Status Review Report: Northwest Atlantic Dusky Shark (*Carcharhinus obscurus*)

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INTRODUCTION

Scope and intent of the present document

The Status Review Team (SRT) was tasked with preparing this status review report for the northwest Atlantic (NWA) population of dusky sharks, *Carcharhinus obscurus*. This report was developed to assist the National Marine Fisheries Service in making its listing determination in response to petitions[1,2] to list the dusky shark as threatened or endangered under the Endangered Species Act (ESA). A positive 90-day finding (78 FR 29100, May 17, 2013) determined the petitions presented substantial information indicating that listing may be warranted for the NWA population of dusky shark but not for the global population.

LIFE HISTORY AND ECOLOGY

Taxonomy and distinctive characteristics

The dusky shark is classified as a requiem shark within the family Carcharhinidae. This family falls under the largest order of sharks, Carcharhiniformes, also known as ground sharks. Dusky sharks, like many requiem sharks, appear gray or bluish-gray in color dorsally and white ventrally. The sharks within the genus *Carcharhinus* also have an internal nictitating eyelid, lack a spiracle, have a second dorsal fin that is less than half the height of the first, well-developed pre-caudal pits, and a heterocercal caudal fin (Castro 2011). The dusky shark has a clearly visible interdorsal ridge and a second dorsal fin with a free tip that is rarely more than twice the fin height (Schulze-Haugen and Kohler 2003). The first dorsal is sloping and originates over the free tips of the pectoral fins or slightly before the free tips (Garrick 1982, Compagno 1984). This species has a broadly rounded snout that is the same size or smaller than the width of the mouth (Castro 2011). The upper teeth are triangular with coarsely serrated edges and are slightly oblique except for the first one or two series on each side of the symphysis. The lower teeth are nearly erect, narrowly cusped, and more finely serrated than the upper teeth (Garrick 1982, Compagno 1984).

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[1]WildEarth Guardians to US Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service, November 9, 2012, “Petition to list the dusky shark (*Carcharhinus obscurus*) under the US Endangered Species Act”

[2]Natural Resources Defense Council to US Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service, February 1, 2013, “Petition to list northwest Atlantic dusky shark (*Carcharhinus obscurus*) as threatened under the US Endangered Species Act”

Distribution and habitat use

Dusky sharks are coastal-pelagic sharks occurring in temperate and tropical waters worldwide ranging from the surf zone, across continental and insular shelves, and adjacent oceanic waters from the surface down to 400 m depth (Compagno 1984). In the NWA, dusky sharks range from off Cape Cod, Massachusetts and Georges Bank to Florida and the Gulf of Mexico (GOM) and Caribbean Sea (Kohler et al. 1998, Kohler and Turner 2010). This species does not use waters with reduced salinities and rarely enters estuarine environments (Compagno 1984, Musick et al. 1993). Small juveniles use nearshore coastal waters as nursery habitat in the NWA from off New Jersey to South Carolina during the summer months (Castro 1993, McCandless et al. 2007, NMFS unpublished data).

The dusky shark is a highly migratory species (HMS) that begins moving north during the spring and returns south during the fall months, often traveling to the extents of its range during these seasonal migrations (Compagno 1984, Musick and Colvocoresses 1986, Kohler et al. 1998, Kohler and Turner 2010). Mark/recapture data (number tagged = 8776 and recaptures =181) from the NMFS Cooperative Shark Tagging Program between 1963 and 2013 show a maximum straight-line distance traveled of 2052 nautical miles (nm), with a mean distance traveled of 572 nm for dusky sharks tagged in the NWA (Kohler and Turner 2010, NMFS unpublished data). All dusky sharks were tagged in United States (US) waters (Atlantic and GOM), with the majority tagged in the Atlantic. Movements between the US Atlantic and GOM, as well as between the US GOM and the Mexican Gulf waters were common, but there were no recaptures in the southwest Atlantic and only one recapture off Central America (Barra de Colorado, Costa Rica) in the Caribbean Sea, which came from a shark originally tagged 45 nm southeast of Montauk Point, New York (Kohler and Turner 2010, NMFS unpublished data).

Mark/recapture data for the dusky shark markedly differ from those of more pelagic species, such as the shortfin mako, *Isurus oxyrinchus* (Kohler et al. 1998). The NMFS CSTP database contains 8619 tagged shortfin makos, similar to the number of dusky sharks (8776) over the same time period, but a total of 1172 shortfin makos have been recaptured to date with much offshore movement and some trans-Atlantic migrations (NMFS unpublished data). The low number of dusky shark recaptures in comparison may in part be attributed to post-release mortality. However, given the prohibited status of the species in domestic fisheries, reduced recapture reporting may also play a role. A high percentage of CSTP high seas recaptures are reported by foreign vessels.

Dusky shark satellite tagging data (N=10, with 6-124 day tag deployment durations) from an aggregation site in the north central GOM during the summer months, revealed dusky shark movements in excess of 200 kilometers (km, 108 nm, Hoffmayer et al. 2014). These sharks primarily used offshore GOM waters associated with the continental shelf edge, spending 87 % of their time at 20 to 125 m and 23 to 30° C (Hoffmayer et al. 2014). Carlson and Gulak (2012) also tracked 3 dusky sharks off the US Atlantic coast with pop up satellite tags and found that these sharks spent just over 70% of their time at depths between 0 to 40 m but dove to depths of 400 m. These sharks spent nearly 60% of their time in water temperatures between 20 to

24°C. The dusky sharks generally traveled about 10 km per day. Two of the sharks were tagged near Key Largo, FL, with one shark tagged in January traveling north to the North Carolina/Virginia border by June and the other tagged in March heading south towards Cuba two weeks later (Carlson and Gulak, 2012). The third dusky shark was tagged off North Carolina in March and the tag popped off early, three days after tagging, not far from the initial tagging site.

The dusky shark is an apex predator with a high trophic level (4.2) and diverse diet including teleosts, cephalopods, elasmobranchs, decapod crustaceans, mollusks, and occasionally marine mammals (Cortés 1999). Juveniles primarily consume pelagic teleosts and cephalopods with an increase in the consumption of elasmobranch prey as their body size increases (Gelsleichter et al. 1999, Simpfendorfer et al. 2001). Stable isotope analysis has also shown a shift to shelf edge foraging in large dusky sharks (Hussey et al. 2011).

Genetics

Genetic data can be used to provide information on a species' range as well as stock structure. Global phylogeographic studies of the dusky shark using maternally inherited mitochondrial DNA and nuclear microsatellite DNA analyses detected significant differentiation between dusky sharks from the NWA and Indo-Pacific regions (Benavides et al. 2011, Gray et al. 2012). Within the NWA there was no evidence of differentiation found between dusky sharks from waters off the US east coast and the GOM (Benavides et al. 2011), as supported by tagging data (Kohler et al. 1998, Kohler and Turner 2010). There is some qualitative evidence of population structure between the NWA dusky sharks and dusky sharks caught off Brazil. The most common haplotype from Brazil is intermediate to the NWA and Indo-Pacific haplotype clusters, indicating this region may have provided a historical connection between the NWA and Indo-Pacific regions (Benavides et al. 2011). Despite the history of severe population declines in the NWA, dusky sharks from all regions showed remarkably similar allelic richness and gene diversity (Gray et al. 2012).

The low nucleotide diversity for the dusky shark and the existence of a morphologically and genetically similar species (Galapagos shark, *Carcharhinus galapagensis*) indicate that the dusky shark is recently derived (Naylor 1992, Musick et al. 2004, Benavides et al. 2011). An ongoing genetic study using mitochondrial DNA sequencing has found that specimens identified as Galapagos sharks from oceanic islands in the NWA are indistinguishable from specimens identified as dusky sharks collected off the US east coast from New Jersey to Florida (Gavin Naylor, College of Charleston, personal communication, 2014). These findings could possibly be attributed to an ancient hybridization event where there has been a directional transfer of mitochondrial genes from one species to another. Alternatively, they could represent two forms of the same species, an offshore and an inshore form. Work continues on this using a wider global sampling scheme and multiple nuclear markers to address the possibility that the observed pattern might be the consequence of an ancient hybridization event.

CSTP mark/recapture data for the Galapagos shark primarily shows movements around Bermuda in the NWA (Kohler et al. 1998, NMFS unpublished data). However, there are three Galapagos sharks tagged off Bermuda that were recaptured within the range of the NWA dusky shark. Two were recaptured off North Carolina, and one off Cuba. Whether or not these two species have the ability to interbreed (i.e. timing and location of opposite sexes ever co-occur during mating season), or if they would produce viable offspring is unknown.

Reproduction and growth

The dusky shark is a placental, viviparous species, giving birth to between 2 and 16 pups per litter (Compagno 1984, Romine et al. 2009, Castro 2011) with an average litter size of 7.13 pups based on a recent study in the NWA (Romine et al. 2009). Size-at-birth for dusky sharks ranges from 85-100 centimeters (cm) fork length (FL, Castro 1983, Compagno 1984). Available data on reproduction suggests a 3-year reproductive cycle (Castro 2009, Romine et al. 2009) with a gestation period of 18 months (Castro 2009). Female and male size at maturity in the NWA is 235 and 231 cm FL (17.6 and 17.4 years of age), respectively (Natanson et al. 1995, Natanson et al. 2013). Maximum validated age estimates are between 38 and 42 years, confirming longevity to at least 42 years of age (Natanson et al. 2013). Logistic growth parameters derived from validated vertebral length-at-age data are L_∞ = 261.5 cm FL, L_o = 85.5 cm FL, t_o = 4.89 years and g = 0.15 year^{-1} for the sexes combined (Natanson et al. 2013). Dusky sharks show annual band pair formation up to approximately 11 years of age based on bomb radiocarbon dating. Annual band pair counts beyond this time frame considerably underestimate true age (Natanson et al. 2013). This may be attributed to slower growth in older individuals making it difficult to identify band pairs at the growing edge, decreased or absence of band pair deposition in mature individuals, or deposition related to somatic growth and reproduction rather than seasonal cues (Natanson and Cailliet 1990, Natanson 1993, Francis et al. 2007, Natanson et al. 2008, Natanson et al. 2013)

FISHERIES AND ABUNDANCE

Historical US Atlantic fisheries

This information is taken from Amendment 2 to the US 2006 Consolidated Atlantic HMS Fishery Management Plan (FMP, NMFS 2007). In response to demand for vitamin A, obtained from shark livers, a shark fishery developed off the east coast of Florida, in the GOM, and in the Caribbean Sea during the late 1930s (Wagner 1966). The development of synthetic vitamin A caused most shark fisheries to be abandoned by 1950 (Wagner 1966). In the late 1970s, a shark fishery developed rapidly once again, this time due to increased demand for their meat, fins, and cartilage worldwide. At the time, sharks were perceived to be underutilized as a fishery resource. The high commercial value of shark fins led to the controversial practice of "finning," or removing the valuable fins from sharks and discarding the carcasses, during this time. Growing demand for shark products encouraged expansion of the commercial fishery throughout the late 1970s and the 1980s. Tuna and swordfish vessels began to retain a greater proportion of their shark incidental catch and some directed fishery effort expanded as well. As catches accelerated through the 1980s, shark stocks started to show signs of decline.

Current US Atlantic fisheries

The dusky shark has been designated as a prohibited species since 2000, following the implementation of the 1999 Fishery Management Plan for Atlantic Tunas, Swordfish and Sharks (NMFS 1999). Much of the following information is taken from the 2013 Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic HMS (NMFS 2013a).

Pelagic Longline

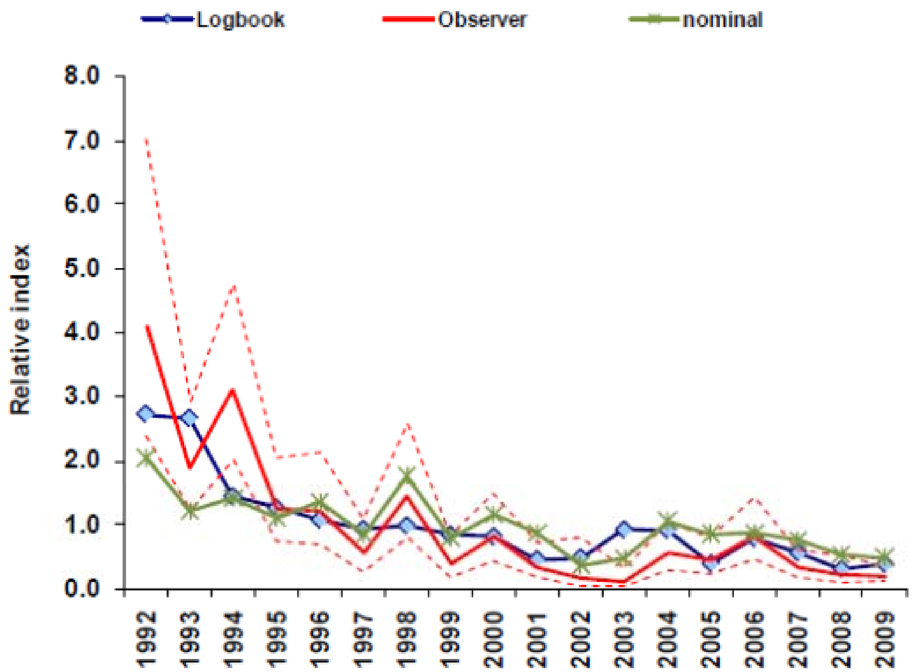
The pelagic longline fishery for Atlantic HMS primarily targets swordfish, yellowfin tuna, and bigeye tuna in various areas and seasons. Secondary target species include dolphin fish, albacore tuna, and, to a lesser degree, sharks. The primary fishing line, or mainline, of the pelagic longline gear can vary from 5 to 40 miles in length, with approximately 20 to 30 hooks per mile. The US pelagic longline fishery has historically been comprised of five relatively distinct segments with different fishing practices and strategies. These segments are: 1) the GOM yellowfin tuna fishery; 2) the South Atlantic-Florida east coast to Cape Hatteras swordfish fishery; 3) the Mid-Atlantic and New England swordfish and bigeye tuna fishery; 4) the US distant water swordfish fishery; and, 5) the Caribbean Islands tuna and swordfish fishery. The pelagic longline is a heavily managed gear type and is strictly monitored. Landings and dead discards of sharks by US pelagic longline fishermen in the Atlantic are monitored annually and reported to ICCAT. From 1992 to 2000, elasmobranchs represented 15% of the total catch by the pelagic longline fishery, with dusky sharks comprising 14.7% of the shark bycatch (Beerkircher et al. 2002). Analysis of reported dusky shark catches from pelagic longline logbook and observer data from 1992-2009 showed similar trends, marked by an initial decrease in the 1990s followed by a more stable trend through the 2000s (Figure 1, Cortés 2010).

Bottom Longline

Bottom longline gear is the primary commercial gear employed for targeting large coastal sharks (LCS) in all regions. Small coastal sharks (SCS) are also caught on bottom longline gear. Gear characteristics vary by region and target species, but in general, bottom longline gear consists of a mainline between 3 and 8 km (1.8 – 5 miles) long with 200-400 hooks attached and is set for 2 to 20 hours. Depending on the species being targeted, both circle and J hooks are used. Fishermen targeting sharks with bottom longline gear are opportunistic and often maintain permits for Council managed fisheries such as reef fish, snapper/grouper, tilefish, and other teleosts. Minor modifications to how and where the gear is deployed allow fishermen to harvest sharks and teleosts on the same trip.

Since 2002, shark bottom longline vessels are required to take an observer if selected; however, observations of the shark-directed bottom longline fishery in the Atlantic Ocean and GOM have been conducted since 1994. From 2005 to 2009, 879 sets were observed in the GOM and southern Atlantic Ocean, with 8.2% of sets (n = 72) catching a total of 192 dusky sharks.

Figure 1. Standardized CPUE (in number) and 95% confidence intervals (dashed lines) for dusky sharks from the pelagic longline observer program compared to the pelagic longline logbook. All indices are standardized to the mean of the overlapping years. The green line is the nominal observer time series (Source: Cortés 2010).



Gillnet Fishery

Since the implementation of Amendment 2 to the Consolidated Atlantic HMS FMP (NMFS 2007), the directed LCS gillnet fishery has been greatly reduced. The 33-head LCS trip limit has essentially ended the strike net fishery and limited the number of fishermen targeting LCS with drift gillnet gear. As a result, many gillnet fishers that historically targeted sharks are now targeting teleost species such as Spanish mackerel, king mackerel, and bluefish. Vessels participating in the Atlantic shark gillnet fishery typically possess permits for other Council and/or state managed fisheries and will deploy nets in several configurations based on target species including drift, strike, and sink gillnets. In 2012, 316 sets comprising various gillnet fisheries were observed. A total of 2 drift gillnet vessels were observed making 10 drift sets on 5 trips in 2012. A total of 5 strike gillnet fishery vessels were observed making 6 strike sets on 6 trips in 2012. During the strike gillnet trips, no dusky sharks were observed on trips that targeted king mackerel in 2012. A total of 62 trips making 300 sink net sets on 18 vessels were observed in 2012. Only one dusky shark was caught during an observed sink net trip targeting smoothhound in 2012 (Mathers et al., 2013).

Commercial Handgear

Commercial handgears, including handline, harpoon, rod and reel, buoy gear and bandit gear, are used to fish for Atlantic HMS by fishermen on private vessels, charter vessels, and headboat vessels. Rod and reel gear may be deployed from a vessel that is at anchor, drifting, or underway (*i.e.*, trolling). However, the shark commercial handgear fishery contributes very little to the overall shark landings.

Commercial Fishery Data: Landings by Species

Tables 1 and 2 show domestic commercial landings of Atlantic LCS, compiled from the most recent stock assessment documents and updates provided by the NMFS Southeast Fishery Science Center (SEFSC).

Table 1. 2008-2012 Commercial Landings of Large Coastal Sharks in the Atlantic Region in pounds (lb) dressed weight (dw). Source: NMFS 2013a.

Large Coastal Sharks	2008	2009	2010	2011	2012
Basking[2]	0	0	0	0	0
Bignose[1]	0	0	0	0	0
Bigeye sand tiger[2]	0	0	0	0	0
Blacktip	258,035	229,267	246,617	176,136	215,403
Bull	43,200	61,396	56,901	49,927	24,504
Caribbean reef[1]	0	0	0	0	0
Dusky[1]	0	0	0	14	172
Galapagos[1]	0	0	0	0	0
Hammerhead, great	0	0	0	0	371
Hammerhead, scalloped	0	0	0	0	15,800
Hammerhead, smooth	0	4,025	7,802	110	3,967
Hammerhead, unclassified	21,631	62,825	43,345	35,618	9,617
Lemon	22,530	30,909	25,316	45,448	21,563
Narrowtooth[1]	0	0	0	0	0
Night[1]	0	0	0	0	0
Nurse	10	0	71	0	81
Sandbar	63,035	54,141	84,339	94,295	46,446
Sand tiger[2]	0	0	18	20	66
Silky	306	1,386	1,049	992	29
Spinner	1,265	20,022	13,544	4,113	10,643
Tiger	14,119	15,172	43,145	36,425	23,245
Whale[2]	0	0	0	0	0
White[2]	117	0	0	0	0
Unclassified, assigned to large coastal	187,670	70,894	2,229	50,711	53,705
Unclassified LCS fins	26,707	33,173	20,545	21,535	15,370
Total, excluding fins	611,918 (278 mt dw)	550,037 (249 mt dw)	524,376 (238 mt dw)	493,809 (224 mt dw)	425,612 (193 mt dw)

[1] Prohibited in the commercial fishery as of June 21, 2000. [2] Prohibited as of April 1997.

Table 2. 2008-2012 Commercial Landings of Large Coastal Sharks in the GOM Region in lb dw (Source: NMFS 2013a)

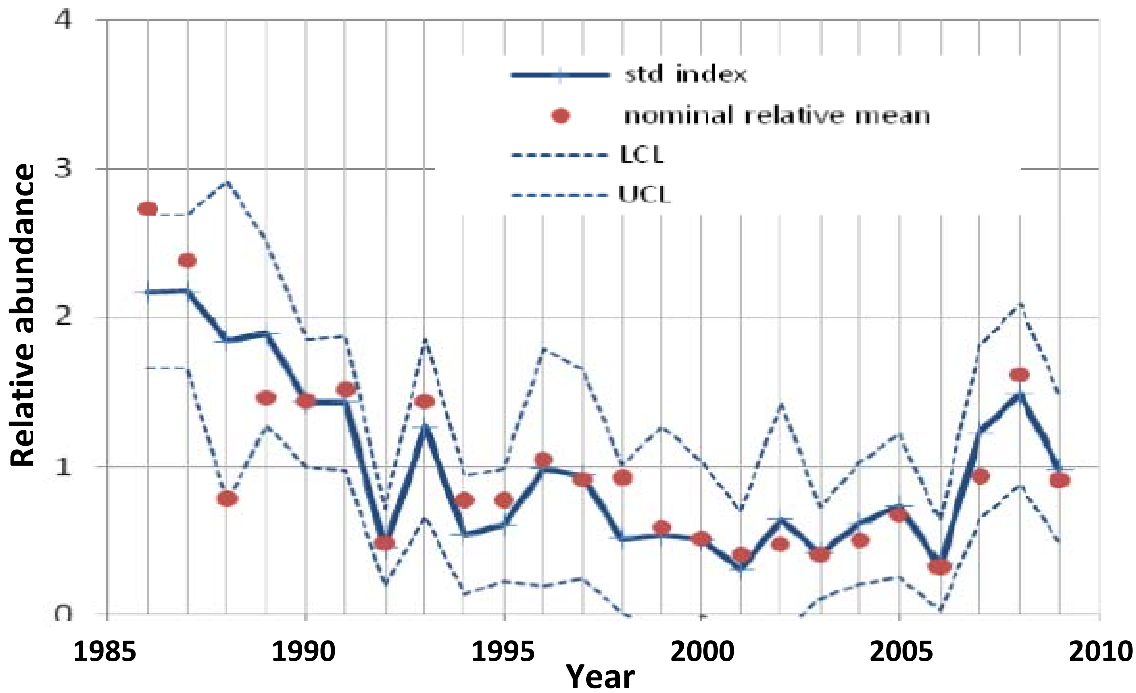
Large Coastal Sharks	2008	2009	2010	2011	2012
Basking[2]	0	0	0	0	0
Bignose[1]	0	0	0	0	109
Bigeye sand tiger[2]	0	0	0	0	0
Blacktip	326,280	374,573	654,942	384,662	405,015
Bull	144,356	150,094	165,894	178,595	255,892
Caribbean reef[1]	0	0	0	0	0
Dusky[1]	0	0	0	0	0
Galapagos[1]	0	0	0	0	0
Hammerhead, great	156	1,430	6,339	49	99
Hammerhead, scalloped	0	0	0	0	33,216
Hammerhead, smooth	0	0	0	0	0
Hammerhead, unclassified	35,332	95,678	51,149	68,709	8,005
Lemon	30,897	54,984	21,081	38,132	29,362
Narrowtooth[1]	0	0	0	0	0
Night[1]	0	0	0	208	0
Nurse	48	147	0	27	11
Sandbar	26,740	113,717	54,914	46,040	23,854
Sand tiger[2]	0	0	0	0	0
Silky	4,488	4,087	270	643	0
Spinner	122,395	17,028	78,951	66,996	49,647
Tiger	17,089	7,874	8,825	21,594	26,209
Whale[2]	0	0	0	0	0
White[2]	0	0	0	27	0
Unclassified, assigned to large coastal	131,724	163,320	0	169,651	188,566
Unclassified LCS fins	23,938	35,142	45,425	40,768	40,693
Total, excluding fins	839,505 (381 mt dw)	982,932 (446 mt dw)	1,042,365 (473 mt dw)	975,333 (442 mt dw)	1,019,985 (463 mt dw)

[1] Prohibited in the commercial fishery as of June 21, 2000. [2] Prohibited as of April 1997.

Recreational Fisheries

Most Atlantic HMS are targeted by domestic recreational fishermen using a variety of handgear including rod and reel gear. Since 2003, recreational fishing for any managed HMS species requires an HMS Angling permit. The recreational landings database for Atlantic HMS consists of information obtained through surveys such as the Large Pelagics Survey, which covers the waters from off Maine through Virginia. Analysis of reported dusky shark catches from the Large Pelagics Survey data from 1986 to 2009 shows a pattern of declines from the 1980s into the 1990s and a recent pattern of slight increases (Figure 2, Walter and Brown 2010).

Figure 2. Standardized index of abundance for dusky shark catch from the Large Pelagics Survey with approximate 95% confidence intervals (LCL and UCL). Source: Walter and Brown 2010.



Mexican Fisheries in the Gulf of Mexico

Artisanal Fisheries

The Mexican shark fishery is part of a diverse multi-species artisanal fishery (Oviedo 2010, Soriano-Velásquez 2011). The fleet uses both gillnet and longline gear to harvest sharks (Oviedo 2010). Shark landings data are collected by 38 Fishery Offices from 185 sites between the borders of Tamaulipas and Quintana Roo (Figure 3, Castillo-Géniz et al. 1998, Oviedo 2010). There has been an overall decline in Mexican shark landings from Gulf of Mexico fisheries in recent years (Figure 4, Soriano-Velásquez 2011). In addition to past fishing pressure, the recent decline is also thought to be a result of rising fuel costs and shifts to other target species (Soriano-Velásquez 2011). Based on an intensive monitoring study of artisanal shark landings from November 1993 to December 1994, Castillo-Géniz et al. (1998) reported that the Campeche region in the southeastern Gulf had the highest landings and effort, where Bonfil (1997) reported that dusky shark catches are rare. In 2010, Oviedo reported that there were 1813 fishing vessels documented fishing in the Mexican waters of the Gulf of Mexico. Areas with the highest shark landings are currently reported to occur in Veracruz and Tamaulipas (Oviedo 2010), where Bonfil (1997) reported that dusky shark catches were common with the addition of the Yucatan region. There is no known nursery habitat for dusky sharks in Gulf of Mexico waters within Mexico's Exclusive Economic Zone (EEZ). Dusky sharks caught in artisanal fisheries primarily occur as large juveniles or adults >1.5 m total length (Bonfil 1994, Bonfil 1997). A qualitative frequency analysis of landings from the southeastern Gulf of Mexico fisheries showed moderate dusky shark catches in the 1980s followed by low catches in the 1990s and no recorded dusky catches in the 2000s (Perez 2011). Socio-economic research on artisanal fisheries targeting octopus in the region, currently one of the most important commercial species, reports that the artisanal fisheries in general are "stagnant" as many of the fishermen are older and younger people are less attracted to fishing as a career (Excartín 2011). This study also indicates that the decline in shark catches within this region may be partially attributed to fisherman changing their target species to more profitable species such as the octopus, which has increased landings in recent years (Excartín 2011).

Figure 3. Mexican shark fishery grounds in the Gulf of Mexico (Source: Castillo-Géniz et al. 1998)

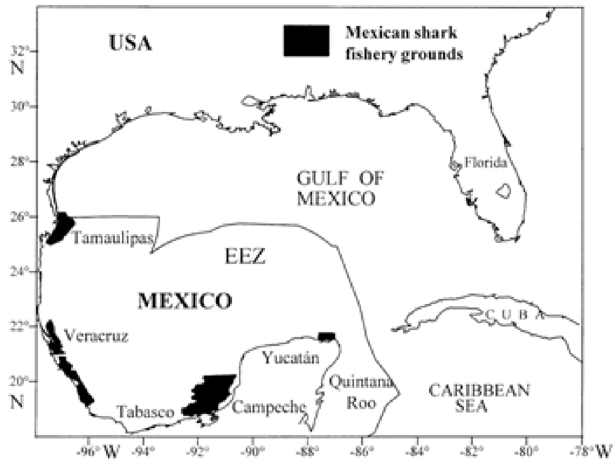
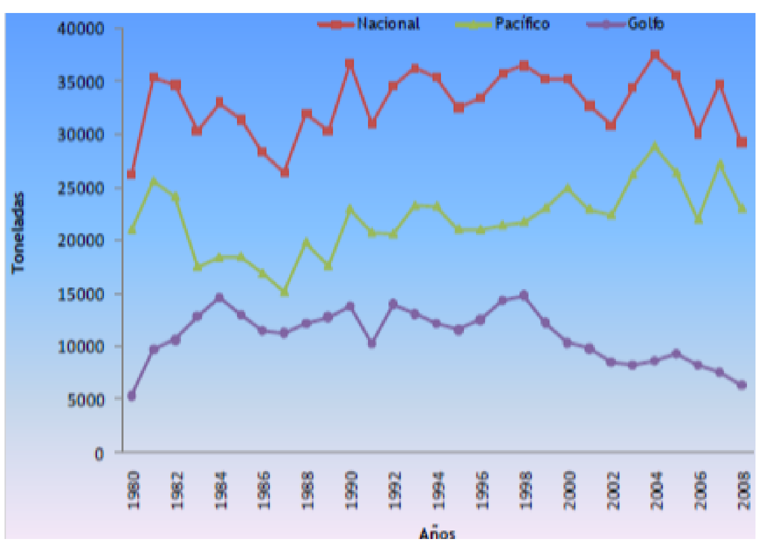


Figure 4. Mexican shark and ray landings by year (Años) in tons (Toneladas). Nacional = National, Pacifico = Pacific, Gulfo = Gulf of Mexico (Source: Soriano-Velásquez 2011)



Pelagic Longline Fishery

The pelagic longline used in the Gulf of Mexico by the Mexican fleet is a selective gear, with yellowfin tuna making up over 70% of the catches (Brown and Ramírez-López 2012). There is 100% observer coverage in this fishery (Xolaltenco-Coyotl et al. 2010, Brown and Ramírez-López 2012). In 2006, shark species made up only 1.4% of the catch by numbers, and no dusky sharks were caught that year (Oviedo 2010). During spring and summer, fleet activity is concentrated in the central, southern, and western portions of the Mexican EEZ and expands into the northern and eastern portions of the Mexican EEZ in the fall and winter (Brown and Ramírez-López 2012). Brown and Ramírez-López (2012) reported fishing effort for this pelagic longline fleet from 1993 to 2006, but zero catch sets (sets when no fish from that set were landed) were only available from 2001 on. Analysis of pelagic longline effort including zero catch sets from 2001 to 2006 shows very little change in effort during this time ($y=30x-58212$, $R^2=0.003$, data from Brown and Ramírez-López 2012).

Illegal Fishing Activity (Brewster-Geisz et al. 2010)

Since the mid-1990s, the United States Coast Guard (USCG) has been aware of Mexican fishing vessels fishing for sharks and other species in the US Exclusive Economic Zone (EEZ) off the coast of Texas. These vessels are usually open fiberglass-hulled with an outboard engine and are approximately 25 to 35 feet in length. Each vessel has a crew of approximately three people. The vessels originate from Matamoros, Mexico, and fish in the area surrounding South Padre Island, Texas, anywhere from zero to twenty miles offshore. These vessels, or lanchas, fish during the day with gillnet and longline gear in US waters for shark and red snapper, which are believed to be more prevalent in the US EEZ off Texas than in the Mexican EEZ near Matamoros. Analysis of detected fishery-related lancha incursions from 2000 to 2009 show an increasing trend at the beginning of the time series which peaked in the mid 2000s followed by a decreasing trend since 2004 ($y=-22.6x+45470$, $R^2=0.81$, data from Brewster-Geisz et al. 2010).

Dusky shark stock assessment (NMFS 2011a)

The dusky shark was assessed through the Southeast Data, Assessment, and Review (SEDAR) process in 2011. The following information is taken from the SEDAR 21 Stock Assessment Report for the Dusky Shark (NMFS 2011a). The SEDAR process is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, GOM, and Caribbean. SEDAR is managed by the Caribbean, GOM, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries, Regional Council, and Interstate Commission representatives. The SEDAR process is organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data

Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products.

Life History Data

The following life history characteristics were recommended by the SEDAR 21 Data Workshop Life History Working Group for dusky sharks given the available data (Table 3):

Table 3. Summary of Dusky Biological Inputs for 2010 Assessment and Sources (Source: NMFS 2011a).

1st year survivorship	male = 0.79, female = 0.765			NMFS 2011a, Section 2.4
Juvenile survivorship	male = 0.81-0.90 , female = 0.78 – 0.885			NMFS 2011a, Section 2.4
Adult survivorship	male = 0.90-0.92, female = 0.89-0.91			NMFS 2011a, Section 2.4
S-R function	Beverton Holt			Cortés et al. (2006)
S-R parameters, priors				
steepness or alpha	0.2-0.3			Cortés et al. (2006), SEDAR21-RD03
Pupping month	May-June			SEDAR21-RD06
Growth parameters	Male	Female	Combined sexes	
L_∞ (cm FL)	373	349	352	Natanson et al. (1995)
k	0.03	0.039	0.040	Natanson et al. (1995)
t_0	-6.28	-7.04	-6.43	Natanson et al. (1995)
Maximum observed age	33, 39			Natanson et al. (1995),P. Turner, p.com.
Sample size	120 total (47 male, 67 female)			Natanson et al. (1995)
Length-weight relationships				
FL in cm	FL = 0.8352 (TL) -2.2973			Natanson et al. (1995)
WT in kg	WT = (3.241510^-5)FL^2.7862			Kohler et al. (1996)
Maturity ogive (sexes combined)	tmat = 20, a= −19.76, b = 0.99			Romine et al. (2009), Natanson et al. (1995)
Reproductive cycle	triennial			Romine et al. (2009), Castro (2009)
Fecundity	7.13 pups (S.D. = 2.06, range 3-12)			Romine et al. (2009)
Gestation	18 months			Castro (2009)
Sex-ratio	1:1			Romine et al. (2009), Castro (2009)
Stock structure	high exchange between Atlantic and Gulf based on tagging data, genetic information suggests one stock			SEDAR21-DW-38, D. Chapman, p.com

Assessment Method

An Age-structured Catch Free Model (ASCFM) was the modeling methodology chosen because of the lack of accurate knowledge of the magnitude of total catches and discards, prohibiting estimates of absolute abundance levels for the population. The ASCFM approach re-scales the model population dynamics as proportional to virgin (unexploited) conditions. The model started in 1960 and ended in 2009, with the historical period covering 1960-1974, the first modern period spanning 1975-1999, and the second modern period spanning 2000-2009. Estimated model parameters were pup (age 0) survival, catchability coefficients associated with indices, a parameter representing the slope of the relationship between pelagic longline effort and fishing mortality for the period 1960-1979, additional variance parameters for each index, relative depletion in 1975, and fishing mortality in the modern periods. Fishing mortality starting in 1980 was modeled using a correlated random walk and so it is not a 'full' parameter. Pup survival was given an informative lognormal prior with median=0.81 (mean=0.85, mode=0.77), a coefficient of variation (CV) of 0.3, and was bounded between 0.50 and 0.99. The minimum spawning stock threshold (MSST), when absolute biomass is estimable, is typically calculated as (1-M)*SSB_{MSY}, with M = natural mortality and SSB_{MSY} = spawning stock biomass at maximum sustainable yield (MSY). Although only relative estimates are possible here (i.e., SSB_{2009}/SSB_{MSY}), it is still possible to calculate SSB_{2009}/SSB_{MSST} as SSB_{2009}/((1-M)*SSB_{MSY}).

Assessment Data

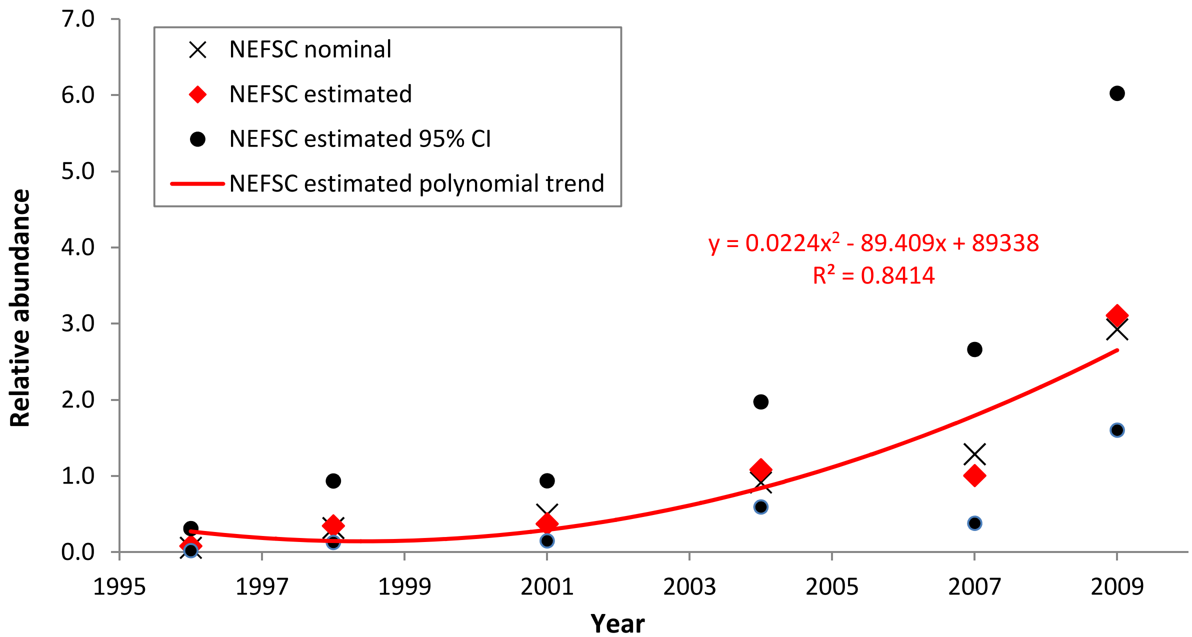
Length-frequency information from animals caught in scientific observer programs, recreational fishery surveys, and various fishery-independent surveys was used to generate age-frequency distributions through age-length keys and generate selectivity curves for different gear types. Life history inputs used in the base model included age and growth, several parameters associated with reproduction, including sex ratio, reproductive frequency, fecundity at age, maturity at age, month of pupping, and natural mortality. The ASCFM uses most life history characteristics as constants and others are estimated parameters, which are given priors and initial values.

Five indices were used in the base model run: two fishery-independent and three fishery-dependent time series. The fishery-independent time series were the Northeast Fishery Science Center (NEFSC) Coastal Shark Bottom Longline Survey (NELL) and the Virginia Institute of Marine Science Shark Longline Survey (VIMS LL) and the fishery-dependent time series were from the commercial bottom longline and pelagic longline observer programs and the Large Pelagics Survey of recreational rod and reel data. Two additional fishery-independent indices were recommended for use in sensitivity runs: the University of North Carolina Shark Longline Survey (UNC LL) and the NEFSC historical longline survey data (NMFS Historical LL). Relative effort series for the three fleets (bottom longline, pelagic longline, and recreational) were used to determine a single, annual weighted selectivity vector for modeling fishing mortality. The fishery-dependent time series were discussed in the Current US Atlantic Fisheries section. Some brief background information on the fishery-independent surveys is provided below.

<u>NEFSC Coastal Shark Bottom Longline Survey (NELL)</u>

The NEFSC Coastal Shark Bottom Longline Survey is conducted by the Apex Predators Program at the NMFS Narragansett Laboratory in Narragansett, RI. The primary objective of this survey is to conduct a standardized, systematic survey of the shark populations off the US Atlantic coast to provide unbiased indices of the relative abundance for species occurring in waters from Florida to the Mid-Atlantic. It also provides an opportunity to tag sharks as part of the NEFSC Cooperative Shark Tagging Program and to collect biological samples and data used in analyses of life history characteristics (age, growth, reproductive biology, trophic ecology, etc.) and other research of sharks in US coastal waters. Data from this survey were used to look at the trends in relative abundance of dusky sharks in the waters off the east coast of the United States from 1996 to 2009. Dusky sharks showed an increasing trend in relative abundance across the time series (Figure 5, McCandless and Natanson 2010).

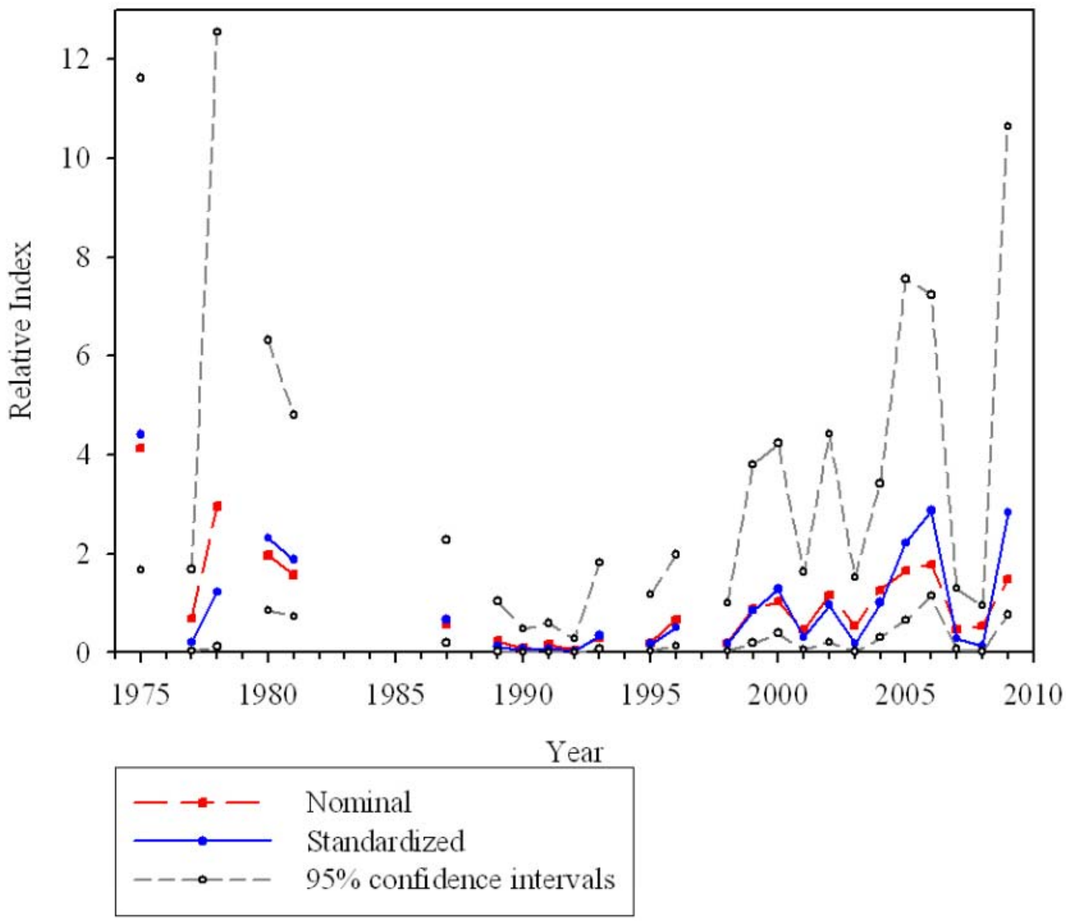
Figure 5. Dusky shark nominal and estimated indices from the NEFSC Coastal Shark Bottom Longline Survey from 1996 to 2009 divided by the mean values with 95% confidence interval (CI) and an estimated polynomial trend line for the NEFSC estimated time series. Source: McCandless and Natanson 2010.



<u>Virginia Institute of Marine Science Shark Longline Survey (VIMS LL)</u>

The VIMS longline survey is a depth-stratified station-oriented field survey of the Chesapeake Bay and coastal waters from Cape Hatteras, NC to Cape Henlopen, DE with most effort taking place in Virginia waters. The gear used was the standard for the commercial longline industry at the beginning of the VIMS program in 1974. Catch rates for dusky sharks decreased from the early 1980s to minima in 1992, then slightly increased and oscillated throughout the remainder of the time series (Figure 6, Romine et al. 2010).

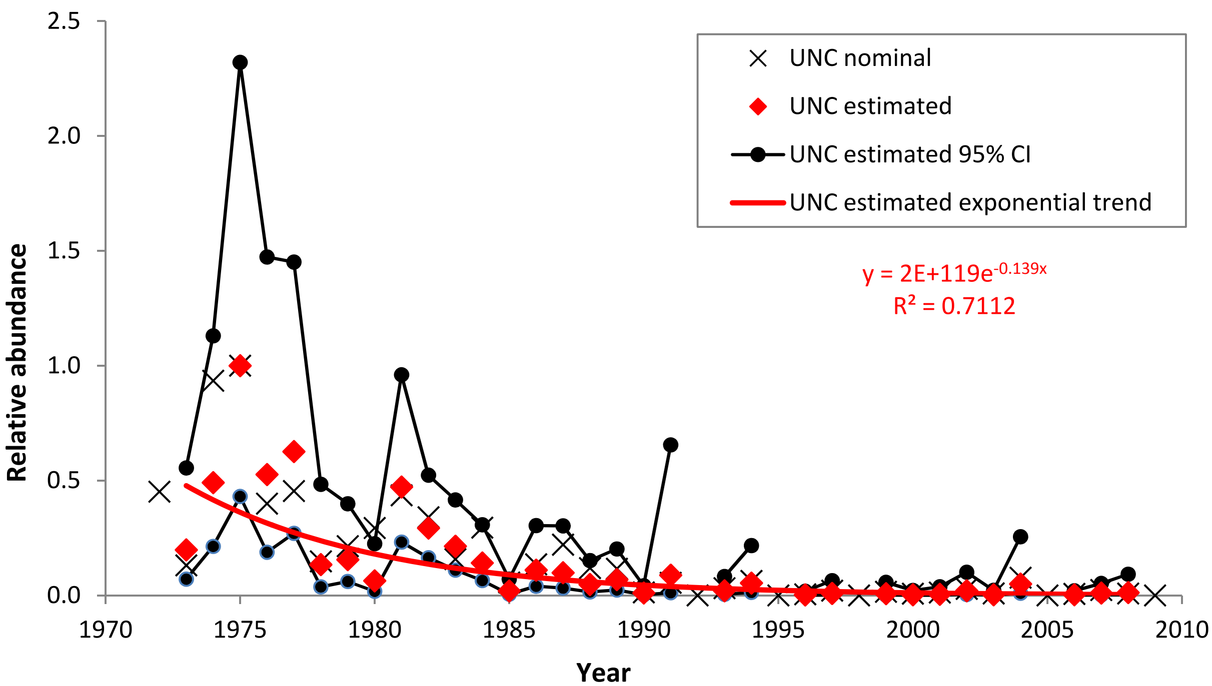
Figure 6. Nominal and standardized abundance indices for dusky sharks caught during the VIMS Shark Longline Survey, indices were divided by their respective mean. Source: Romine et al. 2010.



University of North Carolina Shark Longline Survey (UNC LL)

In North Carolina waters, information about sharks was limited prior to 1972. This led to the establishment of a bi-weekly longline survey (April-November, 1972-present) conducted at two fixed stations south of Shackleford Banks in Onslow Bay, North Carolina by the University of North Carolina (UNC), Institute of Marine Sciences. The survey's objective was to define what sharks occurred in the area, their sizes, life stages, relative abundances and seasonal occurrences. Data analyzed from 1972 to 2009 reveal a declining trend in abundance for dusky sharks from the mid 1970s to the mid 1990s and abundance then appeared to remain at low levels into the 2000s (Figure 7, Schwartz et al. 2010).

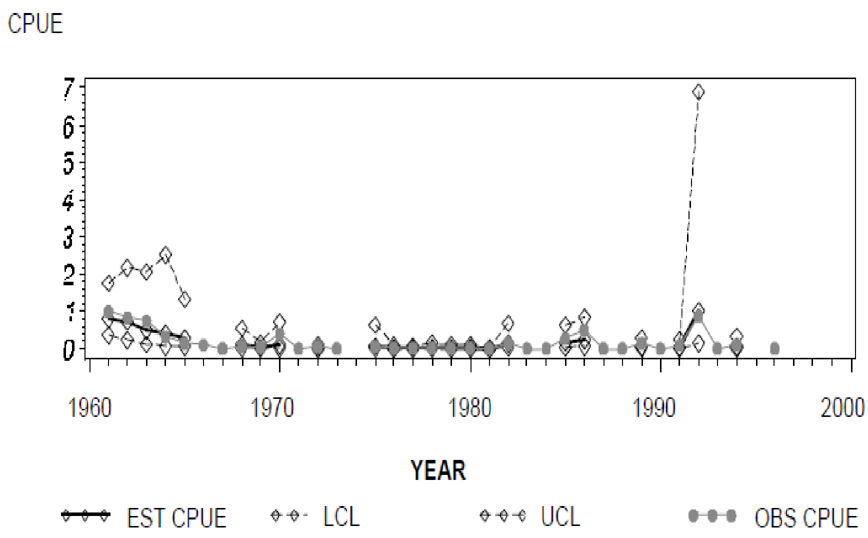
Figure 7. Dusky shark nominal and estimated indices divided by the maximum values with 95% confidence interval (CI) and an estimated exponential trend line for the UNC estimated time series. (Source: Schwartz et al. 2010).



NEFSC historical longline survey data (NMFS Historical LL)

NMFS and its predecessor agencies, the Bureau of Commercial Fisheries (BCF) and the Bureau of Sport Fish and Wildlife, have conducted periodic longline surveys for swordfish, tuna, and sharks off the east coast of the United States since the early 1950s. While the BCF surveys focused on the development of a tuna fishery, the initiation of shark surveys in 1961 at the Sandy Hook Marine Lab responded to concerns about shark attacks off the coast of New Jersey and resort owner demands for legislation that would require sport and commercial fishermen to fish farther offshore. After the initial coastal surveys were conducted between 1961 and 1965, there was a gradual transition from coastal work to offshore effort along the edge of the continental shelf and associated Gulf Stream waters. The shark research program moved from the Sandy Hook to the Narragansett Lab in the early 1970s. Catch per set data obtained from the exploratory longline surveys conducted by the Sandy Hook, NJ and Narragansett, RI labs from 1961 to 1992 were used to develop standardized indices of abundance for dusky sharks. The dusky shark time series begins with a decreasing trend that continues throughout the 1960s followed by a more stable trend throughout the remainder of the time series with a few small peaks in the early 1970s, mid 1980s and early 1990s (Figure 8, McCandless and Hoey 2010).

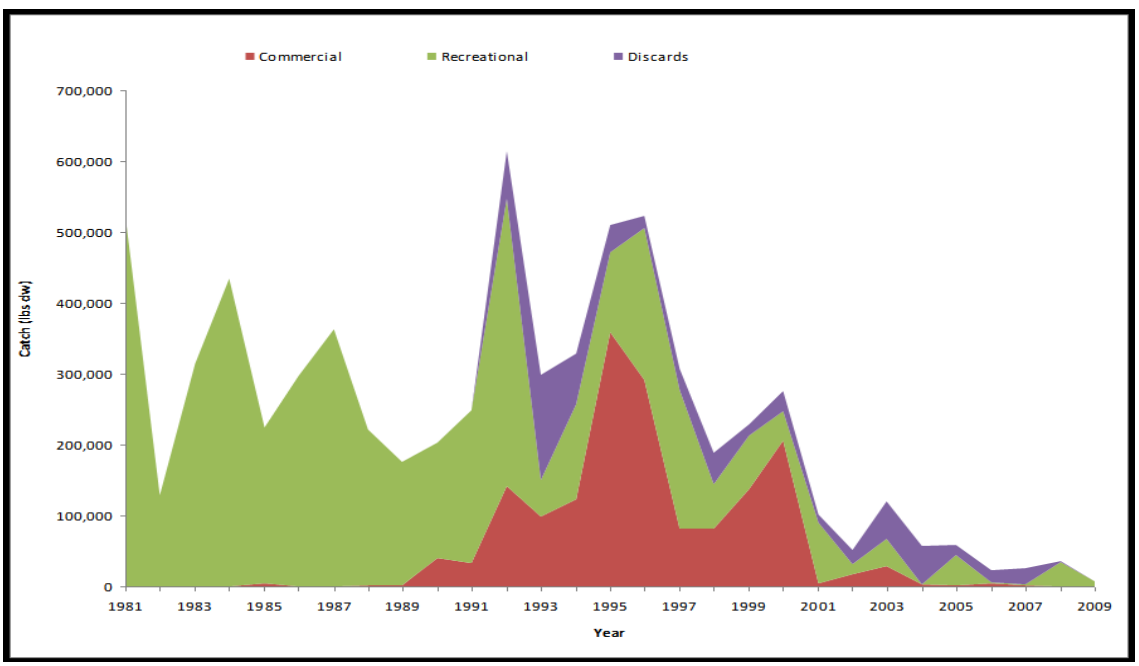
Figure 8. Dusky shark nominal (OBS CPUE) and estimated (EST CPUE) indices divided by the maximum values with 95% confidence limits (LCL, UCL) from the NEFSC Historical longline surveys (Source: McCandless and Hoey 2010).



Catch Trends

Commercial and recreational dusky shark catch information from the US Atlantic and GOM was compiled by the SEDAR Data Workshop (Figure 9) but was deemed highly uncertain, primarily due to misreporting and misidentification, and was not used in the assessment.

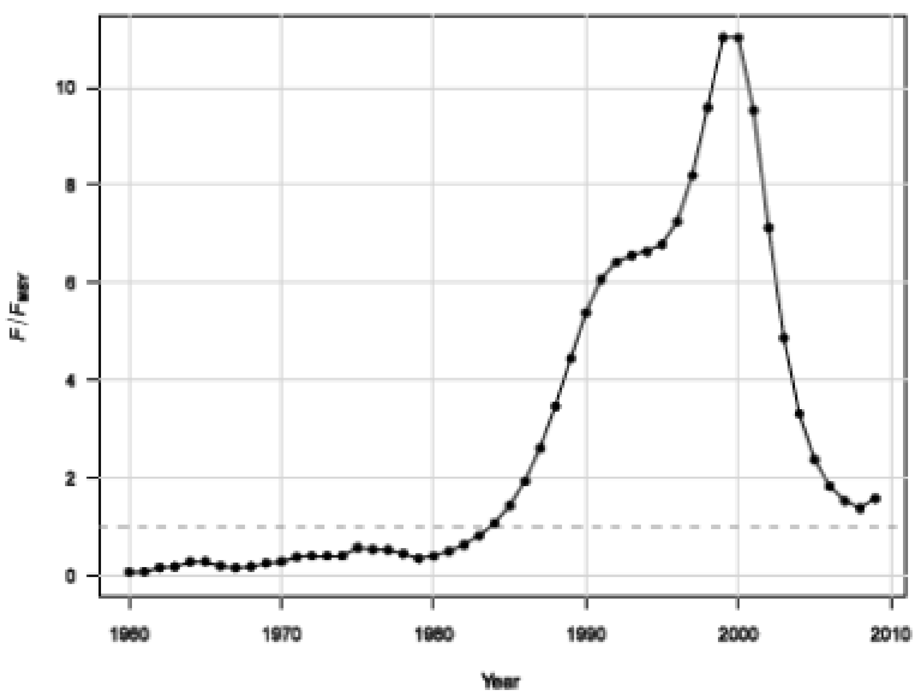
Figure 9. Total catches of dusky shark (in pounds dressed weight) from the US Atlantic and GOM commercial and recreational fisheries, 1981-2009 (Source: NMFS 2011a).



Fishing Mortality Trends

Fishing mortality (F) for dusky sharks in the NWA (including the GOM) was low from 1960 through the early 1980s, and then is estimated to have ramped up to unsustainably high levels in the 1990s, and to have declined following prohibition of dusky shark landings in 2000 (Figure 10, NMFS 2011a). The base ASCFM indicated that overfishing (where $F > F_{MSY}$) has been occurring since 1984 (although there is considerable uncertainty about whether overfishing occurred during the last several years of the time series).

Figure 10. Apical fishing mortality relative to MSY levels for dusky sharks, 1960-2009. The dashed line indicates where $F/F_{MSY} = 1$, the level of fishing mortality at maximum sustainable yield. (Source: NMFS 2011a).



Stock Abundance and Biomass Trends

Recruitment is predicted to have remained at roughly virgin levels until 1990, after which it declined slightly (Table 4). Declines in spawning stock biomass (Figure 11) are estimated to be partially compensated for by increases in pup survival (i.e., density dependent recruitment). All abundance trajectories show relatively little depletion until the late 1980s; by 2009 depletion in spawning stock biomass is estimated to be around 85% (Table 4, Figure 11). The ASCFM predicted an increasing abundance (in numbers) from 2004 to 2009, but a continued decrease in biomass. This apparent contradiction is attributable to decreasing number of older (and heavier) sharks even while the numbers of younger fish are increasing.

Table 4. Predicted relative recruitment (Rec, numbers), abundance (N, numbers), total biomass (B, kg), and spawning stock biomass (SSB, kg). All estimates are presented relative to virgin levels. Source: NMFS 2011a.

Year	Rec	N	B	SSB
1960	1	1	1	1
1961	0.999951	0.998682	0.99921	0.999533
1962	0.99984	0.99731	0.998315	0.998757
1963	0.999654	0.994484	0.996476	0.997603
1964	0.999377	0.991575	0.994436	0.996036
1965	0.999	0.987221	0.991381	0.994032
1966	0.998517	0.983065	0.988229	0.992083
1967	0.998045	0.980735	0.985988	0.990335
1968	0.997621	0.97913	0.984104	0.988484
1969	0.997171	0.977176	0.981979	0.986243
1970	0.996625	0.974156	0.979173	0.983564
1971	0.995969	0.970786	0.976056	0.980355
1972	0.995179	0.965986	0.971978	0.976593
1973	0.994249	0.961134	0.967683	0.972518
1974	0.993235	0.956628	0.963417	0.968183
1975	0.992149	0.952375	0.959156	0.96317
1976	0.990884	0.945623	0.953303	0.957519
1977	0.989446	0.939929	0.947826	0.951703
1978	0.987953	0.934718	0.942461	0.945862
1979	0.98644	0.931074	0.937885	0.940277
1980	0.98498	0.929087	0.934242	0.934502
1981	0.983456	0.926132	0.929824	0.927964
1982	0.981714	0.921662	0.924322	0.920448
1983	0.979689	0.915072	0.917222	0.911471
1984	0.977237	0.9056	0.90777	0.900485
1985	0.974188	0.892397	0.895292	0.886936
1986	0.97035	0.87438	0.878923	0.869936
1987	0.96541	0.85013	0.857326	0.847257
1988	0.958596	0.817544	0.827446	0.817789
1989	0.949334	0.776492	0.789928	0.781932
1990	0.937392	0.727994	0.74518	0.739792
1991	0.922319	0.675232	0.694753	0.693271
1992	0.904215	0.623427	0.643046	0.645458
1993	0.883781	0.576536	0.593565	0.598539
1994	0.861648	0.535644	0.547865	0.553494
1995	0.838149	0.499891	0.505969	0.51039
1996	0.813259	0.467576	0.467093	0.468497
1997	0.786442	0.435832	0.429433	0.426537
1998	0.756545	0.401737	0.390986	0.383609
1999	0.722238	0.364273	0.350945	0.340164
2000	0.682937	0.325586	0.310673	0.299319
2001	0.640916	0.293626	0.275734	0.264761
2002	0.600735	0.272261	0.249197	0.237908
2003	0.566043	0.261757	0.231432	0.2179
2004	0.537919	0.259197	0.220403	0.202705
2005	0.515107	0.261073	0.213653	0.190506
2006	0.495799	0.264839	0.209418	0.180153
2007	0.478666	0.269008	0.206642	0.171011
2008	0.462931	0.272728	0.204682	0.162742
2009	0.448179	0.275546	0.20314	0.155

Figure 11. Spawning biomass relative to MSY levels over time from the base ASCFM model for dusky sharks. The dashed line indicates where $SSB/SSB_{MSY} = 1$, the level of spawning stock biomass at maximum sustainable yield. Source: NMFS 2011a.

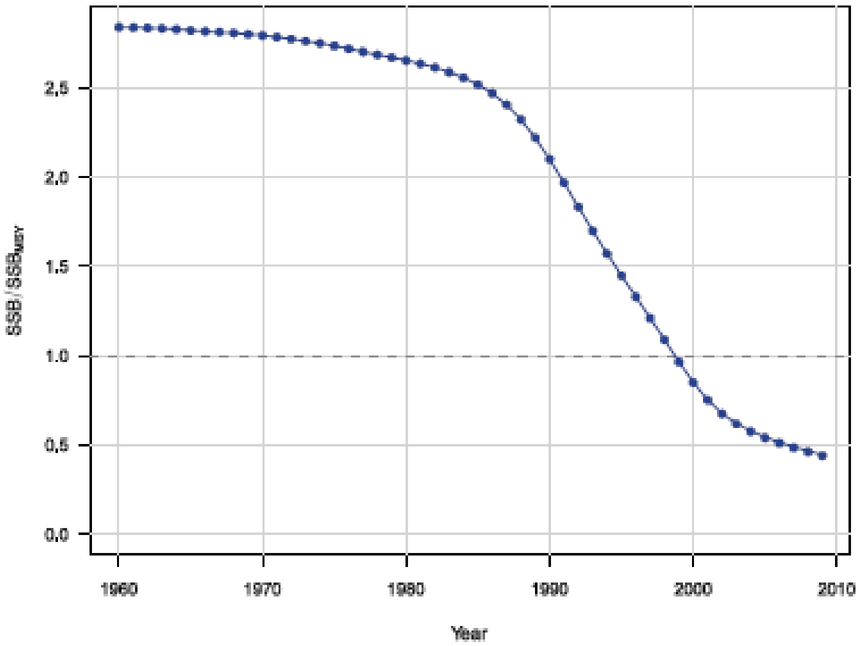
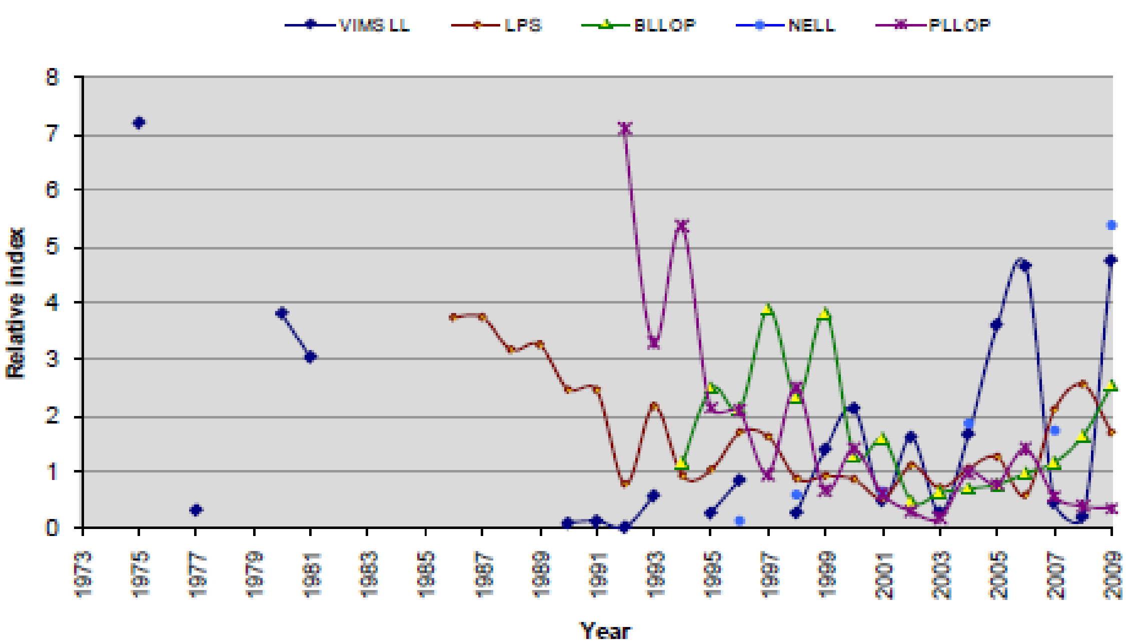


Figure 12. Baseline indices of relative abundance used for dusky sharks. All indices are statistically standardized and scaled (divided by their respective mean and a global mean for overlapping years). Source: NMFS 2011a.



Stock Status Determination Criteria

Assessment results indicated that the dusky shark stock was overfished, values of $SSB/SSB_{MSY} < 1$ (SSB_{2009}/SSB_{MSY} of 0.41 to 0.50), and therefore subject to rebuilding. Current F values over all sensitivity runs also indicated that the stock was subject to overfishing, values of $F/F_{MSY} > 1$ (F_{2009}/F_{MSY} of 1.39 to 4.35). A summary of stock status determination criteria and the SEDAR 21 recommended values are reported in Table 5.

Table 5. SEDAR 21 summary of stock status determination criteria (Source: NMFS 2011a).

Criteria	Recommended Values* from SEDAR 21	
	Definition	Value*
M (Instantaneous natural mortality; per year)	Value used for MSST calculations	0.0666
F_{2009} (per year)	Apical Fishing mortality in 2009	0.055
F_{MSY} (per year)	F_{MSY}	0.035
SSB_{2009}/SSB_0	Relative Spawning stock biomass	0.15
SSB_{MSY} (relative to virgin)	Relative SSB_{MSY}	0.35
SSB_{MSST} (relative to virgin biomass)	$(1-M)*SSB_{MSY}$	0.33
MFMT (per year)	F_{MSY}	0.035
F_{OY} (per year)	$F_{OY} = 75\% F_{MSY}$	0.026
Biomass Status	SSB_{2009}/MSST	0.47
Exploitation Status	F_{2009}/F_{MSY}	1.59

* Values presented are from the base model configuration but it is important to note that that the Review Panel recommended all runs in the addendum be considered equally plausible

Scientific Uncertainty

Likelihood profiling was used to quantify uncertainty in terminal stock status, terminal fishing mortality, and productivity parameters for the base run and for several sensitivity runs. This procedure could also be used to estimate the probability that the stock was overfished or that overfishing was occurring given a specific model configuration. Uncertainty in data inputs and model configuration was examined through the use of sensitivity scenarios and retrospective runs. Eleven alternative runs were conducted in addition to the baseline run. Retrospective analyses, in which the model was refit while sequentially dropping the last three years of data to look for systematic bias in key model output quantities over time, were also conducted. Seven additional sensitivity analyses were run during the Review Workshop to provide verification that the results of the assessment were robust to assumptions about underlying stock productivity, choice of selectivity curves, choice of indices, and index weighting. Time series plots were produced for runs considered by reviewers to have encapsulated uncertainty in assessment results (High M, U-shaped M, High productivity, and Low Productivity, Figure 13). The greatest source of uncertainty about dusky sharks is clearly the amount of human induced removals (e.g., discards) that is occurring. Improving the reliability of removal data would help assessment modeling immensely. Estimates of stock status seemed to be quite robust to changes in life history parameters such as productivity and natural mortality. Estimates of stock status seemed most sensitive to including different groups of indices or to different ways of weighting indices.

Significant Assessment Modifications

The SEDAR 21 Review Panel requested additional sensitivity runs, but no significant changes to the base model configuration were required. A total of 15 sensitivity, including the seven requested by the Review Panel, and three retrospective runs were conducted in addition to the base model (Figure 13):

- Retro2006-2008: Retrospective analyses in which the model was refit while sequentially dropping the last three years of data

- Hierarchical: Use of a single, hierarchical index in place of the five indices used in the base run

- BLL.q: Decrease in catchability starting in 2000 for the bottom longline sector

- High.M: A high natural mortality scenario

- U.shaped.M: A U-shaped natural mortality curve allowing senescence

- No.add.var: A run using index input CV's only (no "additional" or estimated variance)

- VIMS.NELL.only: A run using only VIMS, NELL indices

- All.fish.indep: A run using all fishery-independent indices, including UNC, NMFS historical

- All.indices: A run using all indices ("base" + "sensitivity" indices)

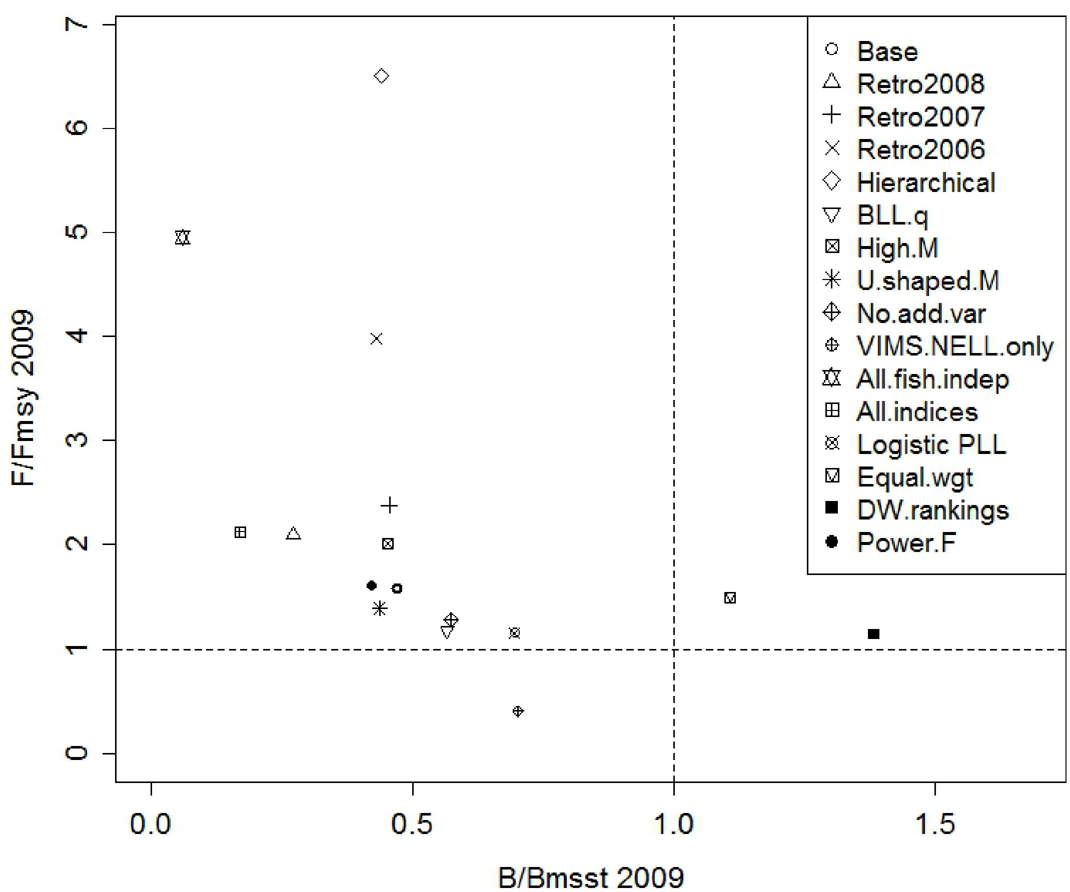
- Logistic PLL: Logistic selectivity specified for the pelagic longline sector

- Equal.wgt: Equal index weighting

- DW.rankings: Utilize a priori rankings from data workshop to weight indices

- Power.F: Fishing mortality from 1960-1979 modeled with a power curve

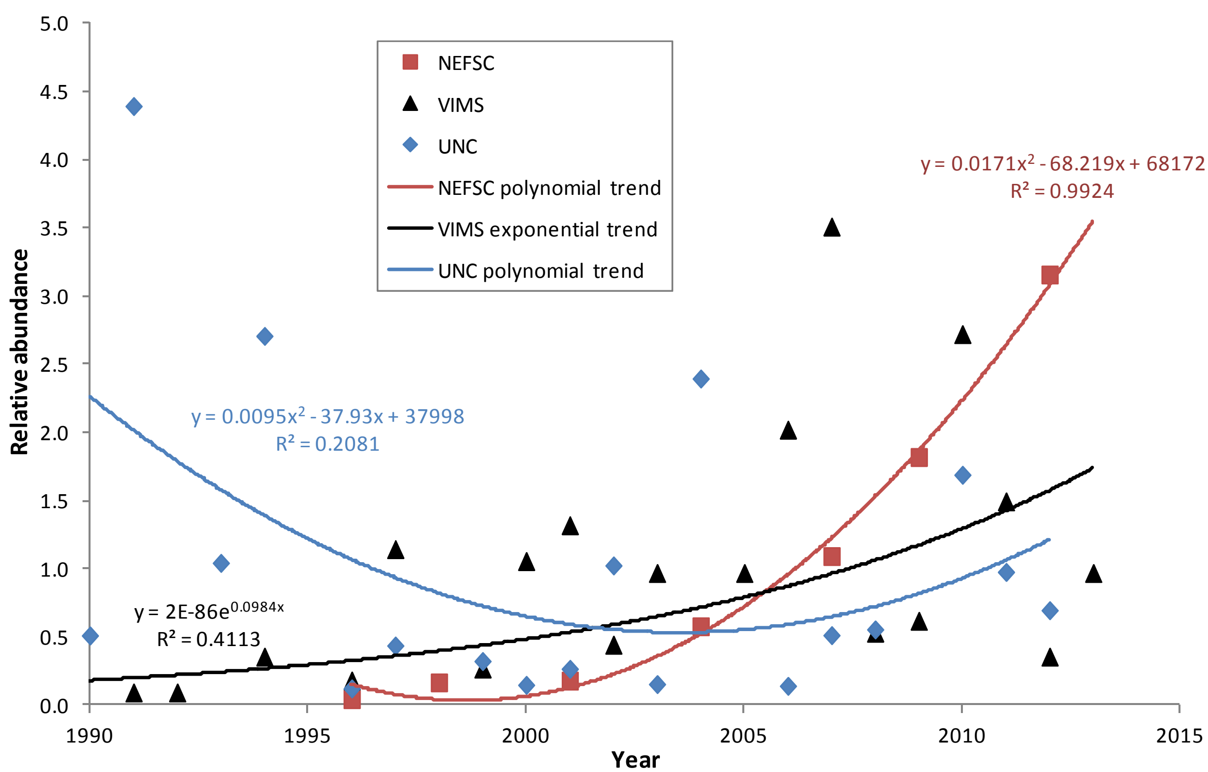
Figure 13. A phase plot summarizing stock status of dusky sharks in the terminal year of the assessment model according to various base, retrospective, and sensitivity runs. Points to the left of the vertical dashed line indicate runs in which the stock is estimated to be overfished; points above the horizontal dashed line indicate runs in which overfishing is estimated to have occurred (Source: NMFS 2011a).



Current abundance trends

For the NWA dusky shark stock, NMFS (2011b) assumed a virgin, or unfished, population existed in 1960. The stock assessment model predicted that the dusky shark population size remained close to virgin levels until the late 1980s when fishing mortality began increasing to unsustainable levels. Dusky shark numbers were estimated to have declined 74% from virgin levels by 2004, but showed a gradual increasing trend throughout the remainder of the time series modeled through 2009. Updated analyses using the same methodology, delta-lognormal generalized linear mixed modeling, as reported during the SEDAR 21 Data Workshop (McCandless and Natanson 2010 and Romine et al. 2010) from the two fishery-independent surveys (NEFSC Coastal Shark Bottom Longline Survey – analysis conducted by Camilla T. McCandless, NEFSC; VIMS Shark Longline Survey – analysis conducted by Robert J. Latour, VIMS) used in the base model of the last stock assessment show that the trends in dusky shark relative abundance based on numbers continues to increase (Figure 14). Analysis of the only fishery-independent time series that is still being conducted (UNC Shark Longline Survey – analysis conducted by Camilla T. McCandless, NEFSC) and was used in sensitivity model runs using the same methodology (delta-lognormal generalized linear mixed modeling) as reported during the SEDAR 21 Data Workshop (Schwartz et al. 2010), also shows an increasing trend in recent years (Figure 14); whereas previous estimates excluding recent data showed an overall decreasing trend with numbers appearing to stabilize at the end of the time series, but no signs of an increase (see Dusky shark stock assessment section, Figure 7).

Figure 14. Dusky shark indices of abundance (index/mean) standardized using a delta-lognormal generalized linear mixed model plotted by year for three fishery-independent time series: NEFSC = Northeast Fisheries Science Center Coastal Shark Bottom Longline Survey, VIMS = Virginia Institute of Marine Science Shark Longline Survey, and UNC = University of North Carolina Shark Longline Survey. Trend lines are best fit regression models of the standardized data (exponential for VIMS and second order polynomial for NEFSC and UNC).



DISTINCT POPULATION SEGMENT (DPS) DETERMINATION

Consideration of the species question

In determining whether to list a species, the first issue is whether the petitioned subject is a valid species. The petitioned subject, the dusky shark, or *Carcharhinus obscurus*, is a valid species for listing. The taxonomic breakdown of *C. obscurus* is as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Chondrichthyes
Subclass: Elasmobranchii
Order: Carcharhiniformes
Family: Carcharhinidae
Genus: Carcharhinus
Species: C. obscurus

Criteria for identification of distinct population segments

After determining whether the petition identifies a species, the next issue is whether any petitioned populations qualify as DPSs within the species. The joint policy of the USFWS and NMFS provides guidelines for defining DPSs below the taxonomic level of species (61 FR 4722; February 7, 1996). The policy identifies two elements to consider in a decision regarding whether a population qualifies as a DPS: discreteness and significance of the population segment to the species.

Discreteness

A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, or if it is delimited by international governmental boundaries. Genetic differences between the population segments being considered may be used to evaluate discreteness. In addition, international boundaries within the geographical range of the species may be used to delimit a distinct population segment. This criterion is applicable if differences in the control of exploitation of the species, management of the species' habitat, the conservation status of the species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment.

Significance

If a population segment is considered discrete, its biological and ecological significance must then be evaluated. Significance is evaluated in terms of the importance of the population segment to the overall welfare of the species. Some of the considerations that can be used to determine a discrete population segment's significance to the taxon as a whole include:

- Persistence of the population segment in an unusual or unique ecological setting;
- Evidence that loss of the population segment would result in a significant gap in the range of the taxon; and
- Evidence that the population segment differs markedly from other populations of the species in its genetic characteristics.

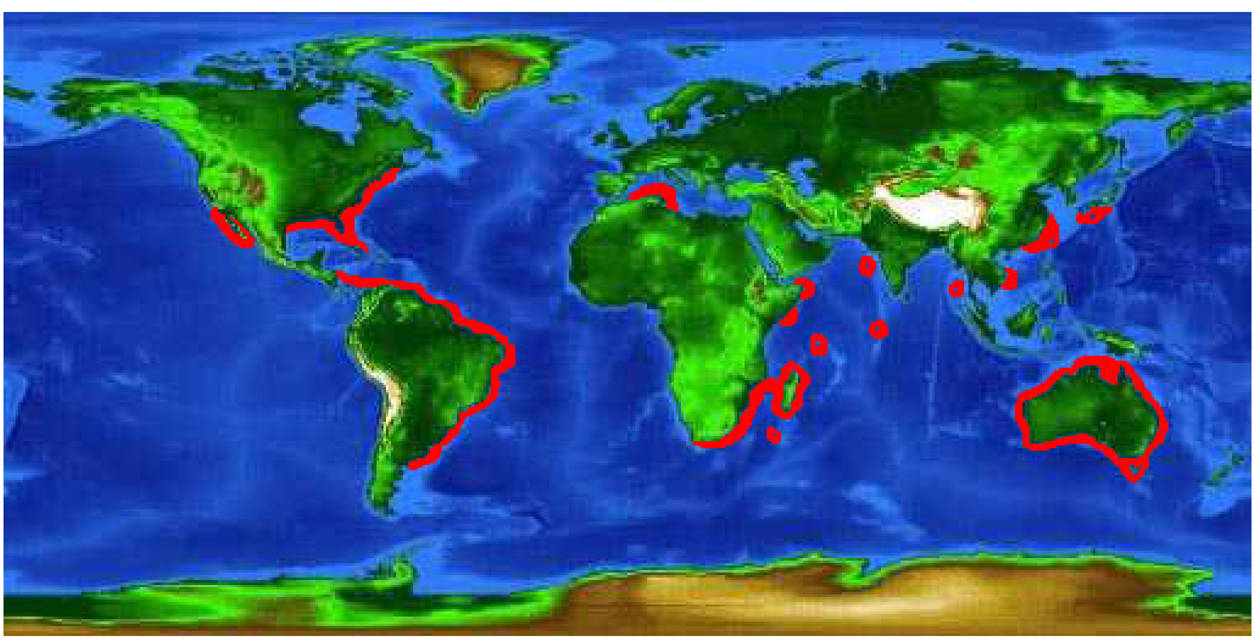
Proposed DPS by Petitioners

NMFS was petitioned to specifically list the northwest Atlantic (NWA) dusky shark under the ESA. Below is an evaluation of whether this NWA subpopulation of dusky sharks meets the criteria of a DPS using the guidance provided above.

Distinct population segment evaluation

Dusky sharks have been reported in temperate and tropical waters worldwide, including the western Atlantic in the north from Nova Scotia to Cuba and the GOM and in the south from Nicaragua to southern Brazil. They are also found in the Mediterranean, Indian and western Pacific including off Madagascar and Australia and in the eastern Pacific from southern California to the Gulf of California (Figure 15).

Figure 15. World distribution map for the dusky shark (Source: Florida Museum of Natural History)



Genetic studies have shown significant differences, using both mitochondrial and nuclear microsatellite DNA between dusky sharks caught in the NWA and Indo-Pacific regions (Figure 16, Figure 17, Benavides et al. 2011, Gray et al. 2012). Benavides et al. (2011) found 25 mitochondrial control region haplotypes and rejected a null hypothesis of panmixia (analysis of molecular variance, $\Phi_{ST} = 0.55$, $p < 0.000001$), detecting significant differentiation between three management units: US Atlantic, South Africa, and Australia. Work by Grey et al. (2012) supports these findings by identifying a strong divergence among NWA, South African, and Australian samples using microsatellite markers ($\Phi_{ST} = 0.01$-0.15, $p < 0.05$).

Figure 16. Mitochondrial control region haplotype frequencies obtained from samples collected across the global distribution of the dusky shark: US east coast (USEC), US Gulf of Mexico (USGOM), Brazil (BRA), South Africa (SAF), west Australia (WAUS), east Australia (EAUS), Taiwan (TAI), and Peru (PER). Known distribution is in light gray, "?" represents unconfirmed parts of distribution. Patterns in the pie charts refer to specific haplotype codes listed in the figure legend. Rare refers to haplotypes that occurred at a low frequency. (Source: Benavides et al. 2011)

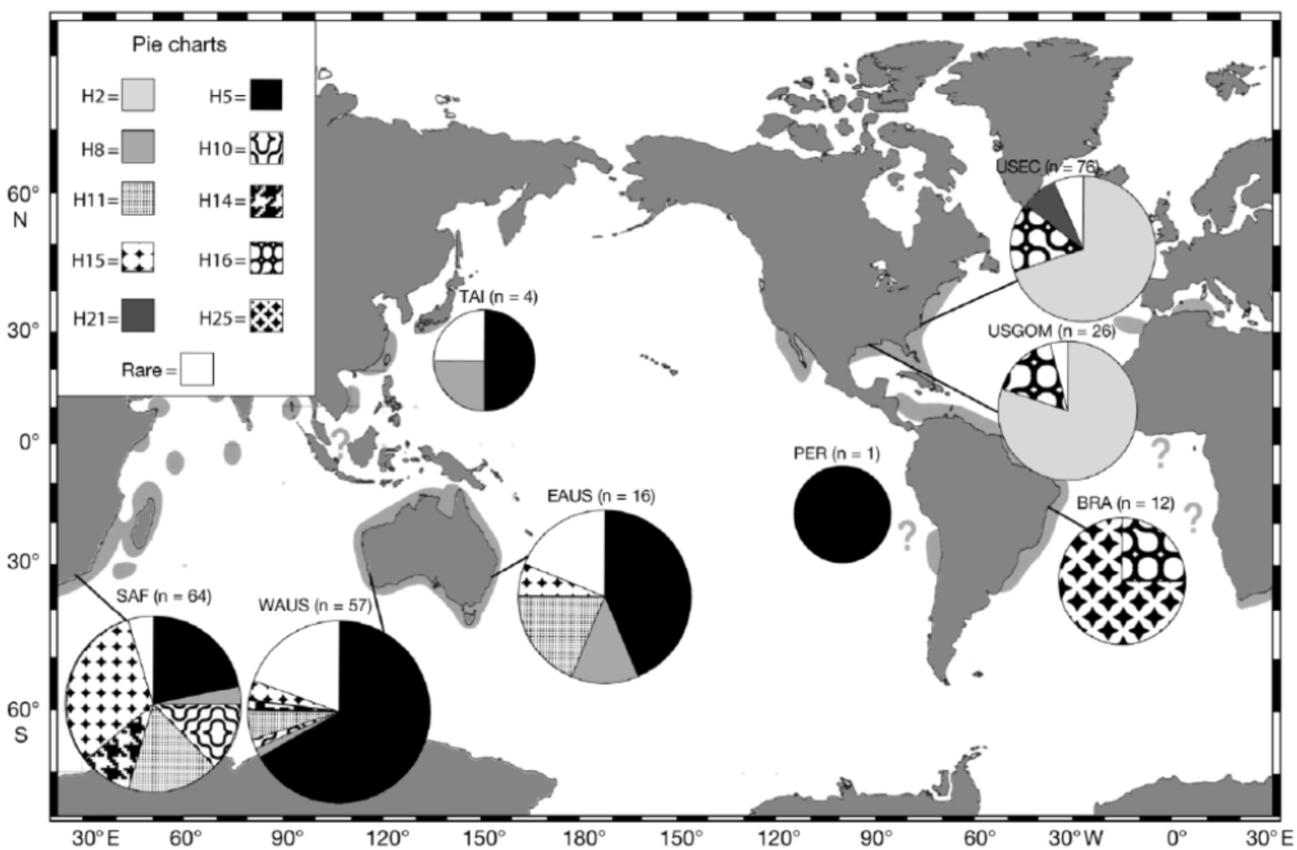
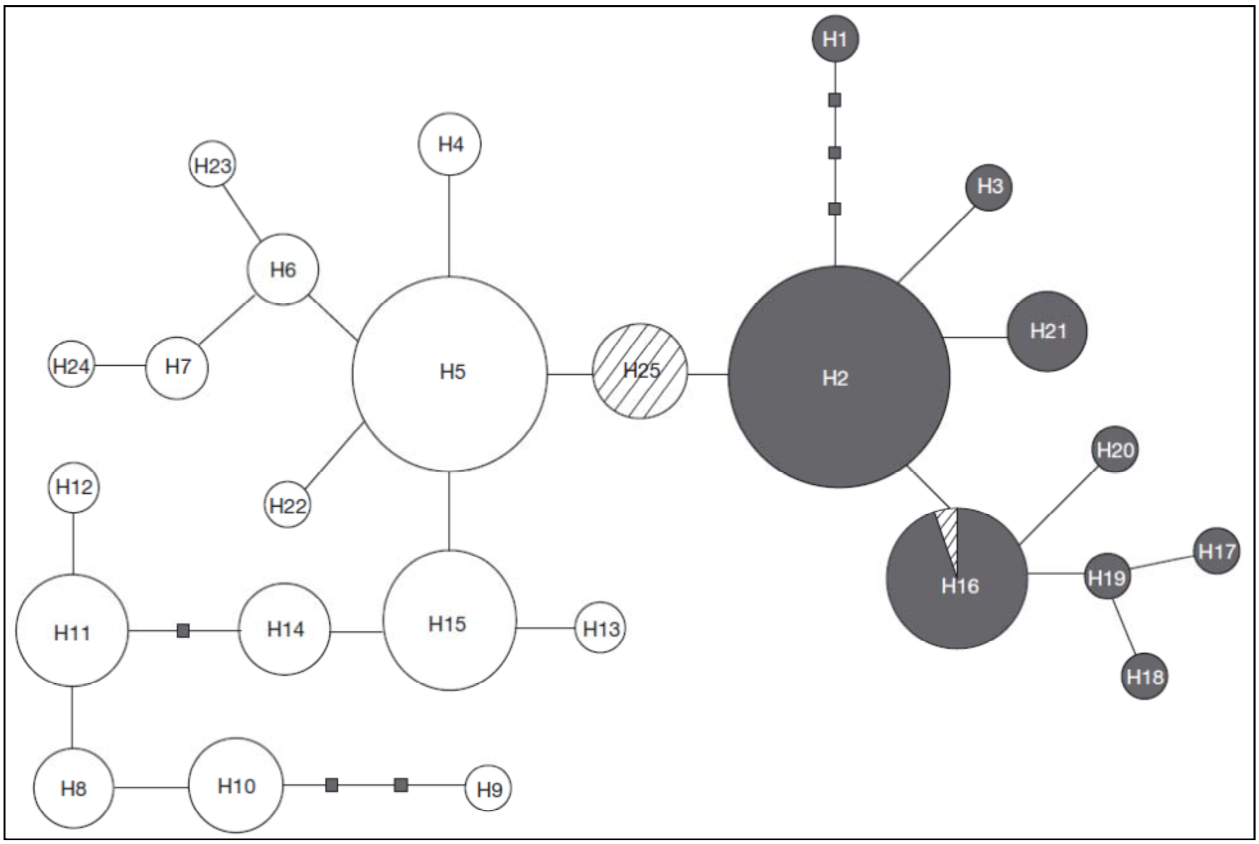
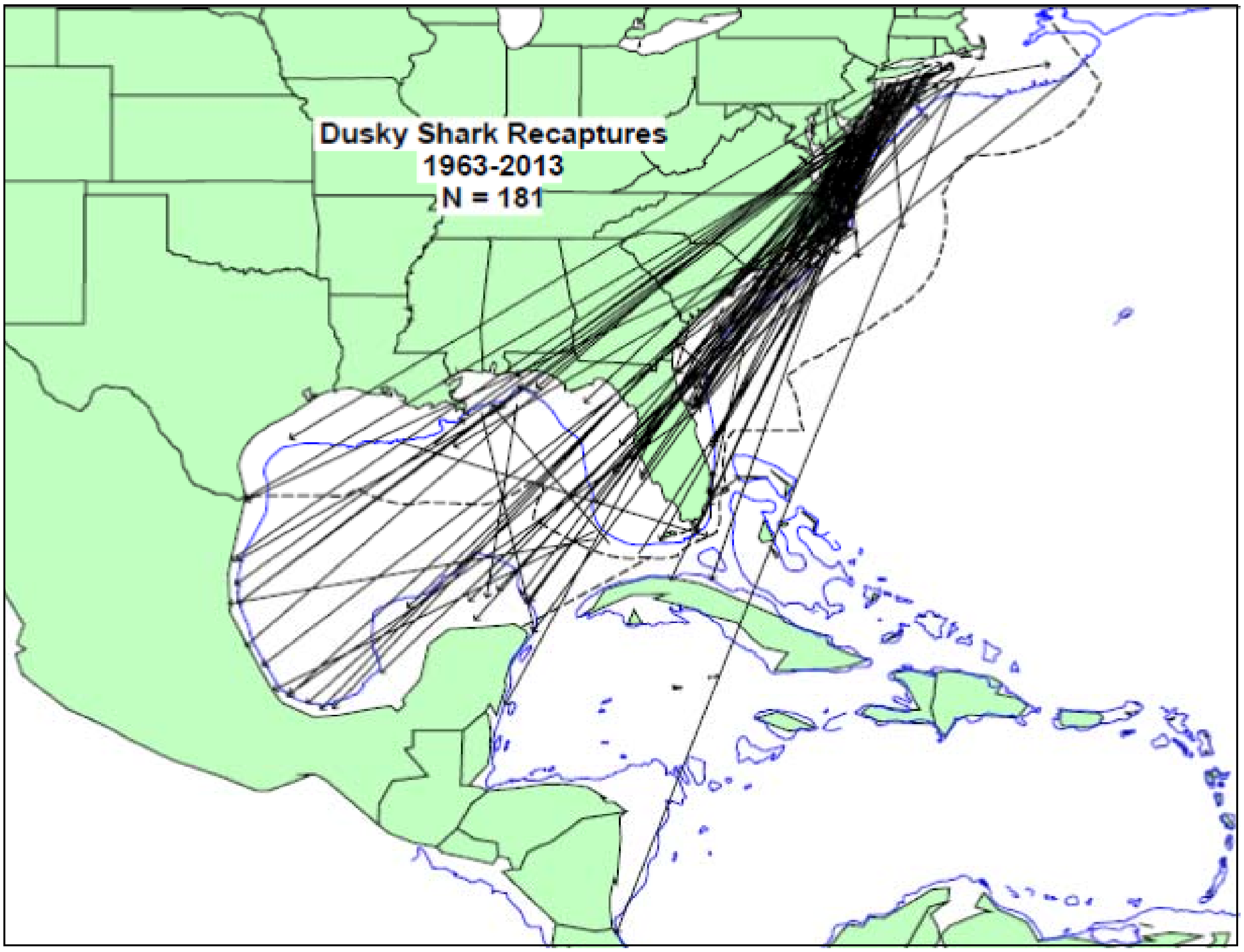


Figure 17. Mitochondrial control region haplotype network (95% confidence), with individual haplotypes denoted by the number in each circle. The size of the circle is proportional to the frequency of the haplotype in the global sample. Solid circles represent haplotypes found in the USA. Open circles represent haplotypes observed in the Indo-Pacific. Striped circles or fractions of circles represent haplotypes directly collected or putatively originating from Brazil. Small squares represent inferred mutational steps between haplotypes. (Source: Benavides et al. 2011)



Mark/recapture data support the genetic findings of a discrete NWA population of dusky sharks. In over 50 years of tagging effort with more than 8500 dusky sharks tagged, there has never been a recapture of a NWA tagged dusky shark within the southwest Atlantic or northeast Atlantic in the NMFS Cooperative Shark Tagging Program (CSTP) database (Figure 18, NMFS unpublished data). However, mark/recapture data show movements between the US Atlantic coast and the GOM and Caribbean Sea, and also a lot of movement between the US and Mexican Gulf (also see Distribution and habitat use section).

Figure 18. Dusky shark mark/recaptures from the NMFS Cooperative Shark Tagging Program. Lines represent the straight line distance between the tagging location (start of line) to the recapture location (arrow tip). The dashed line is the US EEZ and the blue line is the 200 m depth contour. Source: NMFS unpublished data



In terms of significance, loss of the NWA segment of dusky sharks would result in a significant gap in the range of the taxon. Although qualitative data show a potential historical connection between the NWA and Indo-Pacific populations through the southwest Atlantic waters (Figure 17), the study indicates that recovery of depleted NWA stocks would likely rely on reproduction by surviving local females as opposed to replenishment from immigrant females from the southwest Atlantic or Indo-Pacific (Benavides et al. 2011). Therefore, loss of this segment would translate to a significant gap in the current range of the species, specifically the entire northwest Atlantic, from the Gulf of Maine to Florida, and including the GOM and Caribbean Sea.

Conclusion

Based on the criteria for discreteness and significance under the DPS policy, the SRT considers the NWA dusky shark population a distinct population segment that will be considered in the following extinction risk assessment. Table 6 summarizes the DPS rationale.

Table 6. Summary of population characteristics used to determine DPS status

Discreteness	Significance
Genetic Differences: Genetic studies have shown significant differences, using both mitochondrial and nuclear microsatellite DNA between dusky sharks caught in the NWA and Indo-Pacific regions. *Physical/Behavior Factors*: In over 50 years of tagging effort with more than 8,500 dusky sharks tagged, there has not been a recapture of a NWA tagged dusky shark within the southwest Atlantic or northeast Atlantic.	*Loss of segment would result in significant gap in the range of the taxon:* The dusky shark range spans from the Gulf of Maine to Florida and throughout the Gulf of Mexico. This is a significant expanse of distribution and the population would unlikely be rapidly repopulated through immigration.

ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS

The ESA requires NMFS to determine whether a species is endangered or threatened because of any of the factors specified in section 4(a)(1) of the ESA. The following provides information on each of these five factors as they relate to the current status of the dusky shark.

Present or threatened destruction, modification, or curtailment of habitat or range

In the US economic exclusive zone (EEZ), the Magnuson-Stevens Act (MSA) requires NMFS to identify and describe essential fish habitat (EFH), minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify actions to encourage the conservation and enhancement of EFH. The MSA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." (16 USC. § 1802 (10)). The EFH regulations (at 50 C.F.R. 600 Subpart J) provide additional interpretation of the definition of EFH:

> "Waters' include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."

The EFH regulations require that EFH be described and identified within the US EEZ for all life stages of each species in a fishery management unit. FMPs must describe EFH in text, tables, and figures that provide information on the biological requirements for each life history stage of the species. According to the EFH regulations, an initial inventory of available environmental and fisheries data sources should be undertaken to compile information necessary to describe and identify EFH and to identify major species-specific habitat data gaps. Habitats that satisfy the criteria in the Magnuson-Stevens Act have been identified and described as EFH in the 1999 FMPs and in Amendment 1 to the 1999 Tunas, Swordfish, and Shark FMP, and were updated in Amendment 1 to the 2006 Consolidated HMS FMP (NMFS 2009).

To help determine EFH, NMFS has funded two cooperative survey programs intended to help delineate shark nursery habitats in the Atlantic and GOM. The Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Survey and the Cooperative Gulf of Mexico States Shark Pupping and Nursery (GULFSPAN) Survey are designed to assess the geographical and seasonal extent of shark nursery habitat, determine which shark species use these areas, and gauge the relative importance of these coastal habitats for use in EFH determinations. NMFS also used fishery observer data, tagging data and fishery-independent sampling data to determine EFH for dusky sharks in Amendment 1 to the 2006 Consolidated Atlantic HMS FMP (NMFS 2009). These data resulted in EFH areas for neonate dusky sharks in coastal and offshore waters from Florida to Cape Cod, which could provide nursery habitats for this species. Below are the designated EFH areas along the US coast that support various life stages of the dusky shark (Figures 19 and 20, NMFS 2009):

Figure 19. **Neonate/Young of the year (YOY, ≤121 cm TL):** Areas along the Atlantic east coast of Florida to the mid-coast of Georgia, South Carolina to southern Cape Cod.

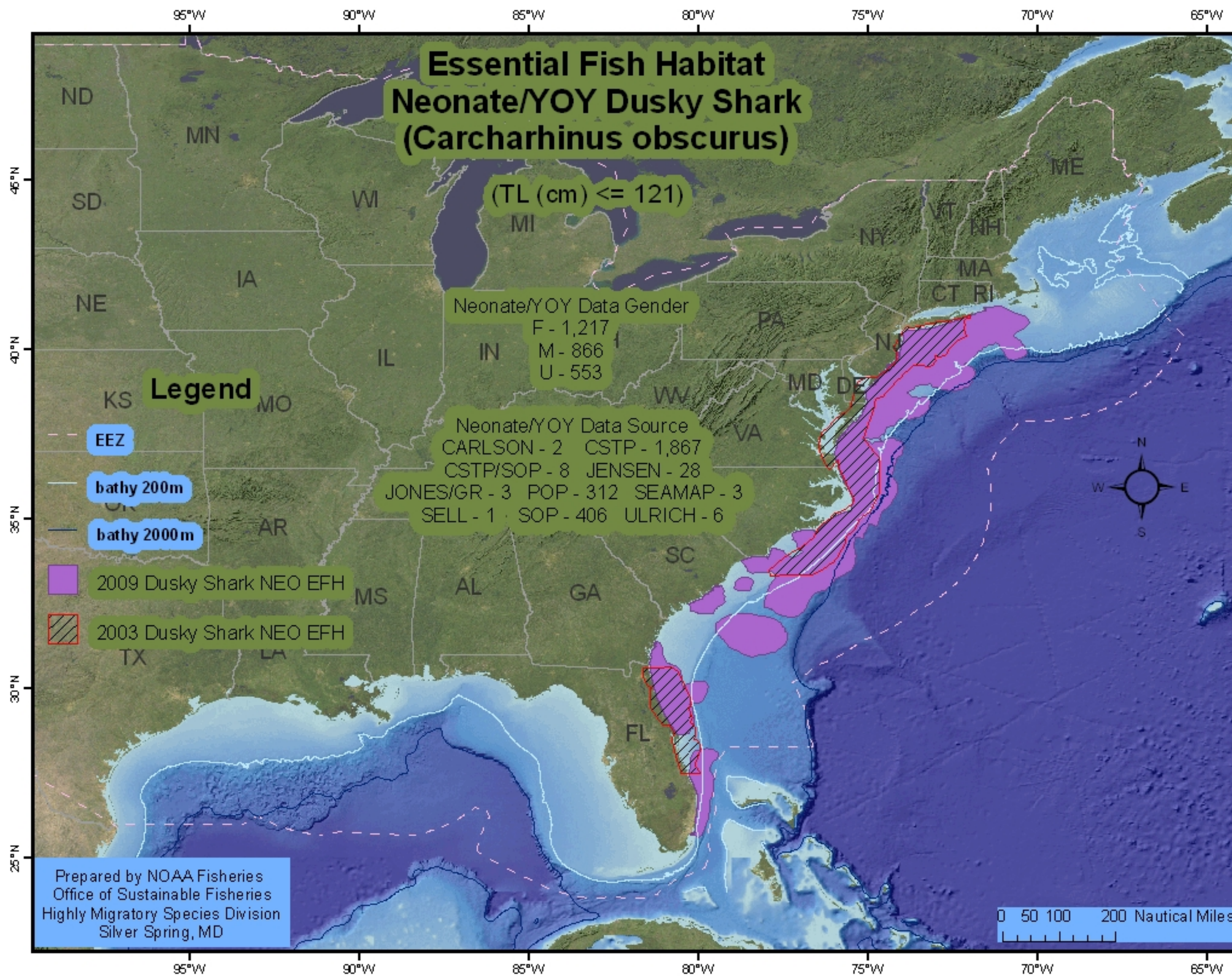
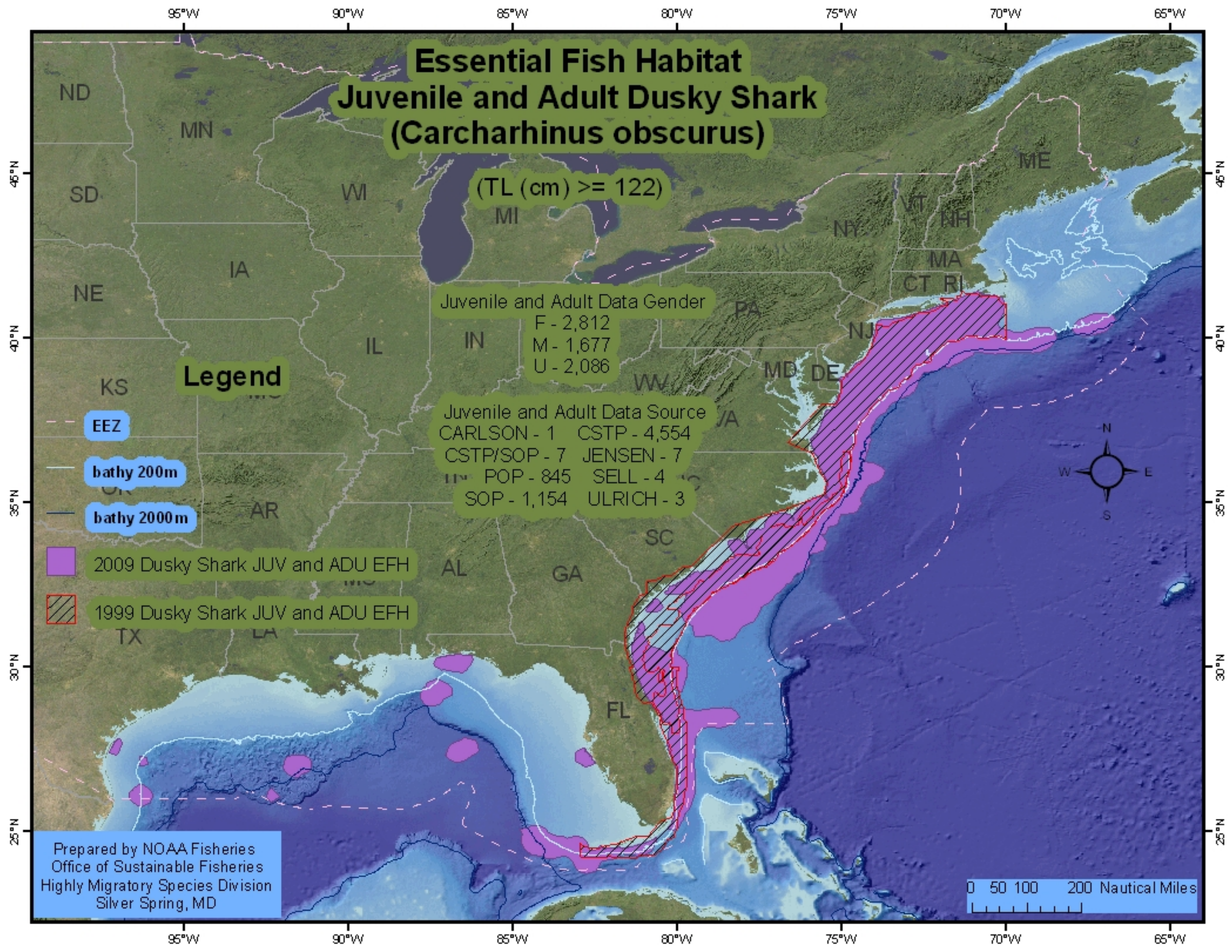


Figure 20. **Juvenile and Adult:** EFH designations for juvenile and adult life stages have been combined and are considered the same. Localized areas in the central GOM, southern Texas, the Florida Panhandle, mid-west coast of Florida, and Florida Keys. Atlantic east coast of Florida and South Carolina to southern Cape Cod.



NMFS analyzed fishing and non-fishing impacts on EFH in the 2006 Consolidated HMS FMP and concluded that while bottom longline gear in general may have an effect on EFH, shark bottom longline gear as currently used in the Atlantic shark fishery was not having more than a minimal and temporary effect on EFH, because it is primarily used in sandy and/or muddy habitats where it is expected to have minimal to low impacts. Likewise, other HMS gears are not considered to have an impact on EFH. HMS gears do not normally affect the physical characteristics that define HMS EFH such as salinity, temperature, dissolved oxygen, and depth. Similarly, other state and federally managed gears were also determined not to have an impact on HMS EFH, with the possible exception of some bottom-tending gears in shark nursery areas in coastal bays and estuaries. However, NMFS anticipates that any impacts resulting from these gears would be minimal and only temporary in nature (NMFS 2009).

EFH regulations require that FMPs identify non-fishing related activities that may adversely affect EFH of managed species, either quantitatively or qualitatively, or both. Estuaries and coastal embayments have been identified as particularly important nursery areas for many species of sharks, while offshore waters often contain important mating and feeding areas. All of these waters are or may be used by humans for a variety of purposes that often result in degradation of these and adjacent habitats, posing threats, either directly or indirectly, to the biota they support (NMFS 2006).

Non-fishing activities that may affect EFH are described in Section 10.5 of the 2006 Consolidated HMS FMP (NMFS 2006) and Amendment 1 to the 2006 Consolidated HMS FMP (NMFS 2009). Broad categories of activities that may adversely affect HMS EFH include, but are not limited to: (1) actions that physically alter structural components or substrate, e.g., dredging, filling, excavations, water diversions, impoundments and other hydrologic modifications; (2) actions that result in changes in habitat quality, e.g., point source discharges; (3) activities that contribute to non-point source pollution and increased sedimentation; (4) introduction of potentially hazardous materials; or (5) activities that diminish or disrupt the functions of EFH. If these actions are persistent or intense enough, they can result in major changes in habitat quantity as well as quality, conversion of habitats, or in complete abandonment of habitats by some species (NMFS 2013b). Estuarine environments, which are most easily prone to degradation by human activity other than fishing, are rarely used by dusky sharks. We also have no information to indicate that any of these activities listed above are affecting dusky shark EFH in a significant way.

Overutilization for commercial, recreational, scientific, or educational purposes

US bycatch and Mexican landings

The US National Bycatch Report (NMFS 2011b) estimated annual dusky shark bycatch from 2005 to 2006 was 2,739 individuals in the US Southeast Region, based on data from the US GOM Reef Fish Bottom Longline fishery (2005 estimate of 798.48 individuals) and the US GOM Reef Fish Handline (Vertical Line) fishery (2006 estimate of 1940.77 individuals). A recent update to this report (NMFS 2013c) estimated dusky annual bycatch was 3,872 individuals from 2006 through 2010, including dusky sharks reported from the US South Atlantic Snapper-Grouper Handline (Vertical Line) Fishery, US South Atlantic Coastal Migratory Pelagic Troll Fishery, and the US Southeastern Atlantic Snapper-Grouper Bottom Longline, as well as the fisheries reporting dusky shark catches in the original report. Estimated annual dusky shark bycatch from 2006 to 2010 using only the fisheries included in both bycatch reports, the US GOM Reef Fish Bottom Longline and Handline (Vertical Line) fisheries (2006-2010 estimated annual bycatch of 804.05 and 255.84 individuals, respectively), shows a decrease in annual bycatch from the 2005 to 2006 annual estimate of 2739 individuals to the 2006 to 2010 annual estimate of 1201.4 individuals. This perceived reduction in bycatch may be attributed to the establishment of an individual fishing quota (IFQ) system for the US GOM commercial red snapper fishery (GOMFMC 2006) and its implementation before the start of the 2007 fishing season. The primary targets of the US GOM Reef Fish Handline (Vertical Line) fishery are red snapper, vermillion snapper, and red grouper. The ITQ system was established to reduce overcapacity in the US GOM commercial fishery for red snapper and to eliminate, to the extent possible, the problems associated with derby fishing, in order to assist in achieving optimum yield. The establishment of the ITQ system may have led to a reduction in the number of participants in the US GOM Reef Fish Handline fishery, as they may have left the fishery or increased targeting of other species to account for any reduction in available quota. The ITQ system also opened the fishery to year round fishing instead of seasonal restrictions, which may have reduced the amount of fishing effort in areas at times when dusky shark interactions were possible. This potential reduction in effort would likely lead to a reduction in dusky shark interactions with handline gear.

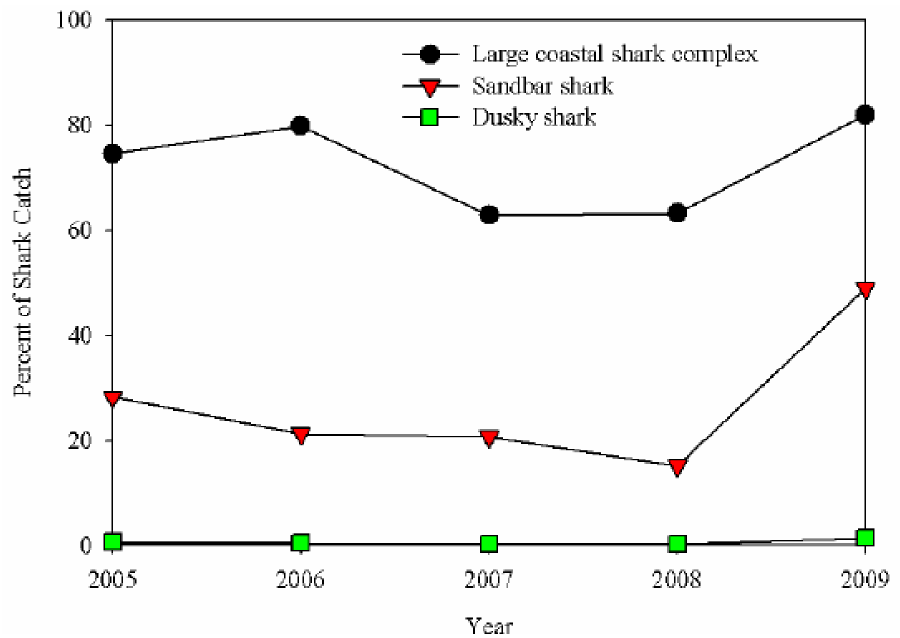
Dusky shark bycatch in the US Atlantic and GOM shark bottom longline fishery was included in the original bycatch report in pounds only, but with the caveat that the estimates given were being refined due to discrepancies in the calculation of total effort (NMFS 2011b). There was no reported dusky shark bycatch in the bycatch report update for the US Atlantic and GOM shark bottom longline fishery (NMFS 2013c). The 2008 prohibition of sandbar shark retention in US recreational and commercial fisheries (except for participants in the NMFS Shark Research Fishery) and the redistribution of commercial effort to target other large coastal shark species in areas where dusky sharks are less likely to be encountered indicates that dusky shark bycatch in the US Atlantic and GOM shark bottom longline fishery is likely negligible (see the Evaluation of adequacy of existing regulatory mechanisms section).

The percent of total catch for dusky sharks observed in the US Atlantic and GOM shark bottom longline fishery from 2005 to 2009 shows a relatively stable trend across years (Figure 21, Hale et al. 2010). The slight uptick seen at the end of the time series is attributed to dusky shark interactions observed in the NMFS Shark Research Fishery targeting sandbar sharks. Analysis of dusky shark annual bycatch in the NMFS Shark Research Fishery since 2009 show an increasing trend through 2012 ($y=38.9x-78047.2$, $R^2=0.45$, Hale et al. 2010, NMFS 2011c, NMFS 2012a, NMFS 2013a), but actual numbers caught are low (average = 161 individuals) compared to overall bycatch estimates (NMFS 2011b, NMFS 2013c). Fishing effort in the NMFS Shark Research Fishery has also remained relatively stable, with an increase in 2011 and then a drop to below original levels in 2012 in an effort to reduce dusky shark bycatch. Permitted vessels averaged 2 trips per month in 2009 and 2010, 2.6 trips per month in 2011, and 1 trip per month in 2012 (NMFS 2010, NMFS 2011c, NMFS 2012a, NMFS 2013a).

Data from the US Atlantic and GOM Pelagic Longline fishery (Pelagic Longline logbook and observer data) were also included in the US National Bycatch reports, but dusky shark bycatch was not broken out separately in the reports, and was instead grouped with other coastal shark species. The US Pelagic Longline logbook and observer data show relatively stable trends of dusky shark catches in recent years (see Current US Atlantic fisheries section, Figure 1) and the annual number of hooks deployed in the US Atlantic and GOM pelagic longline fishery from

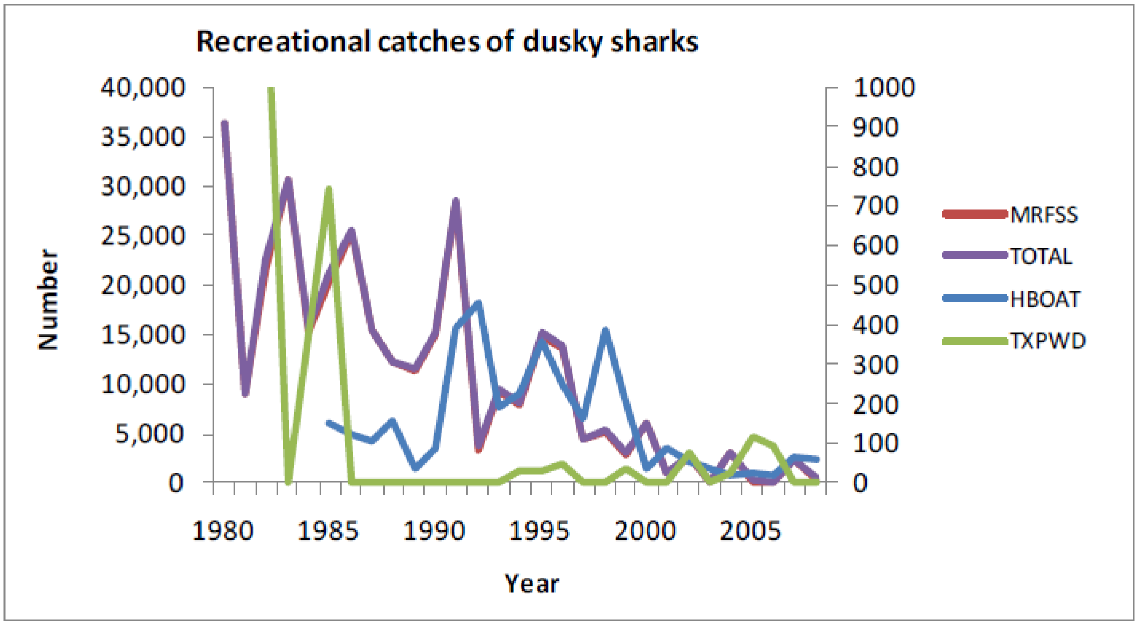
2003 to 2012 has ranged from 5,662,000 to 7,679,000, with no distinct pattern of increasing or decreasing fishing effort (NMFS 2013c).

Figure 21. Percent catch of sandbar and dusky sharks and all large coastal sharks caught in the US Atlantic and GOM as a proportion of the total shark catch for 2005 – 2009 from the US directed shark bottom longline observer program (Source: Hale et al. 2010).



Even though dusky shark retention in recreational fisheries is prohibited, dusky shark landings are still reported. This is likely due to misidentification or lack of knowledge of the current regulations. Data sources used to estimate recreational catches (landed sharks and killed but not landed sharks) were the Marine Recreational Fishery Statistics Survey (MRFSS), the NMFS Headboat Survey (HBOAT) operated by the SEFSC Beaufort Laboratory, and the Texas Parks and Wildlife Department Recreational Fishing Survey (TXPWD). The estimated US recreational catches (see Dusky shark stock assessment section, Figure 9) are based on extrapolations from a subsample of the fishery and are considered highly uncertain. There are also a large amount of unidentified carcharhinid species within the survey databases that likely contribute some additional dusky shark catches currently not accounted for in these estimates. The estimated recreational catch (in pounds dressed weight) appears to be of similar magnitude to the commercial discards in recent years, although the commercial discards show a clear declining trend (see Dusky shark stock assessment section, Figure 9). The recreational catches from these three surveys show no clear trend in recent years (Figure 9 and 22, Source: Cortés and Baremore 2010), but analysis of the total estimated catches by number from 2000 to 2009 reveals an overall decreasing trend (y=-346.7+696865, R^2=0.30, data from Cortés and Baremore 2010).

Figure 22. Estimated US recreational catches of dusky sharks from available sources. MRFSS = Marine Recreational Fishery Statistics Survey, HBOAT = NMFS Headboat Survey, TXPWD = Texas Parks and Wildlife Department Recreational Fishing Survey, TOTAL = estimates from all surveys combined. The HBOAT and TXPWD series use the Y-axis on the right side of the plot.



The recreational dusky shark catch rates from the NMFS Large Pelagics Survey (majority caught and released with only three reported landings since 2000, Walters and Brown 2010) show an overall increasing trend since the prohibition of dusky shark retention in 2000 (See Current US Atlantic fisheries section, Figure 2). Analysis of effort (shark directed trips) from 2003 to 2009 also shows very little change in total effort in recent years (y=7.8214x-15139, R^2 = 0.0525, data from Walter and Brown 2010), indicating that the increasing trend in catch rates may be attributed to increases in the relative abundance of dusky sharks within the areas fished.

Available data on Mexican shark landings and fishing effort indicate that even though regulated Mexican fisheries and illegal fishing practices contribute to dusky shark mortality, these impacts appear to be decreasing or have stabilized in recent years (See Mexican Fisheries in the Gulf of Mexico section).

NMFS (2011a) estimated that the level of exploitation in 2008 was sustainable at near 15% of unexploited levels when projected out into the future (see PROJECTIONS section, Figure 25). Overall estimates of US commercial and recreational bycatch, Mexican landings, and illegal Mexican fishing effort appear to be decreasing. Dusky shark catch rates from a primary source of US bycatch (US Pelagic Longline fishery) and effort from Mexican artisanal fisheries and Mexican and US Pelagic Longline fleets appear to be stabilizing in recent years. The catch rates from the NMFS Large Pelagics Survey, the NMFS Shark Research Fishery, and in the US fishery-independent surveys (see Current trends in abundance section, Figure 14) all show increasing trends in recent years with no overall increases in effort. All of these data sources indicate that overutilization (in the form of US bycatch and Mexican landings) may no longer be a significant threat, and from a fishery management perspective, provides a positive outlook for ending overfishing.

At-vessel and post-release mortality

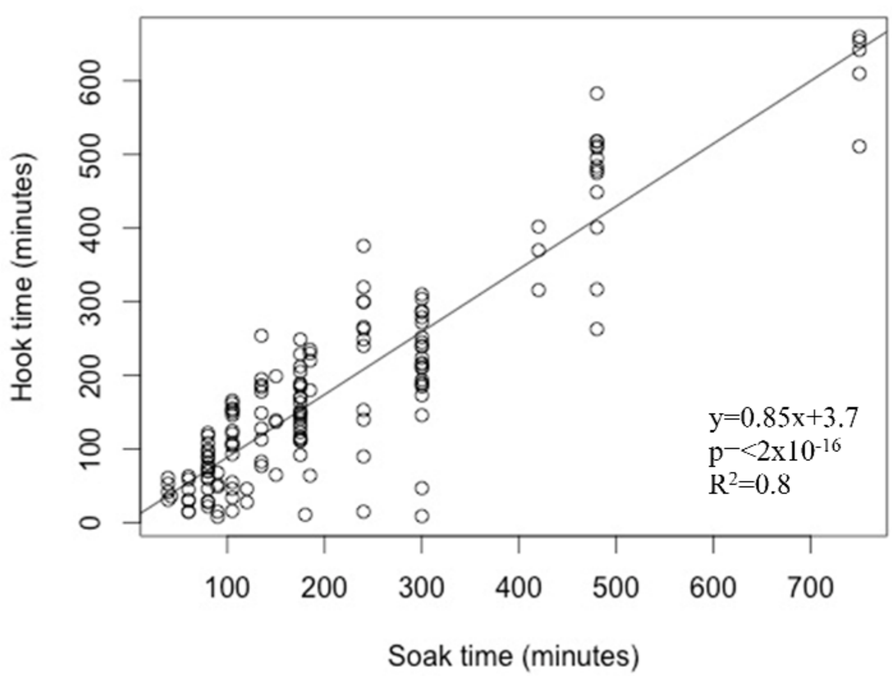
Estimates of commercial at-vessel and commercial and recreational post-release mortality reported in the SEDAR 21 stock assessment report for dusky sharks were not used in the stock assessment model (NMFS 2011a). Due to the uncertainty about the magnitude of total catches and discards, an alternative modeling methodology was used, the Age-structured Catch Free Model (ASCFM), which re-scales the model population dynamics as proportional to unexploited conditions. Fishing mortality rates were not directly input into the ASCFM, but were estimated by the ASCFM using a correlated random walk prior; pup survival was also estimated, and given an informative lognormal prior (median=0.81, CV=0.3, and was bounded between 0.50 and 0.99). Thus, while US bycatch and Mexican landings and their associated fishing mortality (commercial at-vessel and commercial and recreational post-release mortality) still need to be considered as a possible threat to extinction, it will only impact stock projections to the extent that levels of US bycatch and/or Mexican landings increase or decrease from 2009 levels.

NMFS (2011a) estimated a 40% at-vessel mortality rate for dusky sharks in the pelagic longline fishery based on pelagic longline observer data. An updated analysis using pelagic observer program data from 1992 through October 2012 estimated a 34% at-vessel mortality rate (NMFS unpublished data). Dusky sharks suffer higher at-vessel mortality (81 %) during NWA commercial bottom longline operations and this mortality is positively correlated with soak times and bottom water temperatures (Morgan and Burgess 2007). Smaller sharks are more vulnerable to dying on the line than larger sharks with 87.7, 82.4, and 44.4 % at-vessel mortality rates for young-of-the-year (YOY), juvenile, and adult dusky sharks, respectively (Morgan and Burgess 2007). Updated analyses using the same data also found increased at-vessel mortality with longer soak times and decreasing size, resulting in an at-vessel mortality rate of 79% for dusky sharks less than 110 cm fork length (Romine et al. 2009). This species is thought to be an obligate ram ventilator requiring movement, such as swimming with an open mouth, to allow for water to pass through the gills to facilitate oxygen extraction, especially during times of limited oxygen availability. Longline capture prevents or restricts this type of movement. For those sharks that survive capture, the associated physiological stress may compromise their post-release survival (Mandelman and Skomal 2009, Marshall et al. 2012).

A recent study was conducted to investigate post-release mortality from bottom longline capture events (longline sets were modeled after the NMFS Shark Research Fishery) using PSAT tags and the effects of soak time using hook timers on both at-vessel and post-release mortality of dusky sharks (Heather Marshall, University of Massachusetts Dartmouth (UMASSD), personal communication, 2014). At-vessel mortality from this study was 22%, much lower than found through the shark bottom longline observer program reported above (Morgan and Burgess

2007, Romine et al. 2009), but soak times used in this study (average = 2.7 +/- 2.6 hrs, n=34 sets) were consistently shorter than those used by commercial longliners. Study findings indicated that at-vessel and post-release mortality occurred more frequently after 3-5 hrs on the line when up to 67% of all moribund dusky sharks experienced post-release mortality. The total mortality (at-vessel + post-release, including moribund sharks) of captured dusky sharks exceeded 96% when soak-times surpassed 3 hrs. Released dusky sharks (including moribund sharks) exhibited 90% post-release survival when retained less than or equal to 3 hrs on the line, but this reduced to 58% post-release survival when retained on the line for more than 3 hrs. Hook time was a significant factor in predicting at-vessel mortality and was highly correlated with soak time (Figure 23). Since the time a shark is hooked on the line is often similar to the soak time for the corresponding set, this suggests that sharks are getting caught near the beginning of the set and gives weight to the idea that reducing soak-times will not adversely affect catch rates, but may help reduce at-vessel and post-release mortalities (Heather Marshall, UMASSD, personal communication, 2014).

Figure 23. Regression analysis of the significant relationship between hook time (determined by hook-timers) and soak time (determined from the time the first hook is set to when the first hook is removed during gear retrieval) for dusky sharks caught on the longline. The regression relationship is shown by the trend line within the scatterplot, and the line equation, p-value, and R^2 value are shown within the figure. Source: Heather Marshall, personal communication, 2014.



The proportion of recreational live discards that suffer post-release mortality due to handling and other factors was assumed to be zero for previous shark assessments. The SEDAR 21 Life History Working Group (NMFS 2011a) estimated a 6% post-release survival rate for recreationally caught fish based on the findings of Cliff and Thurman (1984), who studied the physiological effects of capture stress on juvenile dusky sharks caught by rod and reel. The majority of dusky shark catches in recreational fisheries are juveniles (Cortes and Baremore 2010).

As stated earlier, estimates of commercial at-vessel and commercial and recreational post-release mortality reported in the SEDAR 21 stock assessment report for dusky sharks were not used in the stock assessment model (NMFS 2011a). An age-structured catch free model (ASCFM) was used instead due to the uncertainty about the magnitude of total catches and discards. In this type of assessment model, the fishing mortality rates are not directly input, but are estimated by the ASCFM. NMFS estimated that the level of exploitation in 2008 was sustainable when projected out into the future (see PROJECTIONS section, Figure 25) and overall levels of US bycatch and Mexican landings appear to be decreasing (see US bycatch and Mexican landings section). For these reasons, the at-vessel and post-release mortality associated with current trends of US bycatch and Mexican landings should not negatively impact future stock projections

Effect of the Shark Fin Trade

Dusky sharks are estimated to make up 1.4% (1.2–1.7%) of the Hong Kong Shark Fin Market, only listed ahead of the least encountered species, the tiger shark, *Galeocerdo cuvier*, (0.13%, Clarke et al. 2006). The dusky shark primer used to genetically identify dusky shark fins cross-amplifies two other species, the Galapagos shark (*C. galapagensis*) and the oceanic whitetip shark (*C. longimanus*). The oceanic whitetip shark fins are easily distinguished from other species based on appearance, so the dusky shark primer was used to indirectly confirm morphological identification (Clarke et al. 2006). Since dusky sharks are genetically indistinguishable from and morphologically very similar to Galapagos sharks, the primer is not able to distinguish between species and; therefore, it is likely the reported percentage of dusky sharks in the fin market is overestimated (Clarke et al. 2006). Dusky sharks have been listed as NMFS prohibited species since 2000 in the NWA and although it is expected that some dusky shark fins from the Hong Kong Shark Fin Market come from the NWA, these numbers are not likely of the magnitude to affect the status of the species in this region.

Disease, competition, or predation

Disease

Various parasitic copepods have been documented on dusky sharks, including *Alebion carchariae*, *Paralebion elongates, Perrisoppus communis, Pandarus satyrus, Pandarus sinuatus, Pandarus smithii, Pandarus cranchii, Nessipus alatus, Nessipus gracilis, Nessipus orientalis,* *Nemesis pallida, Nemesis spinulosis, Eudactylina spinifera, Kroyeria gracilis,* and *Opimia exilis* (Bere 1936, Cressey 1970). Though there are many different types of parasitic copepods associated with dusky sharks, there are also species of diskfishes (Echenidae) that rely on the dusky shark for the host-fish relationship they provide for feeding on those copepods. Cressey and Lachner (1970) found the *Remora remora* and the "white suckerfish" (*R. albescens*) feed on copepods attached to dusky sharks. The connection between the host fish and *R. remora* was noted to be a stable, long-term relationship and that the white suckerfish is rarely caught apart from the host fish, which may indicate that these fish maintain a relationship with and/or close proximity to the host-fish (Cressey and Lachner 1970).

Acanthocephala, cestodes and tremetodes have also been documented on dusky sharks (Linton 1901, Linton 1908, Linton 1921, Bullard *et al*. 2004). Linton (1901) documented one Acanthocephala (*Echinorhynchus agilis*), ten cestodes (e.g., *Discocephalum pileatum, Anthrobothrium laciniatum, Crossobothrium angustum, Phoreiobothrium lasium, P. triloculutum, Platybohrium cerrinum, Tetrarhynchus bisulcatus, T. bicolor, T. spp.*) and one trematode (*Gasterostomum arcuatum*). The cestode *Rhynchobothrium speciosum* (Linton 1921) and nematode *Ascaris brevicapitata* have also been found on dusky sharks (Linton 1921, Linton 1905).

Bullard *et al*. (2004) found a dusky shark in the Indian Ocean with *Dermophthirius carcharhini*, documenting the first record of the *D. carcharhini* distribution extending outside of the Atlantic Ocean. A dusky shark captured in the New York Bight and held in the New York Aquarium for five months, suffered a mortal infection with *D. carcharhini* which was thought to show host specificity as it did not infect the other sharks present in the same tank (Cheung and Ruggieri 1983). Sea lampreys have also been documented on dusky sharks, though the extent to this occurrence is not known as sea lampreys tend to be opportunistic, feeding on a wide variety of bony and cartilaginous fish (Jensen and Schwartz 1994, Wilkie *et al*. 2004, Gallant *et al*. 2006).

In summary, dusky sharks experience some degree of parasitic disease; however, this does not appear to be a significant factor affecting the abundance or persistence of dusky shark populations in the wild. Parasites are common, but there is nothing in the literature to indicate that disease is significantly affecting the abundance of dusky shark in the wild, and the only mortality event due to parasitic disease was recorded from a fish in captivity (Bullard *et al*. 2004). Additionally, as noted above, there are diskfishes that serve in a mutually beneficial relationship with dusky sharks feeding on the parasites.

Competition and predation

Like many other large coastal shark species, dusky sharks tend to be opportunistic feeders and occupy high trophic levels in the marine communities where they occur. Primarily a coastal species, but also found in the outer continental shelf and sometimes in pelagic waters (Castro 2011), dusky sharks have a wide trophic spectrum that includes mostly fishes, cephalopods (squid, octopuses), other elasmobranchs (rays, other sharks), and crustaceans (Cortés 1999). Off the US eastern seaboard, Gelsleichter et al. (1999) reported that dusky sharks feed mostly on teleosts, such as bluefish (*Pomatomus saltatrix*) and summer flounder (*Paralichthys dentatus*) as well as another 10 species belonging to nine teleost families. Elasmobranch fishes, consisting only of rajids and stingrays, and crustaceans (crabs) and cephalopods (squid) were also found in stomach contents but to a much lesser degree. Bowman et al. (2000) also found the diet of the dusky shark off the northeastern US to be dominated by bony fishes, and squid and crustaceans to a lesser extent. Although some of their prey species may have experienced population declines, no information exists to indicate that depressed populations of these prey species are negatively affecting dusky shark population abundance.

Not much is known of resource partitioning and competition for resources in elasmobranch fishes in general, although both are likely to occur in marine communities of which sharks are part (Wetherbee et al. 2012, Heithaus and Vaudo 2012). It is possible that juvenile dusky sharks in particular may have to compete for food resources with other co-occurring sharks and teleosts, but it is unlikely that this competition for food would be important enough to affect their abundance, especially considering the high trophic plasticity and opportunistic behavior of large predatory species like the dusky shark (Cortés et al. 2008).

It is also very unlikely that predation on dusky sharks is a factor influencing their abundance. Adult dusky sharks reach a size of almost 4 m and are considered the largest of the carcharhinid sharks (Castro 2011), with no major predators known. Owing to their large size at birth of about 1 m total length, it is also likely that newborn and juvenile dusky sharks would have very few, if any, major predators that could regulate population size.

In summary, there is no evidence to indicate that competition or predation pose a significant threat to the continued existence of the NWA dusky shark population.

Evaluation of adequacy of existing regulatory mechanisms

The ESA requires an evaluation of existing regulatory mechanisms to determine whether they may be inadequate to address threats to the dusky shark population in the Northwest Atlantic and GOM. Existing regulatory mechanisms may include federal, state, and international regulations. Below is a description and evaluation of current domestic and international management measures that affect the NWA dusky shark population.

Domestic Authorities

US fisheries are managed under the authority of the MSA, 16 USC. 1801 *et seq.* The US Atlantic tuna and tuna-like species fisheries are managed under the dual authority of the MSA, and the Atlantic Tuna Conventions Act (ATCA), 16 USC. 971 *et seq.*

Atlantic Tunas Convention Act

The ATCA authorizes the Secretary of Commerce to administer and enforce all provisions of the International Convention for the Conservation of Atlantic Tunas (ICCAT). Pursuant to this goal, the Secretary cooperates with the duly authorized officials of the government of any party to the Convention as well as any other Federal department or agency or any State. The Secretary of Commerce is authorized to issue regulations deemed necessary to implement the Convention. ATCA also charges the Secretary with issuing regulations for the advancement of any recommendation from ICCAT. However, regulations promulgated under ATCA are, to the extent practicable, to be consistent with FMPs prepared and implemented under the Magnuson-Stevens Act. The authority to issue regulations to implement the recommendations from the ICCAT has been delegated from the Secretary to the NOAA Assistant Administrator for Fisheries.

Magnuson-Stevens Fishery Conservation and Management Act

The MSA establishes the authority and responsibility of the Secretary of Commerce to develop fishery management plans and subsequent amendments for managed stocks. The MSA requires NMFS to allocate both overfishing restrictions and recovery benefits fairly and equitably among sectors of the fishery. In the case of an overfished stock, NMFS must establish a rebuilding plan. The FMP or amendment to such a plan must specify a time period for ending overfishing and rebuilding the fishery that shall be as short as possible, taking into account the status and biology of the stock of fish, the needs of fishing communities, recommendations by international organizations in which the US participates, and the interaction of the overfished stock within the marine ecosystem. The rebuilding plan cannot exceed ten years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the US participates dictate otherwise.

On November 28, 1990, the President of the United States signed into law the Fishery Conservation Amendments of 1990 (Pub. L. 101-627). This law amended the MSA and gave the Secretary of Commerce the authority to manage HMS in the US EEZ of the Atlantic Ocean, GOM, and Caribbean Sea (16 USC. 1811 and 16 USC. 1854(f)(3)). The Secretary of Commerce has delegated authority to manage Atlantic HMS to the HMS Management Division within NMFS, which develops regulations for HMS fisheries and primarily coordinates the management of HMS fisheries in federal waters (domestic) and the high seas (international), while individual states establish regulations for HMS in state waters. However, federally permitted shark fishermen, as a condition of their permit, are required to follow federal regulations in all waters, including state waters, unless the state has more restrictive regulations. For example, federal regulations allow the commercial and recreational retention of lemon sharks (*Negaprion brevirostris*), while the State of Florida prohibits retention of lemon sharks. Therefore, a fisherman who holds a federal permit for sharks would have to abide by Florida's more restrictive state regulations regarding lemon sharks when fishing in Florida state waters.

In 1993, the Secretary of Commerce, through NMFS, implemented the FMP for Sharks of the Atlantic Ocean. This FMP included a number of shark management measures including the establishment of a fishery management unit (FMU) consisting of 39 frequently caught species of Atlantic sharks, separated into three groups for assessment and regulatory purposes (Large Coastal Sharks (LCS), Small Coastal Sharks (SCS), and pelagic sharks). The LCS management unit included dusky sharks, and was assigned a calendar year commercial quota, which was split equally and applied to two fishing periods (Jan. 1 through June 30, and July 1 through Dec. 31). At that time, NMFS identified LCS as overfished and established the quota at 2,436 metric tons (mt) dressed weight (dw) based on a 1992 stock assessment. Under the rebuilding plan established in the 1993 FMP, the LCS quota was expected to increase in 1994 and 1995 up to the MSY estimated in the 1992 stock assessment (3,800 mt dw). But a new stock assessment in 1994 considered that TAC increases could risk preventing stock recovery. Therefore, LCS quotas were capped at 1994 levels. A recreational trip limit of four LCS sharks per vessel was also established in this FMP.

Additional LCS stock assessments were completed in 1996 and 1998. The 1996 stock assessment found no clear evidence of rebuilding and the 1998 stock assessment found that LCS were overfished and would not rebuild under 1997 harvest levels. Based in part on the 1998 stock assessment, NMFS published the final 1999 FMP for Atlantic Tunas, Swordfish, and Sharks, which included numerous measures to rebuild or prevent overfishing of Atlantic sharks in commercial and recreational fisheries, such as reducing commercial LCS quotas and recreational retention limits, and adding dusky sharks (along with 13 additional species) to the list of prohibited shark species. Adding dusky sharks to the list of prohibited shark species was implemented in 2000 and since that time commercial fishermen have not been allowed to retain, possess, land, sell, or purchase dusky sharks, and recreational retention has also been prohibited.

The implementing regulations for the conservation and management of the domestic fisheries for Atlantic swordfish, tunas, sharks, and billfish are published in the 2006 Consolidated HMS FMP (71 FR 58058, NMFS 2006), which consolidated the management of Atlantic sharks, tunas, swordfish, and billfish under one FMP. Since 2006, this FMP has been amended six times, with three more amendments currently in development. Amendment 5b, which is currently in development, is especially relevant as it will address the recent NMFS “overfished” and “overfishing” status determination of the dusky shark stock (76 FR 61092; October 3, 2011). At this time, measures that may be included in Amendment 5b are not existing regulatory measures for dusky shark conservation and management and have not been included in this evaluation of dusky shark extinction risk.

On April 10, 2008, NMFS released the Final Environmental Impact Statement (FEIS) for Amendment 2 to the 2006 Consolidated HMS FMP based on several stock assessments that were completed in 2005/2006 (NMFS 2008). Assessments for dusky sharks and sandbar sharks (*Carcharhinus plumbeus*) indicated that these species were overfished with overfishing occurring and that porbeagles (*Lamna nasus*) were overfished. NMFS implemented management measures consistent with recent stock assessments for sandbar, porbeagle, dusky, blacktip (*Carcharhinus limbatus*), and the LCS complex. The implementing regulations were published on June 24, 2008 (73 FR 35778; corrected version published July 15, 2008; 73 FR 40658). Management measures implemented in Amendment 2 included, but were not limited to, establishing rebuilding plans for porbeagle, dusky, and sandbar sharks consistent with stock assessments, implementing commercial quotas and retention limits consistent with stock assessment recommendations to prevent overfishing and rebuild overfished stocks, modifying recreational measures to reduce fishing mortality of overfished/overfishing stocks, modifying reporting requirements, requiring that all Atlantic sharks be offloaded with fins naturally attached, collecting shark life history information via the implementation of a shark research fishery, and implementing time/area closures recommended by the South Atlantic Fishery Management Council (NMFS 2014).

Commercial fishing impacts on dusky sharks have been reduced in the directed shark bottom longline fishery since 2008 with the implementation of Amendment 2, mainly resulting from prohibiting the commercial harvest of sandbar sharks outside of the Shark Research Fishery (NMFS 2012b). Since 2008, when the shark research fishery was established, NMFS has had 100 percent observer coverage on shark research fishery trips targeting sandbar sharks. The prohibition on the commercial harvest of sandbar sharks outside the research fishery resulted in shark fishermen targeting other species of sharks (e.g., blacktip, lemon, and bull sharks, *Carcharhinus leucas*) that tend to occur in areas closer to shore than sandbar and dusky sharks (NMFS 2014). Anecdotal evidence suggests that in the Atlantic Ocean, vessels that targeted sandbar sharks were more likely to catch dusky sharks because of similar habitat preferences, including depth and water temperature (NMFS 2012b). Therefore, given the prohibition on the commercial harvest of sandbar sharks outside of the shark research fishery and the resultant shift in species targeted by commercial bottom longline fishermen, impacts from the directed commercial bottom longline shark fishery to the extinction risk of dusky sharks are considered negligible.

Because dusky sharks are prohibited from commercial and recreational retention, fishing impacts on dusky sharks in the commercial US Atlantic pelagic longline fishery for swordfish and tunas and recreational rod and reel shark fishery are assumed to be a result of bycatch of dusky sharks and misidentification issues. According to Pelagic Longline Observer Program data from 1992 through October 2012, the at-vessel mortality rate for dusky sharks in the pelagic longline fishery is approximately 34 percent (NMFS unpublished data). The annual number of hooks deployed in the Atlantic pelagic longline fishery from 2003-2012 has ranged from 5,662,000 to 7,679,000, with no distinct pattern of increasing or decreasing fishing effort (NMFS 2013c). Additional measures to reduce interactions (e.g., time/area closures) with dusky sharks in the pelagic longline fishery were proposed in Draft Amendment 5 to the 2006 Consolidated HMS FMP, but were not implemented, with further analysis being conducted on these measures in another FMP Amendment (Amendment 5b, NMFS 2014). Dusky sharks can be difficult to identify due to similarities with other Carcharhinid sharks (e.g., sandbar and silky sharks, *Carcharhinus falciformis*), and have still been reported as landed in NMFS recreational fishing survey data, which may be due to misidentification issues or fishermen not understanding the regulations. Additional management measures to correct this problem have not been implemented at this time. Therefore, existing management measures may be inadequate to decrease the level of dusky shark mortality in the pelagic longline and recreational fisheries. However, pelagic longline bycatch appears to have stabilized at low levels in recent years (see Current US Atlantic fisheries section, Figure 1) and research surveys show increasing abundance trends since 2009 (see Current trends in abundance section, Figure 14), indicating that this current level of fisheries-related mortality may not be significantly increasing the species' extinction risk.

Although dusky sharks have been designated as a prohibited species since 2000 following the implementation of the 1999 FMP, dusky sharks may be collected for research under an Exempted Fishing Permit (EFP) or Scientific Research Permit (SRP). NMFS considers issuing these types of permits on a case-by-case basis and any associated dusky shark mortality coming from this type of research is deducted from the research and display quota annually. In 2012 and 2013, NMFS authorized 5 permits with a total of 110 dusky sharks and 6 permits with a total of 136 dusky sharks, respectively, for research purposes.

The base assessment model and most sensitivity analyses from the most recent stock assessment (NMFS 2011a) indicated that dusky sharks are currently overfished, and that overfishing has been occurring since the mid-1980s. However, apical fishing mortality relative to maximum sustainable yield levels for dusky sharks has declined dramatically since the year 2000 (see Dusky shark stock assessment section, Figure 9), indicating that the prohibition on commercial and recreational retention of dusky sharks has decreased fisheries-related mortality and appears to have reduced, but perhaps not ended, overfishing (NMFS 2011a). Even though dusky sharks were listed as a NMFS prohibited species in 2000, they are still susceptible to gillnet and longline fishing gear. One area of increased gear interaction with dusky sharks was found to be offshore of Cape Hatteras, North Carolina. In 2005, NMFS created the Mid-Atlantic Shark Closure Area, which encompasses North Carolina habitat for many dusky sharks. The area was closed to protect dusky sharks and juvenile sandbar sharks from January through July. Data collected in the Shark Research Fishery and by NOAA scientists conducting bottom longline surveys in the Mid-Atlantic Shark Closure Area indicate elevated interactions with dusky sharks during the time/area closure (Figure 24, NMFS 2012b), suggesting that the Mid-Atlantic Shark Closure area is providing protection to dusky sharks from incidental fishing mortality.

State Fishery Management Regulations

State fishery management agencies have authority for managing fishing activity only in state waters (0-3 miles in most cases; 0-9 miles off Texas and the Gulf coast of Florida). As mentioned above, in the case of federally permitted shark fisherman, fishermen are required to follow federal regulations in all waters, including state waters, unless the state has more restrictive regulations. The Atlantic States Marine Fisheries Commission approved the Interstate FMP for Atlantic Coastal sharks in August 2008 to create consistent regulations across the Atlantic states from Maine to Texas. All Atlantic states, along with Puerto Rico and the US

Virgin Islands, have adopted the same prohibited status for dusky sharks as the federal regulations and in the Interstate FMP for Coastal Sharks, therefore, commercial and recreational retention of dusky sharks is prohibited in state waters.

Additionally, states such as Delaware, Hawaii, Washington, California, Oregon, Illinois, New York, Maryland, and Massachusetts have implemented or are working towards the implementation of shark fin bans. These bans have been developed by states individually, but generally prohibit the purchase or sale of shark fin in the state. These bans may not have much of a direct impact on dusky sharks because of their prohibited status, but may have a broader impact on the shark fishing industry in general, especially if they lead to changes in shark fishing effort, which could indirectly impact dusky sharks.

Mexican regulations (Soriano-Velásquez 2011)

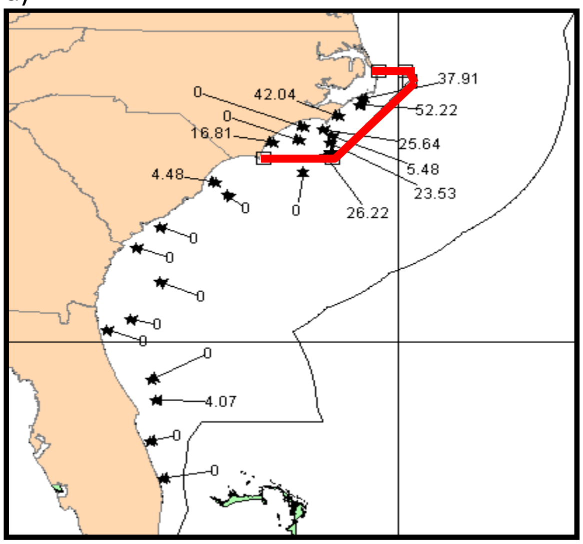
The General Law of Sustainable Fishery and Aquaculture (Ley General de Pesca y Acuacultura Sustentables) regulates the use of living marine resources. Fishery management plans and regulations are implemented through the National Fishing Charter (CNP: Carta Nacional de Pesca). With authority under the CNP, and the National Plan of Action for the Conservation and Management of Sharks, Rays and Similar Species in Mexico (NPOA-Sharks), the National Fisheries Institute (INAPESCA: Instituto Nacional de Pesca) and the management agency, Comisión Nacional de Acuacultura y Pesca (CONAPESCA), implemented NOM 029-PESC-2006 (NOM: Norma Oficial Mexicana) called "Responsible Fishery of Sharks and Rays; specifications for use." NOM 029-PESC-2006 regulates harvesting, designates prohibited species (*Carcharodon carcharias*, *Cetorhinus maximus, Manta birostris, Pristiophorus schroederi, Pristis pectinata, P. perotteti, P. microdon,* and *Rhincodon typus*,), specifies fishing zones and seasons, authorizes gears, and requires permit holders to report data. It promotes full use of catch by prohibiting finning. The goals are to maintain sharks at sustainable levels and reduce incidental catch of sea turtles and marine mammals. Additionally, CONAPESCA recently implemented an annual shark fishing prohibition in Mexican jurisdictional waters beginning on the date of publication of the Agreement (June 11, 2012) until June 30, 2012 and in subsequent years during the period of May 1 to June 30 of each year. In addition to these provisions the prohibition extends to August 31 of each year in the Campeche Bank region.

In the field, INAPESCA surveys fisheries at landing sites. Priorities are biological data including species composition, biometric measures, abundance, sexual maturity, and catch per unit effort. Fishermen are required to report catch, vessel and fishing characteristics, fuel use and other details for each trip. Challenges include poor enforcement, lack of compliance, and inaccurate logbook reporting. Fishermen complain logbook forms are too complex. In response, CONAPESCA and INAPESCA prepared a shark ID guide, and are working to create a friendlier format.

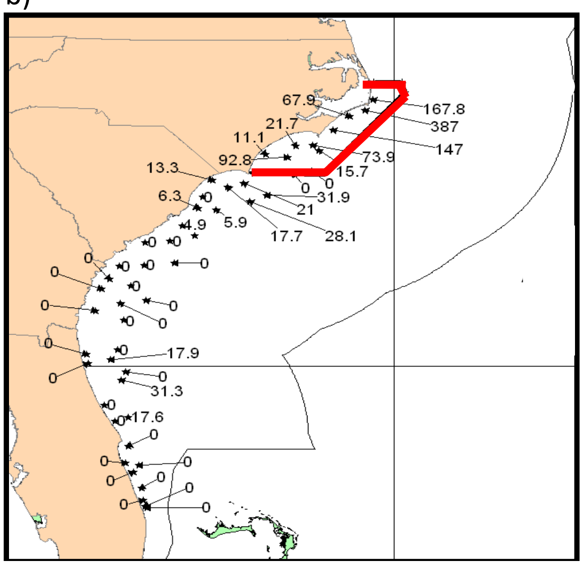
Vast improvements in monitoring and regulating Mexican fisheries have been made in recent years, but many challenges still exist that may jeopardize the ability of NWA dusky shark populations to increase beyond current sustained levels.

Figure 24. NEFSC Coastal Shark Bottom Longline Survey (see NEFSC Coastal Shark Bottom Longline Survey heading in Dusky shark stock assessment section) stations (stars) with labeled dusky shark catch per 10,000 hook hours in 2007 (a), 2009 (b) and 2012 (c). The red line denotes the Mid-Atlantic Shark Closure Area.

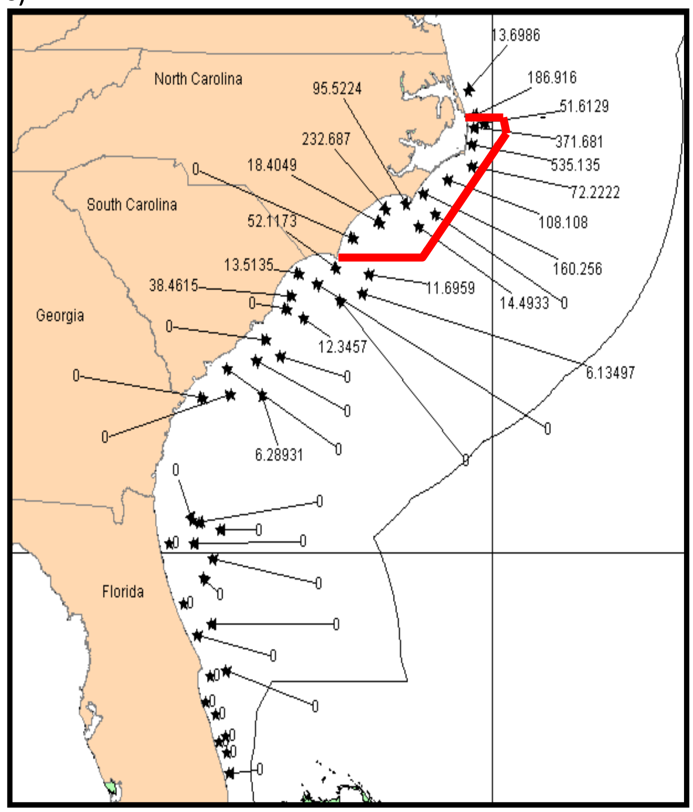
a)



b)



c)



Other natural or manmade factors affecting its continued existence

Productivity

Demographic analyses are often used to assess vulnerability to overfishing based on life history parameters. Productivity expressed as the intrinsic rate of population increase (r) is the key parameter estimated from these analyses, with low estimates of r indicating a species that will be slow to recover from depletion. Musick (1999) suggested the following ranges for evaluating the productivity of marine species based on r (yr^{-1}) values: high = >.50, medium=.16-.50, low=.05-.15, and very low = <.05. Given the late age at maturity, slow growth rate, long life span, and low fecundity of many elasmobranchs, sharks are often at the low to very low end of this scale. Cortés (1998) estimated the annual intrinsic rate of population increase for NWA dusky sharks at .028 per year, given a two-year reproductive cycle and without fishing mortality. Out of 26 Pacific species, Smith et al. (1998) estimated that the dusky shark had the second lowest intrinsic rate of population increase (r=.020 per year) using life history characteristics from the NWA. Productivity values were strongly affected by age at maturity (Smith et al. 1998), which was estimated at 21 years for dusky shark females based on work by Natanson et al. (1995) in the NWA. In 2009, Romine et al. conducted demographic analyses on the dusky shark incorporating hooking mortality and new reproduction data indicating a three-year reproductive cycle. Under zero fishing pressure, Romine et al. (2009) estimated an r of .018 per year (with a range of -.019 to .067 per year given the variability of parameters used in the model). Similar to results from McAuley et al. (2007) on western Australian dusky sharks, Romine et al. (2009) found that dusky shark populations would decline even at low levels of fishing mortality. In 2010, Cortés et al. conducted an ecological risk assessment (ERA) of sharks caught in Atlantic pelagic longline fisheries. ICCAT (2012) recently updated this ERA by adding five previously unassessed sharks, including the dusky shark. In this ERA (ICCAT 2012), productivity for the dusky shark was modeled using updated life history information on age and growth from Natanson et al. (2013) and a three-year reproductive cycle (Castro 2009, Romine 2009). Out of the 20 Atlantic shark stocks assessed by ICCAT (2012), the dusky shark stock had the fifth lowest intrinsic rate of population increase (r = 0.043 per year). Generation time was estimated at 29.6 years (ICCAT 2012), which is 10 years shorter than the NMFS (2011) estimate used during the SEDAR 21 process. The productivity estimated by ICCAT (2012) using the most up to date life history information nearly doubles the r (yr^{-1}) values estimated during previous studies, bringing the relative rating of productivity from very low to borderline between very low and low according to the scale provided by Musick (1999).

Climate change

The effects of climate change are a growing concern for fisheries management as the distributions of many marine organisms are shifting in response to their changing environment. Factors having the most potential to affect marine species are changes in water temperature, salinity, ocean acidification, ocean circulation, and sea level rise. Two recent studies have addressed the vulnerability of dusky sharks to climate change. Chin et al. (2010) conducted a vulnerability assessment of sharks and rays on Australia's Great Barrier Reef (GBR) and NMFS is in the process of finalizing a vulnerability assessment of US northeast fish stocks (Jonathan A.

Hare, NEFSC, personal communication, 2014). These studies identified similar factors for use in their vulnerability assessments, and ranked the level of exposure and sensitivity to these factors using current knowledge and expert opinion. Chin et al. (2010) used a 3 point scale (low, moderate, and high) and NMFS used a 4 point scale (low, moderate, high, and very high) for ranking of the separate components by species. The resulting relative vulnerability for each species was based on logic rules in both studies. Dusky shark exposure rankings were highly influenced by water temperature but sensitivity to this factor was ranked low for both the NWA and Australia's GBR sharks. NWA dusky sharks were assessed a high vulnerability ranking with respect to climate change, primarily influenced by stock status (overfished with overfishing occurring) and population growth rate. Although the population growth rate was taken into account in the GBR study, little is known about the population status of sharks in this area (Chin et al. 2010, McAuley et al. 2012). GBR dusky sharks were assessed a low vulnerability ranking with respect to climate change. If stock status is removed from the NWA climate vulnerability analysis (or status is significantly improved) the overall vulnerability of dusky sharks to climate change would be assessed as low (Jonathan A. Hare, NEFSC, personal communication, 2014).

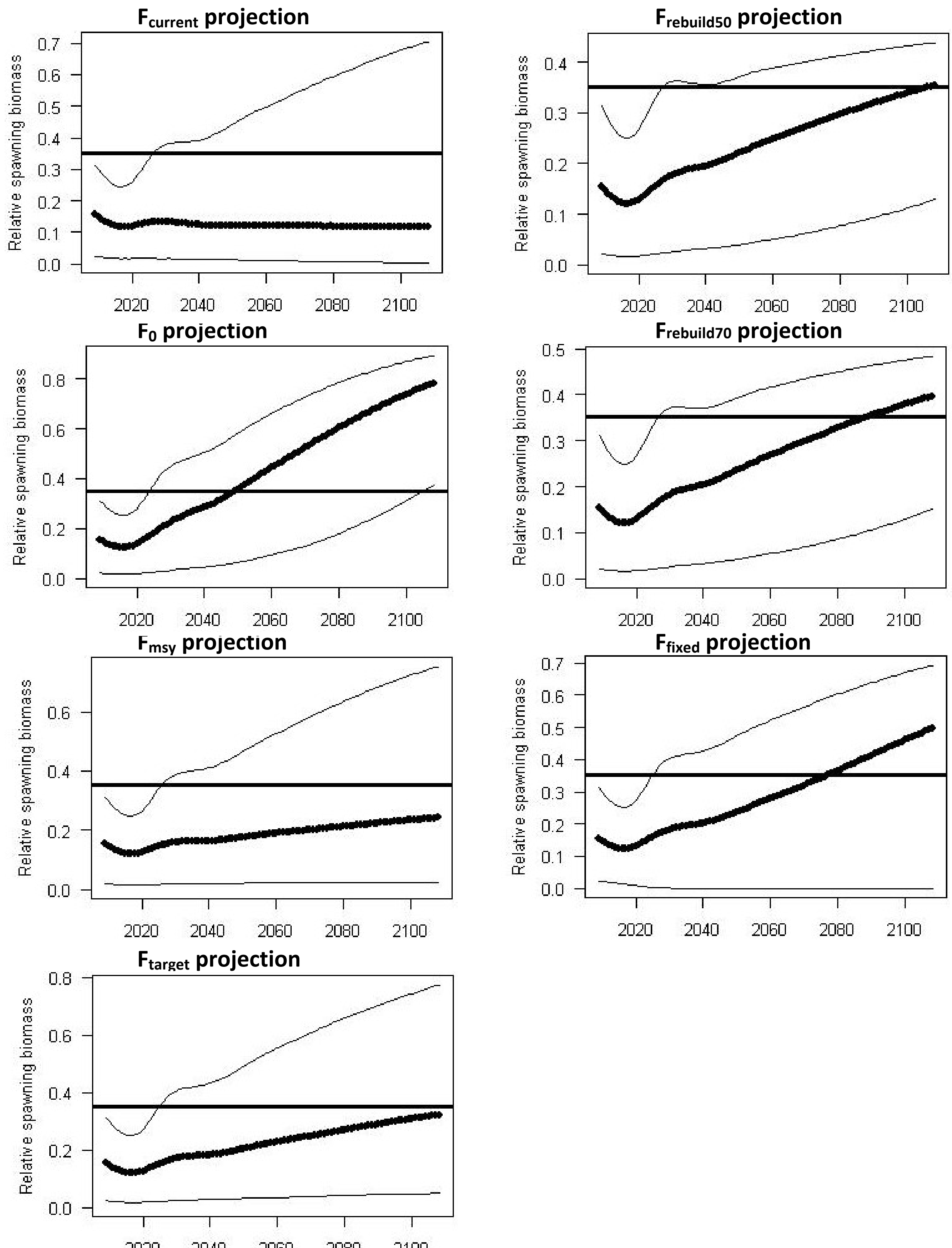
PROJECTIONS

NMFS (2011a) conducted several projection scenarios for the NWA dusky shark population beginning in 2009 and run until the year 2108 to determine the probability of rebuilding within a 100 year time frame. All projections used 10,000 Monte Carlo bootstrap simulations with initial values pulled from a multivariate normal distribution. Moments of the bootstrap runs were summarized using quantiles, with median used for the central tendency, and 30th percentile used as the criterion for whether a projection had a 70% chance of rebuilding by 2108. The projection scenarios are listed below:

- The $F_{current}$ projection - F was held constant at 2009 levels using a modal apical F of 0.055
- The F_0 projection - No fishing mortality
- The F_{msy} projection - F at constant MSY levels using a modal F of 0.035
- The F_{target} projection - reduced F to 0.028 in an effort to ensure that the probability of overfishing in any given year was less than 30%
- The $F_{rebuild50}$ projection - reduced F to 0.027, the maximum F that would allow a 50% chance of rebuilding by 2108
- The $F_{rebuild70}$ projection - reduced F to 0.023, the maximum F that would allow a 70% chance of rebuilding by 2108
- F_{max} projection - F that would allow largest cumulative harvest over time frame, while still allowing a 70% chance of rebuilding by 2108. This projection used an F that maximized the average weight yield per fish recruited to the fishery and results were identical to the $F_{rebuild70}$ projection
- The F_{fixed} projection – Assumes the maximum fixed removals allowing a 70% chance of rebuilding by 2108. Annual removals were reduced to a preset level of 21,200 lbs. (gutted weight) per year

The $F_{current}$ projection scenario indicated a low probability of stock recovery by 2108. However, the current bycatch level was estimated to be sustainable, although below maximum sustainable yield, maintaining spawning biomass levels near 15% of unexploited levels (Figure 25). The F_0 projection resulted in recovery from overfished status near the year 2050 (Figure 25). The F_{msy} scenario indicated that the probability of the stock rebuilding to MSY levels was less than 50% (Figure 25). The F_{target} projection, which reduced F to 0.028 in an effort to ensure that the probability of overfishing in any given year was less than 30%, still did not provide a large enough reduction in F to recover the stock by 2108 (Figure 25). Reducing F to 0.027 (as in the $F_{rebuild50}$ scenario) was enough to result in a 50% chance of rebuilding the stock; however, F had to be reduced to 0.023 (as in the $F_{rebuild70}$ scenario) to achieve a 70% probability of rebuilding the stock by 2108 (Figure 25). The F_{fixed} scenario suggested reducing annual removals to a preset level of 21,200 lbs. (gutted weight) per year would be sufficient to rebuild the stock with 70% probability by 2108 (Figure 25).

Figure 25. Results for the projection scenarios, 2009-2108. The heavy dotted line gives the median projection, while the thin solid lines give 95% uncertainty bounds. The horizontal line represents the corresponding value that would be anticipated at MSY.



EXTINCTION RISK ANALYSIS

Often the ability to measure or document risk factors is limited, and information is not quantitative and very often lacking altogether. Therefore, in assessing risk, it is important to include both qualitative and quantitative information. In previous NMFS status reviews, Status Review Teams (SRTs) have used a risk matrix method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used in Pacific salmonid status reviews as well as in reviews of scalloped hammerhead, Pacific hake, walleye pollock, Pacific cod, Puget Sound rockfishes, Pacific herring, and black abalone (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). In the risk matrix approach, the collective condition of an individual population is summarized at the DPS level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well-founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. Using these concepts, the SRT estimated the extinction risk of the NWA dusky shark DPS based on current demographic risks and threats. The summary of the demographic risks and threats obtained by this approach was then considered by the SRT in determining the DPS' overall level of extinction risk. Specifics on each analysis are provided below.

Methods

Demographic Risks Analysis

After reviewing all relevant fisheries and biological information for the species, including recent stock assessment results, current trends in abundance, natural and human-influenced factors that cause variability in survival and abundance, and possible threats to genetic integrity, each SRT member assigned a risk score to each of the four demographic criteria (abundance, growth rate/productivity, spatial structure/connectivity, diversity). Risks for each demographic criterion were ranked on a scale of 1 (very low risk) to 5 (very high risk). Below are the definitions that the team used for each ranking:

1. **Very Low** - It is very unlikely that the particular factor contributes or will contribute significantly to the risk of extinction

2. **Low** – It is unlikely that the particular factor contributes or will contribute significantly to the risk of extinction

3. **Medium** - It is likely that the particular factor contributes or will contribute significantly to the risk of extinction

4 **High** – It is highly likely that the particular factor contributes or will contribute significantly to the risk of extinction

5 **Very High** - It is very highly likely (extremely likely) that the particular factor contributes or will contribute significantly to the risk of extinction

After scores were provided, the team discussed the range of perspectives for each of the demographic risks and the supporting data on which it was based, and was given the opportunity to revise scores if desired after the discussion. The scores were then tallied (mode, median, range) and reviewed by the SRT and considered in making the overall risk determination. Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. Other descriptive statistics, such as mean, variance, and standard deviation, were not calculated as the SRT felt these metrics would add artificial precision or accuracy to the results.

Threats Assessment

Section 4(a)(1) of the ESA requires the agency to determine whether the species is endangered or threatened because of any of the following factors:

1) present or threatened destruction, modification, or curtailment of habitat or range;
2) overutilization for commercial, recreational, scientific, or educational purposes;
3) disease, competition, or predation;
4) inadequacy of existing regulatory mechanisms; or
5) other natural or manmade factors

After reviewing the best available scientific and commercial data on the dusky shark (see the ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS section for details), the SRT identified and evaluated the following potential threats to the species: loss or degradation of habitat, US bycatch and Mexican landings (also considering impacts of at-vessel and post-release mortality), the shark fin trade, disease, predation, competition, adequacy of current management regulations, biological vulnerability, and climate change.

Similar to the demographics risk analysis, the SRT members were asked to rank the current severity of the threats to the extinction risk of the DPS. The rankings were defined the same as those in the demographics analysis. After scores were provided, the team discussed the range of perspectives for each of the threats, and the supporting data on which it was based, and was given the opportunity to revise scores if desired after the discussion. The scores were then tallied (mode, median, range) and reviewed by the SRT and considered in making the overall risk determination.

Foreseeable future

For the purpose of this extinction risk analysis, the term "Foreseeable future" was defined as the timeframe over which threats can be predicted reliably to impact the biological status of the species. The SRT identified US bycatch and Mexican landings as the primary anthropogenic threat to the extinction risk of the NWA DPS. Since the primary sources of NWA dusky shark bycatch and Mexican landings appear to have stable, if not decreasing, trends since the last assessment and the only change to the management measures in place at that time is the Mexican seasonal closure implemented in 2012, the SRT relied on the NMFS (2011a) projection using the fishing mortality estimated for the final year of the assessment (F = 0.055) as a precautionary approach to determine the foreseeable future. Due to the exponential increase in uncertainty seen in the projections of spawning stock biomass beyond 2045 ($F_{current}$ projection, Figure 25) and after considering the life history of the dusky shark; the team decided that the foreseeable future should be defined as approximately one generation time for the dusky shark, or 30 years.

Overall Level of Extinction Risk Analysis

Guided by the results from the demographics risk analysis as well as the threats assessment, the SRT members used their informed professional judgment to make an overall extinction risk determination for the NWA DPS now and in the foreseeable future. For these analyses, the SRT defined four levels of extinction risk:

1 **Not at Risk** - A species is not at risk of extinction if it exhibits a trajectory indicating that it is not at a low risk of extinction (see description of "Low Risk" below). A species is not at risk of extinction due to projected threats and its likely response to those threats (i.e., long-term stability, increasing trends in abundance/population growth, spatial structure and connectivity, and/or diversity and resilience).

2 **Low Risk** - A species is at a low risk of extinction if it exhibits a trajectory indicating that it is more likely not to be at a moderate level of extinction (see description of "Moderate Risk" below). A species may be at low risk of extinction due to projected threats and its likely response to those threats (i.e., stable or increasing trends in abundance/population growth, spatial structure and connectivity, and/or diversity and resilience).

3 **Moderate Risk** - A species is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely not to be at a high level of extinction (see description of "High Risk" below). A species may be at moderate risk of extinction due to projected threats and its likely response to those threats (i.e., declining trends in

abundance/population growth, spatial structure and connectivity, and/or diversity and resilience).

4 **High Risk** - A species is at high risk of extinction when it is at or near a level of abundance, spatial structure and connectivity, and/or diversity and resilience that place its persistence in question. Demographic risk may be strongly influenced by stochastic or depensatory processes. Similarly, a species may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create such imminent demographic risks.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the SRT adopted the "likelihood point" (FEMAT) method. This approach has been used in previous status reviews (e.g. scalloped hammerhead, Pacific salmon, Southern Resident Killer Whale, Puget Sound Rockfish, Pacific herring, and black abalone) to structure the team's thinking and express levels of uncertainty in assigning risk categories. For this approach, each team member distributed 10 'likelihood points' among the four levels of risks. The scores were then tallied (mode, median, range) and summarized for the DPS. Finally, the SRT did not make recommendations as to whether the species should be listed as threatened or endangered. Rather, the SRT drew scientific conclusions about the overall risk of extinction faced by the species under present conditions and in the foreseeable future based on an evaluation of the species' demographic risks and assessment of threats.

Extinction risk assessment results for the NWA dusky shark DPS

Evaluation of Demographic Risks

Current abundance

SRT scores for current abundance of the NWA dusky shark DPS ranged from 2 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that current trend and levels of abundance are unlikely to contribute significantly to the risk of extinction.

The SRT members agreed that NWA dusky sharks have sufficient data to adequately judge dusky shark abundance and trends. The team relied mainly upon the findings of the NMFS (2011) stock assessment and projections, updated analyses of fishery-independent surveys, and recent trends in reported US commercial and recreational bycatch and Mexican fisheries landings. The NMFS (2011) stock assessment found dusky shark to be overfished with a spawning biomass that was approximately 15% of pre-exploitation levels. Although it is difficult to make absolute statements about the number of dusky sharks in the NWA DPS because of the lack of reliable retention and discard data, fishery-independent surveys suggest that there is still a large number of dusky sharks in the US south Atlantic and GOM, and that this number could be increasing as indicated by both fishery-independent survey data and bycatch data from the NMFS Shark Research Fishery and the NMFS Large Pelagics Survey. Further, increases in biomass were not predicted for 2010-2012 by the NMFS (2011) stock assessment model, which suggests that point estimates for exploitation levels (fishing mortality) may have been biased high and estimates of stock biomass may have been biased low given the abundance trends from the updated fishery-independent survey datasets. Even though the current abundance level with respect to unexploited levels is greatly reduced, it is not reduced to a point where normal environmental changes, current fisheries-related mortality, habitat destruction, Allee effect, or demographic stochasticity could lead to extinction.

Population growth rate/productivity

SRT scores for NWA dusky shark population growth rate/productivity ranged from 2 to 4 with a modal score of 4 and median score of 3.5. A score of 3 represents moderate risk, meaning that the current growth rate/productivity of the NWA dusky shark is likely to contribute significantly to the risk of extinction.

Dusky sharks are long lived, take a long time to become sexually mature, and have few offspring. These life history characteristics limit the productivity of dusky shark, such that they can only tolerate a small level of anthropogenic mortality (at least assuming fishing and natural mortality hazards are additive as is almost universally assumed in fishery models). This also means that it takes them longer to recover from exploitation levels that are too high.

Spatial structure/connectivity

SRT scores for NWA dusky shark spatial structure and connectivity all were given a value of 2. A score of 2 represents low risk, meaning that the spatial structure and connectivity of the NWA dusky shark are unlikely to contribute significantly to the risk of extinction.

NWA dusky shark distribution covers a large range due to the highly migratory nature of the species and there is no evidence of areas within this range where the species no longer occurs. There is also no indication that the dusky shark’s range has contracted from the species’ historical range. In addition, the juvenile stage for this species is not as spatially restricted inshore as it is for many other coastal species.

Diversity

SRT scores for NWA dusky shark diversity ranged from 1 to 3 with a modal score of 1 and median score of 1.5. A score of 1 represents very low risk, meaning that the diversity of the NWA dusky shark is very unlikely to contribute significantly to the risk of extinction.

As stated earlier, based on research by Gray et al. (2012), dusky sharks from all regions show remarkably similar allelic richness and gene diversity. This includes the NWA dusky shark, despite the history of severe population decline. Benavides et al. (2011) also showed that dusky sharks, including the NWA population, exhibit high mitochondrial control region genetic diversity on a global scale in terms of numbers of haplotypes and haplotype diversity.

Threats Assessment

<u>Present or threatened destruction, modification, or curtailment of habitat or range</u>

Loss or degradation of habitat

SRT scores for threat of loss or degradation of habitat to NWA dusky sharks ranged from 1 to 2 with a modal score of 1 and median score of 1.5. A score of 1 represents very low risk, meaning that the threat of habitat loss or degradation to the NWA dusky shark is very unlikely to contribute significantly to the risk of extinction.

Dusky sharks are likely more confined by temperature and prey distributions than by a particular habitat type. Given that they are highly migratory and opportunistic predators, it is very unlikely that the loss or degradation of any particular habitat type would have a substantial effect on the dusky shark population. As discussed in the spatial structure/connectivity section of demographic risks, the juvenile stage of this shark is not as restricted to nearshore coastal areas as other coastal shark species, which likely even further reduces their susceptibility to the loss or degradation of coastal habitats.

<u>Overutilization for commercial, recreational, scientific, or educational purposes</u>

US Bycatch and Mexican landings (also considering impacts of at-vessel and post-release mortality)

SRT scores for threat of US bycatch and Mexican landings, considering impacts of at-vessel and post-release mortality, to NWA dusky sharks ranged from 2 to 4 with a modal and median score of 3. A score of 3 represents medium risk, meaning that the threat of bycatch to the NWA dusky shark is likely to contribute significantly to the risk of extinction.

US commercial and recreational bycatch and Mexican landings are the primary source of anthropogenic mortality for NWA dusky sharks. In the NMFS (2011) stock assessment, the present level of US bycatch and Mexican landings was estimated to be sustainable (although at levels below MSY), and to result in spawning biomass levels near 15% of unexploited levels if projected out into the future (Figure 25). However, there was considerable uncertainty in this projection, with some projection runs resulting in increasing populations and with some projections approaching dangerously low levels after 100 years. However, there appears to be a stable if not decreasing trend in US bycatch and Mexican landings in recent years and the recent uptick in both fishery-independent survey indices and bycatch from the NMFS Shark Research Fishery and NMFS Large Pelagics survey without increases in effort is encouraging, and suggests that present levels of exploitation (in the form of US bycatch and Mexican landings) and associated at-vessel and post-release survival may actually be sustainable. There is still uncertainty, however, and the problem could get worse if longline fishing effort were to increase, given the high rate of at-vessel mortality for longline fisheries, and post-release mortality for at least the bottom longline fishery.

Shark fin trade

SRT scores for threat of the shark fin trade to NWA dusky sharks ranged from 1 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that the threat of the shark fin trade to the NWA dusky shark is unlikely to contribute significantly to the risk of extinction.

Although some illegal harvest for dusky shark fins in the NWA is likely, all indications are that the level of such illegal activity is minimal relative to stock size.

<u>Disease, competition, or predation</u>

Disease

SRT scores for threat of disease to NWA dusky sharks ranged from 1 to 2 with a modal and median score of 1. A score of 1 represents very low risk, meaning that the threat of disease to the NWA dusky shark is very unlikely to contribute significantly to the risk of extinction.

While some disease occurs naturally in dusky shark populations, we have no information indicating that it is negatively affecting the DPS' abundance.

Competition

SRT scores for threat of competition to NWA dusky sharks ranged from 1 to 2 with a modal and median score of 1. A score of 1 represents very low risk, meaning that the threat of competition to the NWA dusky shark is very unlikely to contribute significantly to the risk of extinction.

Resource partitioning and competition for resources in elasmobranchs are likely to occur, and it is possible that juvenile dusky sharks in particular may have to compete for food resources with other co-occurring sharks and teleosts, but it is unlikely that this competition for food would be important enough to affect their abundance, especially considering the high trophic plasticity and opportunistic behavior of large predatory species like the dusky shark.

Predation

SRT scores for threat of predation to NWA dusky sharks ranged from 1 to 2 with a modal and median score of 1. A score of 1 represents very low risk, meaning that the threat of predation to the NWA dusky shark is very unlikely to contribute significantly to the risk of extinction.

There is no evidence to indicate that predation is a significant threat to the dusky shark. This species is an apex predator that reaches large sizes and has few predators of its own. Predation is likely limited to the juvenile life stage, by other larger sharks. Given the species large size at birth, predation is considered a minimal threat to the population.

Inadequacy of existing regulatory mechanisms

SRT scores for the threat posed by the inadequacy of current management regulations to NWA dusky sharks ranged from 2 to 3 with a modal score of 2 and median score of 2.5. A score of 2 represents low risk, meaning that the threat posed by the inadequacy of existing regulatory mechanisms to the NWA dusky shark is unlikely to contribute significantly to the risk of extinction.

The US and Mexican regulations in existence appear to have held bycatch and landings at a sustainable level, although below maximum sustainable yield. Fishery-independent surveys are showing an increasing trend in relative abundance. Overfishing is still occurring according to the base case run of the most recent stock assessment, but the population does appear to be rebuilding even if at a low rate. Maintaining current regulations regarding the Mexican closed season to shark fishing in the Gulf of Mexico, the US Mid-Atlantic Shark Closure Area and no retention of dusky sharks in US recreational and commercial fisheries should aid in stock rebuilding. Additionally, ongoing work to make Mexican fisheries logbook forms more user friendly should help to improve the accuracy of logbook reporting, allowing for better fisheries management practices concerning shark resources. Dusky sharks are still caught as bycatch in US fisheries and given the high at-vessel mortality rates in the bottom longline and pelagic longline fisheries, additional management measures (e.g. reducing soak times, outreach regarding best release practices) may also help to minimize extinction risk to this DPS in the future.

Other natural or manmade factors

Biological vulnerability

SRT scores for threat of biological vulnerability for NWA dusky sharks ranged from 2 to 4 with a modal and median score of 4. A score of 4 represents high risk, meaning that the threat of biological vulnerability for NWA dusky sharks is likely to contribute significantly to the risk of extinction.

Dusky shark are inherently vulnerable to overexploitation due to their low fecundity and late age at maturity. They are long lived and slow to recover from depletion. Updated life history information increased their productivity, but they are still vulnerable to low levels of exploitation/bycatch. Even though the maximum rate of population increase for this species is low compared to most sharks, it is not decreasing or with indications that it could lead to extinction.

Climate change

SRT scores for threat of climate change to NWA dusky sharks ranged from 1 to 2 with a modal and median score of 2. A score of 2 represents low risk, meaning that the threat of climate change to the NWA dusky shark is unlikely to contribute significantly to the risk of extinction.

Dusky sharks are not reliant on estuarine habitats which are thought to be the most vulnerable to climate change. As discussed previously, dusky sharks are highly migratory and opportunistic predators. This gives them the ability to shift their range or distribution to remain in an environment conducive to their physiological and ecological needs. In absence of DPS status/current abundance (accounted for elsewhere), both climate vulnerability analyses (Chin et al 2010 and Jon Hare, personal communication) assess the dusky shark with low vulnerability to climate change.

Overall level of extinction risk

Current level of extinction risk

Likelihood points were attributed to the individual categories for the current level of extinction risk as follows: No Risk (12/60), Low Risk (43/60), Moderate Risk (4/60), High Risk (1/60). Based on the likelihood point distribution, the team was fairly certain that the NWA dusky shark DPS currently has a low risk of extinction, with the majority of likelihood points falling into the low risk category. Uncertainty, demonstrated by the spread of points outside the Low Risk category, indicate a tendency toward the No Risk category with very few likelihood points in the Moderate Risk category and only 1 likelihood point attributed to the High Risk category.

The NMFS (2011) stock assessment for this DPS suggested the population was depleted to around 85% of pre-exploitation levels. However, this assessment also suggested that prohibition on dusky shark retention in US fisheries has come close to ending overfishing, with projected biomass under current management measures stabilizing near current values. These factors, in addition to other current management measures (improved Mexican monitoring measures and the implementation of the US Mid-Atlantic closure area and the annual Mexican closed season to shark fishing in the Gulf of Mexico) suggest that the NWA DPS is likely under low risk of extinction at present. However, because NWA dusky sharks are still landed in Mexican fisheries and caught as bycatch in US fisheries (with high at-vessel mortality rates on longline gear and their susceptibility to post-release mortality in commercial and recreational fisheries) and given their life history traits, there will always be some level of extinction risk associated with this DPS. Fishing mortality has decreased since the US commercial and recreational retention prohibition in 2000 and the relative abundance trends from fishery-independent surveys have increased since the terminal year of the assessment (2009). Following the retention prohibition, dusky shark mortality mainly comes from Mexican landings and US bycatch mortality in the shark bottom longline and pelagic swordfish/tuna longline fisheries. The 2008 prohibition of sandbar shark retention in most US commercial fisheries (except for NMFS Shark Research Fishery permitted vessels) has also led to reductions in dusky shark bycatch and trends in the pelagic longline fishery do not indicate any increases in fishing effort that would lead to extinction of this population.

Overall level of extinction risk through the foreseeable future (30 years)

Likelihood points attributed to the individual categories for the level of extinction risk in the foreseeable future were as follows: No Risk (23/60), Low Risk (32/60), Moderate Risk (3/60), High Risk (2/60). For extinction through the foreseeable future, the majority of likelihood points fell into the low risk category, as seen with current extinction risk. Uncertainty, demonstrated by the spread of points outside the Low Risk category, indicates a stronger tendency toward the No Risk category than seen with current extinction risk. Based on this likelihood point distribution, the team was fairly certain that the NWA dusky shark DPS will have a low to no risk of extinction in the foreseeable future and should likely show improvement from the current status of the population.

For all NMFS (2011a) projection scenarios using data from the most recent stock assessment, abundance is predicted to either stabilize (based on estimated fishing mortality during the last year of the assessment) or increase (based on alternate projections taking into account potential changes in fishing mortality that likely would require changes to current management measures) in the foreseeable future based on median projections (Figure 25). However, there is still some statistical uncertainty about estimated productivity levels. If productivity was overestimated or fishing mortality was underestimated, there could be some cause for concern (as exhibited by, say, the lower 5-10% quantiles of biomass projections, Figure 25). However, recent positive trends in dusky shark abundance indices and increased productivity (faster annual intrinsic rate of population increase and shorter generation time based on updated life history information since the last assessment and projections were conducted) suggest these potential biases are not operative.

Conclusions

Based on a review of the best available information on genetics, movements, and migrations, the SRT determined that the NWA population of dusky sharks is a DPS, as defined by the joint US Fish and Wildlife Service-NMFS interagency policy of 1996 on vertebrate distinct population segments under the ESA. After review of the potential threats to the NWA DPS, the SRT ranked the loss or degradation of habitat, the shark fin trade, disease, predation, competition, current management regulations, and climate change as very low or low risks to extinction. This means that these factors are unlikely or very unlikely to contribute significantly to the risk of extinction. Exploitation (US bycatch/Mexican landings and associated at-vessel and post-release mortalities) and biological vulnerability were the only factors considered as moderate and high risks to extinction, respectively. Although Mexican landings appear to be decreasing and US bycatch levels are relatively low, at-vessel mortality rates are high and dusky shark life history characteristics make them inherently more vulnerable to exploitation/bycatch and slower to recover from depletion than most other shark species. The SRT ranked all of the demographic risks (current abundance, spatial structure/connectivity, and diversity) as very low to low extinction risks except for productivity. As with the biological vulnerability threat, productivity is reliant on life history characteristics making dusky sharks vulnerable to even low levels of exploitation or bycatch. Updated life history information increased the productivity of dusky sharks and even though their maximum rate of population increase is low compared to most sharks, it is not decreasing. Based on the most recent stock assessment, abundance projections, updated analyses, and a thorough review of the potential threats and risks to population extinction, the SRT determined that the NWA dusky shark DPS has a low risk of extinction currently and in the foreseeable future.

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