NOAA Technical Memorandum NMFS-SEFSC-585

AN UPDATE ON THE STATUS OF THE SAND TIGER SHARK, *CARCHARIAS TAURUS* IN THE NORTHWEST ATLANTIC OCEAN

BY

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Introduction

The sand tiger, *Carcharias taurus*, is a coastal shark inhabiting waters in the U.S. Atlantic Ocean from the Gulf of Maine to Florida and throughout the northern Gulf of Mexico (Compagno 1984). Sand tigers were occasionally targeted in recreational fisheries, but have been captured more frequently as bycatch in longline and gillnet fisheries (Goldman 2002).

Declines in sand tiger relative abundance have been reported. Musick et al. (1993) estimated a 75% decline in relative abundance since the mid 1970s for sharks captured primarily in the Atlantic Ocean offshore of Chesapeake Bay. Although evidence was only from one source, this report led to the sand tiger being listed as a prohibited species in the amendment to the National Marine Fisheries Service (NMFS) Fishery Management Plan for Atlantic sharks in 1997 (NMFS 1999). NMFS further identified the sand tiger as a candidate species for listing under the Endangered Species Act (ESA) due to its low productivity and purported decline in abundance resulting from fishing effort (i.e., overutilization). On April 15, 2004, NMFS announced the establishment of a Species of Concern list, a description of the factors that it will consider when identifying species of concern, and revision of the ESA Candidate Species List (69 FR 19976). NMFS transferred 25 candidate species, including sand tiger, to the species of concern list.

Prior to 2004, very little data were available to update the status of the sand tigers. High levels of uncertainty in the life history parameters for sand tigers in the western North Atlantic Ocean were well documented with the reproductive periodicity, age at maturity and maximum age as sources of contention (Gilmore 1993; Gordon 1993; Branstetter and Musick 1994). However, recent studies have lent new insight into the life history of sand tigers (e.g., Goldman et al. 2006) that will provide a better picture of their productivity. Relative abundance trends have not been updated for sand tigers since the nominal series in 1993 (Musick et al. 1993) and these trends may have changed since that time.

Herein, we evaluate new sources of data to provide an update as to whether sand tigers should be retained or removed from the species of concern list. We use the current criteria (71 CFR 55431) that include:

(1) Abundance and productivity: magnitude of decline, natural rarity, and endemism.

(2) Distribution: Population connectivity, limited geographic range, and endemism.

(3) Life-history characteristics: Vulnerable life history strategies (e.g., low fecundity, late maturity, slow growth), resilience to environmental variability and catastrophes, and loss of unique life-history traits.

(4) Threats: Extraction and harvest, habitat degradation and loss, disease, predation, and other natural or man-made factors.

Life history and Productivity

Originally, Branstetter and Musick (1994) investigated age and growth of sand tigers concluding that these sharks exhibit rapid growth and early maturity. However, Goldman et al. (2006) produced revised age and growth estimates based on specimens from the Western North Atlantic Ocean and concluded that sand tigers grow more slowly than described by Branstetter and Musick (1994). Differences in growth models between the two studies are likely related to the assumed frequency of growth band formation. Branstetter and Musick (1994) suggested that sand tigers form two rings per year in their vertebral centra whereas Goldman et al. (2006) determined that only one ring is formed annually. The revised and more widely accepted von Bertalanffy growth equation for sand tigers based on Goldman et al. (2006) is now stated as L_∞ =

295.8 cm TL, k = 0.11 $year^{-1}$, and $t_0 = -4.2$ years for females, and $L_\infty = 249.5$ cm TL, k = 0.16 $year^{-1}$, and $t_0 = -3.4$ years for males. Maximum observed age for female and male sand tigers is 17 and 15 years, respectively. These ages are close to the maximum documented ages of sand tigers in captivity. However, longevity may be longer than 30 years as a sand tiger recently died at the New York Aquarium reportedly held in captivity since the late 1960s (A. Henningsen, pers. comm.). There is also currently a 26-year old female sand tiger shark at the National Aquarium in Baltimore, MD, USA.

Reproductive periodicity has been a source of some contention. Gilmore (1993) stated that sand tigers reproduce annually in the western North Atlantic Ocean and Gordon (1993) believed conspecifics in Australia also reproduced annually. Conversely, Cliff (1989) and Branstetter and Musick (1994) presented evidence supporting a two-year reproductive cycle for sand tigers in South African waters and the western North Atlantic, respectively. Data from fishery-independent surveys in the western North Atlantic Ocean of 46 female sand tigers that were mature, but not pregnant (R.D. Grubbs, personal observation), and observations by Henningsen et al. (2004) of successful captive reproduction over the past 10 years support a 2-year reproductive cycle in sand tigers.

Female sand tigers become sexually mature at a length of 220-230 cm TL and males mature at 190-195 cm TL (Gilmore et al. 1983). Back-transforming length into age from the Goldman et al. (2006) growth model yields ages at maturity of 9-10 years for female and 6-7 years for males.

Sand tigers mode of reproduction is ovoviviparity with adelphophagy followed by oophagy. Initially up to 22,000 ova may be produced during development (Gilmore 1993). Eventually only one embryo develops within each capsule although in some cases 2 or 3 embryos per capsule have been observed in early stages of development. Every pregnant female examined has had only a single embryo per uterus along with the presence of a single functioning ovary (the right ovary) (Gilmore et al. 1983; Gilmore 1993). Size at birth for sand tigers has been estimated at 95-100 cm in total length (TL) from a number of locations based on the smallest free-swimming individuals and the largest embryos observed (Abe et al. 1968; Bass et al. 1975; Gilmore et al. 1983; Branstetter and Musick 1994).

Previous studies have estimated demographic parameters for sand tigers. Productivity determined through a modified demographic technique that incorporates concepts of density dependence was estimated at 5.2% and 7.3% per year depending on the assumed total instantaneous mortality rate (Z=1.5M and 2.0M, respectively; Smith et al., 1998). Population growth rates (λ) estimated by Cortés (2002) using life tables and Leslie matrices were 0.978 yr^{-1}. However, these values were generated using previously published life history estimates.

Using updated life history parameters, Goldman (2002) revised demographic parameters for sand tigers. Instantaneous rates of natural mortality (M) estimated through a variety of methods ranged from 0.18 yr^{-1} to 0.097 yr^{-1} when expressed as annual rates of survivorship. Assuming density-dependent compensation in the life table with zero fishing mortality, Goldman (2002) found sand tigers have very low productivity. Estimated population growth rates (λ) were 0.989 yr^{-1} (0.979-0.999 95% confidence intervals). Mean (and 95% confidence intervals) generation time was 17.1 yrs (15.6-17.8) and net reproductive rate was 0.8 (0.7-1.0). Population growth rate elasticities were 5.5% (5.3-6.0%) for fertility, 54.9% (53.1-56.7%) for juvenile survival, and 39.6% (37.7-41.5%) for adult survival.

Exploitation

U.S. commercial landings of sand tigers were compiled based on NMFS northeast regional and southeast regional general canvass data, which are based on the quantity of seafood products that are sold to licensed wholesale and retail seafood dealers, and the Southeast Fisheries Science Center (SEFSC) quota monitoring data based on southeastern region permitted shark dealer reports. The larger of the two reported landings of sand tiger (southeast regional general canvass landings data vs. the SEFSC quota monitoring data) was taken as the actual landed volume for that species in the southeast. The reported northeast regional general canvass landings, also known as dealer weighout, for sand tigers were then added to obtain the total commercial landings. Northeast regional and southeast regional general canvass landings data are sometimes reported in whole weight (ww) and were further expressed as dressed weight (dw) by using a conversion factor of 1.96 (Cortés and Neer 2005). Landings in the SEFSC quota monitoring system are reported in dressed weight.

Discards of sand tigers in commercial fisheries were compiled from observer reports of commercial fisheries targeting sharks (see Hale et al. 2007 and references therein). Discards are typically recorded in numbers and were further expressed as dressed weight by multiplying numbers by an average weight obtained from back-transforming observed average length into average weight through a published length-weight relationship (Kohler et al. 1998). Recreational fishing estimates (in numbers of fish) were obtained from three data collection programs: 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 (TPWD).

Commercial Fishery

Sand tigers are primarily caught in bottom longline and gillnet fisheries as bycatch. Despite being a prohibited species since 1999, commercial landings of sand tigers still occur. Commercial landings data for sand tigers did not become available until 1987 (Table 1). Commercial landings have varied and averaged 7,607 lb dw, with the highest reported landings occurring in 1998 (38,791 lb) and the lowest (409 lb) in 2002.

Recreational Fishery

Recreational catches for sand tigers have been variable (Table 1). Prior to 1988, an average of 53,759 sand tigers has been reported caught with a peak of 193,878 sharks in 1982. However, even considering the significance of shark tournaments in the early 1980s, the high number of sand tigers sharks reported in the MRFSS survey does not seem plausible. Other suspicious estimates of shark catches from MRFSS have been obtained for the early years of this survey and treated with caution for stock assessment purposes (see SEDAR 11 2006, for example). Since 1988, annual recreational catches of sand tigers have ranged from 6,350 to 0, with an average of 835 sharks per year. Additional data from the Large Pelagic Survey, which collects catch rate information on rod and reel and handline fisheries off the coast of the eastern U.S. from Virginia through Massachusetts, indicate an average of only 4 sand tigers from 1987 to 2007 with most years reporting 0 sharks caught (C. Brown, SEFSC, personal communication).

<u>Trends in size</u>

Linear regressions fit to fork lengths of sharks caught from several data sources did not indicate substantial declines over time. Data from the Virginia Institute of Marine Science

(VIMS) fishery-independent longline survey from 1974 to 2003 show a generally flat trend (Figure 1) with no significant relationship between year and size ($p= 0.32$, $r^2= 0.004$). Median size was 190 cm FL in 1974 and 187 cm FL in 2003. Size of sand tigers slightly increased (slope=0.004, $p= 0.04$, $r^2= 0.03$) since 1961 based on exploratory longline surveys conducted by the NEFSC. Data from the shark bottom longline observer program indicated a significant decrease in size since 1994 (slope=-0.02, $p= 0.005$, $r^2= 0.18$) but this was based on very small sample sizes.

Abundance trends

We examined multiple historic and current data sources for the presence of sand tigers. Of those sources examined, we determined that only 4 data sources contained adequate information for the construction of standardized catch rate series (Table 2). Catch rates were standardized using a form of the generalized linear model analysis (GLM). Some data were standardized using a simple generalized linear model (Maunder and Punt 2004) whereas others utilized the delta method (Lo et al., 1992), which combines separate generalized linear models of the proportion of positive trips (trips that kept or released a sand tiger) and the positive catch rates on successful trips to construct a single standardized abundance index. Further exploration of additional models (e.g. zero-inflated distributions) was performed relevant to the data (see each specific data source below for further explanation). Depending on the data source, time, area, environmental and fishery factors were considered as potential influences on catch rates. For each generalized linear model (GLM), a stepwise approach to quantify and eliminate factors was employed. First, a null model was run with no factors to reflect the distribution of the nominal data. Each potential factor is then added to the null model one at a time. Any factor that caused reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$) and if the reduction in deviance per degree of freedom was at least 1%. This process was repeated, adding factors individually from the most influential to the least until no factor met the criteria. Once a final model was selected using the SAS GENMOD procedure (version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc.), it was run using the SAS GLIMMIX macro. In this model, any interactions including the year factor were treated as a random effect. The final model was evaluated using the Akaike Information Criterion (AIC). Other models where applicable were fit with the R software package (R Development Core Team, 2008) using the glm and zeroinfl algorithms from the stats, lme4, and pscl libraries.

NEFSC Longline Surveys (NEFSC)

The NMFS Sandy Hook Lab (then Bureau of Sport Fisheries and Wildlife) initiated exploratory shark longline surveys in 1961 in response to concerns about shark attacks off the coast of New Jersey. In the 1960s, effort was concentrated in coastal waters with a gradual transition to offshore waters along the edge of the continental shelf and associated Gulf Stream waters by 1970. The shark research program moved from the NMFS Sandy Hook Lab to the NMFS Narragansett Lab in the early 1970s and the shark longline surveys continued with pelagic shark species as the primary target. Recovery of these historic cruise records is part of a larger project to electronically recover and archive historical longline survey and biological observations of large marine predators (swordfish, sharks, tuna and billfish) in the North Atlantic (Hoey et al. 2005).

A total of 1916 longline set records were recovered from historic cruise files. These included: 340 sets by the NMFS Sandy Hook Lab (1961-1970); 1488 sets by the NMFS Narragansett Lab (1975-1996), 44 sets from cruises sponsored by other institutions where NMFS Narragansett staff participated, and 44 sets from opportunistic deployments of scientists aboard volunteer commercial vessels (Hoey et al. 2005). Only sets that were conducted in depths less than 40 m, surface water temperatures less than 30°C and used wire leaders were included in these analyses. Of the 1916 total sets, 417 sets met the criteria and were used to model catch rates of sand tigers. Sand tigers were represented in 12.0% of the total sets.

A two-part generalized linear model (Lo et al. 1992) assuming a binomial distribution for the proportion of positive trips and a Poisson distribution for positive catch rates was used for standardization of the NEFSC data. An offset of the natural log of the number of hooks was used in the Poisson model. Factors considered in the generalized linear models were year (1961-1993), area (latitude <34.5°N, 34.5-37°N, 37.1-39°N, >39.1 N), target (coastal or pelagic), season, depth and temperature. The final model for sand tiger catch rates included area, year and depth in the binomial model and year and temperature in the Poisson model.

There were no longline sets conducted in 1966, 1968, 1970-1976, 1982, 1990 or 1992 that met the criteria for inclusion in these analyses. From the longline sets that were included, there were no catches of sand tigers during 1963, 1967, 1969, 1977-1981, 1983, 1984, 1987, 1988, or 1993. The relative standardized index of abundance from this study shows an overall decreasing trend in abundance, which is driven by a large peak in abundance in the early to mid 1960s. This peak is likely the result of concentrated effort in Delaware Bay, an area of sand tiger aggregation during the summer months (McCandless et al. 2007).

NEFSC Delaware Bay Juvenile Sandbar Shark Longline Survey

Researchers from the NMFS Narragansett Lab have been conducting gillnet and longline surveys for juvenile sandbar sharks in Delaware Bay since 1995. In 2001, a random stratified sampling plan based on depth (0-2 m, 2-5 m, 5-10 m, and 10+ m) and geographic location (nine regions: three across the northern, middle and southern portions of the Bay) was initiated to assess and monitor juvenile sandbar shark population (McCandless 2005). The gear used during this survey is a bottom longline with 50 Mustad 12/0 circle hooks on wire leaders. Although this gear is designed to target small juvenile sandbar sharks, larger sand tigers are occasionally encountered.

A total of 392 sets were conducted between 2001 and 2006 (56 per year) and were used in these analyses. There were no sand tigers caught in 2001 or 2005. Overall, sand tigers were caught in 1.5% of the sets. A simple generalized linear model assuming a lognormal error distribution was used for standardizing catch rates. The dependent variable was the log of the number of sand tigers caught per set. Factors considered in the generalized linear model of sand tiger catch rates were year, area, depth and month. The final generalized linear model for the NEFSC Delaware Bay included year as a single fixed factor. The standardized relative abundance index for this time series shows no clear trend.

Virginia Institute of Marine Science (VIMS)

The Virginia Institute of Marine Science has performed bottom longline sampling since 1974 (Musick et al. 1993). Longlines are fished once a month from May through October at standard stations. A total of 416 sets have been made in the mid-Atlantic Bight region from 1974 to 2006. However, varying levels of support and changing research goals led to certain years being under-sampled. In addition, weather or vessel constraints prevented sampling certain stations or certain months. The VIMS bottom longline survey is performed with gear standard to the industry at the inception of the study, and the gear has remained the same throughout the survey (Musick et al. 1993). Further details on the survey can be found in Musick et al. (1993) and Ha (2006).

Several categorical variables were constructed from the VIMS data set prior to analysis. The factor “station” was developed from standardized stations employed in the survey, but additional stations outside those normally sampled were included with those stations that were similar in location and water depth. “Soak” was the length of time the gear was fished. “Month” was based on the date sampled and depth was collapsed into three levels based on a 5-meter interval. As sand tigers have been observed caught by feeding on other sharks previously hooked on the longline set, the presence or absence of an Atlantic sharpnose shark within the same set was considered as a factor. The dependent variable was number of sand tigers per hook.

Initial analysis of the entire data set (1974-2006) using the delta-lognormal approach did not converge, likely due to years with low sample sizes (<10 sets). To increase model performance, all years with less than 10 sets were eliminated from the index development (i.e. 1974, 1975, 1976, 1977, 1978, 1982, 1983, 1984, 1986, 1987, 1988, 1989). The final data set used to estimate the standardized index of abundance contained 370 sets. At least one sand tiger shark was reported caught in 12.7% of those sets. However, the annual proportion of positive trips varied by year. The highest proportion of positive sets was in 2001 (7.7%) and the lowest proportion was in 1997, 2004 and 2005 (0.0%).

For both the binomial and lognormal models, year, station and depth were significant as main effects. However, the factors year + station explained most of the total deviance and were the final factors included in both models. No model interactions were significant.

The standardized relative catch rate series indicated the population has only slightly decreased since 1980 although variability is high (Figure 2). The standardized catch-per-unit-effort was 0.009 sharks per hook in 1980 and 0.005 sharks per hook in 2006. Since 2001 when sand tigers were listed as prohibited to commercial and recreational harvest the series has remained relatively stable with the exception of a peak in abundance in 2006. A linear regression on the natural logarithm of the absolute catch per unit effort over the entire series resulted in a relatively flat, but significant slope (-0.002, r^2=0.03, p=0.03; Table 3).

Due to its importance in the initial listing of sand tiger shark on the Species of Concern list and the necessity to model the entire VIMS time series (i.e., 1974-2006), we employed an alternate approach for dealing with excess zero observations without partitioning data using a mixture of two distributional forms. Unlike the delta-lognormal approach, the zero-inflated approach used a count model that included some density for zero observations. These zero-inflated models are not part of the exponential family and are therefore not GLMs; however they allow covariate effects to be estimated for both the extra zero and count components of the data, similar to the GLM approaches above (Lewsey and Thomson, 2004). The most commonly used distribution mixture combines a Bernoulli with a Poisson distribution in a zero-inflated Poisson (ZIP) model (Lambert, 1992; Tu, 2002). While ZIP models deal well with excess zeros in a given dataset, count observations still occur that can be too overdispersed for the Poisson distribution to handle. As described in the GLM case above, the zero-inflated negative binomial (ZINB) may be more appropriate in these cases; the Poisson distribution is replaced by a negative binomial distribution and linear models are specified for both the zero and count observations. Further discussion relative to the application of these models can be found in

Minami et al. (2007).

For both models (ZIP and ZINB), catches of sand tigers were more associated with time, effort and location. The most important factors were year, station and soak time. Although the AIC values were similar for both models, with data dominated by zero-valued observations the ZIP may be more appropriate for animals that school in smaller numbers (Minami et al. 2007). Thus, we chose the zero-inflated Poisson model as the best fitting model for the VIMS data. The standardized abundance series indicated the relative population has remained relatively stable and only decreased by 0.9% since 1974.

Shark bottom longline observer program (SBLOP)

The shark bottom longline fishery is active in the Atlantic Ocean from about the Mid-Atlantic Bight to south Florida and throughout the Gulf of Mexico. The bottom longline gear targets large coastal sharks, but small coastal sharks, pelagic sharks, and dogfish species are also caught. Observer coverage from 1994 through the 1st trimester season of 2005 was coordinated by the Commercial Shark Fishery Observer Program (CSFOP), Florida Museum of Natural History, University of Florida, Gainesville, FL (Morgan et al. in press). Starting with the 2nd trimester season of 2005, responsibility for the fishery observer program was transferred to NMFS, Southeast Fisheries Science Center, Panama City Laboratory.

Sand tigers have been reported caught on 5.8% of 1,483 sets since 1994. The highest proportion of positive sets was in 2001 (10.1%) and the lowest in 2000 (0.0%). The effects of the following factors were considered in the generalized linear model: year, season, area, depth, bait type, hook type, and time of day.

Within the delta-lognormal model approach, year, season and depth explained most of the deviance in the probability of catching at least one sand tiger. When modeling the positive trips, year was the only significant factor and showed a reduction in deviance per degree of freedom of at least 1%. No interactions were found to be significant. The abundance index based on bottom longline observer data indicated a relatively flat trend (Figure 2). Linear regression of mean standardized catch rates on year indicated a decreasing slope (-0.06), but not significantly different significant from zero (p=0.28) (Table 3).

Distribution

Sand tigers do not have a limited known range and are not known to be endemic to a specific area. The species is cosmopolitan, being also found in the Indian and Pacific Oceans. In the northwest Atlantic Ocean, sand tigers have been reported from the Gulf of Maine south to Florida and the northern Gulf of Mexico (Bigelow and Schroeder 1948). Areas of higher abundance for sand tigers occur in Delaware Bay, Delaware and off North and South Carolina in warmer months and along the east coast of Florida year-round (Bigelow and Schroeder 1948). Adult sand tigers are also associated with numerous wrecks off North Carolina. Juveniles are found over a wide range of locations along the US east coast and within large bays such as Delaware Bay from the spring through October with peak abundance in June (Bigelow and Schroeder 1948).

Conclusions

We found little evidence to support the conclusion that sand tigers are endemic to any discrete location in U.S. Atlantic waters. Sand tigers have very low productivity—or low rebound potential—and are among those sharks on the “slower” section along the “fast-slow” continuum of life history traits and population parameters described in Cortés (2002). However, a recent Ecological Risk Assessment conducted to assess the vulnerability of 25 species of Atlantic sharks (Cortés et al. 2008) found that while sand tigers have very low productivity, their susceptibility to longline fisheries is low compared to most other species examined, mostly as a result of little overlap between the distribution of the species and that of the fisheries and the high post-capture survival of this species on longlines.

Examination of trends in size suggests that sand tigers were not heavily exploited. Average size for all long term series has remained relatively stable suggesting that growth overfishing has not been occurring. If sand tigers were under severe exploitation, the average size would be expected to decrease over time (Hilborn and Walters 1992). This is particularly true for populations of long-lived animals such as sand tigers.

An analysis of trends in abundance from multiple data sources indicated the lack of a considerable decline in abundance for any series examined. Most series showed low to moderate declines in abundance, from 0.2% to 6.2%. These results conflict with those reported by Musick et al. (1993), which indicated sand tigers declined by as much as 75% from data collected in a fishery-independent survey during the decade from 1980 to1990. Ha (2006) updated the results of Musick et al. (1993) by using a generalized additive modeling approach and found a 99.8% decline in sand tiger shark abundance from 1974 to 2004. The differences in reported declines from those studies and the current study are likely a result of the method utilized for the re-analysis of the data. Because sample sizes were small, both Musick et al. (1993) and Ha (2006) grouped 1974-1976, 1978-1979, 1981-1984 and 1993-1994 by the mean year of all stations in that year category. In our analyses, each year was treated independently. Moreover, the original data used in Musick et al. (1993) and Ha (2006) were refined in this study to reflect the more accurate distribution of station by depth (R.D. Grubbs, personal observation). Finally, in our study we subjected the data to two parametric model forms of standardization (delta-lognormal and zero-inflated Poisson approach) while Musick et al. (1993) only reported unstandardized nominal trends and Ha (2006) applied a generalized additive model (GAM). A generalized additive model is not well-suited to this type of data due to the high proportion of zeros and the sensitivity of the ending year of the time series. The current study models the catch rates of the positive occurrences and the strength of each factor on those catch rates. The interpretability is much improved from Ha (2006), and the zeros are explicitly modeled instead of essentially removed in the early years. The validity of our modeling approach is demonstrated by the fact that both the delta-lognormal and zero-inflated models found station to be the most significant factor affecting abundance and a similar decline in relative abundance (~0.2 and 0.9%).

We acknowledge that the U.S population of sand tigers shark has one of the lowest productivities among sharks in the Northwest Atlantic Ocean. However, despite having very low productivity, results from this study indicate sand tigers do not meet all criteria outlined in the species of concern list (71 CFR 55431). Sand tigers are not limited in their distribution and available evidence indicates that relative abundance and size have not declined substantially since pre-exploitation levels or at least lightly exploited levels. However, the very high levels of uncertainty in relative abundance trends, which were mostly due to the limited data available, suggest that our results should be viewed with caution. Sand tigers are currently “prohibited” from commercial or recreational harvest under the Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS 2006) and recent amendments to that plan based on updated stock assessments are expected to eliminate the major directed shark fishery in the U.S. Atlantic Ocean.

Based on the analysis of all current available information, one could conclude that the sand tiger shark does not meet the endemism and relative abundance decline criteria of the SOC list, but meets the productivity criterion. Owing to the exceptionally low productivity of sand tigers and the relatively low sample sizes on which we based our trend analyses that led to very high levels of uncertainty in our parameter estimates, we are hesitant to remove this species from the NMFS species of concern list and thus recommend that it be retained as a precautionary approach.

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Table 1.--Estimates of total catches for sand tigers from U.S. Atlantic waters, 1981 to 2007.

	Commercial[1]	Recreational[2]	Bottom Longline Discards[3]	
Year	Dressed wt (lb)	Number	Number	Dressed weight (lb)
1981		23649		
1982		193878		
1983		85728		
1984		13993		
1985		25200		
1986		20300		
1987	219	13567		
1988	236	916		
1989	1485	2742		
1990	2395	294		
1991	2952	243		
1992	8801	845		
1993	13390	6350		
1994	11748	70	1	54.7
1995	25168	1625	3	70.8
1996	11971	325	2	17.9
1997	8425	1574	6	50.0
1998	38791	0	0	0.0
1999	6401	0	0	0.0
2000	6554	0	0	0.0
2001	1248	604	2	27.8
2002	409	0	0	0.0
2003	624	0	10	14.4
2004	1832	0	1	28.7
2005	5167	0	15	28.9
2006	4321	1040	1	47.1

[1] Commercial data for 1987-1994 are from the Southeast General Canvass Program only. Data for 1995-2005 are the sum of the Southeast Quota Monitoring System/Southeast General Canvass Program and the Northeast General Canvass Program estimates.
[2] Except for 1987 and 1993 (Texas Parks and Wildlife Department Recreational Fishing Survey) and 1991-93 and 1994-97 (NMFS Headboat Survey), all recreational catches are from the Marine Recreational Fishery Statistics Survey.
[3]Bottom longline discards are taken from observer reports.

Table 2. A summary of data sets examined for the presence of sand tigers. Years refers to the time period of the data set, beginning with the oldest. A year followed by a dash denotes an ongoing survey or program. Type refers to whether the index is from a commercial or recreational source, or is fishery-independent from a scientific survey. Area indicates the area covered by the survey or fishery. NE = northeast, NW = northwest, SE = southeast, SW = southwest. Positive and negative aspects of the data source are indicated. An asterisk indicates the series was utilized in the evaluation.

Data Set	Years	Type	Area	Positive Aspects	Negative Aspects
NEFSC Laboratory Longline Surveys*	1961-1996	Scientific Survey	NW Atlantic Ocean	Long term time series	Missing years in time series
Virginia Institute of Marine Science*	1974-	Scientific Survey	Mid-NW Atlantic Ocean	Long term time series	Missing years in time series
Large Pelagic Survey	1986-	Recreational	Mid-NW Atlantic Ocean	Covers predominant area sand tigers frequent	Few sand tigers recorded
Coastal Fisheries Logbook Program	1995-	Commercial	NW Atlantic Ocean, Gulf of Mexico	Covers variety of sampling gears not examined elsewhere	Misidentification
Shark Bottom Longline Observer Program*	1994-	Commercial	NW Atlantic Ocean, Gulf of Mexico	Wide geographic coverage	Few sand tigers recorded in some years, limited coverage
Mississippi Laboratories Pelagic Longline Survey	1995-	Scientific Survey	NW Atlantic Ocean, Gulf of Mexico	Fishery independent survey, wide geographic coverage	Few sand tigers recorded
NEFSC Laboratory Delaware Bay Surveys*	2001-	Scientific Survey	NW Atlantic Ocean	Fishery independent survey	Limited geographic area, few sand tigers recorded

Table 3.-- Results of best model fits to the various data sources and estimated trend (slope) from the start to end of the time series.

Data set	Years	Error Distribution	Slope	AIC	Final model
NEFSC Laboratory Historical Longline Survey	1961-1996	Delta-Lognormal	-0.027	4780.9 110.2	Year+Area+Depth Year+Temperature
NEFSC Delaware Survey	2001-2006	Lognormal	0.001	723.7	Year
Virginia Institute of Marine Science	1974-2006	Zero-inflated Poisson	-0.009	496.7	Year+Station+Soak
	1980-2006	Delta-Lognormal	-0.002	270.5 70.1	Year+Station Year+Station
Shark Bottom Longline Observer Program	1994-2006	Delta-Lognormal	-0.062	323.0 236.3	Year+Season+Depth Year

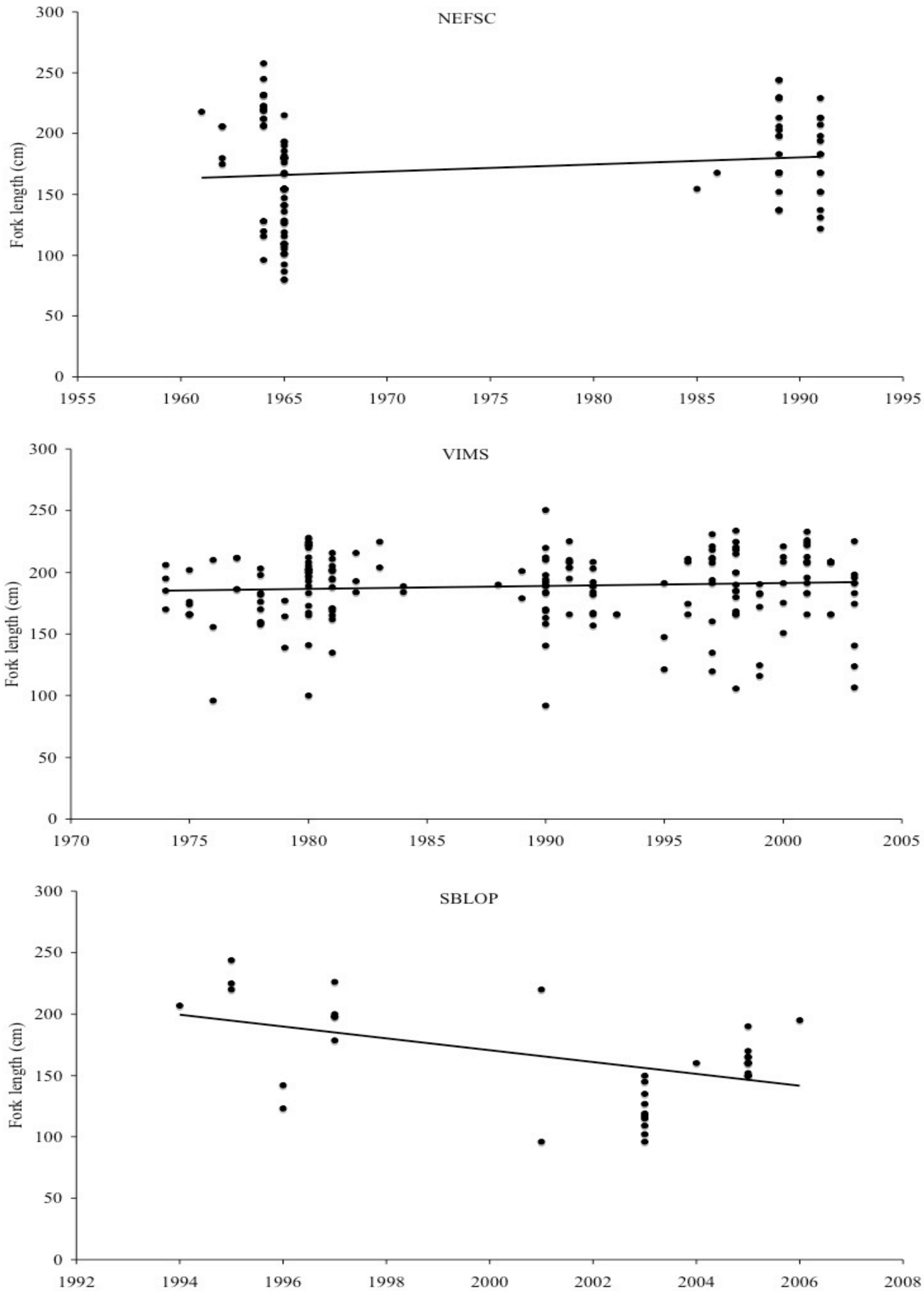

Figure 1.--Lengths of sand tiger sharks measured in the Northeast Fisheries Science Center exploratory longline surveys (NEFSC), Virginia Institute of Marine Science (VIMS) and Shark Bottom Longline Observer Program (SBLOP). The line indicates a linear regression fit to the data.

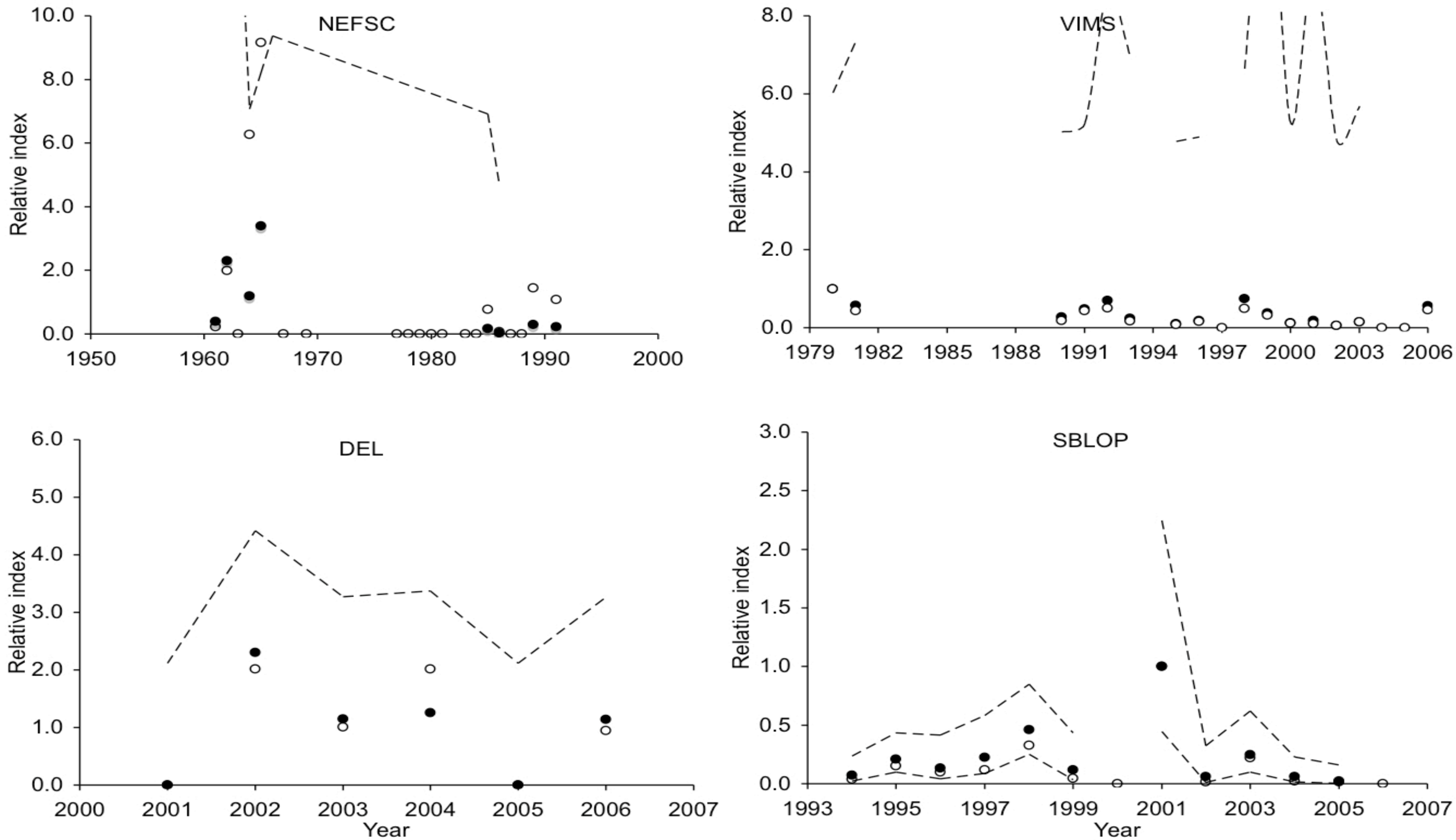

Figure 2.--Standardized relative index (mean/maximum of index) of abundance (solid circles) for sand tigers from three scientific surveys (Northeast Fisheries Science Center exploratory longline surveys (NEFSC); Delaware Bay Survey (DE), and Virginia Institute of Marine Science (VIMS) survey) and the Commercial Shark Bottom Longline Observer Program (SBLOP) based on the final model. Nominal data (circles) are plotted for comparison. Confidence limits (95%) for the standardized index are dotted lines. Some points are not visible because the nominal and standardized values overlap whereas in others cases because there was no standardized estimate due to a zero observed value.