CHAPTER

9

Large Pelagic Fish

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Introduction

Pelagic fish include highly migratory species such as tuna, swordfish, billfish and various species of sharks. The wide ranging distribution of these species across diverse habitat types, their roles as apex predators, and their threatened population status make them prime candidates for inclusion in this assessment. Conservation of large pelagic fishes like tuna, marlin, swordfish and sharks is a high priority because these species represent a particularly threatened group within the characteristic biodiversity of the Northwest Atlantic. Moreover, conservation of these species is especially critical because of their ecological function as apex predators that can substantially control the abundance of other species through direct and indirect food web interactions. In some cases, the presence or absence of top-down control provided by apex predators may have a strong influence at the scale of whole ecosystems (Kitchell et al. 2006; Baum and Worm 2009). However, this influence varies by time and place as mediated by several factors including competition with other predators, trophic complexity, prey preferences, primary productivity, and fishery effects (Pace et al. 1999; Dowd et al. 2006).

Effective conservation and management of pelagic fishes is difficult due to their wide ranging distribution (basin-wide to circumglobal), their natural vulnerability to overfishing and their high value as harvest species. However, in recent years increased concern and attention by stakeholders, researchers and management agencies have begun to lay the groundwork for additional actions needed to promote recovery for these species. Many of the products of historic and current efforts to better understand the conservation needs for large pelagics within the Northwest Atlantic region are described below.

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Selection of Target Species

Target species were selected based on the following criteria: (1) level of threat as assessed by the 2008 IUCN Red List, (2) intrinsic vulnerability (Cheung et al. 2005; 2007), and (3) current population status. All of the sharks in this have been assessed under the IUCN Red List, but the commercially valuable teleost fish have either not been evaluated or are considered 'data deficient', thus not able to undergo an evaluation. The dusky shark for example is a National Marine Fisheries Service (NMFS) Species of Concern, and was considered for Endangered Species Act Listing, but was not listed due to incomplete data (NMFS 2004). The Canadian government considered listing of the porbeagle under their Species at Risk Act, but rejected the listing based on the impact to the commercial fishing industry and the governmental cost of monitoring (NMFS 2008).

In consideration of the criteria outlined above, along with input from expert reviewers, the following species were selected for inclusion in this assessment:

- Atlantic bluefin tuna *(Thunnus thynnus)*
- Albacore tuna *(Thunnus alalunga)*
- Bigeye thresher *(Alopius superciliosus)*
- Blue marlin *(Makaira nigricans)*
- Dusky shark *(Carcharhinus obscurus)*
- Great hammerhead *(Sphyrna mokarran)*
- Porbeagle *(Lamna nasus)*
- Sand tiger *(Carcharia taurus)*
- Sandbar shark *(Carcharhinus plumbeus)*
- Scalloped hammerhead *(Sphyrna lewini)*
- Shortfin mako *(Isurus oxyrinchus)*
- Swordfish *(Xiphias gladius)*
- Thresher shark *(Alopius vulpinus)*
- White marlin *(Tetrapturus albidus)*

Population Status and Importance of the Northwest Atlantic Region

The species included in this assessment have wide geographic distributions and travel significant distances throughout their life to feed and breed, and are consequently labeled as highly migratory species. These species use the Northwest Atlantic for both feeding and breeding purposes.

According to the NMFS Highly Migratory Species Division (HMS) 2009 Stock Assessment and Fishery Evaluation (SAFE) for Atlantic HMS, seven of the target species are overfished; and seven are experiencing overfishing. The International Commission for the Conservation of Atlantic Tunas Stock Assessments suggests that bluefin and albacore tuna are overfished (ICCAT 2004). Globally, bluefin tuna spawning stock sharply declined between 1970 and1993, began increasing until 1998, and then continued to decline to the present. Based on these biomass estimates, International Commission for the Conservation of Atlantic Tuna (ICCAT 2004) determined that there was a 50% probability of rebuilding the stocks (albacore and bluefin) by 2023 only if implementation and enforcement of current regulations worked perfectly, including a severe reduction in fishing effort by 2023, and if future recruitment stayed at about the 1990s level and was unaffected by recent spawning biomass level. Catch per unit effort (CPUE) for bluefin tuna, blue marlin, and white marlin plummeted in the 1990s; but began to recover in 2000 (ICCAT 2004). CPUE began declining again since 2002 for both white and blue marlin. This conclusion is supported by other assessments. For example, Safina and Klinger (2008) report a 92% decline in bluefin tuna landings over a forty-year time period, from 1964 to 2005. ICCAT considers blue marlin, white marlin, and shortfin mako "possibly overfished." Albacore at age 5 yrs appeared to peak in 1979 and then declined through 2008.

Swordfish biomass projections indicate a short term increase in spawning stock biomass starting in 2005, with a 50% probability of the stock rebuilding by 2009 (ICCAT 2008). Within United States populations, ICCAT catch per unit effort (CPUE) data for swordfish has dropped by about fifty percent since the 1980s, but is currently rebuilding. IUCN's (2007) Review of Chondrichthyan Fishes indicates that all of the sharks listed here are a "harvest threat." Porbeagle population size is estimated to be 10-20% of the 1961 population (Campana et al. 2003).

In sum, most large pelagic species are in trouble. Substantial additional detail on population status and current management strategies for the fourteen target species and several other large pelagics is contained within the documents reviewed for this section (SAFE for Atlantic Highly Migratory Species; IUCN Shark Specialist Group 2000; White Marlin Status Review Team 2002; Mahon and McConney 2004; NMFS Final Consolidated HMS Fishery Management Plan 2006; IUCN Red List 2008). Additionally, ICCAT provides catch per unit effort statistics, size statistics, observer data, and nominal catch statistics. The Northwest Atlantic Fisheries Organization (NAFO) also provides catch statistics. A global atlas of tuna and billfish catch, from 1950 onward, is available through the Food and Agriculture Organization website.

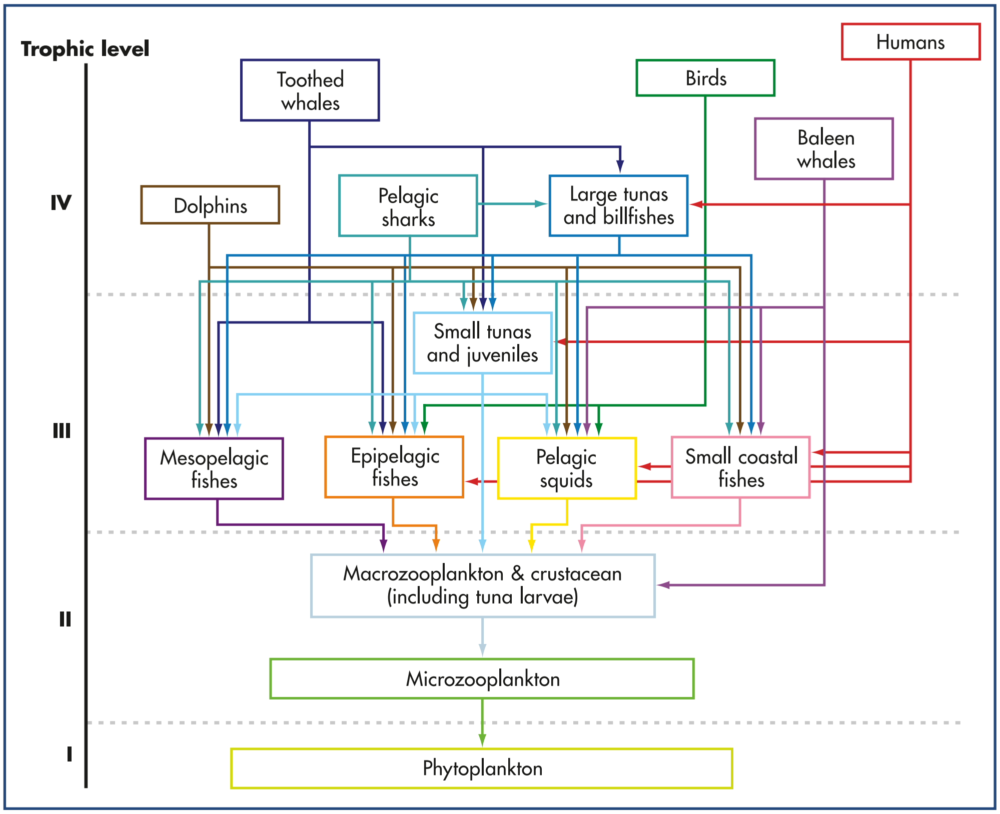

Figure 9-1. An example of the complex food web that large pelagic species occupy in the ecosystem (FAO 2010).

Ecosystem Interactions and Ecological Dependencies

Large pelagic fish are an essential component of the Northwest Atlantic pelagic food web, thus play a key role in the ecosystem. Many of the selected target species feed broadly and opportunistically across the food chain. However, regionally and at certain times, a given age class may focus their feeding on just a few species (Cayré et al. 1988). Tunas and billfishes prey on squid, smaller fish, and crustaceans (Logan et al. 2006). The larger individuals feed on pelagic fishes, and are at the top of the trophic web (Figure 1). Smaller individuals (e.g., juvenile tunas and billfishes) prey on zooplankton (mainly crustaceans). Smaller individuals of all fourteen target species are preyed upon by sharks, cetaceans or larger fish like mackerels, tunas, and swordfishes.

Adults of all of the fourteen target species function as apex predators - large animals at the top of complex food webs without significant predators except humans. Consequently, they play a critical role in energy flow through marine food webs (NOAA 2009) and are sometimes considered to be keystone species with disproportionate influence on ecosystem structure. Their presence (or absence) can affect ecosystem patterns and processes at multiple trophic levels and potentially lead to fundamentally altered ecosystem state conditions (Baum and Worm 2009).

Northwest Atlantic Distribution and Important Areas

Methods

To understand the distribution of pelagic fish target species relative to the Northwest Atlantic and identify critical sites, the following questions were addressed:

- Where are the greatest areas of co-occurrence? *(richness of target species)*
- Where are the most important areas for *essential fish habitat?*
- Where has the species been found consistently over time? *(persistence)*

Observation data were provided by NMFS. This data is compiled from numerous sources, including cooperative tagging programs, mandatory logbook reporting for some fisheries, recreational surveys, and published literature. Approximately 96% of the data points originated from two fisheries-dependent tagging programs: the Cooperative Tagging System run by Southeast Fisheries Science Center, and the Cooperative Shark Tagging Program run by Northeast Fisheries Science Center, the two most comprehensive long-term data sets available. The data provides tagging, and recapture information when available, from tagged individuals, and is given as point locations, with year information associated. A detailed description of the data sources is provided on pg. 10-3 of the HMS document, 2006 Final Consolidated Atlantic Highly Migratory Species Fishery Management Plan. Data were provided in a summarized form by ten minute squares (TMS), where each square contained multiple survey points by life stage and was binned by decade (1965-1974; 1975-1984; 1985-1994; and 1995-2004). Because this assessment explores ecologically important areas within a set boundary, we analyzed gridded points within the study area or within a buffer, extending out to 1500m depth, to 4000m. In the southern area of the Northwest Atlantic, we extended a circular buffer of equivalent spatial scale. At the surface, this equated to 110 km.

Essential fish habitat (EFH) polygons were obtained from the NMFS website, while the sandbar shark EFH was provided by HMS upon request. Source data for EFH polygons (currently being updated by NOAA) were compiled and mapped for the 1999 HMS FMP by NOAA Fisheries, Office of Habitat Conservation and the Highly Migratory Species Division. EFH polygons were available for juvenile and adult life stages for all target species, with the exception of the sand tiger (adult only). Neonate polygons were only available for dusky shark, porbeagle, sand tiger, sandbar shark, shortfin mako, swordfish (larvae), and thresher.

Data limitations

Comprehensive fishery-independent surveys of the studied species are not currently available. The data used in this analysis is derived primarily from fisheries-dependent tagging data, and fishing effort varies considerably throughout the region and likely through time. As we were not able to correct for the bias imposed by variable fishing efforts, true abundances could not be determined from this data, and consequently, we focused on metrics that are less sensitive to fishery bias.

Data Analysis

Richness of target species: To outline the diversity of target species at particular points in space, the number of target species observed within a TMS was summed and mapped based on all available data (1965-2004). Maps were created for total number of targets and by age class (where data was available). The darkest colors on the map indicate the areas with greater numbers of target species or target species within an age class

Persistence: The persistence score refers to the consistency with which a target species was observed in the same general area (TMS) over time. For this calculation, we combined juvenile and adult observations as an indicator that the species was present. The persistence score was calculated by summing the number of decades that a given target species was recorded (e.g. one decade = 1, four decades = 4). The darkest colors indicate areas where target species were consistently observed over all decades.

Areas identified as essential fish habitat: To understand how much of the region is considered EFH, the number of target species whose EFH overlapped each TMS was determined and summarized by total target species and by age class.

Maps, Analysis, and Areas of Importance

Aggregated pelagic distributions (as described by the indicators outlined above) are described below in relation to broad scale bathymetry patterns (Figure 2).

Richness of target species

Across all target species, areas with the highest number of species being observed in these fishery-dependent datasets include: the shelf-slope break for the entire region; south of Block Island Sound along the 50 m isobath for the Southern New England subregion; and the Cape Hatteras area, the area between Washington and Norfolk canyons, and isolated TMS along the coast for the Mid-Atlantic Bight subregion (Figure 3a). For neonates, the majority of observations were located in the Southern New England subregion, just south of Block Island Sound extending from the coast to beyond the 50 m isobath and along the Hudson canyon, as well as a thin strip along the coast in the Mid-Atlantic Bight subregion, particularly by Delaware Bay, Chesapeake Bay, and Cape Hatteras (Figure 3b). In addition, some TMS are located along the shelf-slope break. For juveniles, the majority of observations were located along the 50 m isobath in the Southern New England subregion, and coastal areas outside of the Delaware and Chesapeake Bays, as well as along the shelf-slope break between the 200-1000m isobaths for both subregions (Figure 3c). For adults, the majority of observations were located along the shelf-slope break between the 200-1000 m isobaths, with isolated TMS largely along the 50 m isobath (Figure 3d).

Persistence

The areas where many target species were consistently observed in these fishery-dependent datasets over four decades in the Southern New England and Mid-Atlantic regions, included mouths of major bays and rivers and the region from the Hudson canyon to Block Island sound along the 50 m isobath (Figures 4-17). The dusky shark shows the highest persistence at the Hudson canyon and south of Long Island. The sandbar shark is highly persistent at the mouth of Narragansett Bay, the Hudson River, Delaware Bay and Chesapeake Bay. The sand tiger shows medium levels of persistence in Delaware Bay and Chesapeake Bay; and outside of both Pamlico and Albemarle Sounds. The shortfin mako shows spatial persistence at the Hudson canyon and south of Long Island, along a 50 m band, as well along a band from 200-2000 m in all subregions. Blue marlin persist just outside the study area, south of Cape Hatteras; around Norfolk canyon and Baltimore canyons, and out to 1000 m. White marlin shows high persistence along the shelf slope break in the Mid-Atlantic Bight and Southern New England subregion. Swordfish shows high levels of persistence along the shelf-slope break for all subregions. Atlantic bluefin tuna show the highest levels of persistence in the Block Island Delta, and Hudson canyon, around Cape Ann and Cape Cod Bay, Gulf of Maine. Albacore tuna, porbeagle, scalloped hammerhead, great hammerhead, bigeye thresher, and thresher shark show limited spatial persistence. This suggests that the use of the region by large pelagic species may not be geographically fixed.

Areas identified as essential fish habitat

EFH has been identified for these federally managed fish species by NOAA's Office of Habitat Conservation, Habitat Protection Division. Each EFH designation consists of areas of habitat essential to the long-term survival and health of fisheries and includes waters and substrate necessary for spawning, breeding, feeding, or growth to maturity for all life stages of fish.

Overall, the patterns of target species richness we identified are similar to the patterns identified by overlaying the EFH. Figure 18a shows the cumulative EFH for all fourteen target species within the Northwest Atlantic. For neonates, the area with the greatest EFH concurrence is in the SNE subregion, offshore to Long Island, with a slight 'hot spot' in the 200 m isobath in the Block Island Delta region; and in the Mid-Atlantic Bight subregion, off Delaware Bay and Albemarle Sound (Figure 18b). For

Figure 9-2. Bathymetry of the Northwest Atlantic region.

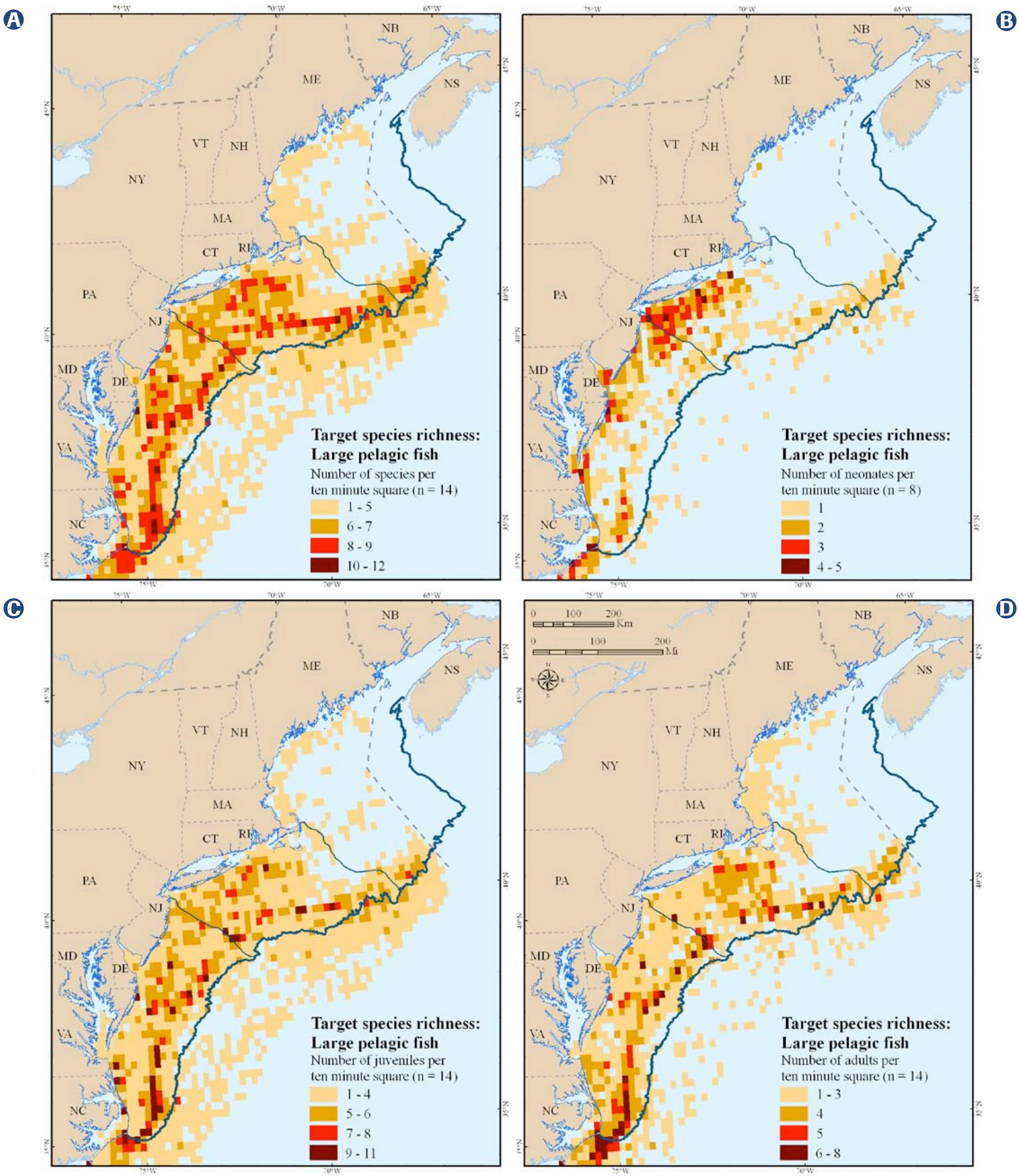

Figure 9-3. Richness of large pelagic target species in the region.

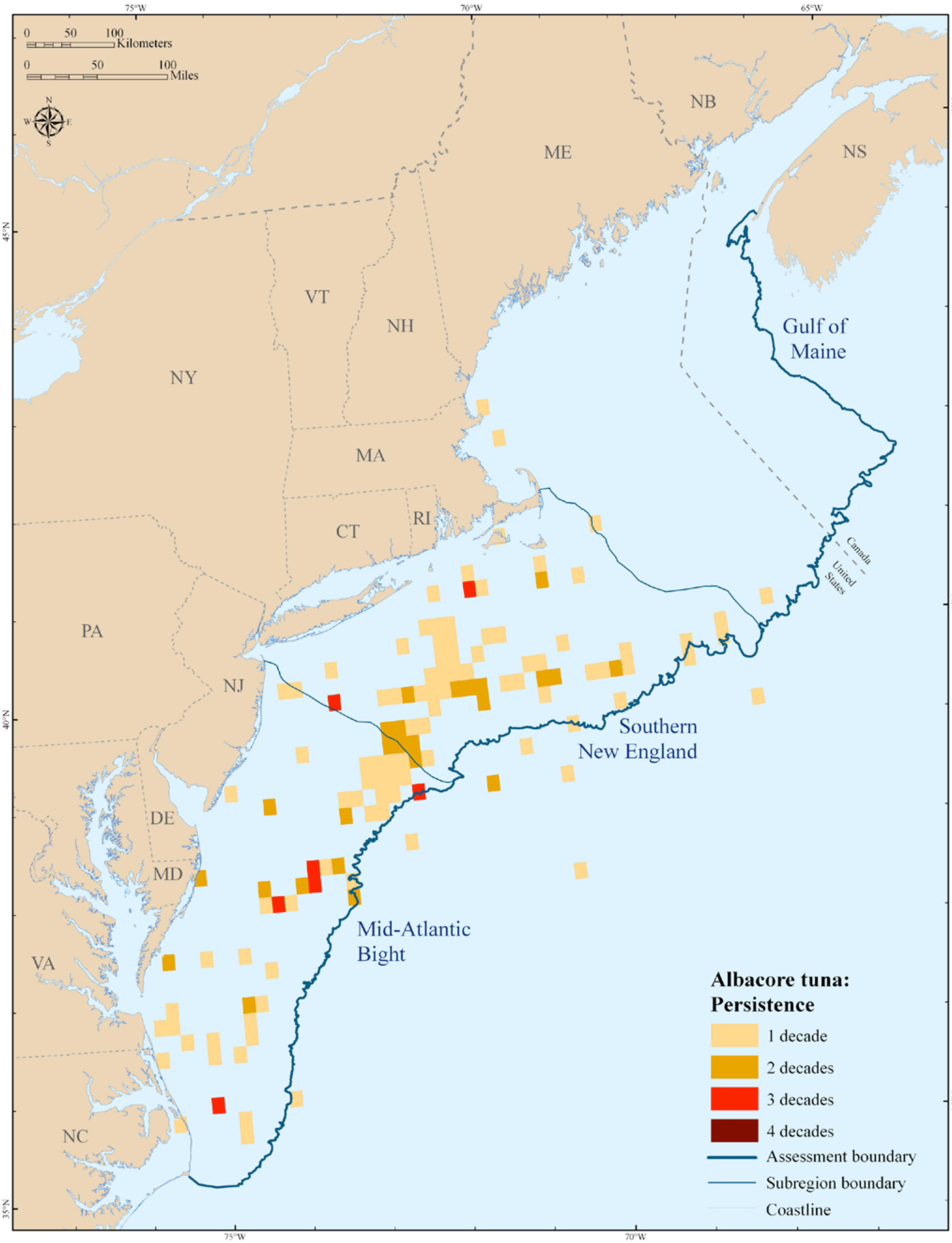

Figure 9-4. The persistence of Albacore tuna by TMS over time.

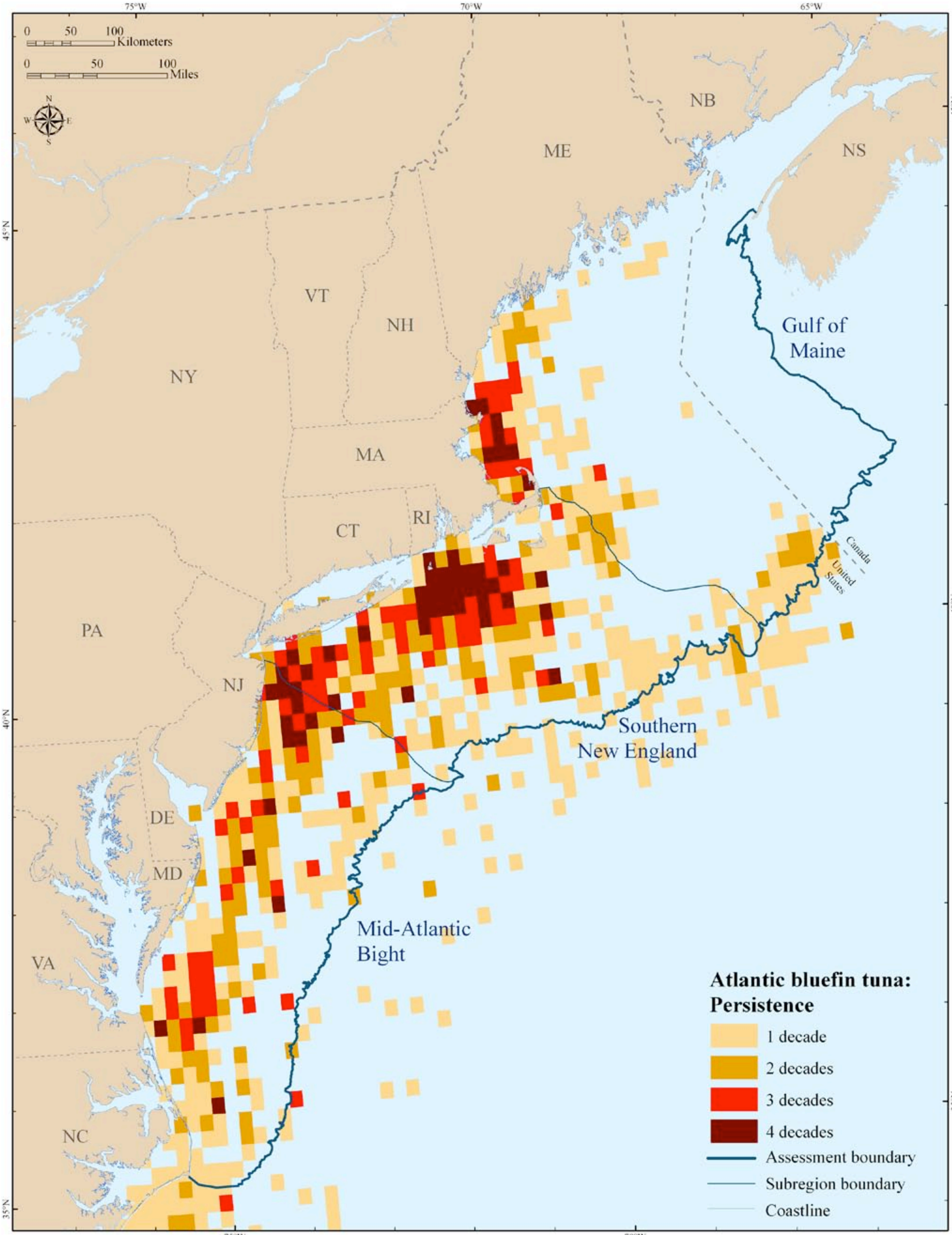

Figure 9-5. The persistence of Atlantic bluefin tuna by TMS over time.

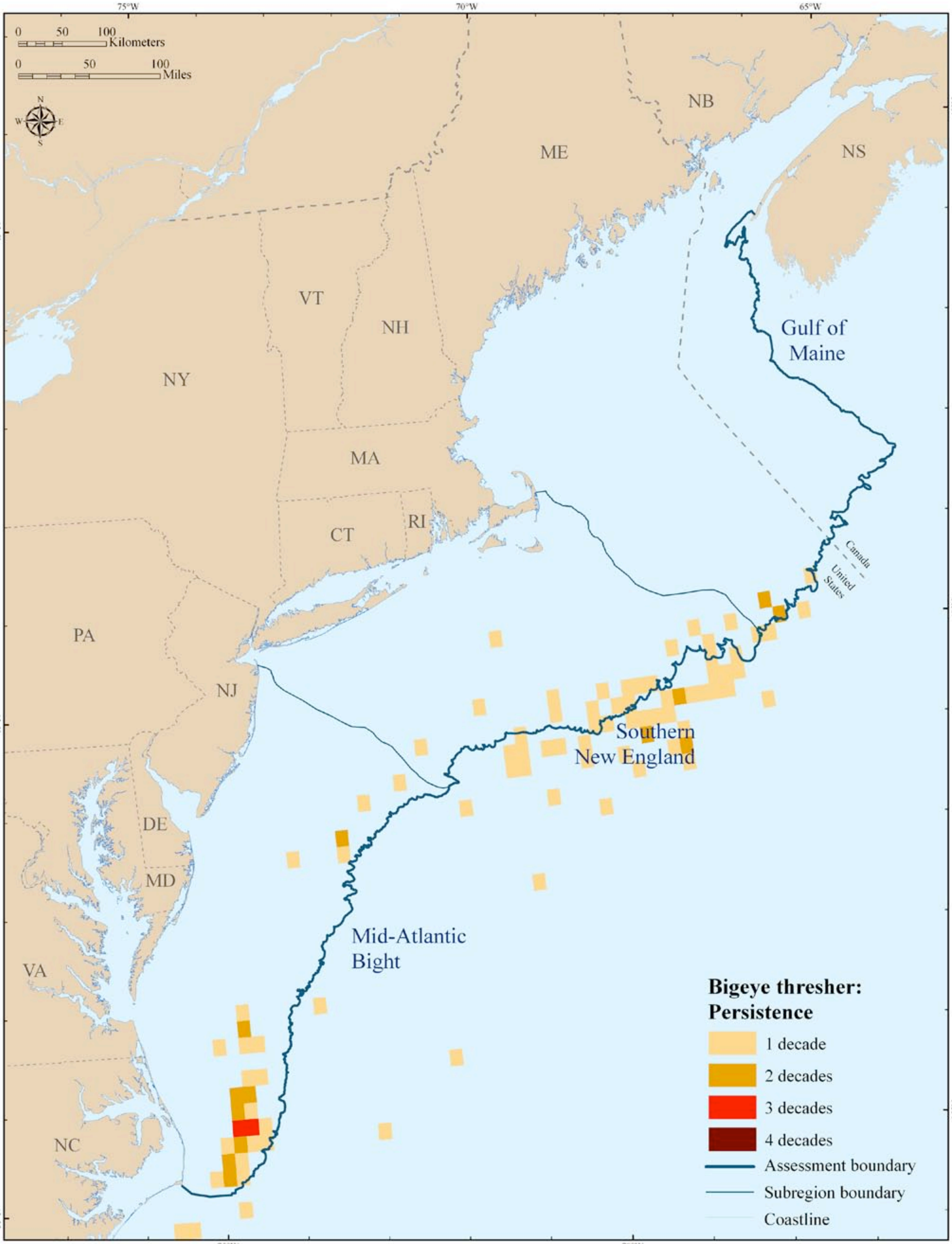

Figure 9-6. The persistence of bigeye thresher by TMS over time.

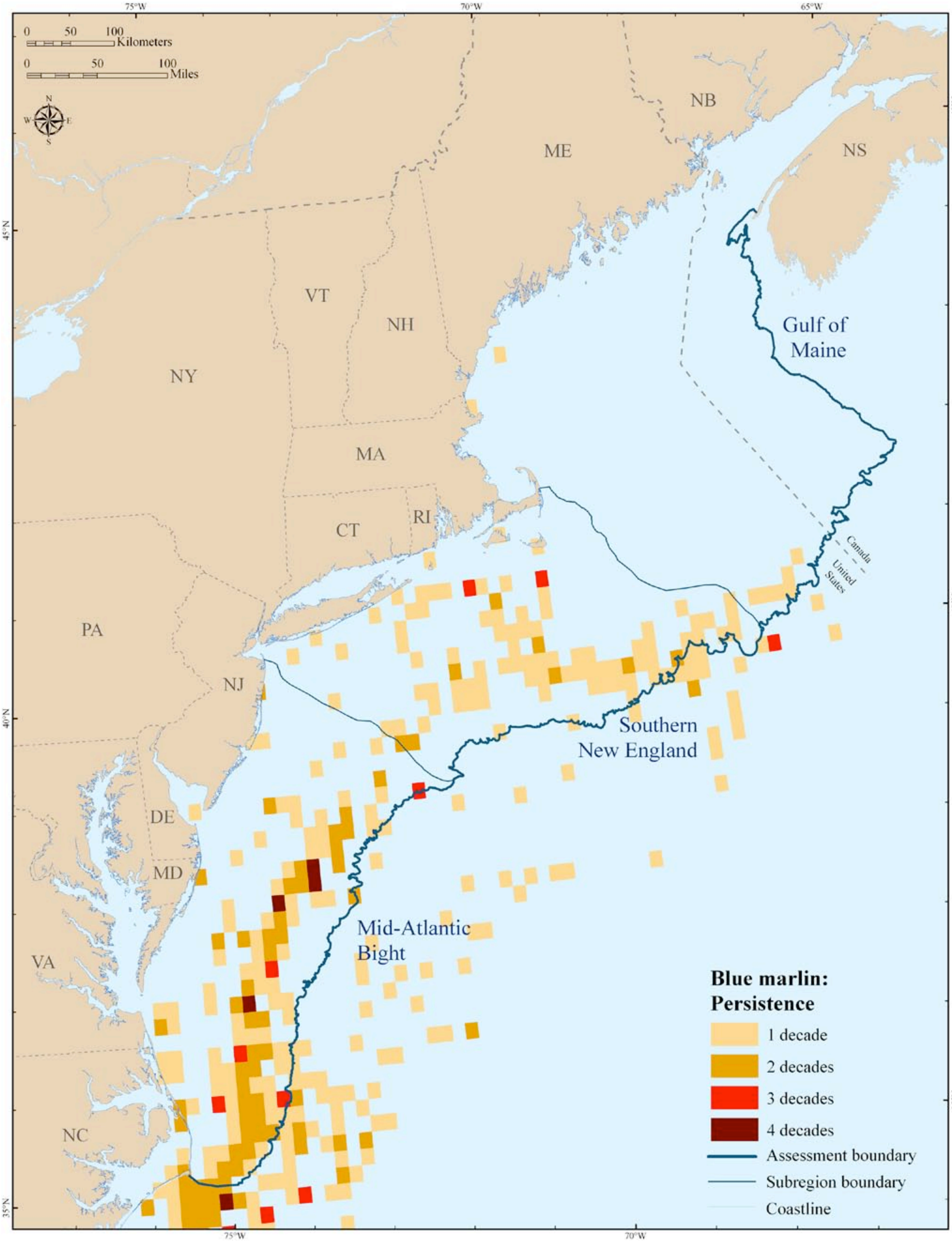

Figure 9-7. The persistence of blue marlin by TMS over time.

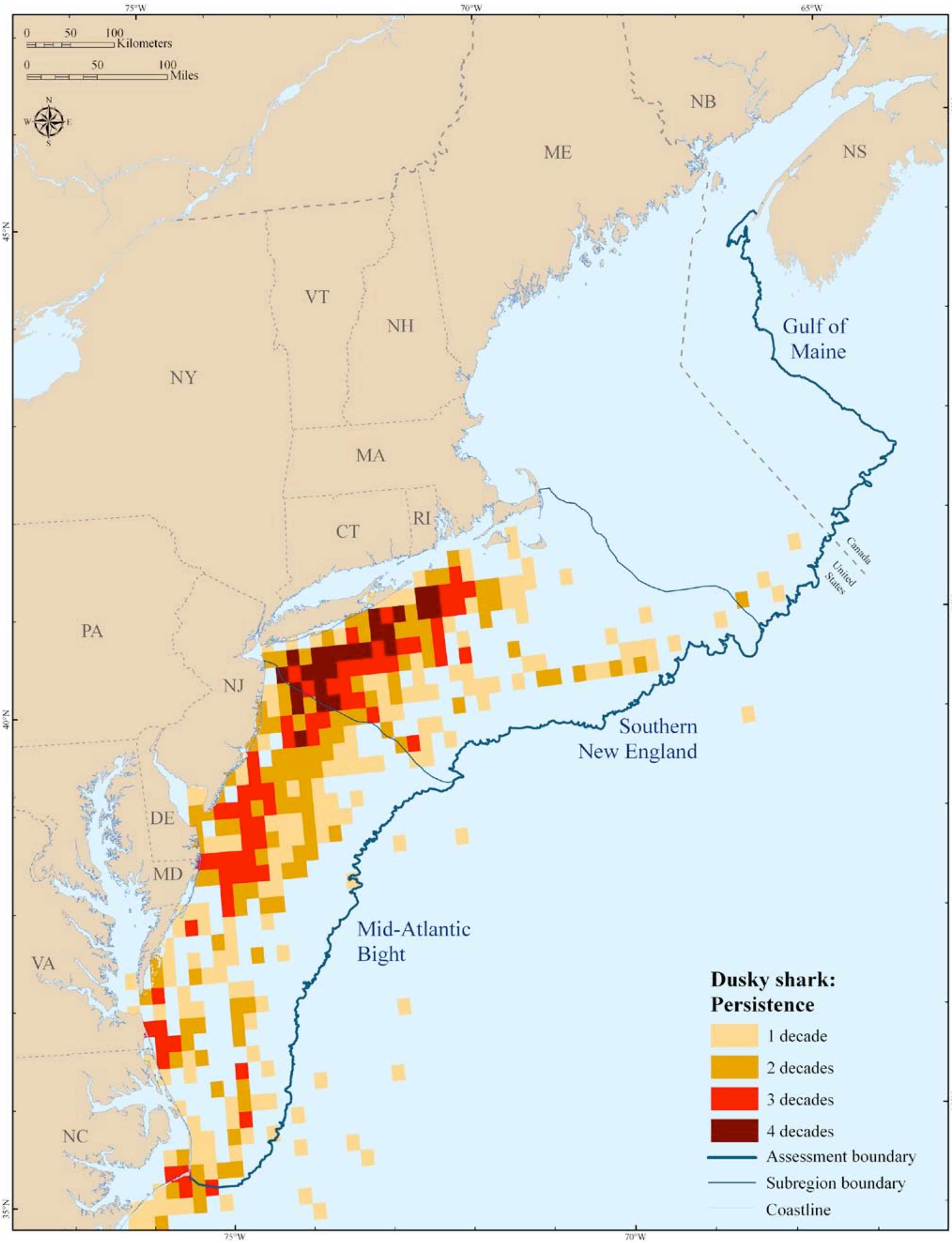

Figure 9-8. The persistence of dusky shark by TMS over time.

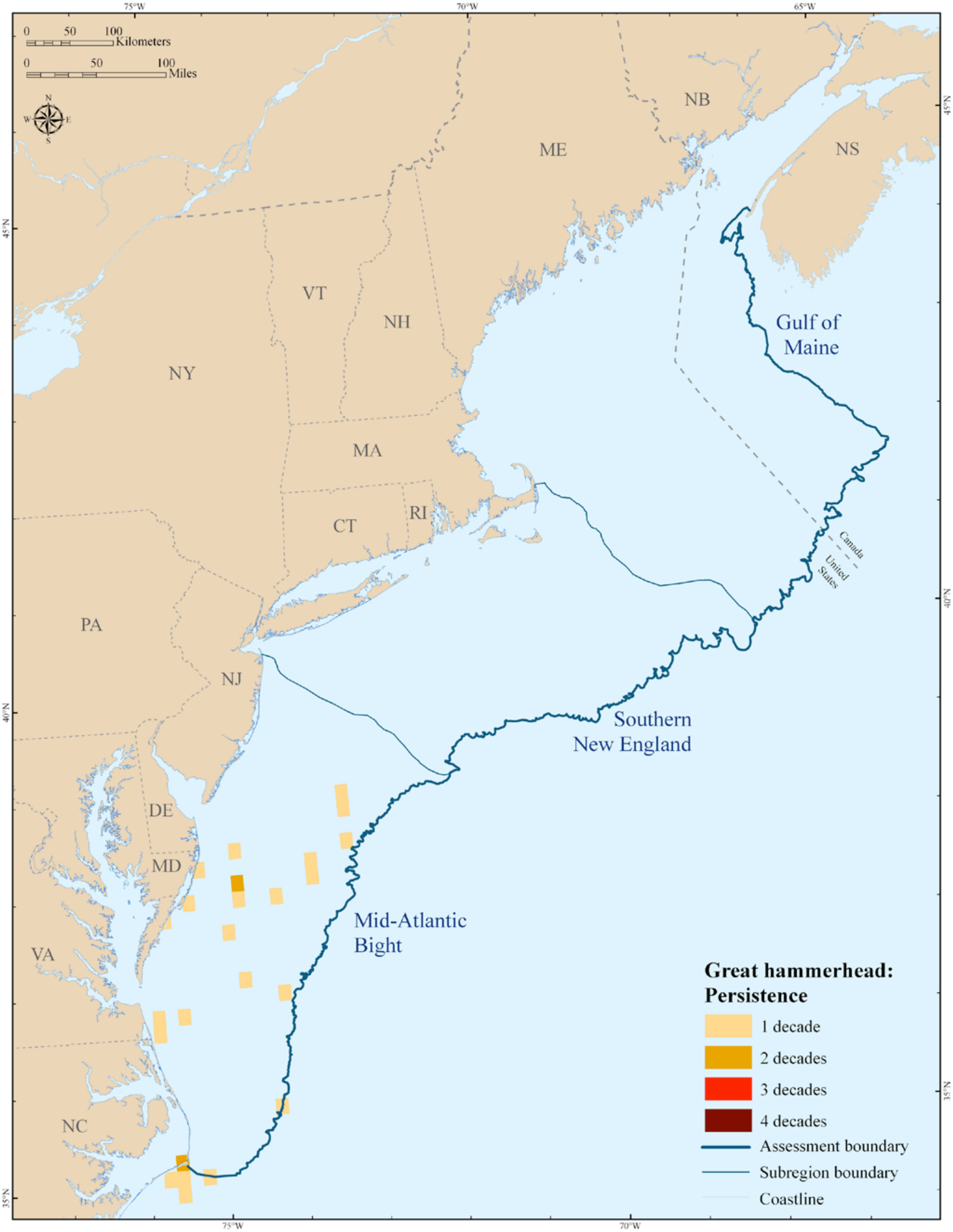

Figure 9-9. The persistence of great hammerhead by TMS over time.

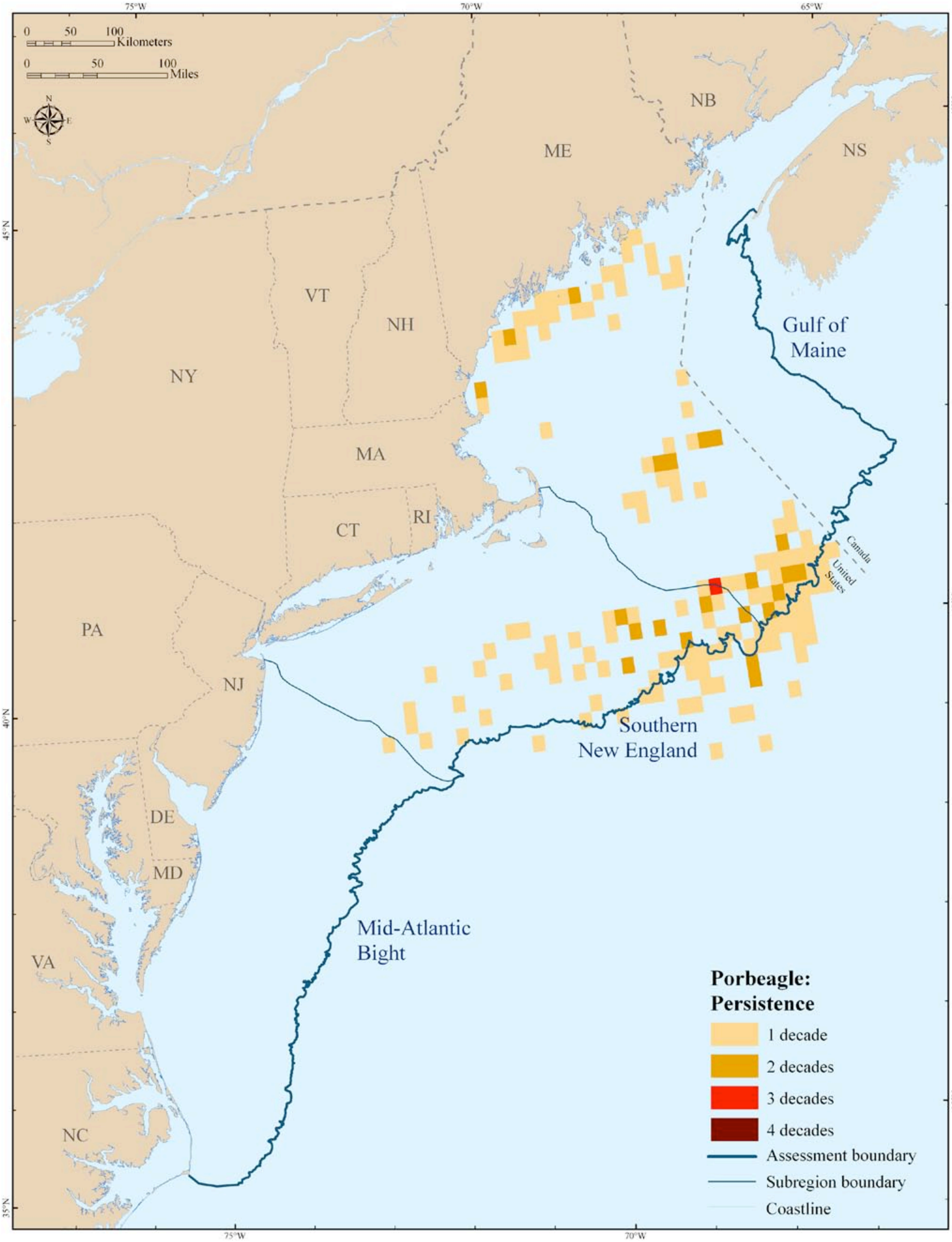

Figure 9-10. The persistence of porbeagle by TMS over time.

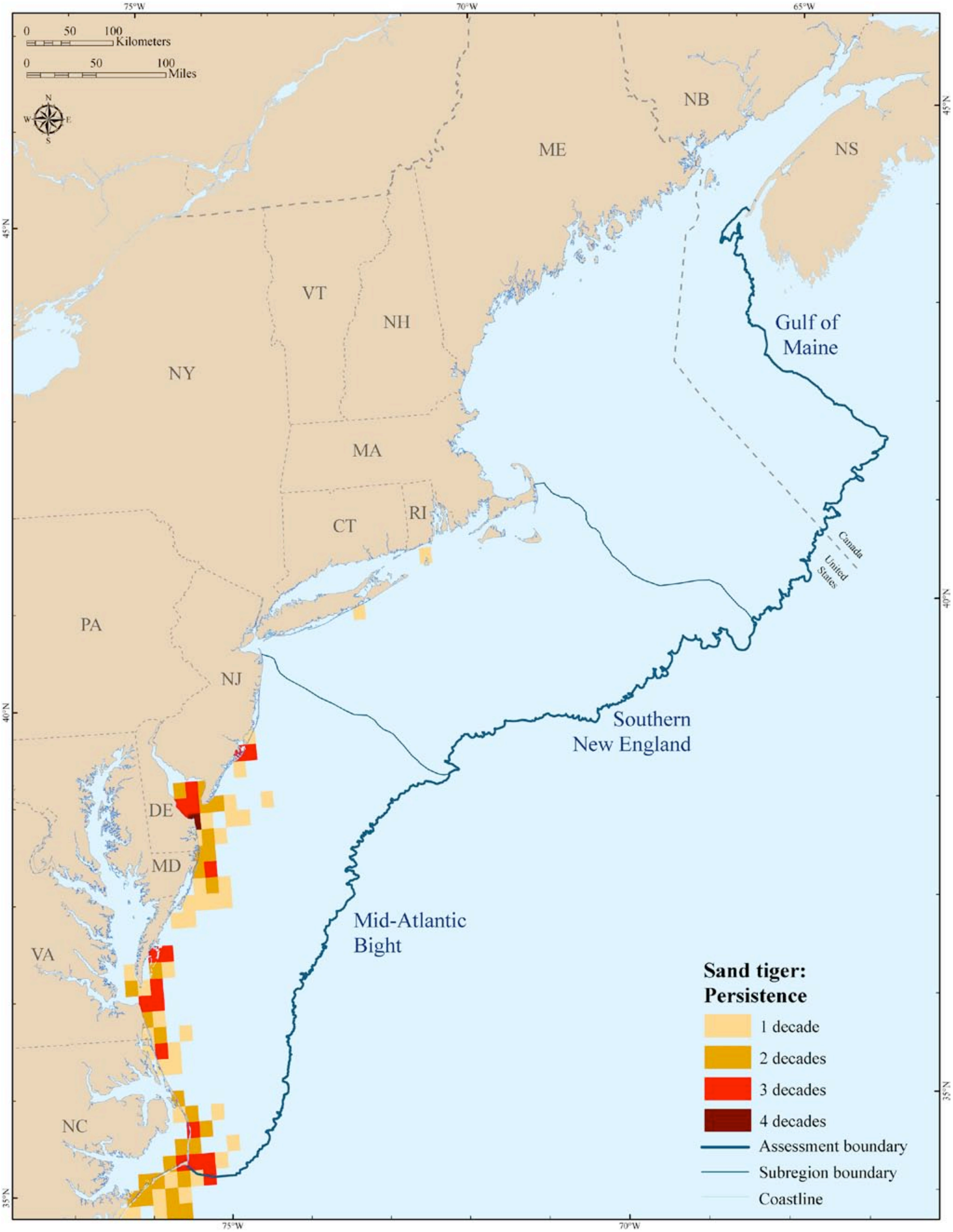

Figure 9-11. The persistence of sand tiger by TMS over time.

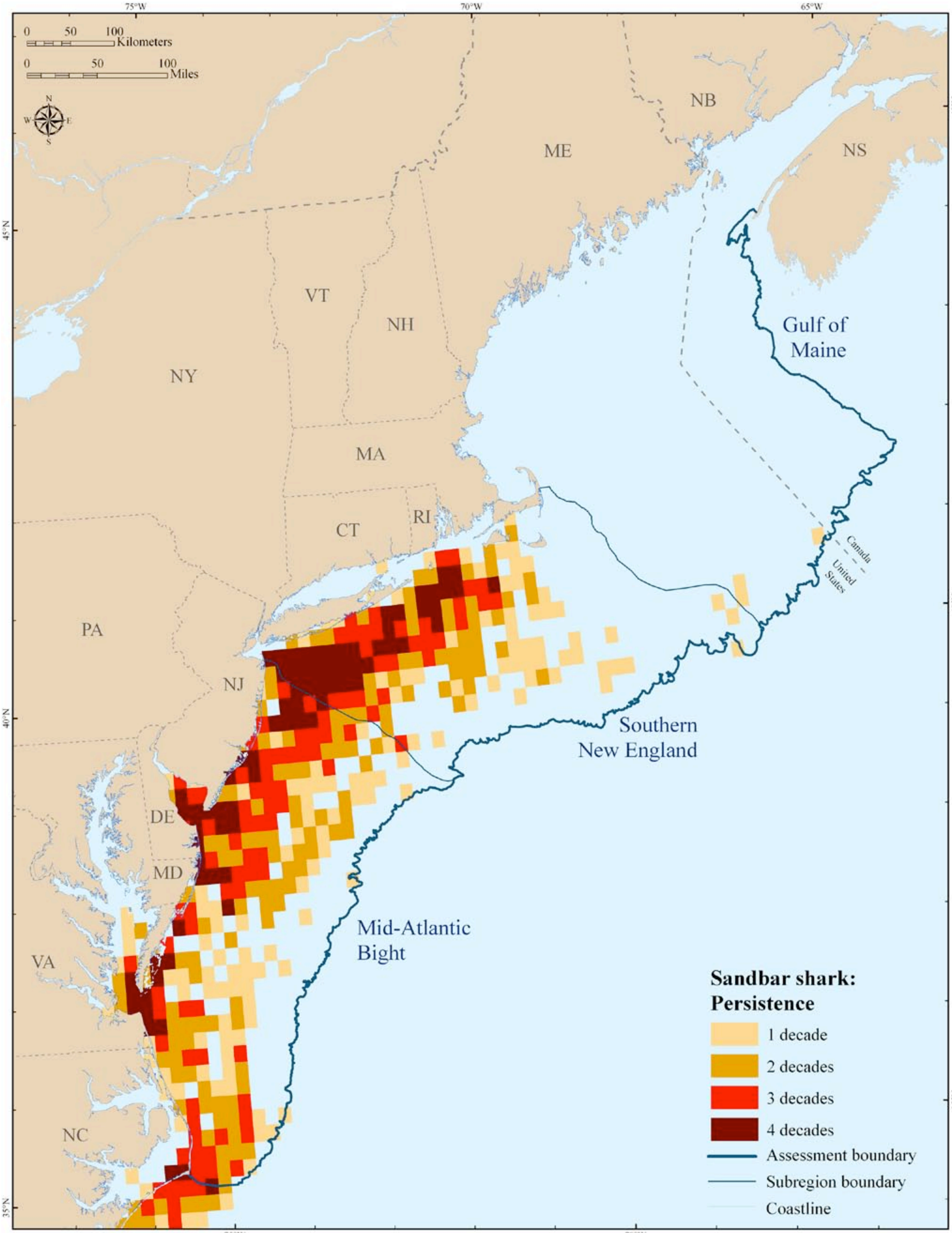

Figure 9-12. The persistence of sandbar shark by TMS over time.

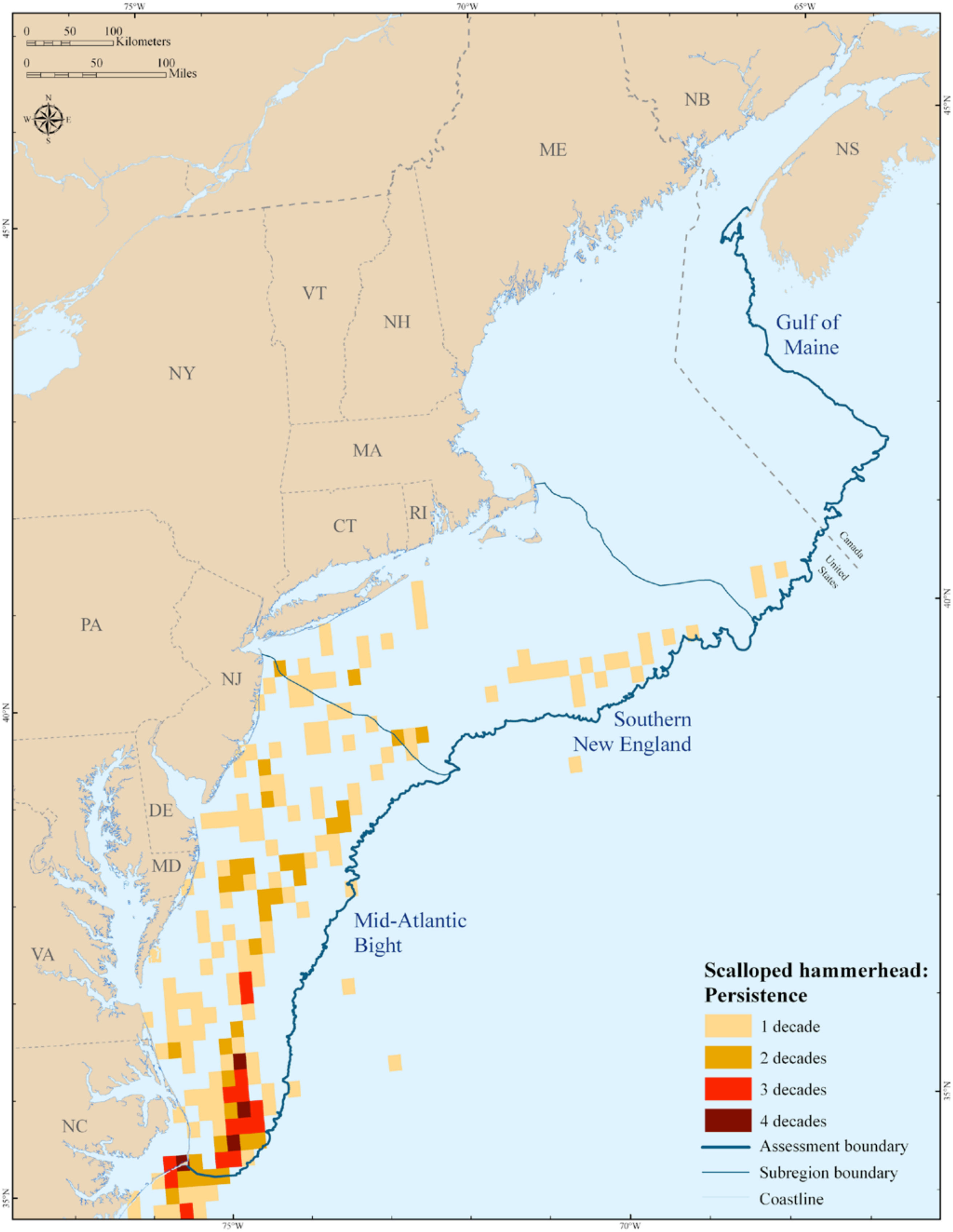

Figure 9-13. The persistence of scalloped hammerhead by TMS over time.

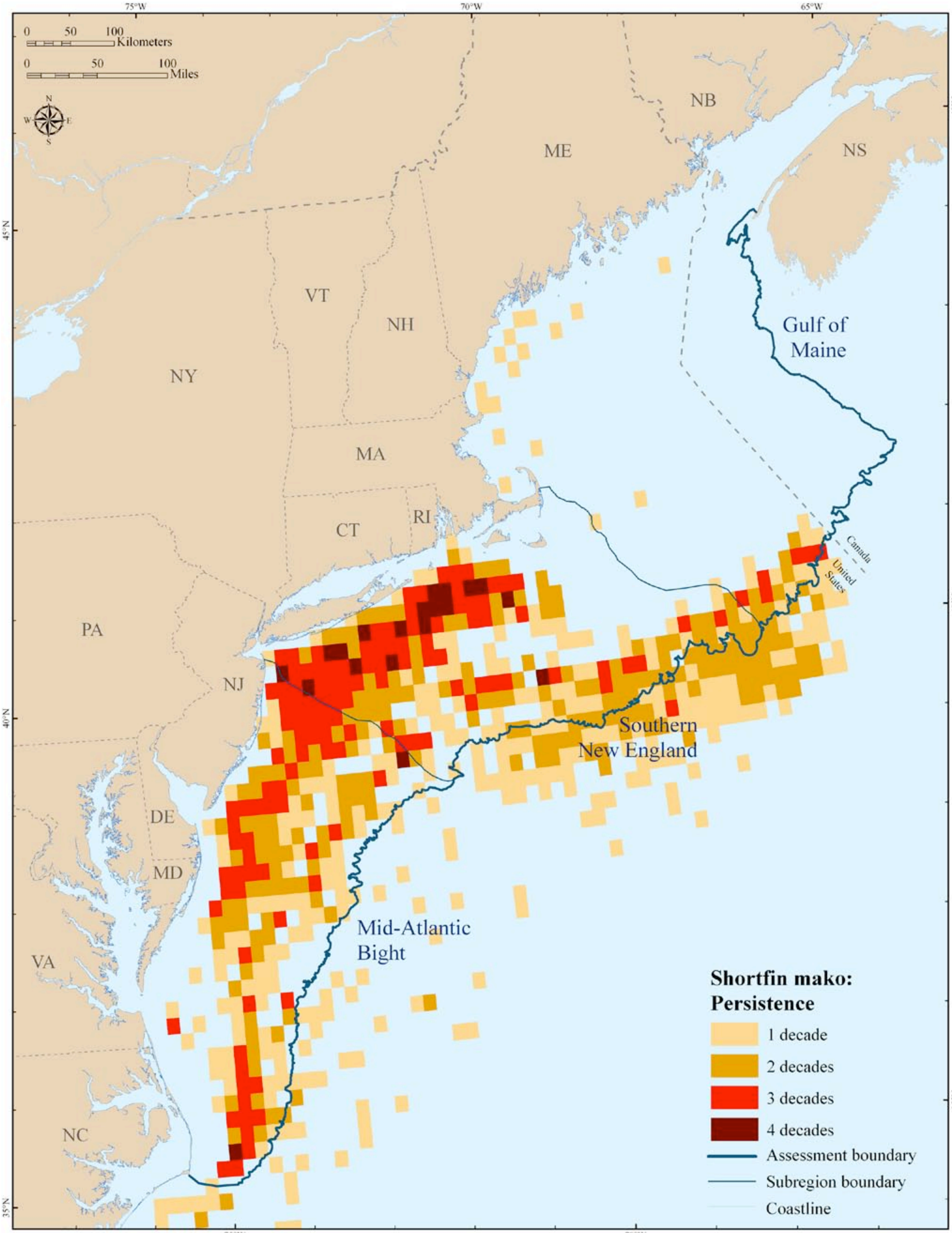

Figure 9-14. The persistence of shortfin mako by TMS over time.

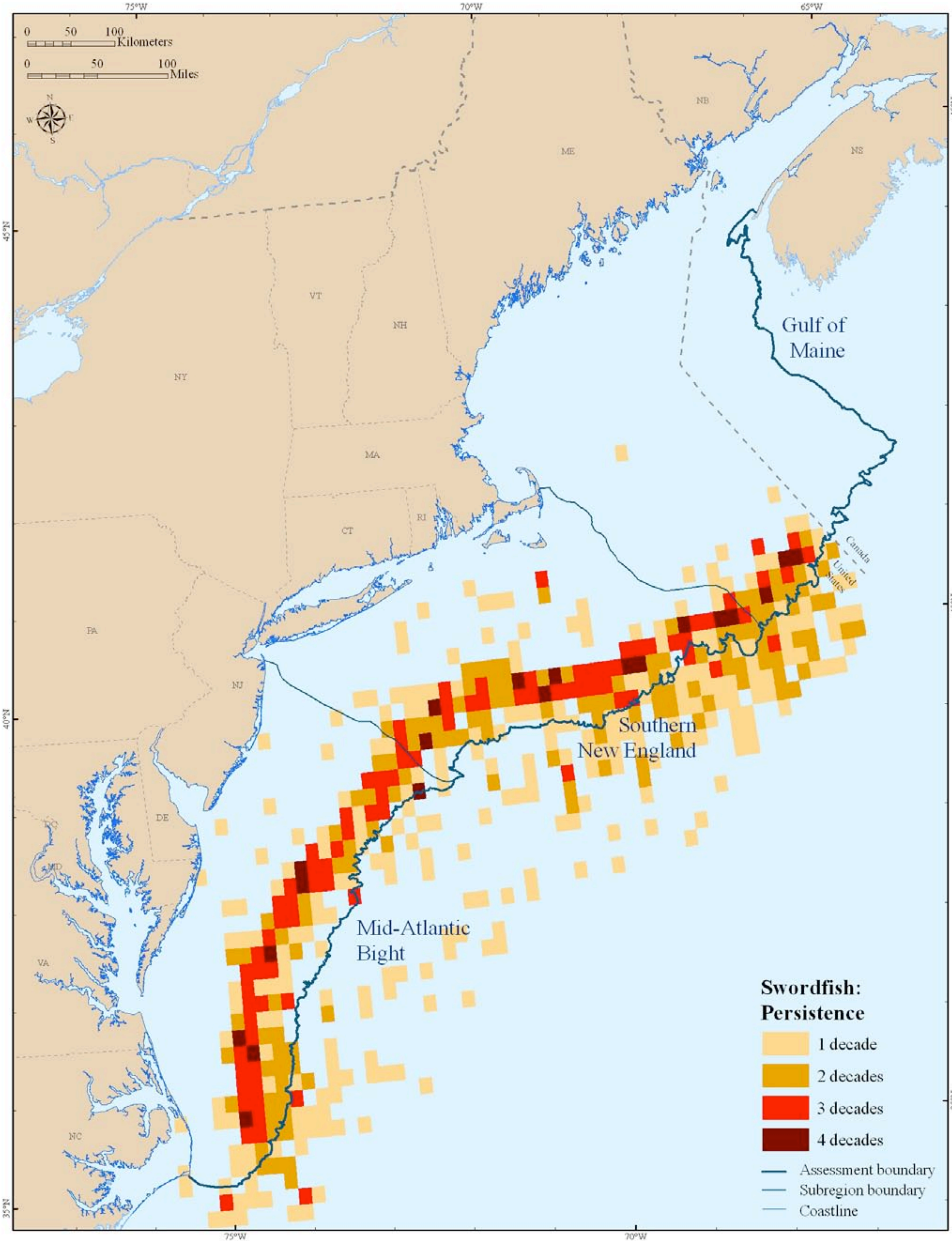

Figure 9-15. The persistence of swordfish by TMS over time.

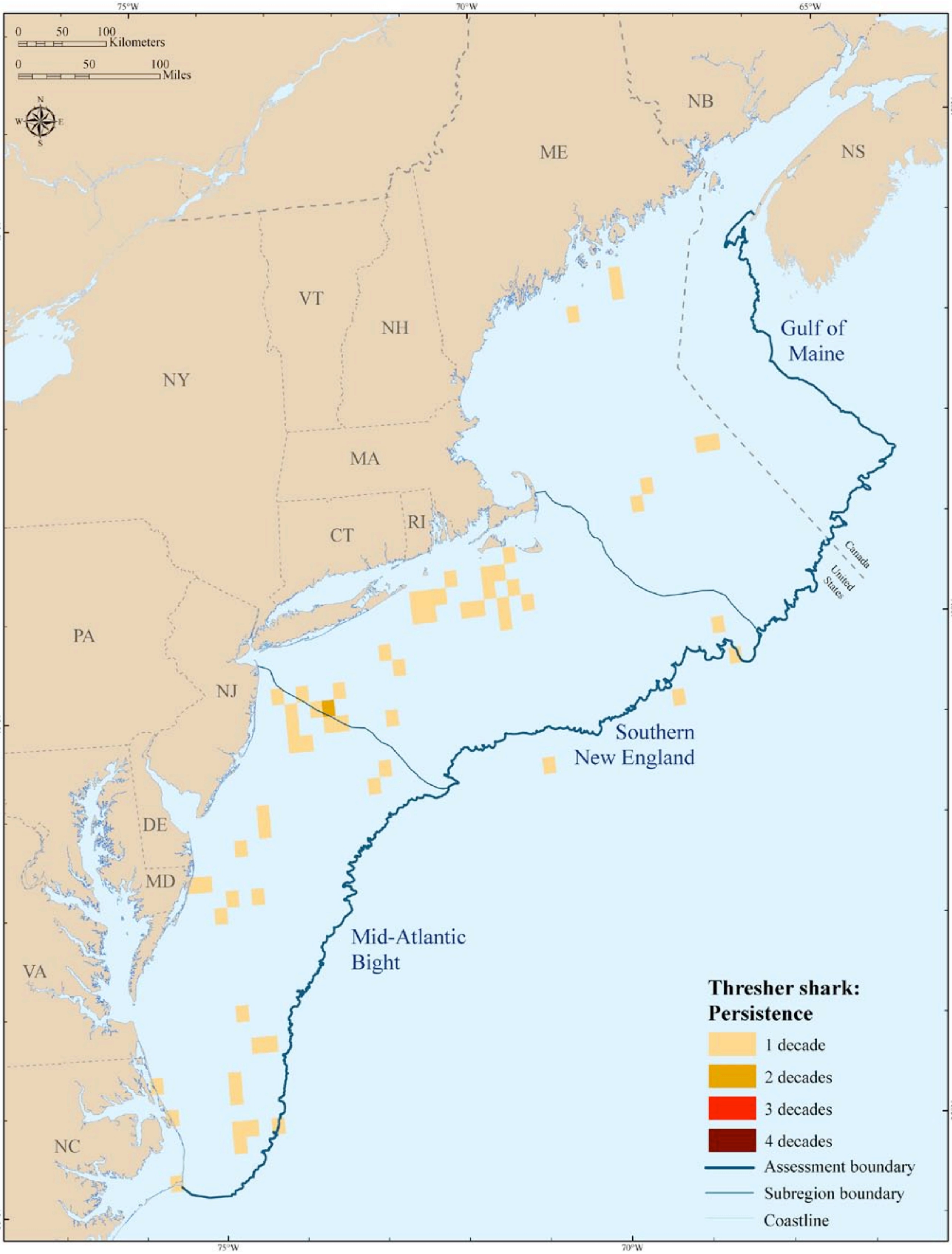

Figure 9-16. The persistence of thresher shark by TMS over time.

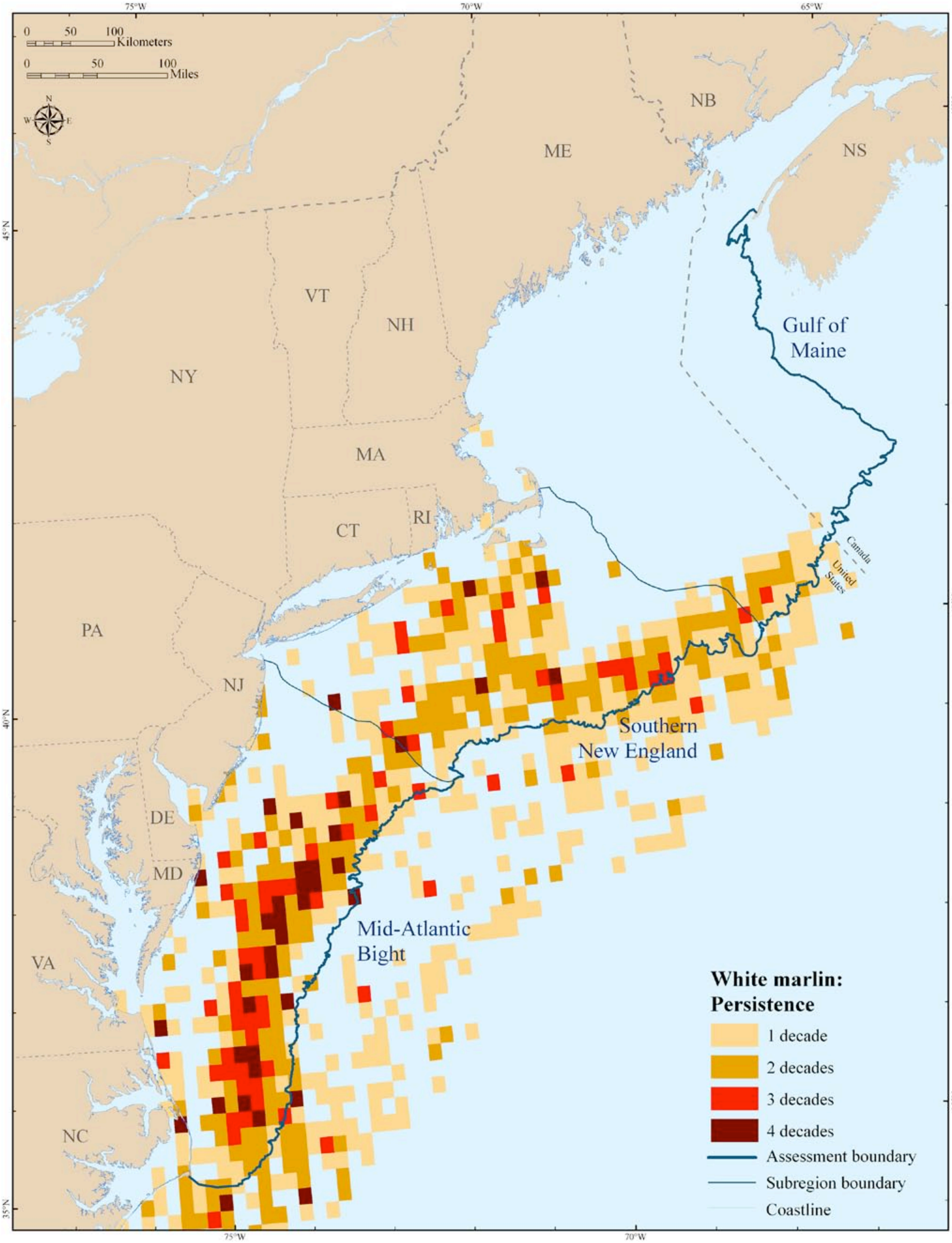

Figure 9-17. The persistence of white marlin by TMS over time.

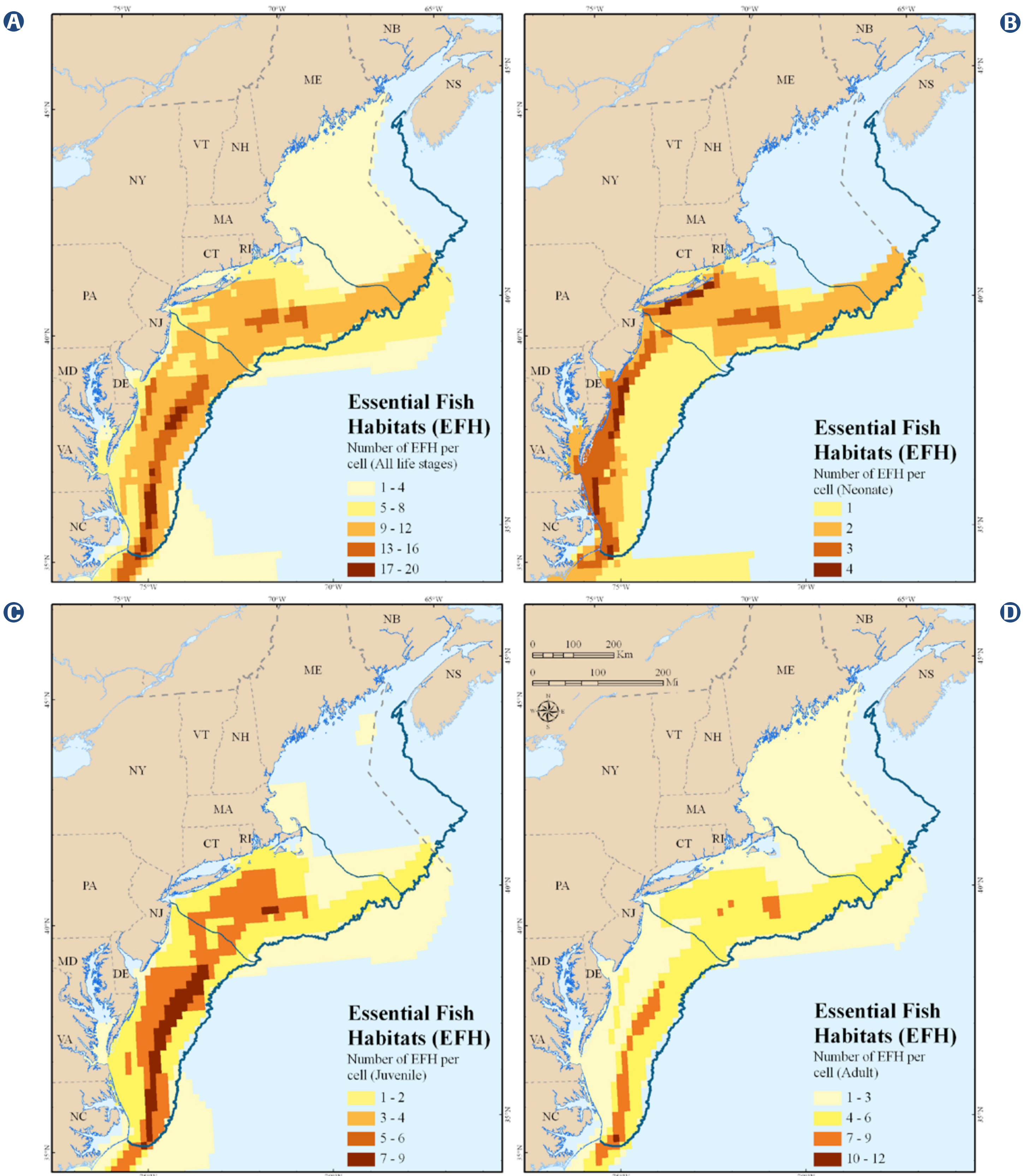

Figure 9-18. Areas designated as essential fish habitat for target species and life stages.

juveniles, the area with the greatest EFH concurrence is the SNE subregion, offshore to Long Island, between Hudson and Veech Canyons, including the Block Island Delta; the Mid-Atlantic Bight, to the 1000 m isobath, primarily between Baltimore and Wilmington Canyons, but extending south to Cape Hatteras; and a pathway along the Hudson canyon (Figure 18c). For adults, the area with the greatest concurrence is along the entire shelf-slope break out to 2000 m (Figure 18d).

Human Interactions and Threats

Threats to large pelagic species include overfishing (direct mortality of targeted species); bycatch (indirect mortality, largely by longline and gillnets, including accidental catches by recreational fisherman, and incidental catches by commercial fisherman (IUCN 2008); and climate change. Secondary threats are impacts to habitat: in particular, habitat loss and degradation of estuaries and shallow bays used by the two species of sharks in our region. Effective conservation of sharks will require attention to both habitat restoration and fishery conservation challenges.

Overfishing

Seven of the species are considered overfished (albacore tuna, blue marlin, bluefin tuna, dusky shark, sandbar shark, shortfin mako, and white marlin) and seven are threatened by overfishing (bigeye thresher, dusky shark, great hammerhead, porbeagle, sand tiger, scalloped hammerhead, thresher shark). Among the shark target species, the most commonly caught species is the shortfin mako, with an estimated annual catch of 6,000-8,000 tons (ICCAT 2005). Outside of the Exclusive Economic Zones, illegal, unreported unregulated fishing continues to occur (Dulvy et al. 2008). Globally, the fishing of pelagic sharks is increasing due to the sharkfin trade as well as the increasing value of shark meat (Simpfendorfer et al. 2008). According to Simpfendorfer et al. (2008), fin trade data suggest that the bigeye thresher and thresher shark may be caught at similar levels as the shortfin mako.

Bycatch

Sharks comprise the highest percentage of bycatch (25% of catch from 1992-2003) in the United States Atlantic pelagic longline fishery for tuna and swordfish (Mandelman and Werner 2007), and include bigeye thresher, thresher shark, white marlin, great hammerhead and dusky shark. Schindler et al. (2002) suggest that longline fisheries will have very different effects on slow-growing species, such as the pelagic sharks, in contrast to the teleosts. Hoey and Moore (1999) reported the order of bycatch in pelagic longlines as follows, with highest number of the target species caught first: mako, dusky shark, hammerheads, thresher shark, sandbar shark, and porbeagle.

To understand the distribution of these types of fishing within the region, the spatial locations of fishing trips for the gillnet fishing, pelagic longline, and bottom longline industry for the years 2001-2006 are shown in Figure 19-21 (source: Fishing Vessel Trip Reports (FVTR) data, provided by NOAA). It should be noted that the FVTR data does not show various state-licensed inshore fisheries that may have bycatch implications for these target species. For gillnet fishing, the Gulf of Maine/Georges Bank and Southern New England subregion show the greatest number of days fished. The highest intensity of fishing occurs within and north of Stellwagen Bank, as well as Jeffreys Bank, the Great South Channel, and Block Island Sound, with isolated high use of gillnets in the Hudson outflow/canyon area. Pelagic longlining occurs along the shelf/slope break in the Southern New England and Mid-Atlantic Bight subregions. For bottom longline fishing, the greatest and spatially broadest intensity is in the Gulf of Maine subregion, northeast of Stellwagen Bank; in the Southern New England subregion, along the Great South Channel, and roughly along the 100 m isobath between the Block Island Delta and Veech Canyon, and, with the Mid-Atlantic Bight subregion, along the Hudson canyon.

Climate Change

In general, any change in physical characteristics of the ocean could affect the distribution of pelagic species, and factors that can influence these changes include temperature, wind patterns, and pH. Currently, only a few cases

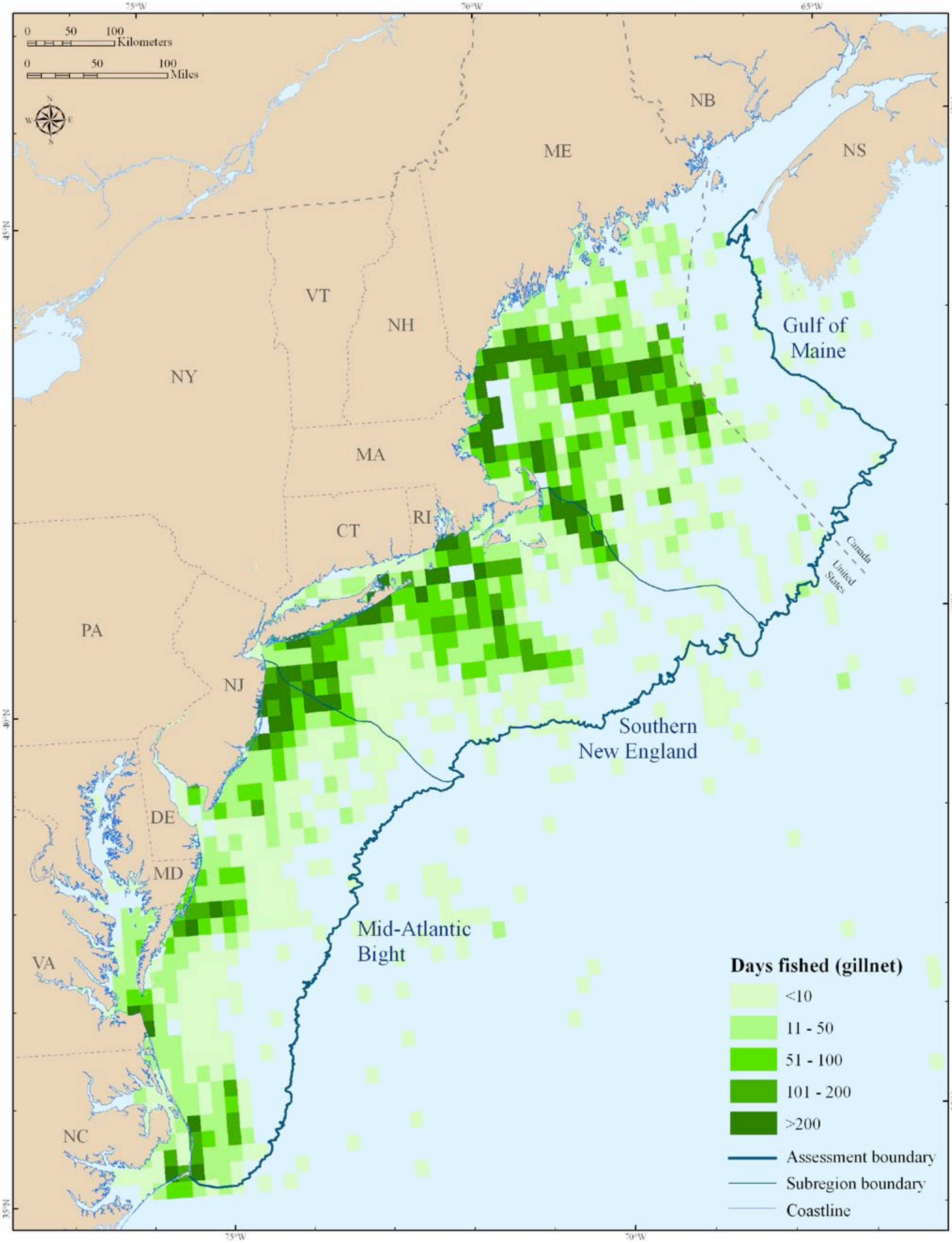

Figure 9-19. Number of days fished by gillnet.

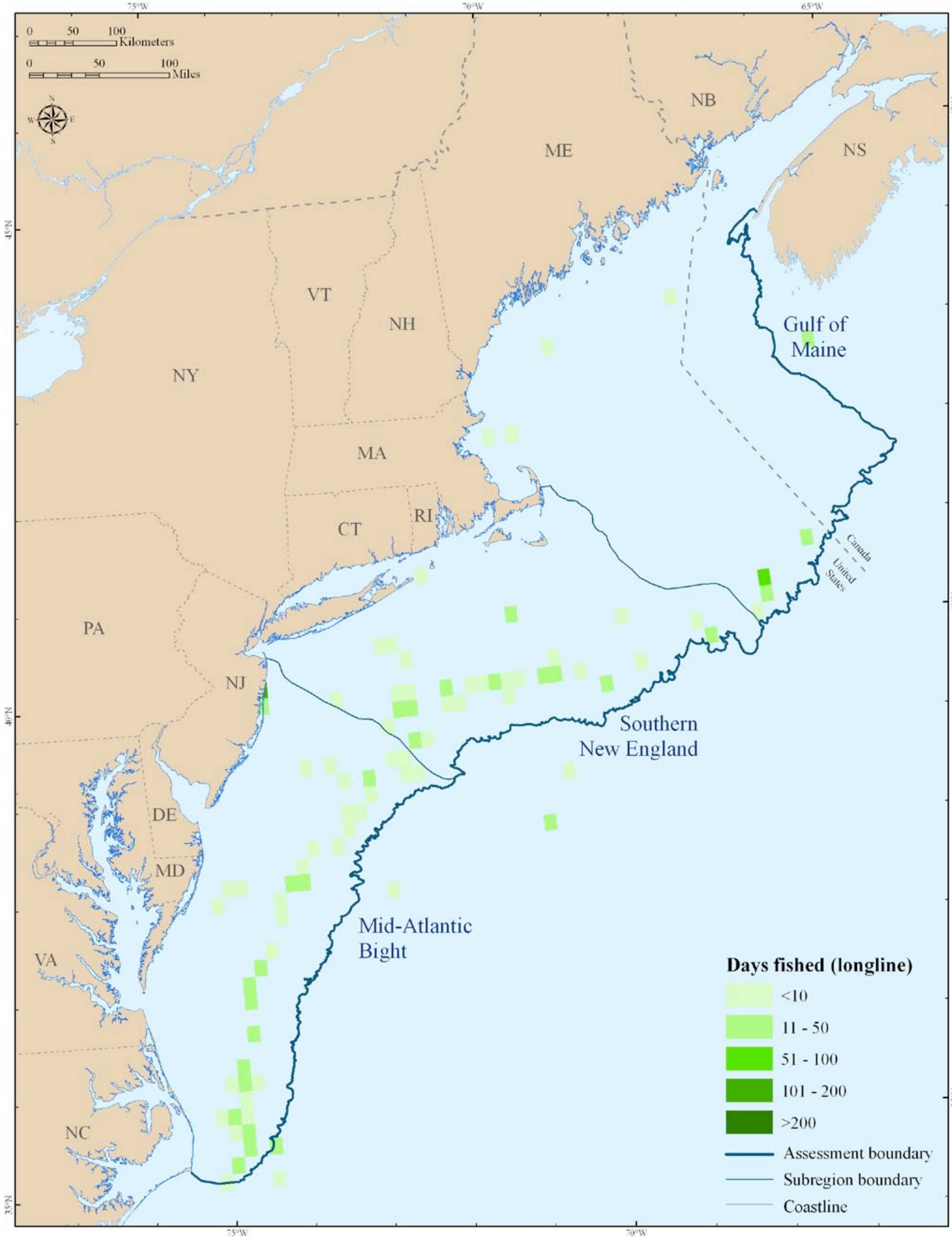

Figure 9-20. Number of days fished by pelagic longline.

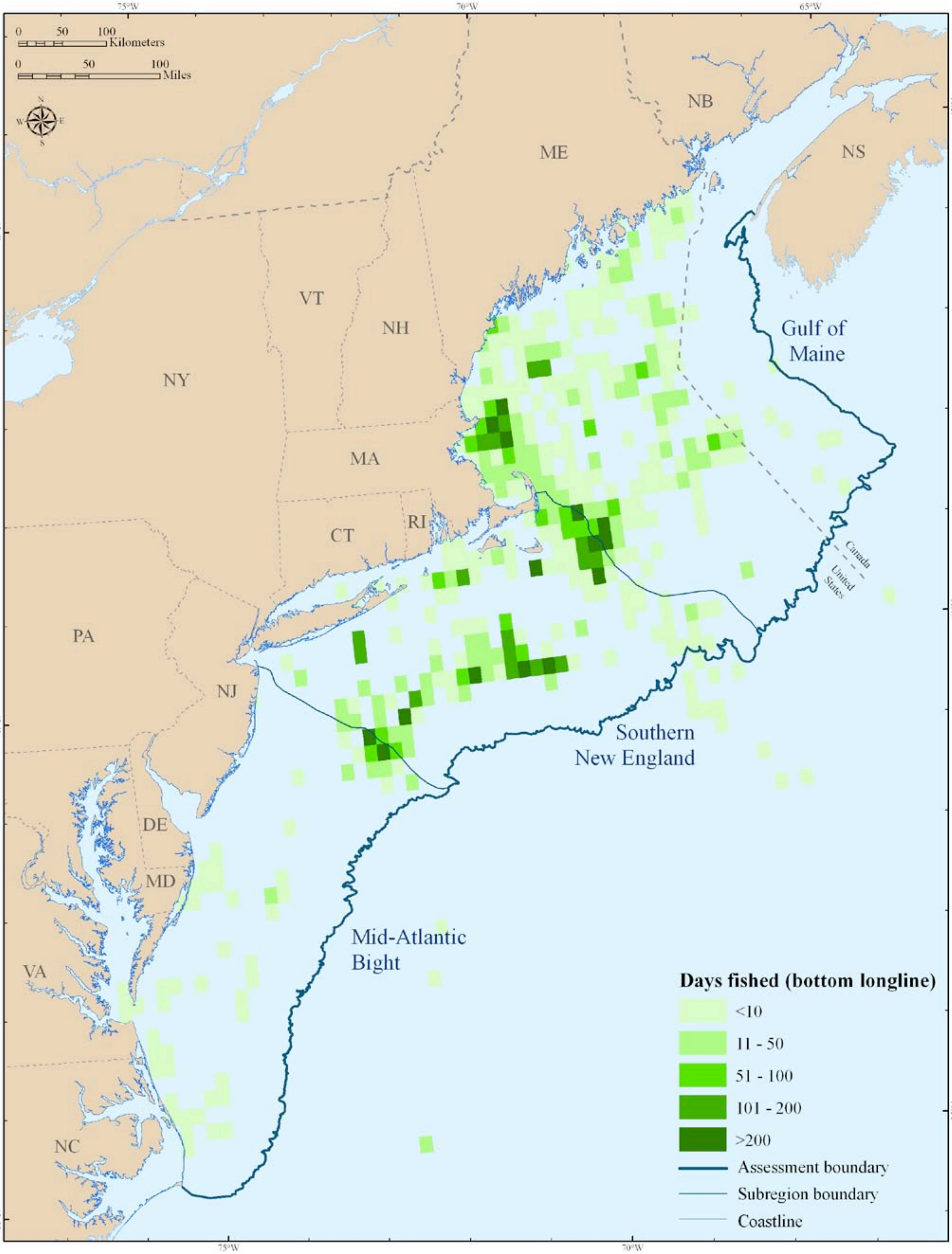

Figure 9-21. Number of days fished by bottom longline.

have documented climate change impacts (see reviews in UNEP/CMS 2006; Hobday et al. 2006), but there are several programs currently collecting information on climate change, including GLOBEC's Climate Impacts on Oceanic Top Predators (CLIOTOP) program (Maury and Lehodey 2005). Likely impacts include sea surface temperature changes and corresponding changes in the food web, wind forcing changes, acidification, changes in prey populations, and increased pollution at the sea surface.

Changes in ocean temperature in time and position could affect the distribution of pelagic species. On the United States east and west coast, sea surface temperature has increased, causing shifts in timing of zooplankton, which affects the entire food web (see Moran 2008; Scripps Institute of Oceanography 1995). Wind also indirectly impacts pelagic species by mixing the surface waters (Cury and Roy 1989). If significant changes to wind forcing do occur, this could impact coastal pelagic systems (Bakun and Weeks 2004). The productivity of pelagic systems could change, depending on the relative balance of nutrients, light, and timing of phytoplankton production.

There is notable concern about the pH changes occurring in the open ocean. While it is expected to be small compared to benthic habitats, acidification could impact lower trophic levels. The scalloped hammerhead, sand tiger, and sandbar shark – all of whom feed to some degree on benthic invertebrates - could be impacted. Other, fast-swimming, high metabolic species such as the tuna and billfish could be affected by changes to their metabolism (Pörtner and Farrell 2008). These animals are at the edge of physiologic extremes in their energy and oxygen needs. Change in prey populations will also potentially affect these species. CLIOTOP is analyzing the role of climate change on loligo squid, a key prey item for tunas and billfishes (Pecl and Jackson 2006). Squid are expected to be very sensitive to climate change, particularly increased temperature. They are expected to respond extremely rapidly, and may be good indicators for climatic impacts.

In summary, the individual and combined threats of global climate change described above could have both subtle and dramatic impacts to pelagic fish populations. While the science regarding the nature and likelihood of these impacts is advancing rapidly, substantial uncertainty remains. In the face of such uncertainty, an extra precautionary approach is indicated when managers must make key decisions regarding abatement of known threats such as overfishing, bycatch, and nearshore habitat loss and degradation. Conservation measures that abate non-climate change related impacts will help to increase resiliency of populations while explicit climate change adaptive management strategies are still being developed and tested.

Management and Conservation

Regulatory Authorities

Unlike the other fish species, these animals are not regulated by the regional fisheries management councils. Since 1992, within the United States Exclusive Economic Zone (EEZ), Atlantic highly migratory species, including tuna, swordfish, billfish (the two marlin species) and sharks are managed by NMFS HMS, under the dual authority of the Magnuson-Stevens Fishery Conservation and Management Act and the Atlantic Tunas Convention Act. NAFO is a regional, non-regulatory body. Its objective is regional cooperation and consultation on fisheries of the NAFO Convention Area of the Northwest Atlantic, including swordfish, porbeagle, shortfin mako, and large sharks; the NAFO Convention does not apply to tunas or marlin.

Because of the circumglobal distribution of many of the species and the fact that the species are often found outside of exclusive economic zones, management requires international cooperation through ICCAT. Note that ICCAT only regulates Atlantic tunas, swordfish and billfish; it does not regulate Atlantic sharks. If ICCAT makes a management recommendation, the United States must implement it, under the Atlantic Tunas Convention Act. All fourteen of the selected species for this chapter are included in Annex 1 of the UN 1982 Convention of the Law of the Sea (UNCLOS) as highly migratory species. Under UNCLOS, the UN held a 1993 Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. As a result of this Conference, the Fish Stock Agreement (FSA) was created relating to the conservation and management of straddling fish stocks and highly migratory stocks. The FSA entered into force in 2001.

Current Conservation Efforts

Federal

HMS has developed a range of fishery management regulations, ranging from gear restrictions to spatial closures (some are year-round; others are closed for certain periods). Fishing is prohibited for the following four shark species: bigeye thresher, dusky shark, sandbar shark (except fisherman participating in research), and sand tiger. For the teleost fishes, see 50 CFR part 635. Commercial fishermen are restricted by quotas, trip limits, and limited access permits; recreational fishermen are restricted by minimum size as well as bag limits. In 2002, the U.S. banned shark finning in U.S. waters. The United States and Australia are the only two shark fishing nations (out of 87) to develop a National Plan of Action for the Conservation and Management of Sharks.

A summary of recent (2006-2007) NMFS Atlantic HMS Management actions with respect to fisheries is provided in Table 1.2 of the Stock Assessment and Fishery Evaluation Report for Atlantic Highly Migratory Species (NMFS 2009). The 2006 consolidated HMS FMP summarizes state management.

Within United States waters, HMS has designated some temporally closed areas to fishing, including in our region: the Northeastern U.S. Closure is closed in June (effective since 1999), and partially, the Mid-Atlantic closure is closed for 6 months, from Jan. to July (effective since 2005). Outside of the Northwest Atlantic, the Charlestown Bump is closed 3 months, from Feb. to April (effective since 2001), the Florida East Coast is closed all year (effective since 2001), and the De Soto Canyon in the Gulf of Mexico is closed all year (effective since 2000).

Non-Governmental Organizations (NGO)

Several NGOs are working towards protecting pelagic fish within the Northwest Atlantic, primarily focusing on federal and international fisheries policy (including marine protected areas, both year-round and seasonal, depending on the species and efforts to reduce total allowable catch and bycatch), and market-based approaches to encourage sustainable fisheries. The Natural Resources Defense Council has identified North Atlantic swordfish as one of their key fish species to protect. They promote the continued closure of more than 6,500 square miles of the Georges Bank seafloor to fishing and the creation of a marine reserve within the Gulf of Mexico, a key spawning area for bluefin tuna. In April 2008, Blue Ocean Institute called for a five-year moratorium on possession of bluefin tuna throughout the western Atlantic and the closer of Gulf of Mexico spawning areas to all gear capable of catching bluefin tuna during this fish's spawning season. Also, Blue Ocean Institute produces a "Guide to Ocean Friendly Seafood" accessible online or through their new "fishphone" system. World Wildlife Fund is working at a global level, mainly in Europe, to address population declines in Atlantic bluefin tuna and porbeagle. Environmental Defense Fund works within New England, the tri-state area (NY, NJ and CT) and Long Island Sound to protect and restore coastal estuaries, bays, wetlands and cod and to reduce nitrogen loading. They promote sustainable fisheries by advocating catch share policies in New England that gives fishermen a financial stake in fisheries. IUCN recommends listing for all shark species studied in this assessment under the Convention on Migratory Species, to provide additional regulatory mechanisms. Currently, only the shortfin mako, porbeagle, whale shark, great white, and basking shark are listed.

Species Accounts

Atlantic bluefin tuna *(Thunnus thynnus)*

Atlantic bluefin tuna are found throughout the western Atlantic, from Florida to Newfoundland and are considered apex predators (Collette and Nauan 1983; Lutcavage and Kraus 1995). In what is thought to be a single stock, bluefin tuna move seasonally from mid-April to June, from spawning grounds outside the Northwest Atlantic region (Gulf of Mexico and in the FL Straits) to feeding grounds along the Northwest Atlantic region (Mather et al. 1995; Block et al. 2005). Recent tagging studies have shown that they can swim thousands of miles across the Atlantic, with a maximum distance traveled of 5820 km in less than a year (304 days) (Rooker et al. 2007). Bluefin tuna are a thermoconserving species and are found in water temperatures from 6-27°C (Collette and Klein-MacPhee 2002). They usually remain in oceanic waters, but are seen across the continental shelf and are often found in coastal embayments during summer when food resources are in abundance (Collette and Nauen 1983).

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Growth rate is slow and maturity is late and occurs about age 8 for the Western Atlantic population (Turner et al. 1991). This species is relatively long-lived and can live up to 30 years (Collette and Klein-MacPhee 2002). Spawning occurs every year, but individuals appear to spawn only every 2-3 years; timing appears to be linked to temperature (Fromentin and Powers 2005). Genetic studies of young of year animals show that the Western Atlantic and Juveniles and adults do overlap, however, in central and eastern North Atlantic foraging grounds and in mid-Atlantic/transatlantic migrations (Block et al. 2005; Lutcavage et al. 1999; Rooker et al. 2007). Adult bluefin are large (up to a TL of 458 cm and wt of 684 g) and feed opportunistically on fish (sand lance, Atlantic herring, mackerel and bluefish), squid and crustaceans (Chase 2002; Estrada et al. 2005). A study of diet across five different feeding grounds in New England shows spatial differences; for example, 50% of the diet in Cape Cod Bay consisted of demersal fish (Chase 2002). In the Gulf of Maine, their preferred prey is herring (Golet et al. 2007). Their distribution in this subregion has been shown to be significantly correlated with the distribution of the herring, which is also correlated to SST (Schick and Lutcavage 2009). Predators of adult bluefin tuna include other large pelagic species like toothed whales, swordfish, and sharks (Tiews 1963).

Albacore Tuna *(Thunnus alalunga)*

North Atlantic albacore are found throughout the Atlantic Ocean and Mediterranean Sea (Collette and Nauan 1983). Throughout its range, albacore migrate over great distances and move in groups that may include different kinds of tuna like skipjack and bluefin tuna. There are two separate stocks of albacore (North and South Atlantic) and there appears to be no mixing between the stocks (Collette and Nauan 1983). Albacore tuna typically feed in the upper layers of the ocean, but have been documented diving to a depth of 500 m in search of prey (Consoli et al. 2008).

North Atlantic albacore are presumed to spawn in the Sargasso Sea and surrounding waters during the boreal summer and their larvae live in the upper 100 m of water at a temperature range of 15 to 20°C (Pusineri et al. 2005). Juvenile fish range from 40 to 90 cm long and are constrained to the same range and temperature. Albacore become sexually mature when they reach 90 cm in length and an age of about 5 years (Collette and Nauan 1983).

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Maximum reported age is 12 years and albacore can reach a maximum fork length of 140 cm and weight of 60.3 kg. Like bluefin tuna, albacore are opportunistic feeders. Their main prey is fish (60% of biomass) and cephalopods (39%) (Pusineri et al. 2005). Studies of feeding behavior in the central Mediterranean Sea have shown preference to other pelagic species like medium sized fish, cephalopods, and crustaceans (Consoli et al. 2008; Dragovich 1969).

Swordfish *(Xiphias gladius)*

Swordfish range throughout the tropical, temperate, and cold-water areas (Collette and Klein-MacPhee 2002). Adult swordfish are found in coastal waters, but are primarily oceanic and concentrations are seen between water masses associated with boundary currents like the Gulf Stream (Govoni et al. 2003). Swordfish are found in the upper layers of the ocean, but feed throughout the water column. This population is genetically different from that found in the Mediterranean Sea, and mixes only slightly with the Mediterranean population west of Gibraltar and south of the NW African coast (Bremer et al. 2005a, b). Atlantic swordfish have two distinct populations, North Atlantic and South Atlantic, as demonstrated by mitochondrial and nuclear DNA studies (Bremer et al. 2005a). They annually migrate thousands of miles along the eastern seaboard of the United States and Canada, moving toward temperate or colder waters during the summer for feeding and back to warmer waters in fall for spawning and overwintering (HMS FMP 2002). In swordfish, the brain and eyes are warmer than the water in which they live, which protects the species on deep foraging dives (Collette and Klein-MacPhee 2002).

In the Northwest Atlantic, swordfish segregate by size and sex; the larger individuals, primarily females, can be found in colder, higher-latitude waters, but the females, along with the males, are eventually found in the warmer breeding areas (Palko et al. 1981). Spawning occurs throughout the year in several warm-water locations (e.g. south of the Sargasso Sea/upper Caribbean Sea, Southeast coast of United States) (Collette and Klein-MacPhee 2002). Larvae are most often found at temperatures greater than 24°C and are often found in nursery areas in the Gulf of Mexico and Florida (NMFS 2009). These regions to the south of the Northwest Atlantic may also serve as juvenile fish nursery areas (NMFS 2009). Swordfish are opportunistic feeders, eating at different depths and at different trophic levels during the diurnal vertical migration (Stillwell and Kohler 1985). The main prey items in the Northwest Atlantic region are predominantly squid, followed by gadids, scombrids, butterfish, bluefish, and sand lance (Stillwell and Kohler 1985).

Blue Marlin *(Makaira nigricans)*

Blue marlins are found throughout the Atlantic Ocean in offshore areas mostly between 45°N and 35°S (Nakamura 1985). They are highly migratory and seasonal movements are correlated to changes in sea surface temperature (especially the 24° C isotherm). Blue marlin are solitary and do not typically school (Nakamura 1985). ICCAT (2001) considers there to be a single Atlantic stock of blue marlin.

Blue marlins spawn outside the Northwest Atlantic region in marine habitats (Nakamura 1985). Female blue marlin mature when they reach 104 to 134 lbs, while males mature at smaller weights, from 77 to 97 lbs (NMFS 1999). Pelagic eggs and fast-growing larvae are found in the same habitat as the spawning region. Larvae are found in marine waters with a temperature of >24°C and are generally bounded by 100-2000m isobath or to the EEZ (NMFS 1999). Pelagic juveniles are obligate marine and found within temperatures ranging between 22 and 31°C. From Jan-April adult blue marlins are found in the SW Atlantic (5-30° N) and from June-Oct. in NW Atlantic (10-35° N). Maximum total length recorded for both males and females is 500 cm (NMFS 1999). Maximum weight of males is 170-175 kg, while females grow larger and faster than males, and can reach a maximum weight of over 900kg (NMFS 1999). Blue marlin feed at a wide variety of depths and their diet consists of other medium sized oceanic organisms like tuna and squid (Collette and Klein-MacPhee 2002).

White Marlin *(Tetrapturus albidus)*

Atlantic white marlin are distributed widely in the Atlantic Ocean, in coastal and offshore areas, mostly ranging from 45°N to 45°S (NMFS 2009). Animals are generally found alone, but can be found in small schools grouped by size or sex (Nakamura 1985). This species follows the thermocline and is usually found in the upper 20 to 30 m of the water column, but may dive to depths of 200 to 250 m in warmer areas. White marlin are only found at the higher latitudes of their range in the warmer months. Tagging data has shown that white marlin undergo extensive migrations; maximum movement has been 6523 km, with a mean displacement of 719 km (Orbesen et al. 2008).

Spawning occurs outside the Northwest Atlantic in marine waters of the Caribbean during early summer at water temperatures greater than 68° F (NMFS 2008). Known spawning areas include the area northeast of Little Bahama Bank, northwest of Grand Bahama Island, and southwest of Bermuda (NMFS 1999). Spawning activity occurs during the spring (March through June) in northwestern Atlantic tropical and sub-tropical waters marked by relatively high surface temperatures (20° to 29°C) and salinities (> 35 ppt). When female white marlin reach 20 kg and 130 cm in length, they become sexually mature (NMFS 2009). Females spawn by releasing eggs and may do so up to four times a year (NMFS 2009). Both larvae and juveniles are oceanic and pelagic. Adult white marlin can grow larger than 300 cm and weight 82 kg (Nakamura 1985). Females grow larger than males. White marlin are known to stun or kill their prey with their bill, but also consume prey whole (Nakamura 1985). The majority of their prey consists of fishes, crustaceans, and cephalopods.

Bigeye Thresher *(Alopias superciliosus)*

Bigeye thresher sharks are coastal and oceanic and found throughout the world in tropical and temperate seas (NMFS 2009). Within the Western Atlantic, bigeye threshers range from New York to Florida (Compagno 2001). They are found in waters over the entire continental shelf, in both shallow and deep waters (Gruber and Compagno 1981). Recent studies have determined that bigeye threshers may not have the thermoconserving mechanisms, the ability to maintain a body temperature above ambient water temperature, that the thresher shark has (Sepulveda et al. 2005).

Male bigeye thresher males mature at about 279 to 300 cm in length when they reach between 9 and 10 years of age and live up to about 19 years (Compagno 2001). Females mature at approximately 294 to 355 cm in length when they reach between 12 and 13 years of age and live for 20 years (Compagno 2001). The exact location of breeding grounds has not yet been identified for these sharks (NMFS 2009). These sharks are ovoviviparous and births may occur through the year, although in the eastern Atlantic births may occur more frequently in the fall and winter (Compagno 2001). Gestation period is thought to be about 12 months long, and females give birth to two fully developed pups per litter that are 100 to 140 cm long (Gruber and Compagno 1981; Compagno 2001). Juveniles of this species are both coastal and oceanic and most are found along the eastern Atlantic coast and Gulf of Mexico just outside 200m depth contour (Kohler et al. 1998). Adults are marine and can range from inshore shallow depths of 1 m to the high seas at depths of 500 m, but mostly below 100 m (Compagno 2001). Maximum published total length for females is 422 cm; males 357 cm (Compagno 2001); and weight is 363.8 kg. These animals feed on squid and pelagic fishes (e.g. herring and mackerel), small billfishes and bottom fishes (e.g. hake) (Compagno 2001; NMFS 2009). Many scientists believe that they stun or kill their prey with their large, elongated tail fin; bigeye thresher caught by their tails on longlines and sport fishing supports this theory (Compagno 2001).

Thresher Shark *(Alopius vulpinus)*

Thresher sharks are circumglobal in tropical to cold-temperate seas (Compagno 2001). They are found in coastal waters over continental shelves and around islands, where they are abundant inshore, but have been found up to 366 m (Strasburg 1958; Compagno 2001). These sharks throughout the Northwest Atlantic, mostly along or within the 200 m depth contour (Kohler et al. 1998; NMFS 2009). The thresher shark has a thermoconservation mechanism, meaning that they are able to maintain a body temperature above ambient water temperature (Sepulveda et al. 2005).

At this time, there is limited information on thresher shark breeding grounds within Northwest Atlantic. The size at which they reach sexual maturity at about 330 cm in males and 260-450 cm in females, which may vary by region (Collette and Klein-MacPhee 2002). These sharks are ovoviviparous and female sharks have an average litter size of 2-4 pups per litter (Collette and Klein-MacPhee 2002). Juveniles are marine and often found inshore and in warm shallow bays (Compagno 2001). These animals show spatial and depth segregation by sex (IUCN 2007a). Adult thresher sharks are apex predators at the highest trophic level of Atlantic sharks (Estrada et al. 2003). These sharks may cooperate with each other to hunt and, like the bigeye thresher, stun their prey using their large tail fin. Thresher sharks may grow to a total length of 600 cm (Collette and Klein-MacPhee 2002). This species feeds on schooling fishes, including squid, herring, mackerels, bluefishes, clupeids, and occasionally seabirds (Compagno 2001).

Porbeagle *(Lamna nasus)*

The porbeagle shark is commonly found in deep, cold temperate waters of the North Atlantic, South Atlantic, and South Pacific Oceans (Castro 1983). This species is common in pelagic waters (from coastal waters up to 300 m), and is most abundant on the continental shelf, but has occasionally been found far from land (Castro 1983; Compagno 2001; Collette and Klein-MacPhee 2002). Porbeagles are thermoconserving and can maintain body temperatures that are 7-10°C warmer than ambient water temperatures (Carey and Teal 1969). The porbeagle generally prefers waters colder than 18°C (Collette and Klein-MacPhee 2002). Porbeagle may occur singly as well as in schools and feeding aggregations (IUCN 2007a). Tagging data suggest maximum travel of 1000km (Campana et al. 2003). Porbeagle populations of the Northwest Atlantic are mostly separate from those of the northeast, and populations in the northern hemisphere are most likely separate from those in the southern hemisphere (Francis et al. 2008). They tend to come inshore and to the surface during summer months, but stay at depth in offshore waters during winter (Collette and Klein-MacPhee 2002).

In the Northwest Atlantic, porbeagle sharks breed between New Jersey to Newfoundland from fall to winter and pregnant individuals are caught from Massachusetts to Maine year-round (Campana et al. 2003). Gestation lasts between 8 and 9 months (Francis et al. 2008). These sharks are ovoviviparous and oophagus during late stage of development (Collette and Klein-MacPhee 2002). The pelagic, obligate marine juveniles are born in spring to summer and there are approximately 4 pups per litter with each between 60-70 cm in total length (Collette and Klein-MacPhee 2002). Males mature at a length between 155-177 cm and females are mature by 208 cm, at ages 6-10 and 12-16, respectively (Francis et al. 2008). Maximum total length is 302 cm (females); 250 cm (males), and the maximum weight recorded is 251 kg and age is 26 years (Francis et al. 2008). Pelagic fish and squid dominate the porbeagle diet in deep water, while demersal and pelagic fish dominate their diet in shallower water (Francis et al. 2008). Gastropods and crabs have also been documented in stomach samples.

Shortfin Mako *(Isurus oxyrinchus)*

Adult shortfin makos are found circumglobally in temperate and tropical seas (Collette and Klein-MacPhee 2002). In western Atlantic, these sharks range from the Gulf of Maine to southern Brazil and Argentina. Shortfin makos are usually solitary and found in littoral and epipelagic zones from surface waters down to about 500 m (Compango 2001). These sharks prefer clear water and are commonly found from 17-22°C (Compango 2001). Shortfin makos are strong-swimming, active species, and like the porbeagle, are thermoconserving and can maintain body temperatures 1-10°C above ambient (Carey and Teal 1969). North Atlantic populations are geographically distinct from other areas, but there is no evidence of multiple sub-species (Heist et al. 1996).

Shortfin makos reproduce approximately every three years and gestation is approximately 15-18 months (Collette and Klein-MacPhee 2002). Shortfin makos are ovoviviparous and oophagous at later stages of development (Collette and Klein-MacPhee 2002). Mothers give birth from late spring to early summer to 10-20 pups per litter (Collette and and Klein-MacPhee 2002). Both males and females grow at the same rate until 11 years old; females continue to grow (Bishop et al. 2006). Maximum size of males and females, respectively, in the North Atlantic Ocean, is 260-298 cm and 340-275 cm (Natanson et al. 2006). Life span estimates and have been recorded as 25 years for females and 29 and 28 years for males and females, respectively (Cailliet and Mollet 1997; Bishop et al. 2006). They feed primarily on schools of fish and consume both pelagic and bony fishes (Collette and Klein-MacPhee 2002). Shortfin makos are also known eat cephalopods and take larger prey such as swordfish and other sharks. They are reported to be one of the fastest sharks and are known to jump out of the water when in pursuit of prey (Compagno 2001; IUCN 2007a).

Great Hammerhead *(Sphyrna mokarran)*

Great hammerheads are solitary, circumtropical sharks and are found in both shallow and oceanic waters (Castro 1983). In the North Atlantic, this species is only found in the waters off North Carolina and southward and are commonly found there during the summer months. The great hammerhead utilizes shallow inshore waters along the Gulf Coast of Florida as nursery areas throughout the warm months, but the location of their pupping grounds in this area is not known (Hueter and Tyminski 2007).

These sharks are viviparous with a yolk-sac placenta and gestation is at least 7 months long (Compagno 1984). Females carry a litter of 13-42 pups that range between 56 and 70 cm in length, where births occur in the summer. Great hammerheads are the largest species of hammerhead and the maximum published total length is 610 cm (Compagno 1984). The species prefers to feed on stingrays, bony fishes, and other sharks.

Scalloped Hammerhead *(Sphyrna lewini)*

Scalloped hammerheads are a circumtropical species, from coastal areas near continents to oceanic islands far offshore (Piercy et al. 2007). The most abundant hammerhead species, the scalloped hammerhead ranges from the shallow depths to at least 275 m (Castro 1983; Compagno 1984). In the Northwest Atlantic, this shark occurs from New Jersey southward and may be the most abundant shark off the Carolinas in the summer months (Castro 1983).These sharks forms large, true schools at different stages of its life, though solitary individuals of both young and adults also occur (Castro 1983). Recent research suggests there is a cryptic species of scalloped hammerhead found in the northwestern Atlantic from coastal North Carolina to Florida (Quattro et al. 2006).

Similar to the great hammerhead, scalloped hammerheads are viviparous and have large litters consists of 15-31 pups that are 38-45 cm in size (Castro 1983). Their gestation period lasts at least 9 months. Females move inshore to shallow waters to give birth during the summer months in SC, GA and FL. Several studies have found nurseries in the shallow coastal waters of South Carolina and have identified the importance of coastal South Carolina waters as primary and secondary nursery areas (Castro 1993; Abel et al. 2007; Ulrich et al. 2007). Juveniles utilize this nursery habitat for at least one year (Duncan et al. 2006). Studies by Klimley (1985; 1993) on schooling behavior show how these sharks use complex body cues to establish social rank during daylight hours, and geomagnetic cues to navigate between seamounts at night, when the schools break up to hunt for prey. Male scalloped hammerheads reach sexual maturity at 140 to 165 cm and reaching at least 295 cm in length (Compagno 1984). Females reach sexual maturity around 212 cm and reaching at least 309 cm. Maximum published total length is 430 cm, weight is 152.4 kg and age is 35 years (Branstetter 1987). Scalloped hammerheads feed on fish, crustaceans, stingrays and small sharks (Compagno 1984).

Dusky Shark *(Carcharhinus obscurus)*

Dusky sharks are common in warm-temperate and tropical waters worldwide and are found from the surf zone to offshore waters (Collette and Klein-MacPhee 2002). They are commonly found at the surface to 400 m in depth (Compagno 1984). They avoid estuaries and areas of low salinity. Within the region, the dusky shark does not usually come north of Cape Cod, but an occasional sighting may occur in the Gulf of Maine (Collette and Klein-MacPhee 2002).

Dusky sharks are viviparous and females give birth to approximately 10 pups per litter ranging in size between 90 and 100 cm (Collette and Klein-MacPhee 2002). Females apparently mate during the spring in alternate years and gestation is thought to be 16 months or more (Castro 1983; Compagno 1984). Females move inshore to shallow bays and estuaries to drop their pups, and then depart the nursery area (Compagno 1984). This birthing may occur over a span of several months in a given region and has been reported as occurring from late winter to summer. Nursery areas within the region extend from the NJ to south of Cape Hatteras (Collette and Klein-MacPhee 2002). Males mature at about 290 cm and females mature at about 300 cm (Castro 1983). Adults are highly migratory in temperate and subtropical areas of western north Atlantic and move north during the warmer summer months and retreat south when the water cools (Compagno 1984). Maximum total length can reach over 400 cm. Dusky sharks primarily eat fish, along with small elasmobranchs and crustaceans (Gelsleichter et al. 1999).

Sandbar Shark *(Carcharhinus plumbeus)*

The sandbar shark occurs throughout the world and is a cosmopolitan species (Castro 1983). This species is abundant, both inshore and offshore, in temperate and tropical waters (Compagno 1984). In the western Atlantic, sandbar sharks range from southern Massachusetts to Argentina and are also found in the Gulf of Mexico, Bahamas, Cuba and south and west Caribbean. They are a bottom-dwelling species that is commonly found at river and bay mouths, in harbors, in shallow muddy or sandy bays (Compagno 1984). They tend to avoid sandy beaches and the surf zone, coral reefs and rough bottom, and are rarely seen at the surface, with the exception of nursery zones (Castro 1983; Compagno 1984). They range in depths from extremely shallow water to 280 m depth.

Sandbar sharks are viviparous and gestation ranges from 11 to 12 months, with a 1-year resting stage between pregnancies (Collette and Klein-MacPhee 2002). Litters range from 6-10 pups and size at birth is 50-60 cm. In the western Atlantic, sandbar shark nursery areas are typically in shallow coastal waters from Massachusetts to Florida, including primary and secondary nurseries in the this region in Martha's Vineyard, Delaware Bay, Chesapeake Bay, Great Bay (NJ), and the waters off Cape Hatteras, North Carolina (Springer 1960; Jensen et al. 2002; Merson and Pratt 2001; Conrath and Muskick 2007; Grubbs and Musick 2007; McCandless et al. 2007; Merson and Pratt 2007). There is some evidence of natal philopatry, sharks that return to the same nursery area, in juveniles

(Hueter et al. 2004). Maturity appears to reach maturity at total length 170 cm and females at 180 cm (Collette and Klein-MacPhee 2002). Sandbar sharks tend to school and are usually segregated by sex, except during the mating season. Maximum published total length is 250 cm is this slow-growing species (Collette and Klein-MacPhee 2002). They primarily eat small bottom fishes, some sharks and rays, and occasionally mollusks and crustaceans (Compagno 1984).

Sand Tiger *(Carcharias taurus)*

The sand tiger is a common warm temperate and tropical in all areas except the east Pacific (Compagno 2001). In the Northwest Atlantic, this species has been found throughout the entire region, but are higher in abundance from Delaware Bay to North and South Carolina in the warmer months (Carlson et al. 2009). Restricted to coastal waters, the species is found in areas ranging from the surf zone, in shallow bays where they sometimes enter mouths of streams and around coral and rocky reefs to a depth of at least 190 m to the outer continental shelves (Compagno 2001). A strong but slow swimmer, sand tiger sharks are more active at night. They are able to maintain near-neutral buoyancy and hover motionless in the water column by gulping air at the surface and holding it in the stomach. These sharks are found near or on the bottom, but also occur in midwater or near the surface, usually at depths < 20m (Compagno 2001).

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These sharks are ovoviviparous and usually only two pups are born per litter due to intrauterine cannibalism (Carlson et al. 2009). Gestation is 9-12 months and it is believed this species gives birth between March and April in winter in the southern portions of its range, and the neonates migrate northward to summer nurseries (Compagno 2001). Nursery areas in this region include Narragansett Bay, Delaware Bay, Sandy Hook estuary and Chesapeake Bay, as well as coastal sounds (NMFS 2009). In the Northwest Atlantic, mature males and juveniles occur between Cape Cod and Cape Hatteras, while mature females (including pregnant females) inhabit waters between Cape Hatteras and Florida (Gilmore 1983). Males maturing at about 190 to 195 cm, while females mature at 220 cm, and maximum total length is 320 cm (Compagno 2001). These sharks catch schooling prey by systematically surrounding and concentrating them before feeding. Sand tiger sharks have a diverse diet, feeding on bony fishes, sharks (including juvenile sandbar sharks), stingrays, squid, and crustaceans (Gelsleichter et al. 1999).

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