11	509	10	724	18	601	17	444
Congo, Dem. Rep. of the	-	-	-	-	5	287	5	299	3	112
Congo, Republic of	17	410	15	410	17	800	6	350	6	200
Costa Rica	75	282	66	251	112	628	17	257	39	2851
Cuba	-	-	-	-	4	204	4	182	4	118
Ecuador	131	2,627	184	3,388	226	4,399	123	2,662	76	656
Gabon	-	-	3	189	3	322	1	97	0	0
Guinea	40	2,228	51	3,290	56	3,288	50	2,300	12	1,000
Guinea-Bissau	2	160	-	-	-	-	2	107	-	-
India	107	12,504	98	8,946	135	8,310	168	13,211	51	3,086
Indonesia	1,43	10,833	2,37	13,563	1,607	13,570	514	8,654	367	4,391
Japan	164	6,824	164	8,591	131	8,759	116	5,081	103	2,434
Kiribati	2	170	1	26	3	50	2	80	1	8
Kuwait	-	-	-	-	1	23	(1)	17	0	0
Liberia	4	415	8	679	3	317	1	50	1	59

Table 2.3.2 Continued

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)
Malaysia	347	1,394	260	1,614	417	1,981	298	1,542	687	3,563
Maldives	9	57	4	22	0	0	0	0	0	0
Marshall Islands	16	495	11	539	24	1,717	23	564	3	113
Panama	47	3,310	37	1,457	24	1,481	43	906	58	458
Papua New Guinea	12	1,288	17	1,220	25	2,200	1	268	8	658
Peru	155	6,945	202	10,990	206	13,648	134	6,379	146	4,153
Philippines	59	418	168	731	154	1125	83	740	213	1503
Saudi Arabia	6	133	4	140	11	644	5	210	5	200
Senegal	54	1500	35	1000	96	2870	63	2100	69	1300
Seychelles	7	167	5	157	4	218	11	589	11	280
Sierra Leone	(1)	15	3	61	2	44	3	51	0	0
Singapore	296	15,901	390	23,088	238	20,295	2260	42,199	2583	37,557
Somalia	-	-	-	-	-	-	-	-	3	74
South Korea	34	1,063	80	3,137	93	4,491	95	3,568	28	621
Suriname	93	192	54	539	178	561	5	63	33	118
Thailand	5,005	24,795	7,141	32,545	7,723	40,245	5,455	27,008	3,892	20,868
Togo	31	2,900	38	4,100	33	3,600	36	2,900	18	1,100
Trinidad and Tobago	186	1,600	129	740	364	2,281	538	2,672	421	2,062
United Arab Emirates	460	13,242	501	17,912	479	14,823	306	11,842	302	7,764
Uruguay	16	269	12	188	10	87	9	94	5	32
Venezuela	7	113	13	46	16	77	0	0	0	0
Vietnam	347	1,540	98	504	223	1,105	(1)	20	8	295
Yemen	260	10,736	431	13,942	347	12,428	54	369	90	322
Total	14,940	220,106	18,106	239,398	16,991	274,657	13,331	213,265	11,674	147,529
Mean value		$14,733/mt		$13,222/mt		$16165/mt		$15,998/mt		$12,637

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	2009	2010	2011	2012	2013
Bangladesh	276	955	-	-	1
Brazil	85	50	60	40	31
Ecuador	131	184	226	118	75
El Salvador	19	-	-	11	9
Guyana	132	126	75	208	209
India	1,624	933	425	116	130
Indonesia	1,367	2,320	1,395	500	310
Maldives	9	4	-	-	-
Pakistan	80	83	91	96	99
Senegal	27	18	35	91	54
Singapore	218	192	210	220	210
South Korea	34	80	93	95	28
Sri Lanka	70	70	90	60	30
Uruguay	-	14	8	12	5
Yemen	260	431	347	54	90
TOTAL (mt)	4,332	5,460	3,055	1,621	1,281

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. To learn more about the United States' international shark conservation activities go here.

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, catch and trade data, stock assessments, and life history data collection. 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 identify and monitor shark product trade in light of new additions of several shark species to CITES Appendix II, NMFS in partnership with the U.S. Fish and Wildlife Service and several NGO partners have been working to build capacity in

Latin America, the Caribbean, and West Africa. These efforts have been broad covering topics from CITES requirements, chain of custody, and species identification using several visual guides, morphological tools (iSharkFin), and genetic techniques. With support from NMFS, the first regional CITES shark workshop was held in Brazil in December 2013. NMFS also supported a regional CITES shark workshop in Dakar, Senegal. The NMFS Office of International Affairs also awarded a grant to WWF for a pilot project to establish genetic identification labs in Ecuador and provide training on the use of genetic equipment. Ecuador was chosen due to their already well-established fishery monitoring program which will facilitate a 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.

3.2 Regional Efforts

The U.S. Government continues to prioritize 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,[1], 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.

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

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 the first 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)

Since 2006, CCAMLR has prohibited directed fishing on shark species in the Convention Area, other than for scientific research purposes. CCAMLR requires that any bycatch of shark, especially juveniles and gravid females, taken accidentally in other fisheries, shall, as far as possible, be released alive. The conservation measure with these requirements is silent on shark finning.

In 2011 and 2013, the United States proposed a revision of the conservation measure to require that any sharks retained be landed with fins naturally attached to discourage the finning of sharks incidentally caught and improve the opportunities to collect data of such sharks. In 2014, the United States was joined by Brazil, Chile, and the European Union in making the proposal. The proposal has been met with strong support from many members but consensus has yet to be reached. The United States re-tabled the proposal, modified with an explicit prohibition of shark finning, for the 2015 annual meeting with Australia, Brazil, Chile, and European Union as co-sponsors.

Inter-American Tropical Tuna Commission (IATTC)

In 2005, the IATTC adopted Resolution C-05-03, which placed controls on shark finning by applying a five percent fin-to-carcass weight ratio requirement. For several years, IATTC proposals have been submitted to replace current controls on shark finning in Resolution C-05-03 with a prohibition on the retention of shark fins that are not naturally attached to the carcass until the first point of landing. The United States supported such a proposal, sponsored by the EU in 2014, but the Commission could not reach consensus.

In 2013, the IATTC adopted a United States sponsored Resolution that prohibited, among other things, the intentional setting of purse seine nets on whale sharks. These prohibitions went into effect on July 1, 2014. The IATTC scientific staff presented summary information for hammerhead shark at the 2014 meeting of the Scientific Advisory Committee, but did not have enough data to complete the stock assessment. A summary of available information on hammerhead sharks caught in the eastern Pacific Ocean (EPO) indicated that there is not enough data to conduct statistical analyses for the artisanal fisheries, and there is scarce information on the longline fisheries. The purse seine bycatch data shows an overall declining trend in catch for hammerhead sharks in the EPO.

Similarly, the IATTC scientific staff has been unable to conduct a stock assessment for silky shark in the EPO due to a lack of historical catch data. Updated stock status indicators for silky shark, presented during the 2014 meeting of the IATTC Scientific Advisory Committee suggest that the northern and southern stocks in the EPO are in decline. A silky shark management measure, similar to that adopted by the WCPFC in 2013 and ICCAT in 2011, has been proposed at IATTC meetings since 2012. The EU sponsored a silky shark proposal in 2014 to prohibit retention of silky shark. Although the United States strongly supported the proposal, the IATTC could not achieve consensus.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

At the 2014 ICCAT Annual meeting, the United States co-sponsored a proposal to require that all sharks be landed with their fins naturally attached. The list of co-sponsors was expanded to include: Belize, Brazil, Ghana, EU, Panama, Sao Tome & Principe, Senegal, South Africa, Trinidad & Tobago, Guatemala, Egypt, Cote d'Ivoire, Gabon and the United States. 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 2015 Annual Meeting. Proposals relating to porbeagle sharks were also circulated, but were not adopted by the Commission.

A recommendation for Atlantic shortfin mako requires parties to improve domestic data reporting systems and provide additional information to ICCAT about how they monitor and manage catches of shortfin mako sharks.

Western and Central Pacific Fisheries Commission (WCPFC)

At its 8th Regular Session of the Commission in March 2012, the Commission added the whale shark to the list of key species. In 2012, 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 is very similar to one adopted in 2012 for oceanic whitetip shark. In 2014, NMFS issued a proposed rule for domestic implementation of the oceanic whitetip shark, whale shark, and silky shark CMMs and solicited public comment.

Stock assessments for the North Pacific blue shark were completed in 2014. The Scientific Committee 10 (SC10) recommended that though it was not likely that the North Pacific blue shark was overfished or experiencing overfishing, that catch and effort data should be closely monitored for this species. SC10 also recommended that the Commission consider the analysis of longline shark mitigation methods to reduce catch rates and mortality of all sharks, and called for SC11 to review the development of whale shark safe release guidelines for longliners and purse seiners.

At SC10, Secretariat of the Pacific Community Oceanic Fisheries Program issued a report on the progress implementing the Shark Research Plan (SRP), announcing that the SRP had successfully completed five stock assessments on WCPFC key shark species, planned a six stock assessment, an indicator analysis for all key shark species, and catch history estimations for several key species. WCPFC contractors also presented their development of Limit Reference Points for elasmobranchs at SC10.

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

The 14th ISC Plenary, held in Taipei, Chinese-Taipei from 16-21 July 2014, was attended by members from Canada, Chinese Taipei, Japan, Korea, and the United States, as well as the Western and Central Pacific Fisheries Management Commission and the North Pacific Marine Science Organization. The Plenary reviewed results, conclusions, new data and updated analyses of the Shark Working Group. The Plenary endorsed the findings that the North Pacific blue shark is not overfished nor experiencing overfishing based on an updated assessment conducted using both a Bayesian surplus production model and an age-structured fully-integrated model (Stock Synthesis). The Plenary noted the strides the SHARKWG had made in incorporating best available scientific information into stock assessment work, enhanced stock assessment reports and the increased transparency in the Working Group's efforts. The ISC SHARKWG's work plan for 2015 includes completing the first shortfin mako shark (*Isurus* *oxyrinchus*) assessment and advancing research on fishery data, assessment methods and shortfin mako and blue shark life history. The SHARKWG held three meetings in 2014 to work on the updated North Pacific blue shark stock assessment and to advance shortfin mako fishery and life history data compilation. The SHARKWG also sponsored its second Shark Age and Growth Workshop. The Age and Growth Workshop and final blue shark assessment data preparatory meeting were held in January 2014 in La Jolla, United States. The blue shark assessment meeting was held in June 2014 in Keelung, Chinese-Taipei. The shortfin mako data preparatory meeting was held in November 2014 in Puerto Vallarta, Mexico. Active participants in the meetings have included Chinese Taipei, Japan, Mexico, the United States, IATTC, WCPFC 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 16th Meeting of the Conference of the Parties (CoP16) to 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 was 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 (WCO)
Related to actions taken in CITES and RFMOs to increase protection and enhance the monitoring and trade of commercially-exploited shark species, the WCO's 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 have established 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 of the 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 UN General Assembly (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)

The 11th Meeting of the Conference of Parties was held November 4-9, 2014, in Quito, Ecuador. A record number of 21 shark, ray, and sawfish species (proposed by Kenya, Egypt, Fiji, Costa Rica and Ecuador) were listed on one or both of the CMS appendices. The United States was active in the expansion of CMS work on shark conservation. Also, an adopted resolution on shark and ray conservation urges all Parties to enact legislation or regulations requiring that sharks be landed with all fins naturally attached, in order to combat the practice of removing shark fins and discarding the remainder of the shark carcass at sea. It also urges Parties to develop National Plans of Action for Sharks which apply to a nation's fishing fleet on the high seas, as well as in national waters. The documents from the meeting can be found at: http://www.cms.int/en/meeting/eleventh-meeting-conference-parties-cms#cop11-documents.
In February 2010, the United States, along with 10 other States signed a global Memorandum of Understanding (MOU) for Migratory Sharks under the auspices of the Convention on Migratory Species. The United States is one of 36 Signatories, including 35 national governments 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)

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 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. In 2013 and 2014, deployment of baited and un-baited remote underwater video cameras to measure fish and shark abundance levels, including extending surveys into deeper waters (30-100m) 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 centimeters total length (TL) by age 5, and attaining a maximum size of 403 centimeters TL. The maximum likelihood growth model indicated that the fastest growing individuals attain 400 centimeters TL by age 5, and the largest reach a maximum size of 444 centimeters TL. The largest shark captured during the study was 464 centimeters TL but individuals greater than 450 centimeters TL were extremely rare (0.005% of sharks captured). It was concluded that tiger shark growth rates and maximum sizes in Hawai'i 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).

Maximum age and missing time in shark vertebrae: the limits and validity of age estimates using bomb radiocarbon dating

The aim of this work was to provide an overview of how bomb radiocarbon dating can work for shark vertebrae with some insight on how the method can fall short of expectations (Andrews et al., 2014). Bomb radiocarbon dating has become a common tool in determining valid measures of age for large shark species. In most cases, estimates of age were made by counting growth-band pairs in vertebrae and usually in the *corpus calcareum* of vertebral cross-sections. These estimates of age have been either supported or refuted using measured radiocarbon values (reported as $\Delta^{14}C$) that are equated to a year-of-formation, and subsequently compared to an appropriate $\Delta^{14}C$ reference record. While the approach seems straightforward, the application is not, and an effective ageing project may require some significant assumptions that are sometimes overlooked. Two of the most important considerations are the sources of carbon available to the vertebrae and the use of a valid $\Delta^{14}C$ reference to provide validated age estimates. Recent findings for some species indicate the vertebrae cease growth, and as a consequence, ages have been underestimated by decades (i.e. sand tiger shark, *Carcharias taurus*). However, proper alignment of the $\Delta^{14}C$ measurements from vertebral samples to the $\Delta^{14}C$ reference record does not always provide well-defined ages and many are still considered estimates that require some assumptions (i.e. white shark, *Carcharodon carcharias*).

Validated lifespan of sand tiger shark Carcharias taurus 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 (WNA) and southwestern Indian Oceans (SIO). 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 the 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 for adult sharks from the SIO 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 will investigate alternate ageing methods to determine whether vertebrae of *C. taurus* record age throughout ontogeny, or cease to be a reliable indicator at some point in time. This work was the first to report the $\Delta^{14}C$ values for marine vertebrates from the SIO and the first to report vertebral age estimates for *C. taurus* outside of the Atlantic Ocean (Passerotti et al., 2014).

White Shark in NE Pacific

Age validation studies of large shark species using bomb radiocarbon ($\Delta^{14}C$) 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 $\Delta^{14}C$ 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, PIFSC 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, which is 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).

Southwest Fisheries Science Center (SWFSC)

Abundance Surveys

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

In 2014, the SWFSC conducted its twenty first juvenile shark survey for mako and blue sharks since 1994. The 2014 annual abundance survey was completed between 25 June and 14 July aboard *F/V Ventura II*. 28 survey sets were completed and a total of 5,719 hooks were deployed during survey sets. Average surface water temperature recorded at the beginning of each survey set was 69.8 °F (21.03 °C), which is the third highest in survey history. Preliminary data indicate that the nominal survey catch rate was 0.03 per 100 hook-hours for blue sharks and 0.429 per 100 hook-hours for shortfin mako. Survey catch totaled 124 fish; four (4) different species were caught including shortfin mako shark, blue shark, pelagic ray, and opah.

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 2014, SWFSC scientists and volunteers conducted the survey aboard the F/V *Outer Banks*. 49 longline sets were made in relatively shallow, nearshore waters and a total of 4,900 hooks were fished during the 18-day cruise. A total of 247 fish across a range of species were sampled during the survey. 285 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 1.58 thresher sharks per 100 hook-hours, which is down from the previous year. The nominal catch rate in 2014 was the second lowest since the survey began in 2006 and the recent five-year trend is downward.

Electronic Tagging Studies

Since 1999, SWFSC scientists have used data logging tags and satellite technology to characterize the essential habitats of large pelagic fish 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 (CICESE), Canadian colleagues at the Department of Fisheries and Oceans Pacific Biological Station in Nanaimo, British Columbia, and the Tagging of Pelagic Predators program on shark tagging.

In 2014, 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). In addition, in collaboration with Guy Harvey Institute and a recreational angler in the SCB, one 215 centimeters TL mako was tagged with a SPOT in October 2014. Of the tags deployed since 2012, 7 were still reporting in late 2014 (Figure 1).

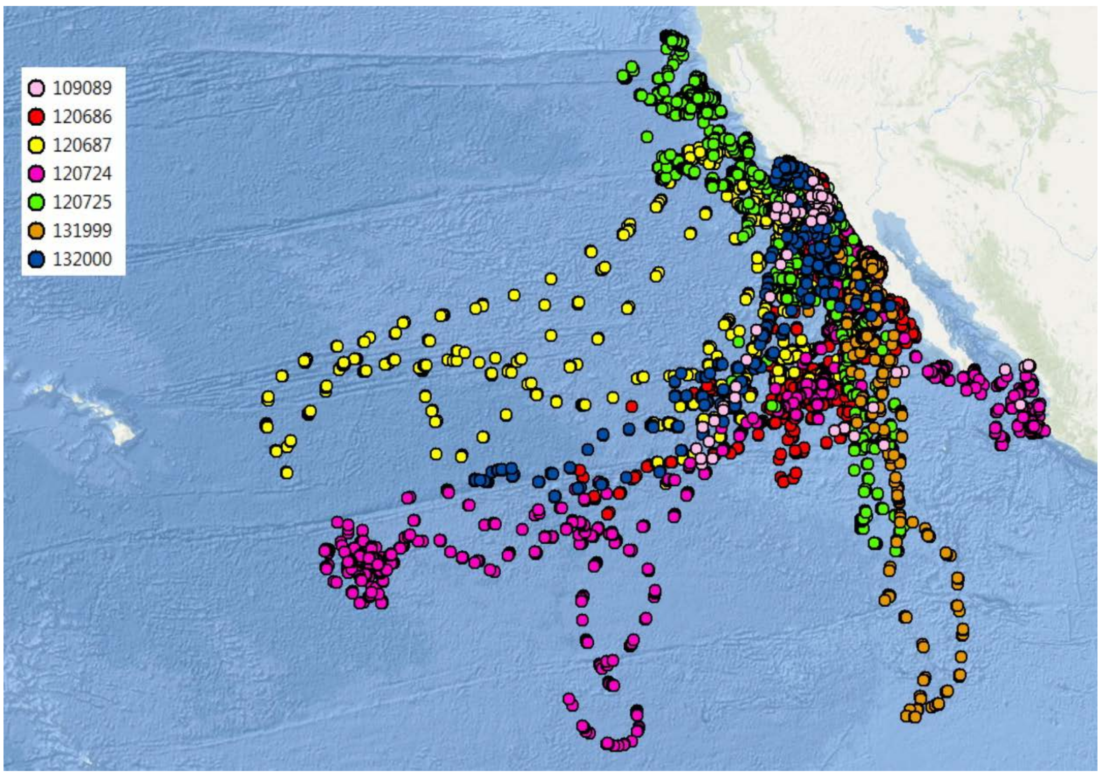


Figure 4.1.1 Tracks of seven shortfin mako sharks tagged since 2012 that were still reporting at the end of 2014. Different colors represent different animals.

All SPOT and PSAT data for mako sharks tagged in the Southern California Bight between 2002 and 2013 are currently being analyzed and a manuscript is being drafted. Preliminary analysis of SPOT tagged sharks with tracks longer than 6 months indicates that mako sharks frequented the waters of the Southern California Bight from July to October followed by dispersion to the north, south and offshore. Tags which recorded data for more than 12 months showed that 77% of tracked makos returned to the Southern California Bight the following summer.

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, more than 3,500 individuals have been injected with OTC. During the 2014 SWFSC shark surveys, 109 shortfin makos, 134 thresher, and 35 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 have collected and shared samples from blue and shortfin mako sharks for a reference collection covering a large range of size classes for both species. The plan to conduct an ISC SHARKWG assessment of North Pacific shortfin makos in 2015 led to a focus on mako age and growth during 2014. Published reports of differing growth and band pair deposition rates between member labs have led participating scientists to examine the consistency of their counts on a sample of validated mako vertebrae. Images of OTC injected vertebrae from Wells et al. (2013) were chosen as the vertebrae to be used in this inter-laboratory count review. Once potential sources of counting error have been mitigated, participating national scientists will move forward with the ageing of mako shark vertebrae from the reference collection. Ultimately these efforts will lead to an improved growth model for shortfin makos in the North Pacific.

In July of 2014, a large adult male mako which had been injected with OTC in 2008 was recaptured after more than 6 years at liberty (2,196 days). This represents the first recapture of a large adult male mako injected with OTC and subsequently recaptured in the northeastern Pacific after an extended period at liberty. Originally measured at 194 centimeters fork length (FL), the animal measured 217 centimeters (FL) upon recapture, indicating that over a six year period the animal had grown 23 centimeters, an average of 3.8 centimeters per year. This is well below estimated growth rates for juvenile makos (27-36 centimeters between their first and second summer and 20-29 centimeters in the following year). Previous ageing work on makos in the northeastern Pacific has indicated that juveniles deposit band pairs on their vertebrae at a rate of two band pairs per year (Wells et al., 2013). The band pair count from this adult animal clearly indicates that, post OTC injection, the shark displayed annual band pair deposition (5+ bands in six years). Based on the juvenile age validation work done by Wells et al. (2013), the results from this animal indicate that male makos experience a shift in deposition rates from two band pairs per year as juveniles, to one band pair per year as adults. Proper age determination and accurate growth models are important components of a stock assessment. A shift in band pair deposition rates will affect growth models (length-at-age) for shortfin mako in the northeast Pacific and consequently, estimates of age-at-maturity and longevity. More research will be needed to corroborate the timing of this shift in band pair deposition in males, and determine if the same shift occurs in females.

Work continued on age validation of common thresher sharks. During 2014, 134 common threshers were injected with OTC. Since 1998, a total of 1,594 common thresher sharks ranging in size from 45 to 240 centimeters FL have been injected with OTC. Vertebrae from 60 of these sharks (size range at tagging: 63-145 centimeters FL) have been returned with an average time-at-liberty of 352 days. Of those, 26 of these samples were from individuals at liberty for over 10 months with a maximum time-at-liberty of 1,389 days (3.8 years). An abstract describing the preliminary results and conclusion that common thresher deposit one vertebral band pair per year was presented at the ICES 5th International Otolith Symposium in October 2014.

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 centimeters, mass = 600.1 kilograms) 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. In 2014 the results from the dissection and subsequent analyses were prepared for publication. Analyses of tissue isotopes, contaminants and stomach contents suggest a high trophic level and a significant reliance on coastal waters in and around the Southern California Bight. Mercury and contaminant concentrations were far above FDA limits for consumption (Lyons et al 2014).

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. DNA samples were collected during research cruises in 2014 from 116 shortfin makos, 104 blue sharks, 139 common threshers, 5 soupfins (*Galeorhinus galeus*), 4 leopard sharks (*Triakis semifasciata*), one brown smoothhound (*Mustelus henlei*) and 5 pelagic stingrays (*Pteroplatytrygon violacea*). Additional samples were obtained by fishery observers on commercial drift gillnet trips. Sample processing continued to examine stock structure for a number of shark species including shortfin mako, common thresher, silky (*Carcharhinus falciformis*), and pelagic thresher sharks.

A study of pelagic thresher sharks throughout the Pacific identified strong genetic heterogeneity among populations (Cardeñosa et al. 2014). Two distinct populations were identified on either side of the Pacific with a high degree of spatial overlap in the central Pacific and near complete segregation of groups on either side. Analyses of nuclear data suggest there is little to no gene flow between these populations. Given the discrete geographic range of these populations and their reproductive isolation, it's possible that this may represent the early stages of speciation.

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

Monitoring and Assessment Activities

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

The NWFSC conducts annual trawl surveys of the West Coast, designed primarily to acquire abundance data for West Coast groundfish stocks. The tonnages of all shark species collected during these surveys are documented. In 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, currently uses mitochondrial DNA sequencing to identify the species of suspected sharks seized by agents of Federal and State law enforcement agencies, and continues to develop 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 2014, 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. 2014a and 2014b, or the most recent North Pacific Groundfish Stock Assessment and Fishery Evaluation Reports.

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 173 PSATs on spiny dogfish at locations across the Gulf of Alaska, British Columbia (Canada), and Puget Sound (Washington, USA) waters. To date, 151 tags have been recovered, (6 of which were physical recoveries, resulting in high resolution data). 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 and some crossed over to Russian and Japanese waters. 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. The historical method resulted in low precision of age estimates, particularly for older fish exhibiting spine erosion. This prompted a search for improved methods of ageing. Spiny dogfish were aged by historical methods using dorsal fin spines and by a proposed new method involving vertebral thin sections. Centrum edge analysis confirmed an annual banding pattern on vertebrae. Ages were determined by multiple readers using both fin spines and vertebrae thin sections obtained from the same specimens. We estimated inter-reader precision and variance associated with each structure. The two structures yielded similar ages for younger animals, while for older animals age agreement depended on the quality of the thin sections. Similar to other ageing structures, individual variability can impact thin section quality, particularly in larger older animals. We were unable to fully validate vertebral thin section ages of larger, older animals because of variability in thin section quality and limited sample size. Each method has advantages and disadvantages. The dorsal fin spine method was validated previously by both oxytetracycline and bomb radio carbon dating, but between-reader agreement is poor. Moreover, worn or broken dorsal fin spines, common in older animals, require another step, where lost annuli are estimated through regression methods, which introduce an additional source of error into age estimation. In comparison, the vertebral thin section method substantially improved between-reader agreement and does not require the additional regression step, but processing of vertebrae is time consuming, the quality of the thin section impacts the age estimates, and validation of ages for larger animals has not yet been realized. In summary, the vertebrae thin section method is promising, but more work is required to examine individual variability in thin sections (i.e. quality) and ages need to be compared among the two methods from a larger sample size of large, old fish that have been age validated by bomb radio carbon dating.

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 was some suggestion that it will work for Pacific sleeper sharks. Unfortunately, no banding patterns were visible on vertebrae of Pacific sleeper sharks. We are preparing to investigate other structures, such as the eye lens or the nueral arch.

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 percent. Greenland sharks were found to diverge from the two groups by 0.6 percent and 0.8 percent at CO1, and 1.5% and 1.8 percent 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 numbers instead of weight, 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, currently managed as part of the “Shark Complex” with harvest limits specified in tons. Management of the species is reliant on using estimates of total catch weight that are dependent on observed weight data. Sleeper sharks are 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. Thus, they are uniquely challenging to manage. Conversely, observers are generally able to obtain accurate counts, 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 retrieved. The goal of this study is to investigate if managing by numbers would be an improvement for sleeper sharks. Current catch estimates show that most of the sleeper shark catches occurs in longline fisheries, where observed weight data is likely biased low because of the difficulty bringing large animals onboard. Overall, count data may provide a better estimate of total sleeper shark catch than currently used weight estimates. We discuss how counts could be incorporated into the existing harvest specification process and associated issues with a change in management methods.

Using tag data to inform biomass estimates for spiny dogfish.

In the Gulf of Alaska (GOA) many data-poor stocks are managed using Tier 5 approach, where the product of the biomass and a fishing mortality rate is used to determine harvest specifications. This method requires that a reliable biomass is available. The biennial GOA trawl survey is considered “unreliable” or “at best an index of relative abundance” for this species, therefore the species does not qualify for Tier 5 designation. In this study we are using archival tag data to examine if the reliability the bottom trawl survey biomass for this species can be improved. The goals of this study are to 1) examine if the trawl survey overlaps with spiny dogfish distribution, both horizontally and vertically; 2) determine if a catchability (q) parameter can be estimated for the species to apply to the trawl survey biomass; and 3) investigate if the trawl survey biomass can be adjusted to be considered “reliable”. Temperature and depth data was recovered from 121 tags, where the release and/or recovery locations were in the GOA during the same time frame as the trawl survey. A preliminary analysis of a subset of the tags showed that average depth by time of day in the summer was less than 50 meters for all hours, with 95 percent confidence intervals ranging from the surface to 200 meters. Based on the tagging data and trawl survey haul data, the tagged spiny dogfish spent approximately 9 percent of the time within the depth range of the trawl survey gear.

Northeast Fisheries Science Center (NEFSC)

Biology of the White Shark (Carcharodon carcharias)

Descriptive statistics and GIS analyses of a 210-year database were used to quantify the seasonal distribution and habitat use of WNA white sharks. Relative indices of abundance from historical NEFSC surveys and tournament data, the directed shark longline observer program, and visual records of white sharks in WNA were analyzed to determine temporal trends of white shark abundance. Study results provide an optimistic outlook for their recovery (Curtis et al. 2014).

Age and Growth of the Bull Shark (Carcharhinus leucas)

Age and growth of the WNA bull shark was completed using 121 vertebral samples collected between 1966 and 2010 (Natanson et al. 2014). Maximum age based on vertebral band pair counts was 25 (184 centimeters fork length (FL)) and 27 (196 centimeters FL) years for males and females, respectively. Based on published length at maturity estimates, males and females mature at 15-17 (176 - 185 centimeters FL) and 15 (189 centimeters FL) years, respectively.

Age validation in Sand Tiger Shark, Carcharias taurus, using bomb radiocarbon analysis

Archival vertebrae of sand tigers from both the north Atlantic and south Indian Oceans were processed for bomb radiocarbon analysis to validate growth band periodicity and longevity (Passerotti et al. 2014). Results from the WNA validated vertebral age estimates up to 12 years, but indicated large adult ages were underestimated by 11-12 years. Validated lifespan for females and males reached at least 40 and 34 years, respectively.

Biology of the Spiny Dogfish (Squalus acanthias)

As part of the NEFSC spiny dogfish tagging study in the Gulf of Maine, Southern New England, and Georges Bank regions, 34,604 sharks were tagged and 891 were recaptured. 150 fish were injected with oxytetracycline (OTC) and returned for age validation through 2014. Research on the seasonality of pupping and gestation period continued; a year and a half of the two year sampling plan is complete.

Smooth Dogfish (Mustelus canis) Movement Patterns

Smooth dogfish mark and recapture data between 1963 and 2013, from the Cooperative Shark Tagging Program (CSTP) were summarized with 1134 tags and 37 recaptures (Kohler et al. 2014). Maximum displacement distance was 460 nautical miles with distance traveled increasing with increasing FL. A north-south seasonal migration pattern was evident with movements between MA and NC. There was no movement between the Atlantic and Gulf of Mexico.

Sand Tiger Movement Patterns

NEFSC collaborative research funded by a Species of Concern grant contributed to a study using satellite telemetry on sand tigers in the WNA. Results showed that juveniles undergo extensive seasonal coastal migrations, traveling distances of approximately 2,500 kilometers over a 4-5 month period from October to February; from as far north as northern New England south to central Florida before returning north the following spring (April – May) (Kneebone et al. 2014).

Recreational Shark Fishing Data and Samples

In 2014, biological samples and catch data for more than150 pelagic sharks from nine recreational fishing tournaments were added to the NEFSC historic recreational shark fishing tournament database. Staff also worked with multiple partners to stage an all-release, satellite tag tournament in NY; 2014 results included deployment of SPOT tags on two tiger sharks, three shortfin makos and one blue shark, as well as numerous conventional tags on shortfin makos and blue sharks.

Southeast Data, Assessment, and Review (SEDAR) Process

Staff participated in the SEDAR 39 Data Workshop for Atlantic smooth dogfish and the Gulf of Mexico smoothhound complex and presented multiple working papers, including: Kohler et al. 2014, McCandless 2014a, McCandless 2014b, McCandless 2014c, McCandless and Frazier 2014, McCandless and Greco 2014, McCandless and Gottschall 2014, McCandless and Grahn 2014, McCandless and Mello 2014, McCandless and Olsewski 2014, McCandless et al. 2014b, McCandless et al 2014c, McCandless et al. 2014d.

Endangered Species Act (ESA)

Staff contributed to and led the Status Review Team for the WNA dusky shark. A Status Review Report (McCandless et al. 2014a) was provided to NMFS Protected Resources indicating that the WNA dusky shark was at low risk for extinction. This report was released to the public in December 2014 with a negative 12-month finding that listing under the ESA is unwarranted.

Essential Fish Habitat (EFH) Designations

Staff provided updates to the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) and the Cooperative Shark Tagging Program (CSTP) data and results from ongoing research for the Stock Assessment and Fisheries Evaluation Report and the NMFS HMS Management Division 5-year review of EFH designations for all managed shark species, and provided reviews of the draft document.

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 (five 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 2014, a total of 94 trips, with a total of 126 bottom longline hauls, were observed. Sharks comprised 99 percent of the catch, teleosts, 0.5 percent, and batoids, 0.5 percent. Sandbar and blacktip sharks comprised most of the shark catch. Small coastal shark species (e.g. Atlantic sharpnose shark) were also caught. Prohibited shark species were also caught, including the dusky shark, sand tiger shark, Caribbean reef shark, and white shark but in low numbers. 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 237 sets comprising various gillnet fisheries were observed in 2014. 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

Coastal shark abundance and community structure was quantified across 10 geographic areas in the northeastern Gulf of Mexico using fishery-independent gillnet data from 2003 to 2011. A total of 3,205 sets were made in which 14,244 carcharhiniform sharks, primarily juveniles, were caught comprising 11 species from three families. The three most abundant species, Atlantic sharpnose, bonnethead, and blacktip sharks, were consistently captured over all sampling sites regardless of environmental conditions; however, some species (e.g., bull, blacknose, finetooth, and sandbar sharks) were restricted to a specific area or a range of areas. Two-way crossed analysis of similarity found geographic area to significantly influence shark species-life stage assemblages, while season did not. Resemblance matrices between environmental data and shark community assemblage found the two were weakly but significantly correlated, with the combination of salinity and water clarity producing the highest Spearman rank correlation value. Species diversity varied by geographic area, but was generally highest in areas with the greatest amount of fresh and saltwater fluctuations. Results suggest that estuarine conditions adjacent to river mouths may affect juvenile shark assemblages across similar latitudes and some areas of the northeastern Gulf of Mexico may be considered important nursery areas for select shark species. This study provides important insight into the habitat use of a variety of coastal shark species and can be used to better manage these species through the determination of critical habitat (Bethea et al. 2014).

Electronic Tagging Studies and Movement Patterns of Large Pelagic Sharks

SEFSC scientists are using fin-mounted smart position tags (SPOT) to study the horizontal movement patterns of tiger (*Galeocerdo cuvier*), scalloped (*Sphyrna lewini*) and great (*S. mokarran*) hammerheads in the Gulf of Mexico (tiger, scalloped, and great hammerhead). This work is part of a collaborative effort with Louisiana Department of Wildlife and Fisheries and the University of Southern Mississippi. The information collected in this study is intended to address fisheries interactions and improve the management and conservation of these ecologically important sharks in the Gulf of Mexico. In 2014, fin-mounted SPOT tags were deployed on 23 sharks; 18 scalloped hammerheads, 5 tiger sharks, and 3 great hammerheads. Tags from 18 of the 23 sharks (15 scalloped hammerhead, 5 tiger, and 1 great hammerhead) reported location data with a mean reporting duration of approximately 90 days, with one tiger shark reporting locations over a one year. The lone reporting great hammerhead spent the majority of its time nearshore, while both scalloped hammerheads and tiger sharks traversed continental shelf and slope waters. Data are being analyzed to investigate any possible season, sex, and size differences in movement patterns.

Electronic Tagging of Whale Sharks (Rhincodon typus)

The SEFSC, in collaboration with Louisiana Department of Wildlife and Fisheries and the University of Southern Mississippi, has been deploying popup satellite archival tags (PSAT) and towable smart position tags (SPOT) for the past several years on whale sharks in the northern Gulf of Mexico to describe their vertical and horizontal movements. In 2014, ten PSAT and two SPOT tags were deployed on whale sharks during a large aggregation encounter on July 10th at Ewing Bank, a topographic feature off the coast of Louisiana. All PSAT tags reported data. Six of the tags remained on the sharks for longer than seven months and three were retained for a full year. The sharks spent the majority of their time in the northern Gulf of Mexico, however, several individuals utilized the southwest Gulf of Mexico during the fall and winter. None of the sharks left the Gulf of Mexico. With the addition of the 2014 tags, nearly 35 tags have been deployed on whale sharks in the northern Gulf of Mexico and a detailed analysis of the data is currently underway.

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 2016.

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 Florida State University, scientists are examining age, growth, and reproduction of Cuban dogfish. In addition, research is also being conducted with the Bimini Biological Station on the life history of the lemon shark. Studies on the life history of Atlantic blacktip shark, finetooth, blacknose shark, smoothhound sharks, and various species of deepwater sharks, including gulper and lantern sharks continued in 2014.

Cooperative Research: Uruguay–U.S. Pelagic Shark Research Project
An ongoing collaborative project with Uruguay's fisheries agency (DINARA) aims to advance knowledge on movement patterns, habitat use, and susceptibility of pelagic sharks to longline fisheries in the western South Atlantic. By the end of 2014, twelve satellite tags had been deployed on blue sharks to date, and five tags were providing real time data, which, along with data for Ecological Risk Assessments, are used as outreach to promote the collaboration between NOAA and DINARA.

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 2014). 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 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 percent 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 (greater than100 meters) than many species of conservation concern (e.g., sea turtles, billfishes, and some sharks) that are caught in shallower water (less than 100 meters). From 2007 to 2011, this study examined the depth distributions of hooks for 1154 longline sets, a total of 3,406,946 hooks, and recorded captures by hook position on 2642 sets, a total of 7,829,498 hooks, in the American Samoa longline fishery (Watson and Bigelow, 2014). 23 percent of hooks had a settled depth less than 100 meters. Individuals captured in the three shallowest hook positions accounted for 18.3 percent of all bycatch. The study analyzed hypothetical impacts for 25 of the most abundant species caught in the fishery by eliminating the three shallowest hook positions under scenarios with and without redistribution of these hooks to deeper depths. Distributions varied by species: 45.5 percent (of a sample size of 10 individuals) of green sea turtle (*Chelonia mydas*), 59.5 percent (of a sample size of 626 individuals) of shortbill spearfish (*Tetrapturus angustirostris*), 37.3 percent (of a sample size of 435 individuals) of silky shark (*Carcharhinus falciformis*), and 42.6 percent (of a sample size of 150 individuals) of oceanic whitetip shark (*C. longimanus*) were caught on the three shallowest hooks. Eleven percent (of a sample size of 20,435 individuals) of all tuna and 8.5 percent (of a sample size of 10,374 individuals) of albacore were caught on the three shallowest hooks. Hook elimination reduced landed value by 1.6–9.2 percent and redistribution of hooks increased average annual landed value relative to the status quo by 5–11.7 percent. 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).

Using net illumination to reduce elsamobranch bycatch.

PIFSC has 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. Analysis of 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 (605 nautical miles 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.

Figure 4.2.1: Orange LEDs attached to experimental gillnet.

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

Testing Deep-set 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 many mako sharks. On four cruises from 2011-2014, SWFSC collaborated with longline fishers aboard the chartered F/V *Ventura II* off central and southern California to target swordfish during the day. Over all four cruises and 54 sets, a total of 149 marketable fish were landed (including 9 swordfish, 97 opah, and 31 Pomfret). Of the 449 non-marketable fish caught, 417 were blue sharks. A deep-set longline fishery off southern and central California would likely be a mixed fishery including some tunas and opah in their marketable catch. 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 and blue shark catch was high. 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. Additional efforts by commercial fisheries with fewer constraints on the timing and location of fishing are needed to truly assess the potential for this fishery.

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 both unwanted finfish bycatch (including blue sharks) and bycatch of species of concern. As with the deep-set longline research being conducted by the SWFSC, 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. A description of the development of DSBG and initial gear experiments was published in early 2015 (Sepulveda et al., 2015). DSBG trials performed in 2014 focused on assessing catch and non-target catch rates and assessing potential market dynamics. DSBG deployments from research and cooperative vessels resulted in the capture of over 90 swordfish in 2014. The collective marketable catch rate was over 94 percent suggesting high selectivity and very low catch of blue sharks. Per vessel catch rates ranged from 0.6 to 1.70 fish per 8 hour soak period. Initial market analyses revealed DSBG swordfish price-point to be similar to harpoon caught product and nearly double that of the existing net fishery. In 2015 the team has petitioned the Pacific Council for exempted status in an attempt to move the DSBG experiment towards future implementation off the U.S. West Coast.

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.

Thresher Sharks Released from the Recreational Fishery

Researchers from the SWFSC, WCR, 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, which was published in 2010, involved releasing sharks which had been captured using tail-hooking techniques, which are common practice in the southern California fishery. The results from this work revealed that survivorship is low for large sharks (greater than 185 centimeters FL) that endure fight times that exceed 85 minutes (Heberer et al., 2010). The second and third phases of the research effort were analyzed and submitted to Fisheries Research in 2014 and published in early 2015 (Sepulveda et al. 2015). The study compared the survivorship of sharks that are tail-hooked but break away, trailing the tackle, including a one pound trolling lure commonly used when angling for sharks, with the survivorship of sharks caught by mouth hooking. For the trailing gear investigation the overall survivorship rate was 22 percent. It is likely that the trailing weight interfered with movement and/or feeding. For the mouth-based trials, all common thresher sharks survived the acute effects of capture (100 percent survivorship). Overall, the results from all phases of this study indicate that methods which maximize mouth-based capture and reduced fight times should be adopted as best fishing practices by the fishery to reduce the mortality of released thresher sharks.

Blue Sharks Released from the Experimental Deep-set Longline Gear

Given the large numbers of blue sharks caught during the deep-set longline experiment and concerns about associated mortality, a second objective of the deep-set longline 2014 cruise was to conduct a study of the post-release mortality of blue sharks. This study included the measurement of a number of previously established condition factors (i.e. eye reflex, body movements), measures of blood lactate, and the use of satellite tags to actually document mortality. Lactate levels were measured in 47 sharks, 15 satellite tags were deployed and condition factors were determined for 85 individuals. The condition factors most closely linked to higher lactate levels had to do with full body movements, sharks that were moving had lower lactic acid levels. Of the 14 tags that reported, 4 tags indicated that the sharks had died within a day of release. The 4 mortalities had the 4 lowest condition scores and 4 of the 5 highest lactate levels. Soak time was not a factor. While additional work is needed, these results show promise for estimating post-release mortality based on a condition factor and blood lactate levels.

Northeast Fisheries Science Center (NEFSC)

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

This ongoing cooperative research is directed toward coastal and pelagic shark species caught on recreational and commercial fishing gear. This work is collaborative with researchers from 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 continues to conduct 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 the great hammerhead are typically caught as bycatch in a variety of fisheries and are listed as globally Endangered by the International Union for the Conservation of Nature. 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 temperature–depth recorders on contracted commercial vessels fishing with bottom-longline gear to assess factors related to mortality. A total of 273 sets were deployed with fifty-four 485 hook timers. Scalloped and great hammerheads had at-vessel mortality rates of 62.9 percent and 56.0 percent, respectively. Median hooking times for scalloped and great hammerheads were 3.5 h and 3.4 h, respectively, and 50 percent mortality was predicted at 3.5 hours and 3.8 hours. When these data are considered for potential management strategies to reduce the mortality of hammerhead sharks, a limitation on gear soak time would probably 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 scalloped and great hammerheads. Results of this research were presented at the Sharks International 2014 conference, held 2–6 June 2014, in Durban, South Africa, and are part of a special issue on ‘Advances in Shark Research’ in the African Journal of Marine Science.

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. Controlled experiments are being conducted comparing catchability, at-vessel mortality, and post-release survivorship in longline sets using J style hooks and those using circle hooks. A contracted fishing vessel is deploying 300 hooks per set and with the exception of hook type, all other factors remain constant. Soak time is limited to the average rate observed for the fishery. All gangions are two m long and constructed of a snap, 363 kilogram test monofilament line and a swivel, to which the leader and hook are attached. The two experimental treatments are Lindgren-Pitman Inc. 0° offset 18/0 circle hooks and Mustad 12/0 J hooks. Post-release survivorship will be assessed tagging sandbar sharks with a satellite pop-up archival transmitting (PAT) tag. Survival of post-captured PAT tagged animals (of a sample size of 20 individuals) will be inferred from data provided by the PAT tag. Data from six tags has been analyzed and preliminary results suggest that two animals suffered mortality, one tag pulled, and three animals survived. Overall, preliminary results find no significant differences between hook types in catch rates, little or no significant differences in at-vessel mortality, and no significant differences in post-release mortality by hook type. However, post-release mortality may be higher than expected.

Section 5: Additional Information About Ongoing NOAA Shark Research

Alaska Fisheries Science Center (AFSC, Auke Bay Laboratory)

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

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

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

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 description), 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).

Trophic Ecology of Pacific Sleeper Sharks in the Eastern North Pacific Ocean
Stable isotope ratios of nitrogen (reported in $\delta^{15}N$) and lipid normalized carbon (reported in $\delta^{13}C'$) were used to examine geographic and ontogenetic variability in the trophic ecology of Pacific sleeper sharks in the eastern North Pacific Ocean (Courtney and Foy 2012). Mean muscle tissue $\delta^{13}C'$ values of Pacific sleeper sharks differed significantly among geographic regions of the eastern North Pacific. Linear models identified significant ontogenetic and geographic variability in muscle tissue $\delta^{15}N$ values. The trophic position of Pacific sleeper sharks in the eastern North Pacific, estimated from previously published stomach content data, was within the range of Pacific sleeper shark trophic position predicted from a linear model of muscle tissue $\delta^{15}N$ (3.3–5.7) for sharks of the same mean total length (L_T; 201.5 centimeters). However, 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 $\delta^{15}N$ 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 ten 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.

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 ten 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. In addition to the work discussed above, the sections below describe other research also being carried out at the center.

Electronic tagging data analyses

Since 2004, scientists at the SWFSC have been opportunistically tagging common thresher sharks with electronic tags during the annual shark surveys. To date twenty-nine common thresher sharks have been tagged with either PSAT3, SPOT4, or both. Of the 27 PSAT3 tags released, four were recovered and 16 transmitted data. Of the SPOT4 tags deployed, all failed to report, despite confirmation of survivorship from paired PSAT tags, showing that this technology is not useful tags for tracking common thresher sharks. Tagged threshers ranged in size from 89-200 centimeters fork length, 127 ± 30 centimeters (mean ± SD), with the majority under the estimated size at maturity (160 centimeters) for this species (Smith et al. 2008). Preliminary analyses indicate that threshers spend much more time near the surface in the mixed layer than they do at greater depths, and that vertical excursions below the mixed layer primarily occur during the day (Figure 2), potentially due to their unique hunting strategy which relies on visual prey detection. Data from stomach contents and coastal pelagic prey densities are being analyzed to further investigate their movements relative to their preferred prey.

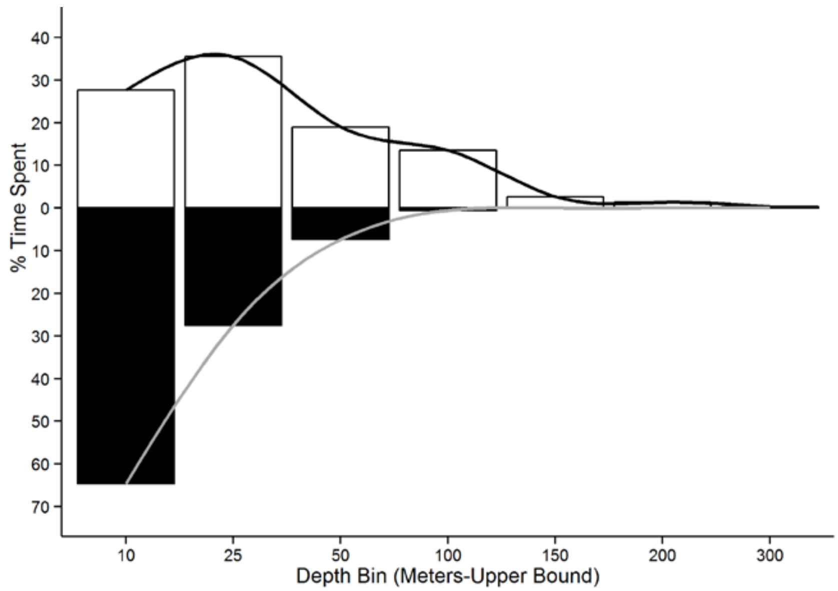
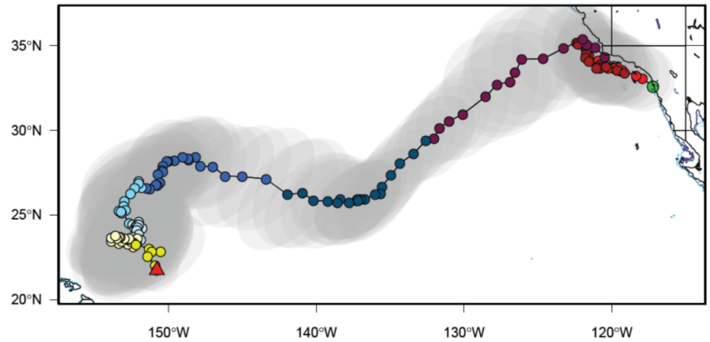


Figure 5.1. Swimming depth histogram of tagged common thresher sharks during night (black bars) and day (white bars). Depth bins are labeled by the upper bounds of the bin, i.e. 10 indicates 0-10 meters.

The horizontal movements of these animals are harder to characterize than vertical movements, because the light-based geolocation estimates determined from PSATs are less accurate than the locations from the SPOT tags. Despite this difficulty, data from tags are being analyzed using a Bayesian approach and then integrated with commercial catch data to improve our understanding of the long distance horizontal movements of threshers. A manuscript on the movement of thresher sharks is currently being drafted.

Basking shark electronic tag data analyses

The SWFSC has an ongoing basking shark research program. During 2014, data from four sharks tagged with satellite tags in 2010 and 2011 were analyzed and the results prepared for publication. The four sharks showed impressive plasticity in geographic movements and vertical behaviors depending upon the region and distance from shore, as has been shown in the Atlantic. Of the two tracks that progressed into winter months, one shark went south along the Baja Peninsula while the other shark moved southwest to waters just north of Hawaii (Figure 3). A comparison of vertical movements with acoustic back-scatter data in the Central Pacific reveals that basking sharks track a consistent scattering layer as they move between 450-470 meters during the day and 250-300 meters at night. Scatter data reveal the presence of small crustaceans and gelatinous zooplankton in this layer. The potential presence of smaller prey such as copepods cannot be resolved with the frequencies used in this study. Interestingly, basking sharks appear to leave daytime depths a few hours prior to sunset which is uncommon for most deep scattering layer (DSL) predators but has been observed in copepods. This suggests that copepods may still be important prey offshore, as they are in nearshore waters, however additional data are still needed.



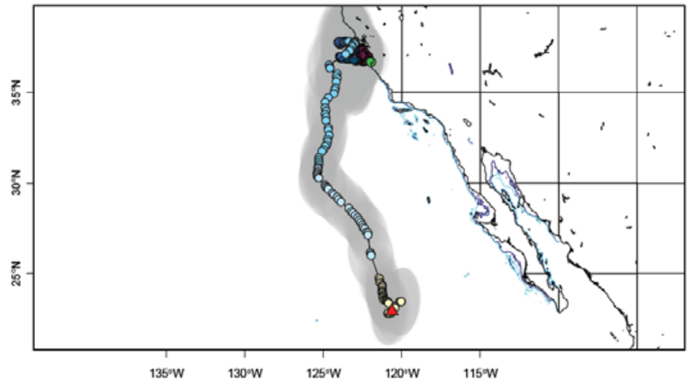


Figure 5.2. (Top) The track of a basking shark tagged on 6/7/2011 off San Diego. The tag released as programmed on 2/2/2012. (Bottom) The track of a basking shark tagged on 8/2/2011 off Monterey. The tag released as programmed on 1/29/2012. Green circles indicate tagging location; red triangles are pop off locations.

Population Genetics Studies

Continuing work on shortfin mako genetics has provided new insight into possible sex-biased gene flow. Earlier work using mitochondrial control region DNA sequences detected population heterogeneity between the north and south Pacific as well as between the southeast and southwest Pacific. Unlike the mitochondrial data, recently completed nuclear microsatellite studies have yielded no significant signals for population heterogeneity. As mitochondrial DNA is inherited maternally this suggests that there is a degree of female philopatry to nursery grounds in these separate regions. The lack of heterogeneity using the nuclear markers suggests that there is sufficient male-mediated geneflow among these regions to genetically homogenize populations.

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, SWFSC researchers have been analyzing the stomach contents of pelagic sharks since 1999. Stomachs are obtained primarily from the CADGN observer program.

Stomach content Analysis

Stomach content analysis of blue, shortfin mako and thresher sharks is ongoing. Interannual variation provides insight into the relative abundance of mid trophic level prey. The stomachs of several species of pelagic sharks caught during the 2013 fishing season were analyzed in 2014. For the 2013 season, shortfin mako stomachs (n=54) contained Pacific saury (F=28; F=Frequency of prey occurrence), market squid (F=9), paper nautilus (*Argonauta sp.*) and *Gonatus spp*. squid (F=5). Jumbo squid (*Dosidicus gigas)* was found only in one stomach in contrast to prior seasons when it was dominant. Blue shark stomachs (n=5) contained *Gonatus spp*. squid (F=5), octopus squid (F=5), and *Histioteuthis spp.* (n=3). Common prey in thresher shark stomachs (n=16) was market squid (F=5) and Pacific saury (F=2).

Stable isotope analysis of Pelagic Sharks, Swordfish and their prey

In addition to the ongoing analysis of stomach contents, researchers at the SWFSC have been collecting stable isotope samples from highly migratory predators, as well as prey found in their stomachs. Collected tissue samples are being analyzed for both δ^{14}C and δ^{15}N in order to further our understanding of the trophic ecology of these mobile species across a wider time frame then stomach content analysis alone can provide. So far, 90 predator muscle samples and 86 prey samples have been processed and results are currently being compiled.

Blue and Thresher Shark Spiral Valve Parasite Analysis

The basic principle underlying the use of parasites as tags in shark population studies is that sharks may become infected with a parasite only when they come within the endemic area of that parasite. The endemic area is the geographical region in which conditions are suitable for the transmission of the parasite (MacKenzie and Abaunza 1998). In addition, different parasites can be associated with different prey.

A preliminary study on the spiral valve parasite content of blue and thresher sharks was started in 2011. These species co-occur along the U.S. and Mexico West Coasts during certain times of the year. While they are both caught in the CADGN fishery, a prior study showed that their diet and ecological differ (Preti et al. 2012). The contents of 20 blue and 20 thresher shark spiral valves were analyzed for parasite loads in order to determine if there are differences in parasite loads between these two shark species, and how parasites are associated with different prey and the areas where these predators forage. Preliminary results show that blue and thresher sharks have different parasites in their spiral valves suggesting that the two predator species spend time in different areas and/or eat different prey (Table 5.1).

Table 5.1 Parasites found in the spiral valves of blue and thresher sharks.

Parasite species	Host	Parasite Class
Prosobothrium armigerum	Blue	Cestoda
Anthobothrium laciniatum	Blue	Cestoda
Paraorygmatobothrium prionacis	Blue	Cestoda
Platybothrium auriculatum	Blue	Cestoda

Unid. Phyllobothriid	Blue	Cestoda
Gymnorhynchus sp.	Blue / Thresher	Cestoda
Acanthocelius sp.	Blue	
Cestode fragments	Blue	
Gymnorhynchus sp.	Blue	
Paraorygmatobothrium exiguum	Thresher	Cestoda
Lacistorhynchus tenuis	Thresher	Cestoda
Anisakis sp. larvae	Thresher	Nematoda
Hysterothylacium incurvum	Thresher	Nematoda
Piscicapillaria sp.	Thresher	Spirurid Nematod
Rhadinorhynchus cololabis	Thresher	Acanthocephala
Pennella remains	Thresher	Subclass (Copepoda)

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

The CADGN fishery targets swordfish in the California Current. With the exception of ocean sunfish, blue sharks have historically been caught in greater numbers than any other fish species taken in this fishery. Nearly all blue sharks are discarded at sea due to lack of market value. A 2009 analysis of the 1990-2008 observer data reveals that 32percent of blue sharks captured were released alive. In 2007, researchers from the SWFSC and the WCR began deploying PSAT tags on sharks released from the CADGN fishery to assess survivorship in order to determine more accurate estimates of fishery removals 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 2013-2014 season, 15 blue sharks (100 to 200 centimeters FL) had been tagged by fishery observers. Three of the 15 sharks were released in "good" condition; ten were released in "fair" condition; and two 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. However, the number of tagged sharks is low and we hope to tag three more sharks in "poor" condition in order to strengthen the findings. In general, when sharks are brought to the vessel alive, most are in "good" or "fair" condition. No tags have been released during the past two seasons due to low effort and few "poor" condition candidate blue sharks caught, but SWFSC scientists hope to complete the study during the 2015-2016 season.

Pacific Islands Fisheries Science Center (PIFSC)

Age Validation using Bomb Radiocarbon Dating

PIFSC scientists in collaboration with Northeast Fisheries Science Center 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 ten years.

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 5.1) 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, 2013, 2015).
- The Pacific Remote Island Areas of Howland and Baker in the U.S. Phoenix Islands and Jarvis Island, and Palmyra and Kingman Atolls in the U.S. Line Islands (2000, 2001, 2002, 2004, 2006, 2008, 2010, 2012, 2015).
- American Samoa, including Rose Atoll and Swains Island (2002, 2004, 2006, 2008, 2010, 2012, 2015).
- 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, 2012, 2015).

Table 5.2 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 5.2), only four species are typically recorded in sufficient frequency by towed divers to allow meaningful statistical analyses: grey reef shark (*Carcharhinus amblyrhynchos*), Galapagos shark (*Carcharhinus galapagensis*), whitetip reef shark (*Triaenodon obesus*), and blacktip reef shark(*Carcharhinus melanopterus*). Analyses show a highly significant negative relationship between grey reef and Galapagos shark densities and proximity to human population centers (e.g., proxy for potential fishing pressure and other human impacts). Average combined numerical density for these two species near population centers is less than 10 percent of densities recorded at the most isolated islands (e.g., no human population, very low present or historical fishing pressure or other human activity). Even around islands with no human habitation, but within reach of populated areas, grey reef and Galapagos shark densities are only between 15 and 40 percent of the population densities around the most isolated near-pristine reefs. Patterns in whitetip and blacktip reef shark numbers are similar, but less dramatic.

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 kilometers 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. Because all CRED shark data were gathered by SCUBA divers: (1) safe diving practices limited surveys to reefs areas of 30 meters 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 three to ten percent of their baseline values (Figure 6.3). These results show the extent of the detrimental effect of human activities on reef shark population. However, the exact cause of the decline is not known. The likely causes are probably related to prey population depletion (i.e., reef fish biomass around populated islands is about 50-80 percent lower than on pristine reefs) and direct removal through fishing (bycatch, recreational, or targeted) (Nadon et al. 2012).

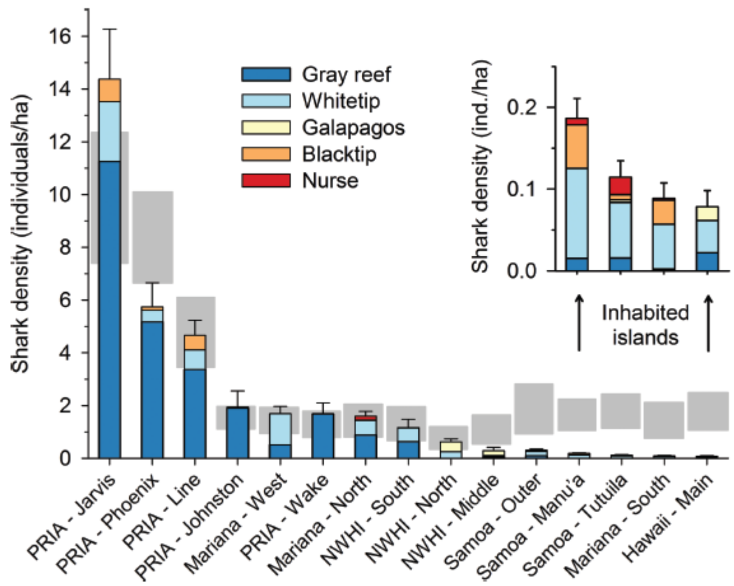


Figure 5.3: Mean (SE) observed densities of reef sharks in the U.S. Pacific. Colors represent actual densities; gray rectangles represent model predictions in the absence of humans.

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, like theEl 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 given that these species spend most of their time in the warmest available water. In 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).

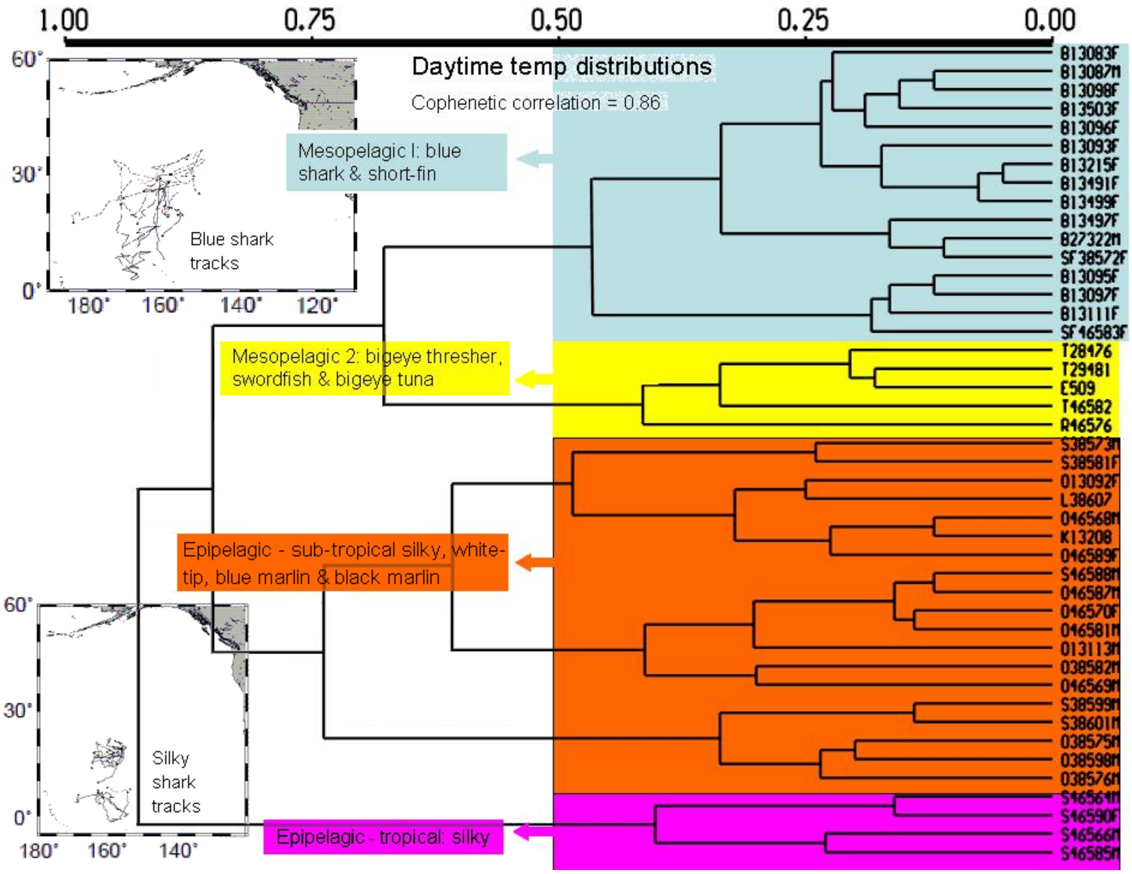


Figure 5.4: Clustered relationships among pelagic animals using daytime temperature preferences from pop-up satellite archival tags (PSATs). B = blue shark, SF = shortfin mako, T = bigeye thresher, E = bigeye tuna, R = swordfish, S = silky shark, O = oceanic whitetip shark, K = black marlin, L = blue 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 meters, 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 funded by the NMFS National Bycatch Program since 2005 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 like 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 centimeters to bait in the presence of the metal, with the metal approximately the size of a 60 gram 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 peodymiun/praseodymium (Nd/Pr) 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).

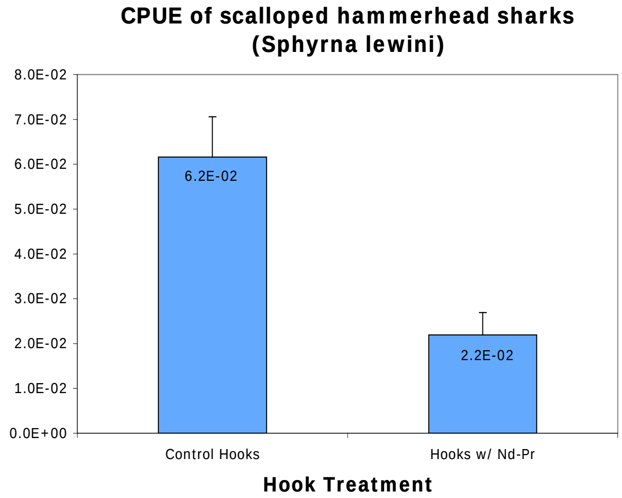


Figure 5.5: Catch per unit effort of scalloped hammerhead sharks on longlines with Nd/Pr alloy attached versus control hooks.

In addition, field trials on pelagic sharks were initiated via collaboration with the Southwest Fisheries Science Center (SWFSC). 13 sets were completed for the experiment during the 2010 cruise in addition to the 25 sets completed 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).

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).

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.

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 meters 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, including weights that do not spring back toward fishermen when branch lines break.

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, like fish size, water temperature, fight time, and fishing gear could influence survival.

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

PIFSC scientists have been developing biochemical and physiological profiling techniques for use in estimating post-release survival of blue sharks, which are frequently caught as bycatch by Pacific longliners. Using NOAA research vessels, they captured 211 sharks, of which 172 were blue sharks. Using blue sharks, PIFSC scientists and collaborators developed a model to predict long-term survival of released animals (verified by PSAT data) based on analysis of small blood samples. Five parameters distinguished survivors from moribund sharks: plasma Mg2+, plasma lactate, erythrocyte Hsp70 mRNA, plasma Ca2+, and plasma K+. A logistic regression model incorporating a combination of Mg2+ and lactate successfully categorized 19 of 20 (95 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 percent CI, 9 – 25 percent).

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 for blue shark; greater than 95 percent based on PSATs for 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 meters) 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 percent CI, 9 – 25 percent), 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).

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, 2013, and 2014. 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 in place 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 (MMPA), 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 237 sets comprising various gillnet fisheries were observed in 2014. Set locations ranged from North Carolina to the Florida Keys in the Atlantic 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 21 kilometers per day with an average of 433 kilometers in total. Overall, mean proportions of time at depth revealed dusky sharks spent the majority of their time in waters 20–40 meters deep, but did dive to depths of 440 meters. Tagged sharks had varied movement patterns. One shark 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 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 researchers from fully determining its movement patterns in and around the closed area. Four dusky sharks were tagged in 2014; the tag pulled early on one animal, one animal traveled 311 kilometers onto the Blake Plateau before it died near Jacksonville, Florida after 126 days; the remaining two animals died within 76 and 85 days of release, respectively**.**

Habitat use and movement patterns of dusky sharks (Carcharhinus obscurus) in the northern Gulf of Mexico.

The dusky shark (*Carcharhinus obscurus*) is the largest member of the genus *Carcharhinus* and inhabits coastal and pelagic ecosystems circumglobally in temperate, subtropical and tropical marine waters. In the western North Atlantic Ocean (WNA), dusky sharks are overfished and considered vulnerable by the International Union for the Conservation of Nature. As a result, retention of dusky sharks in commercial and recreational fisheries off the east coast of the United States (US) and in the northern Gulf of Mexico is prohibited. Despite the concerns regarding the status of dusky sharks in the WNA, little is known about their habitat utilization. During the

[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.

summers of 2008 and 2009, pop-up satellite archival tags were attached to ten dusky sharks (one male, nine females) at a location where they have been observed to aggregate in the north central Gulf of Mexico southwest of the Mississippi River Delta to examine their movement patterns and habitat utilization. All tags successfully transmitted data with deployment durations ranging from 6 to 124 days. Tag data revealed shark movements in excess of 200 kilometers from initial tagging locations, with sharks primarily utilizing offshore waters associated with the continental shelf edge from Desoto Canyon to the Texas/Mexican border. While most sharks remained in US waters, one individual moved from the northern Gulf of Mexico into the Bay of Campeche off the coast of Mexico. Sharks spent 87 percent of their time between 20 and 125 m and 83 percent of their time in waters between 23 and 30 °C. Since dusky sharks are among the most vulnerable shark species to fishing mortality, there is a recovery plan in place for US waters; however, since they have been shown to make long-distance migrations, a multi-national management plan within the WNA may be needed to ensure the successful recovery of this population.

Electronic Tagging Studies and Movement Patterns of Large Pelagic Sharks
SEFSC scientists are using fin-mounted smart position tags (SPOT) to study the horizontal movement patterns of tiger (*Galeocerdo cuvier*), scalloped (*Sphyrna lewini*) and great (*S. mokarran*) hammerheads in the Gulf of Mexico (tiger, scalloped, and great hammerhead). This work is part of a collaborative effort with Louisiana Department of Wildlife and Fisheries and the University of Southern Mississippi. The information collected in this study is intended to address fisheries interactions, and improve the management and conservation of these ecologically important sharks in the Gulf of Mexico. In 2014, fin-mounted SPOT tags were deployed on 23 sharks; 18 scalloped hammerheads, 5 tiger sharks, and 3 great hammerheads. Tags from 18 of the 23 sharks (15 scalloped hammerhead, 5 tiger, and 1 great hammerhead) reported location data with a mean reporting duration of approximately 90 days, with one tiger shark reporting locations over a one year. The lone reporting great hammerhead spent the majority of its time nearshore, while both scalloped hammerheads and tiger sharks traversed continental shelf and slope waters. Data are being analyzed to investigate any possible season, sex, and size differences in movement patterns.

Electronic Tagging of Whale Sharks (Rhincodon typus)
The SEFSC, in collaboration with Louisiana Department of Wildlife and Fisheries and the University of Southern Mississippi, has been deploying pop-up satellite archival tags (PSAT) and towable smart position tags (SPOT) for the past several years on whale sharks in the northern Gulf of Mexico to describe their vertical and horizontal movements. In 2014, 10 PSAT and 2 SPOT tags were deployed on whale sharks during a large aggregation encounter on July 10^{th} at Ewing Bank, a topographic feature off the coast of Louisiana. All PSAT tags reported data. Six of the tags remained on the sharks for longer than seven months and three were retained for a full year. The sharks spent the majority of their time in the northern Gulf of Mexico; however, several individuals utilized the southwest Gulf of Mexico during the fall and winter. None of the sharks left the Gulf of Mexico. With the addition of the 2014 tags, nearly 35 tags have been deployed on whale sharks in the northern Gulf of Mexico and a detailed analysis of the data is currently underway.

New record of a goblin shark *Mitsukurina owstoni* (Lamniformes: Mitsukurinidae) in

the western North Atlantic Ocean

On 19 April 2014, a female goblin shark, *Mitsukurina owstoni*, was captured in a commercial shrimp trawl in the northern Gulf of Mexico. The shark, estimated to be approximately 5 meters in length, was captured at a depth of approximately 490 meters and released alive shortly after capture. This specimen represents the second goblin shark ever recorded in the Gulf of Mexico.

Do Vertebral Chemical Signatures Distinguish Juvenile Blacktip Shark (*Carcharhinus limbatus*) Nursery Regions in the Northern Gulf of Mexico?

Identifying and protecting shark nurseries is a common management strategy used to help rebuild overfished stocks yet we know little about connectivity between juvenile and adult populations. By analyzing trace metals incorporated into vertebral cartilage, it may be possible to infer natal origin based on nursery-specific chemical signatures. To assess the efficacy of this approach, we collected juvenile blacktip sharks, *Carcharhinus limbatus*, (n = 93) from four regions in the Gulf of Mexico in 2012 and 2013 and analyzed their vertebral centra with laser ablation–inductively coupled plasma–mass spectrometry (LA–ICP–MS). Changes in Sr:Ca, Ba:Ca, and Pb:Ca concurrent with birth were consistent with changes from a marine environment to one influenced by freshwater input. Multi–element chemical signatures were significantly different among regions and year-classes. Year–class specific linear discriminant function analysis (LDFA) yielded classification accuracies of 81 percent for 2012 and 85 percent for 2013, though samples were not obtained from all four regions 2012. Combining year-classes resulted in an overall classification accuracy of 84 percent thus demonstrating the utility of this approach. Our results are encouraging yet highlight a need for more research to better evaluate the efficacy of vertebral chemistry to study elasmobranch population connectivity.

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 essential fish habitat (EFH). The Group initiated a juvenile shark abundance index survey in 1996. The index is based on random, depth-stratified gillnet sets conducted throughout coastal bays and estuaries in coastal areas of the Gulf of Mexico from April to October. The species targeted in the index of abundance survey are juvenile sharks in the large and small coastal management groups. This index has been used as an input to various stock assessment models. A database containing tag and recapture information on elasmobranchs tagged by GULFSPAN participants 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 2016.

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 primarily 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 acoustic tracking, PSAT and SPOT tags. Large sawfish generally remained in coastal waters within the region where they were initially tagged, travelling an average of 80.2 kilometers from deployment to pop-up location. The shortest distance moved was 4.6 kilometers and the greatest 279.1 kilometers, averaging 1.4 kilometers day^{-1}. Seasonal movement rates for females were significantly different with the greatest movements in autumn and winter. Smalltooth sawfish spent the majority of their time at shallow depths (96 percent of their time at depths less than 10 meters) and warm water temperatures (22–28°C). Over short time periods, movements appeared primarily tidal driven with some evidence that animals moved into shallow water during the ebbing or flooding tides. Adult sawfish sexually segregated seasonally with males found by mangrove-lined canals in the spring and females predominantly found in outer parts of the bay. Males migrated from canals starting in late May potentially as temperatures increased above 30° C. Some males and females migrated north during the summer, while others may have remained within deeper portions of Florida Bay. Male sawfish displayed site fidelity to Florida Bay as some individuals were recaptured 1–2 years after originally being tagged. We hypothesize that mating occurs in Florida Bay based on aggregations of mature animals coinciding with the proposed mating period, initial sexual segregation of adults followed by some evidence of females moving through areas where males show seasonal residency, and a high percentage of animals showing evidence of rostrum inflicted injuries. The combination of methods providing movement data over a range of spatial and temporal scales reveals that sub-tropical embayments serve as essential habitat for adult smalltooth sawfish. Given sawfish show a degree of site fidelity punctuated by limited migratory movements, emphasizes the need for conservation and management of existing coastal habitats throughout the species' range.

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.

Population structure of blacksnose sharks in the western North Atlantic Ocean

Patterns of population structure and historical genetic demography of blacknose sharks in the western North Atlantic Ocean were assessed using variation in nuclearencoded microsatellites and sequences of mitochondrial DNA (mtDNA). Significant heterogeneity and/or inferred barriers to gene flow, based on microsatellites and/or mtDNA, revealed the occurrence of five genetic populations localized to five geographic regions: the southeastern U.S Atlantic coast, the eastern Gulf of Mexico, the western Gulf of Mexico, Bay of Campeche in the southern Gulf of Mexico and the Bahamas. Pairwise estimates of genetic divergence between sharks in the Bahamas and those in all other localities were more than an order of magnitude higher than between pairwise comparisons involving the other localities. Demographic modelling indicated that sharks in all five regions diverged after the last glacial maximum and, except for the Bahamas, experienced post-glacial, population expansion. The patterns of genetic variation also suggest that the southern Gulf of Mexico may have served as a glacial refuge and source for the expansion. Results of the study demonstrate that barriers to gene flow and historical genetic demography contributed to contemporary patterns of population structure in a coastal migratory species living in an otherwise continuous marine habitat. The results also indicate that for many marine species, failure to properly characterize barriers in terms of levels of contemporary gene flow could in part be due to inferences based solely on equilibrium assumptions. This could lead to erroneous conclusions regarding levels of connectivity in species of conservation concern.

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.

An assessment of the diet and trophic level of Atlantic sharpnose shark *Rhizoprionodon terraenovae*

A re-assessment of the diet of the Atlantic sharpnose shark was conducted to provide an update on their trophic level. Atlantic sharpnose shark primarily consume teleosts, but previously unreported loggerhead sea turtles (*Caretta caretta)* were also found in the diet. Analysis suggests that calculated trophic level may depend on diet and geographic area.

Life history of bonnethead sharks in the western North Atlantic Ocean

The age, growth and maturity of bonnetheads Sphyrna tiburo inhabiting the estuarine and coastal waters of the western North Atlantic Ocean (WNA) from Onslow Bay, North Carolina, south to West Palm Beach, Florida, were examined. Vertebrae were collected and aged from 329 females and 217 males ranging in size from 262 to 1,043 millimeters and 245 to 825 millimeters fork length, LF, respectively. Sex-specific von Bertalanffy growth curves were fitted to length-at-age data. Female von Bertalanffy parameters were L_∞ =1036 millimeters LF, k =0·18, t_0= −1·64 and L_0 =272 millimeters LF. Males reached a smaller theoretical asymptotic length and had a higher growth coefficient (L_∞ =782 millimeters LF, k =0·29, t_0= −1·43 and L_0 =266 millimeters LF). Maximum observed age was 17·9 years for females and 16·0 years for males. Annual deposition of growth increments was verified by marginal increment analysis and validated for age classes 2·5+ to 10·5+ years through recapture of 13 oxytetracycline-injected specimens at liberty in the wild for 1–4 years. Length (LF50) and age (A50) at 50 percent maturity were 819 millimeters and 6·7 years for females, and 618 millimeters and 3·9 years for males. Both female and male *S. tiburo* in the WNA had a significantly higher maximum observed age, LF50, A50 and L_∞, and a significantly lower k and estimated L_0 than evident in the Gulf of Mexico (GOM). These significant differences in life-history parameters, as well as evidence from tagging and genetic studies, suggest that *S. tiburo* in the WNA and GOM should be considered separate stocks.

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 2,300 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 percent. 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 from 2 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 recaptured multiple times with times at liberty ranging from 12 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, elder individuals.

Figure 5.6: Scalloped hammerhead captured in the Gulf of Mexico during a bottom longline survey.
Source: NMFS SEFSC

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

The SEFSC continues to collaborate with Uruguay's fisheries agency (DINARA) to advance knowledge on movement patterns, habitat use, 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.

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 (32 surveys have been completed through 2014). The primary objective is assessment of the distribution and abundance of large and small coastal sharks across their known ranges in order to develop a time series for trend analysis. The surveys, which are conducted at depths between 9 and 366 fathoms, were designed specifically for stock assessment purposes. The bottom longline surveys are the only long-term, nearly stock-wide, fishery-independent surveys of western North Atlantic Ocean sharks conducted in U.S. waters and neighboring waters. Recently, survey effort has been extended into depths shallower than 5 fathoms (9.1 meters) to examine seasonality and abundance of sharks in inshore waters of the northern Gulf of Mexico and to determine what species and size classes are outside of the range of the sampling regime of the long-term survey. This work is being done in cooperation with SEAMAP partner institutions. For all surveys, ancillary objectives are to collect biological and environmental data, and to tag and release sharks. The surveys continue to address expanding fisheries management requirements for both elasmobranchs and teleosts.

Northeast Fisheries Science Center (NEFSC)

Fishery Independent Surveys and Recreational Monitoring of Coastal and Pelagic Sharks

Fishery Independent Coastal Shark Bottom Longline Survey

The fishery independent survey of Atlantic large and small coastal sharks is conducted bi-annually in U.S. waters, depending on funding. Its primary objective is to conduct a standardized, systematic survey of the shark populations off the U.S. Atlantic coast to provide unbiased indices of relative abundance for species inhabiting the waters from Florida to the Mid-Atlantic (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 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 percent 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. Staff analyzed the dusky shark catches from this survey through 2012 to update the index of abundance for use in the Status Review for the northwest Atlantic Dusky Shark in response to petitions to list the species under the Endangered Species Act (McCandless et al. 2014a). Also in 2014, staff prepared the contract for the fishing vessel in support of the next survey scheduled for spring of 2015.

Figure 5.7. Releasing a sandbar shark during the NEFSC Coastal Shark Bottom Longline Survey. Source: L.J. Natanson / NMFS photo.

Fishery Independent Pelagic Shark Longline Survey

NMFS and its predecessor agencies, the Bureau of Commercial Fisheries and the Bureau of Sport Fish and Wildlife, conducted periodic longline surveys for swordfish, tunas, and sharks off the east coast of the United States starting in the early 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 2014, a total of 473 sandbar sharks were caught with 95 percent 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 2014 (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 2014, a total of 45 sand tigers were caught and released and 93 percent of these sharks were tagged with conventional tags bringing the total since the beginning of the survey to 283 sand tigers.

Figure 5.8. 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 (1961-2014) 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 2014, biological samples for life history studies and catch and morphometric data for more than 150 pelagic sharks were collected at nine recreational fishing tournaments in the northeastern United States. Participation at recreational shark tournaments and the resultant information is very valuable as a monitoring tool to provide long-term data that can detect trends in species and size composition, provide critical specimens and tissue for life history and genetic studies, provide outreach opportunities for recreational fishermen and the public, and finally, to provide additional information on movements that complement the NMFS Cooperative Shark Tagging Program (CSTP). Additionally, analysis of the white shark catches recorded from five long-term tournaments sampled by the NEFSC were used to develop a relative index of abundance for use in a recent publication on historical trends in abundance (Curtis et al. 2014).

In 2014, 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) for an all-release, satellite tag shark tournament in Montauk, LI, NY called 'Shark's Eye.' This is the second year for this only satellite tag, all-release shark tournament held in the Northeast US; rules required the mandatory use of circle hooks, heavy tackle and safe handling practices. Results from the second year included six electronic SPOT tags that were put on two tiger sharks, three shortfin makos and one blue shark, as well as numerous conventional tags on shortfin makos and blue sharks. Location data from the spot tags were made available on the OCEARCH website. Additionally, there was a two-day public outreach event where much information was given out on NOAA Fisheries research.

<u>NEFSC Historical Longline Survey Database</u>

The NEFSC recovered the shark species catch per set data from the exploratory shark longline surveys conducted by the Sandy Hook and Narragansett Laboratories from 1961 to 1991. In addition to the fishery-independent surveys conducted by the NEFSC, scientific staff 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 smooth dogfish, Atlantic sharpnose, blacknose, sandbar, and dusky sharks caught during the UNC shark survey (Schwartz et al. 2010, Schwartz et al. 2013, McCandless et al 2014d). Additionally, white shark catches from the NEFSC exploratory longline surveys were used to develop an index of relative abundance for a recent publication on historical trends in abundance (Curtis et al. 2014). 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.

Southeast Data, Assessment, and Review (SEDAR) Process

NEFSC Staff participated in the SEDAR 39 Data Workshop for the assessment of the Atlantic smooth dogfish population and the Gulf of Mexico smoothhound complex. A working paper for Atlantic smooth dogfish was presented during the workshop summarizing mark/recapture data from the Cooperative Shark Tagging Program (Kohler et al. 2014). In addition, five working papers detailing multiple indices of abundance for Atlantic smooth dogfish were developed using longline survey data from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) survey (McCandless 2014b), the South Carolina Department of Natural Resources (McCandless and Frazier 2014), and the University of North Carolina (McCandless et al. 2014d); as well as, gillnet survey data from the North Carolina Division of Marine Fisheries (McCandless et al 2014c) and gillnet observer data from the Northeast Fisheries Observer Program (McCandless and Mello 2014). Multiple indices of abundance were also developed for six working papers using trawl survey data from the University of Rhode Island (McCandless 2014c), Rhode Island Department of Environmental Management (McCandless and Olsewski 2014), Connecticut Department of Energy and Environmental Protection (McCandless and Gottschall 2014), New York State Department of Environmental Conservation (McCandless and Grahn 2014), New Jersey Division of Fish and Wildlife (McCandless et al. 2014b), and Delaware Division of Fish and Wildlife (McCandless and Greco 2014). Additionally, staff co-chaired the Indices Working Group for the SEDAR Data Workshop and produced Indices Working Group Reports summarizing working group recommendations for both the Atlantic smooth dogfish and smoothhound complex. Staff also developed a working paper for the SEDAR Assessment Workshop detailing the hierarchical analysis of the recommended indices of abundance to create a single index of abundance to use in sensitivity analyses during the SEDAR Assessment Workshop for both the Atlantic smooth dogfish and the Gulf of Mexico smoothhound complex (McCandless 2014a).

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 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.

Endangered Species Act
NEFSC staff contributed to and led the Status Review Team for the Northwest Atlantic dusky shark, in response to a positive 90-day finding indicating that petitions presented substantial information that listing under the Endangered Species Act as threatened or endangered may be warranted for this population. Multiple analyses were produced and data were summarize from all available resources for use by the Status Review Team to produce a comprehensive review and extinction risk analysis for the Northwest Atlantic dusky shark population. NEFSC staff provided NMFS Protected Resources with a Status Review Report (McCandless et al. 2014a) indicating that the Northwest Atlantic dusky shark distinct population segment was at low risk for extinction and this report was released to the public in December 2014 with a negative 12-month finding indicating that listing under the Endangered Species Act was determined to be unwarranted.

Pelagic Nursery Grounds
Pelagic shark biology, movements, and abundance studies continued in 2014 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 6.9). In 2007 and 2008, two real-time satellite (SPOT) tags and five pop-up satellite archival tags (PSAT) tags were deployed on shortfin makos and one PSAT tag was deployed on a blue shark. A total of 500 blue sharks have been double tagged using two different tag types to help evaluate tag-shedding rates used in sensitivity analyses for population estimates and to calculate fishing mortality and movement rates for this pelagic shark species. In 2014, an additional 220 sharks were tagged bringing the total to over 3,600 with over 280 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 Channel's 'Swords: Life on the Line,' a series documenting the lives of commercial longline fishermen.

Figure 5.9. 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

Figure 5.10. Tagging a juvenile sandbar shark during the NEFSC COASTSPAN Program Survey.
Source: W. David McElroy / NMFS photo.

through longline and gillnet sampling and mark-recapture data (see Figure 6.10). In 2014, our COASTSPAN participants were the Massachusetts Division of Marine Fisheries (MDMF), Stony Brook University, Virginia Institute of Marine Science, North Carolina Division of Marine Fisheries, South Carolina Department of Natural Resources, Georgia Department of Natural Resources, and the University of North Florida. MDMF staff also conducts a survey in the U.S. Virgin Islands using COASTSPAN gear and methods. The NEFSC staff conducts the survey in Narragansett and Delaware Bays. 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 2014, data from these COASTSPAN surveys were provided to NMFS Highly Migratory Species Management Division for use in a 5-year review of Essential Fish Habitat designations for all managed shark species. Additionally, data from the COASTSPAN survey conducted in Delaware Bay were used to produce indices of abundance for Atlantic smooth dogfish that were presented in a working paper at the SEDAR Data Workshop in May 2014 (McCandless 2014b).

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

Habitat Utilization and Essential Fish Habitat of Sand Tiger Sharks

Funding was received in 2006 through the 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. Despite their small size and young age, the available tagging data revealed that juvenile sand tigers undergo extensive seasonal coastal migrations along the US east coast. Individual tagged sharks were observed to travel distances of approximately2,500 kilometers over a 4 to 5 month period from October to February; migrating from as far north as northern New England south to central Florida before returning north the following spring (April to May). In general, two distinct migratory periods (northward: April to June; southward: October to January) were apparent throughout a calendar year, when sharks moved along the coastline (in less than 80 meters of water) between summer and winter habitat. Depth data obtained in this study suggest that juvenile sand tigers follow coastal bathymetric contours throughout their extensive coastal migration. Temperature preferences exhibited by juvenile sand tigers in this study were very similar to those reported for sub-adult and adult sand tigers throughout their range. Off the East Coast of the US, juvenile sand tigers experienced temperatures ranging from 9.8 to 24.2˚C, spending the majority of their time (91 to 99 percent) between 10.0 and 20.0˚C. The data from this study was contributed to a larger study conducted by our grant partner from Massachusetts Division of Marine Fisheries and the combined results led a publication on movement patterns of juvenile sand tigers along the east coast of the United States (Kneebone et al. 2014).

Essential Fish Habitat (EFH) Designations

NEFSC staff participates on a working group with others from the NMFS HMS Management Division and SEFSC to update and refine the EFH designations for managed shark species. This process was ongoing in 2014 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. Additionally, staff provided updates to previously supplied data and results from ongoing research for the NMFS HMS Management Division 5-year review of Essential Fish Habitat Designations for all managed shark species, and provided reviews of the draft document.

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.

Figure 5.11. Blue shark ready to be tagged and released.
Source: Lisa J. Natanson / NMFS photo.

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.

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, as well silky, dusky, sandbar, and longfin mako shark species.

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 percent. Blue sharks made frequent trans-Atlantic crossings from the western to eastern regions, and were shown to move between most areas; the mean distance traveled was 857 kilometers, 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 (1990s) 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 percent 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 Program began tagging spiny dogfish in the Gulf of Maine, Southern New England, and Georges Bank regions in 2011. This project aims to answer long-standing questions about stock structure, movement patterns, and life history to update and improve spiny dogfish stock assessments. Over a 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, 891 have been recaptured through 2014. Some tagged dogfish were injected with oxytetracycline (OTC) for an age validation study. As of 2014, 150 fish that were OTC injected have been recaptured and returned to the NEFSC for age validation.

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. 30 samples of mature females will be obtained and dissected each month and sampling will continue for two years. By the end of 2014, a year and a half of sampling was accomplished; all months except October were sampled for the first year.

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. NEFSC staff in cooperation with staff from Greater Atlantic Regional Fisheries Office, Southeast Fisheries Science Center, Massachusetts Division of Marine Fisheries and the Florida Museum of Natural History published a study on white sharks in the Northwest Atlantic that provides an optimistic outlook for their recovery (Curtis et al. 2014). This study built upon previously published data combined with recent unpublished records to present a synthesis of 649 confirmed white shark records compiled over a 210-year period (1800-2010) and is the largest white shark dataset yet compiled for the Northwest Atlantic. Descriptive statistics and GIS analyses were 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.

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 submitted for publication in the Journal of Heredity in 2014.

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 (Hamady et al. 2014). Age estimates were up to 40 years old for the largest female, fork length (FL): 526 centimeters, and 73 years old for the largest male (FL: 493 centimeter). These results dramatically extend the maximum age and longevity of white sharks compared to earlier studies, and hint at possible sexual dimorphism in growth rates. Using the validated work as a basis to age the species, the ageing work was completed in 2014 and a manuscript was submitted for publication in Marine and Freshwater Research.

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 centimeters FL and females ranged from 62 to 263 centimeters 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 centimeters FL, and estimated median size at maturity was 188 centimeters 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 centimeters FL; the estimated median size at maturity was 216 centimeters 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 centimeters FL) for males and 24 years (244 centimeters FL) for females. The growth of both sexes was similar until approximately age 8 (185 centimeters FL), after which male growth slowed. The growth of females slowed at a later age (approximately 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 centimeters FL) provided the best fit for the band counts (asymptotic length [$L\infty$] = 225.4 centimeters FL; growth coefficient [k] = 0.17). For females, the standard three-parameter von Bertalanffy growth model provided the best fit to the band counts ($L\infty$ = 274.5 centimeters FL; k =0.09; theoretical age at a length of zero [$t0$] = −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 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. In 2014, the results were obtained and used to re-age the common thresher shark. A draft manuscript detailing the results was produced for future publication.

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 centimeters TL (50 percent maturity was estimated to be 83.6 centimeters TL). Females mature between 113 and 123 centimeters TL (50 percent maturity was estimated to be 120.9 centimeters 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 centimeters 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 (less than 70 centimeters TL; less than 2.0 kilograms 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 millimeters 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 millimeters L_T for males, and occurs at age 9 years and 540 millimeters 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 2,213 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 meter 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 (mtCR) 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. 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 centimeters 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.

Sand Tiger (Carcharias taurus)

There is a great deal of ambiguity in the age and growth data of sand tiger. 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 were processed for bomb radiocarbon analysis in an effort to validate growth band periodicity and longevity in the species (Passerotti et al. 2014). 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. Validated lifespan for *C. taurus* individuals in this study reached at least 40 years for females and 34 years for males.

Basking Shark (Cetorhinus maximus)

Age and growth of the basking shark was examined using vertebral samples from 13 females (261 to 856 centimeters TL), 16 males (311 to 840 centimeters TL) and 11 specimens of unknown sex (376 to 853 centimeters 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 to 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 centimeters FL, Lo=85.5 centimeters, 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 conjunction with Doug Adams of the Florida Fish and Wildlife Conservation Commission, age and growth of the bull shark was completed (Natanson et al. 2014) using 121 vertebral samples collected between 1966 and 2010 in the western North Atlantic Ocean. The maximum age based on vertebral band pair counts was 25 (184 centimeters FL) and 27 (196 centimeters FL) years for males and females, respectively. The logistic (male: *asymptotic FL* = 204.8 centimeters, *growth coefficient* = 0.163 yr^{-1}) and Gompertz (female: *asymptotic FL* = 215.1 centimeters, *growth coefficient* = 0.154 yr^{-1}) growth models fitted the size-at-age data best for males and females, respectively. Based on previously published estimates of length at maturity, males mature at 15-17 years (176 - 185 centimeters FL) and females at 15 years (189 centimeters FL).

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.

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 percent) than in the inshore sample (45 percent), but the volume of stomach contents in those with food was higher inshore (0.6 percent body weight (BW) versus 0.4 percent BW). Season also played a significant role in the diet. The lowest percentage empty (9.6 percent), the largest average stomach content volume (0.8 percent 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 percent of the current diet by weight and 86.9 percent 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 percent of their body weight per day to fulfill energetic demands. The daily energetic requirement was broken down by using calculated energy content for the current diet of 4909 kilojoules per kilogram. Based on the proportional energy of bluefish in the diet by weight, an average shortfin mako could consume roughly 500 kilograms of bluefish per year off the northeast coast of the United States.

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.

Figure 5.12. Juvenile sandbar shark on NEFSC COASTSPAN Survey bottom longline. Source: NMFS photo.

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 (greater than 3.3 percent 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 percent) 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 kilometers) varied, though 68 percent 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.

Smooth Dogfish (Mustelus canis)

Quantitative ontogenetic, sexual, and monthly differences in food habits and feeding patterns of smooth dogfish were examined in Delaware Bay with 98 percent of the stomachs containing food with an average of eight 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 is 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 young of the year (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

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, 4,906 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. 98 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 entitled, 'Corkscrew Killer.'

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 2014, information was received on 5,000 tagged and 600 recaptured fish bringing the total numbers tagged to 249,000 sharks of more than 50 species and 15,000 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 percent observer coverage on the recreational boats and observers alternatively using each tag type and recording tag data, release condition, and total catch and effort. This will allow an initial evaluation of these tags by getting feedback from the participants on how easy each tag is to handle, how well they stay on the tagging needle, and how easily the dart head penetrates the shark skin. This feedback on tag use and subsequent recaptures will enable us to begin to evaluate these tag types for future use.

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

The NEFSC Integrated Mark-Recapture Database System (I-MARK) provides a platform to keep multi-species tagging program data in a common format for management and analysis. Initiated by the Cooperative Research Program, the database design and application were developed collaboratively by the shark, yellowtail flounder, black sea bass, and scup tagging programs and Data Management Systems. A web application is used for data input and quality control. I-MARK was designed to track fish and tags independently. It consists of several web application modules including inventory of tags, initial release events, subsequent recapture events, bulk data entry of cruise releases, contact name and address information, map display, reports and statistical queries. Fate of animal, fate of tag, double tags, and multiple recaptures can be accommodated within the database. Extensive quality control is achieved using the web application to enter and maintain the I-MARK data. These audits can be applied to data for all fisheries or a specific fishery and encompass standard audits such as checking data type, land locations, and allowable values as well as more complex validations which check relationships between the fate of animal, fate of tag and event type. A constituent release recapture letter is generated by the web application with a map, size, location, time at liberty and distance traveled information. 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 kilometers) and vertical (surface to 1,300 meters) 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 meters of the water column. In the late fall and winter months, some of the porbeagles moved to mesopelagic depths (200-1,000 meters). 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 percent) were males and 1,758 (40 percent) were females resulting in a 1:0.67 male: female sex ratio. The largest measured male and female fish were 109.2centimeters and 114centimeters FL, respectively. The mean fork length for both males and females and overall was 71 centimeters. A total of 77 sharks were recaptured from 1969 through 2012 with an overall recapture rate of 1.7 percent and mean distance traveled of 103 nautical miles. Young of the year had the highest displacement (187 nautical miles) relative to the other life-stages (juvenile, 140 nautical miles; mature, 83 nautical miles). The Atlantic sharpnose shark at liberty the longest was 7.3 years and was recaptured 70 nautical miles from its original tagging location. The longest distance traveled was 570 nautical miles 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 percent of the total number of sharks tagged.

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 percent) were males and 3,004 (76 percent) were females resulting in a 1:3.22 male: female sex ratio. The largest measured male and female bonnetheads were 122centimeters FL and 135centimeters FL, respectively. The mean fork length for both males and females was 60.4 and 77.3centimeters FL, respectively and overall was 73.2centimeters FL. A total of 172 sharks were recaptured from 1972 through 2012 with an overall recapture rate of 4.2 percent and mean distance traveled of 10.0 nautical miles. Young of the year had the highest mean displacement (32 nautical miles) relative to the juvenile and mature sharks (11 nautical miles and 6 nautical miles, respectively). The bonnethead at liberty the longest was 7.0 years (2,572 days) and was recaptured 1 nautical mile from its original tagging location off the coast of South Carolina. The longest distance traveled was 301 nautical miles 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.

Figure 5.13. Tagged blacktip shark on NEFSC Coastal Shark Bottom Longline Survey. Source: NMFS photo.

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 (sample size of 33 individuals) 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.

Smooth Dogfish (Mustelus canis) Movement Patterns

Off the US Atlantic coast, the smooth dogfish is an abundant coastal species, commonly distributed in bays and inshore waters from Massachusetts to Florida on the east coast of the US with Cape Cod and Nantucket Shoals as a boundary to their dispersal northward. This species has only been caught as an occasional stray in Massachusetts Bay, the Gulf of Maine, and Passamaquoddy Bay at the mouth of the Bay of Fundy. Smooth dogfish mark/recapture data from the Cooperative Shark Tagging Program were summarized with 1,134 sharks tagged and 37 of these tagged sharks recaptured, yielding a total of 1,171 smooth dogfish capture locations between 1963 and 2013 (Kohler et al. 2014). Smooth dogfish were tagged from the Gulf of Maine to the Gulf of Mexico within 200 m depth throughout their range. Females were caught more often than males, resulting in a male to female sex ratio of 1:3.2. The largest smooth dogfish was estimated as a 130 centimeters FL female. Capture locations for mature females and YOY overlap off Long Island NY, in Delaware and Chesapeake Bay, and along coastal North Carolina. Maximum displacement distance was 460 nautical miles with distance traveled increasing with increasing FL for the 12 fish at liberty less than 1 year. Seasonal changes in tagging locations were evident. This north-south seasonal migration pattern is further revealed by recaptures at liberty for less than one year with movements between Cape Cod, MA and North Carolina. Overall, none of the smooth dogfish moved between the Atlantic and Gulf of Mexico.

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

This ongoing cooperative research is directed toward coastal and pelagic shark species caught on recreational and commercial fishing gear. This work is collaborative with researchers from Massachusetts Division of Marine Fisheries (MDMF) and many other state and academic institutions. These studies use blood and muscle sampling methods, including hematocrit, plasma ion levels, and red blood cell counts, coupled with acoustic tracking and 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.

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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 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