CHAPTER

5

Marine Fishes: Introduction & Methods

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Introduction

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The North Atlantic region is known for its highly productive waters, a result of its strong tidal flows, complex circulation patterns, varied seafloor topography and diverse sediment types. Accordingly, large and sustained catches of demersal and pelagic fish have fueled regional economies for centuries. The diversity of fishes in the region may be explained by the variety of available habitats combined with the extraordinary adaptability of these creatures - the most diverse class of living vertebrates.

Distinctive fish habitats are places where singular oceanographic processes occur on a regional or local scale. Often, these correlate with physical or structural features such as anomalies of temperature, areas of high primary productivity, regions of diverse seafloor topography, or geographically isolated settings. For demersal fish, species abundance has been found to be associated with depth, temperature, sediment type, sediment diversity, and habitat complexity (Mahon et al. 1998; Stevenson et al. 2004; Auster et al. 2001; Lough et al. 1989; Charton and Perez-Ruzafa 1998; DeLong and Collie2004; Lindholm et al. 1999.) Similarly, the abundance of pelagic fish is correlated with thermal fronts (Etnoyer et al. 2004).

This assessment focuses on identifying those places in the region that have been consistently important to fish productivity and diversity over decades. The deep basins, shallow banks, and major channels of the Gulf of Maine, for example, are tied to water masses with distinct layering and corresponding diversity. Farther south, the broad continental margin, large estuaries, and deep submarine canyons, function as nursery areas for estuary dependent fishes and migratory pathways for large pelagic species. The extremely heterogeneous aspect of the region ensures that not all areas are equivalently important with respect to fish productivity. In the chapters that follow - demersal fish, diadromous fish, small and large pelagic fish - we use a single consistent methodology, based on the persistence of individual species over decades, to identify areas that may be particularly important for the conservation of each species. We chose to focus on persistence, weighted by abundance, because the latter varies greatly from year to year, reflecting temporal variation in population sizes, fluctuating prey bases, and other factors unrelated to the physical structure of the region. In contrast, places where a species persists over decades are more likely to correlate with perennial factors important to productivity and diversity. When possible, however, we weighted the persistence score by the abundance of the species in each decade studied, to identify areas where a species not only persisted, but persisted at high abundance.

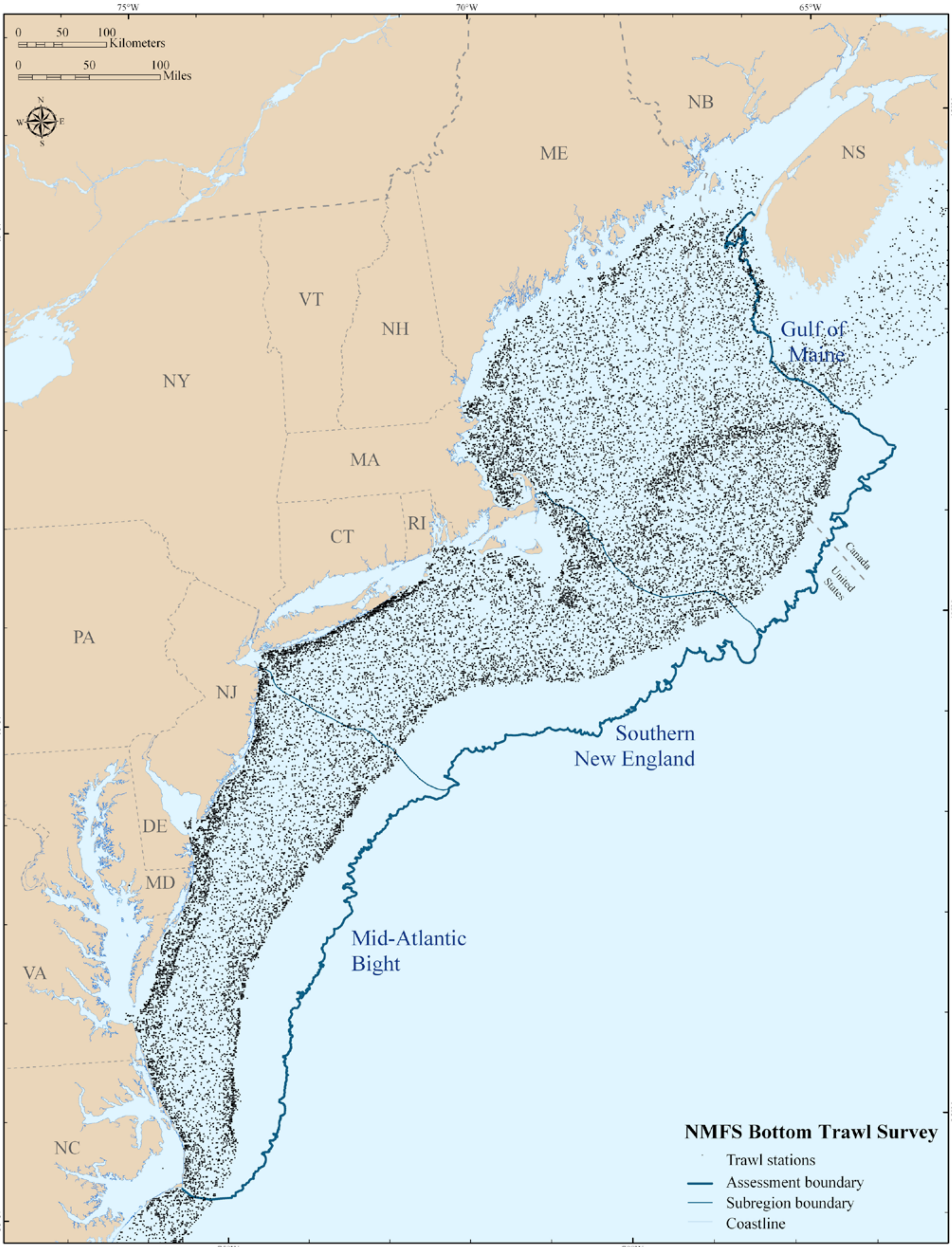

Figure 5-1. Map showing the distribution of all bottom trawl survey points used in this analysis.

Methods

In each of the following fish chapters we discuss how the target species were selected and examine their distribution, abundance trends, and areas of persistence in the region. Specifically, three questions concerning the distribution of fish species in the Northwest Atlantic were addressed with this analysis:

- What is the general distribution of the species in the region? (distribution)
- Where in the region has the abundance been increasing or decreasing? (trends in abundance)
- Where in the region has the species been consistently found over time at the highest abundances? (weighted persistence)

Data

To answer these questions, data from the National Marine Fisheries Service (NMFS) spring and fall bottom trawl surveys (1968 – 2006) were analyzed (Figure 5-1). All analyses were conducted on a species by species basis to account for differences in the catchability of each species. Comparisons among species were not performed. We limited the data to valid records collected in the fall or spring as these two seasons were surveyed using similar gear and methods over a similar geographic area. To ensure that each record was comparable, the number of fish per tow was adjusted based on correction factors developed by NOAA's Northeast Fisheries Science Center to account for changes in survey vessels, trawl net design, and trawl doors over time.

Binning data by decades

Individual trawl survey points do not overlap from year to year. Thus, in order to calculate temporal trends in abundance and persistence the region was partitioned into a grid of ten minute squares (TMS), with each square containing multiple survey points covering a range of years. The binned data set was examined to determine the smallest time interval (annual, biannual, 5-yrs, 10-yrs) for which consistent values could be calculated for most squares. The 10-yr decadal period was selected because it allowed for a robust analysis that included almost all of the TMS in the region. In other words, most squares contained at least one survey point from each decade (1970-1979, 1980-1989, 1990-1999, and 2000-2006). TMS that did not have survey points in at least three or four decades were excluded from the analysis. For the remaining TMS, each one was scored based on the presence of the species of interest within each decade.

Data limitations

A limitation of these surveys is that different species demonstrate varying degrees of susceptibility to being caught by the survey gear (i.e., catch coefficients for cod are much higher than those for wolffish or other species). Otter trawl systems like the one utilized to conduct survey sampling are specifically designed to capture a variety of demersal fish species, including many of the species analyzed in this assessment. It is important to note, however, that the catch rates for various species within the group are variable. Catchability coefficients are generally higher for demersal, round-bodied species (e.g., Atlantic cod, haddock, pollock), and lower for flat-bodied fish (e.g., Atlantic halibut, summer flounder) and pelagic species (e.g., bluefin tuna, Atlantic herring). In additional, catch rates at any given location can be heavily influenced by day/night differences in species distribution within in the water column, and by seasonal variations in species distribution within their geographic range. Some species are also able to avoid capture in trawls by using sensory or behavioral capabilities.

Additionally, trawl samples are particularly difficult to conduct in areas of high habitat complexity, such as boulder fields, canyons, or the seamounts just outside the Northwest Atlantic region. The survey also may miss key nearshore areas and some offshore areas (e.g., Nantucket Sound) due to survey vessel depth limitations. Many of these coastal areas, especially bays and estuaries, are critical for earlier life stages of fish. For future analyses, a goal is to merge inshore trawl sampling conducted by individual states with the results presented here. As such, it should be recognized that while analyses derived from the trawl survey database are indeed informative, results obtained from other data sources should also be considered. Finally, any shifts in movement due to changes in temperature caused by climate change may not be reflected in these snapshots.

Distribution

A basic distribution map was created for each species that shows the trawl survey points where the species was captured weighted by its relative abundance (Figure 5-2a). All spring and fall trawl data from the years 1968 through 2006 were used and the maps were produced by season. Because the data were skewed toward low abundances, the raw catch values were transformed into a cumulative percentile. Tows in which the target species was caught were then divided into four quartiles based on percentage of the total catch of that species per season. This transformation allows the abundance patterns to be displayed in meaningful units.

Trends in Abundance

Using the binned data described above, trends in average abundance over four decades were calculated for each TMS for each species. Only squares with four decades of sampling were used. For this analysis, a linear regression line was fit to the average abundance values for each of the four successive decades. Regression lines with a p-value less than 0.1 (90% probability) were considered to show a significant trend. Positive slopes indicated an increasing trend in abundance, negative slopes indicated a decreasing trend, and insignificant regressions indicated no trend. By mapping these results for each species, the spatial locations where changes in abundance were detected were highlighted (for an example, see Figure 5-3).

Regressions were also used to analyze overall trends in species abundances based on the individual (unbinned) samples. From these analyses, significant changes in abundance of a given species in a given season across the full 36-year period were detected for many species. Note that although sometimes there is a significant change in the abundance of a species when spatial location is not considered, for some species changes in abundance were only revealed by studying the spatially linked regression map results. By using both of these trend results, both overall population trends and the distinct changes in the spatial locations of abundance over time were explored.

Persistence

Persistence refers to the consistency with which a species was caught in the same general area over time. To be included in this analysis, a TMS had to have data from at least one survey point from each of three or four decades. Those TMS that did not meet these criteria were excluded from the analysis. For the remaining TMS, we scored each one based on the presence of the species of interest within each decade.

Score 1 = The species was present in 1 out of the sampled decades
Score 2 = The species was present in 2 out of the sampled decades
Score 3 = The species was present in 3 out of the sampled decades
Score 4 = The species was present in 4 out of the sampled decades

For example, a TMS with a persistence score of 4.00 indicated that the species was caught in the trawl survey at least once in each of the 4 decades sampled (Figure 5-2c).

Weighted Persistence

The weighted persistence score is a variation of the persistence score in which each decade is weighted by the average abundance of the species over the decades it was present. Abundance was measured as the numbers of individuals of a given species caught per sampling tow. Because the abundance data were skewed toward low abundances with a few very high abundances, values were log-transformed and mean log abundance were calculated for each decade within each TMS. These decadal mean scores were averaged across all decades to obtain a grand average for each TMS. The grand average was then normalized across all TMS for the species of interest to create a metric of abundance ranging between 0.0 and 1.00 for each TMS, with low abundance defined as 0-0.49 and high abundance defined as 0.50 – 0.99 (Figure 5-2b)

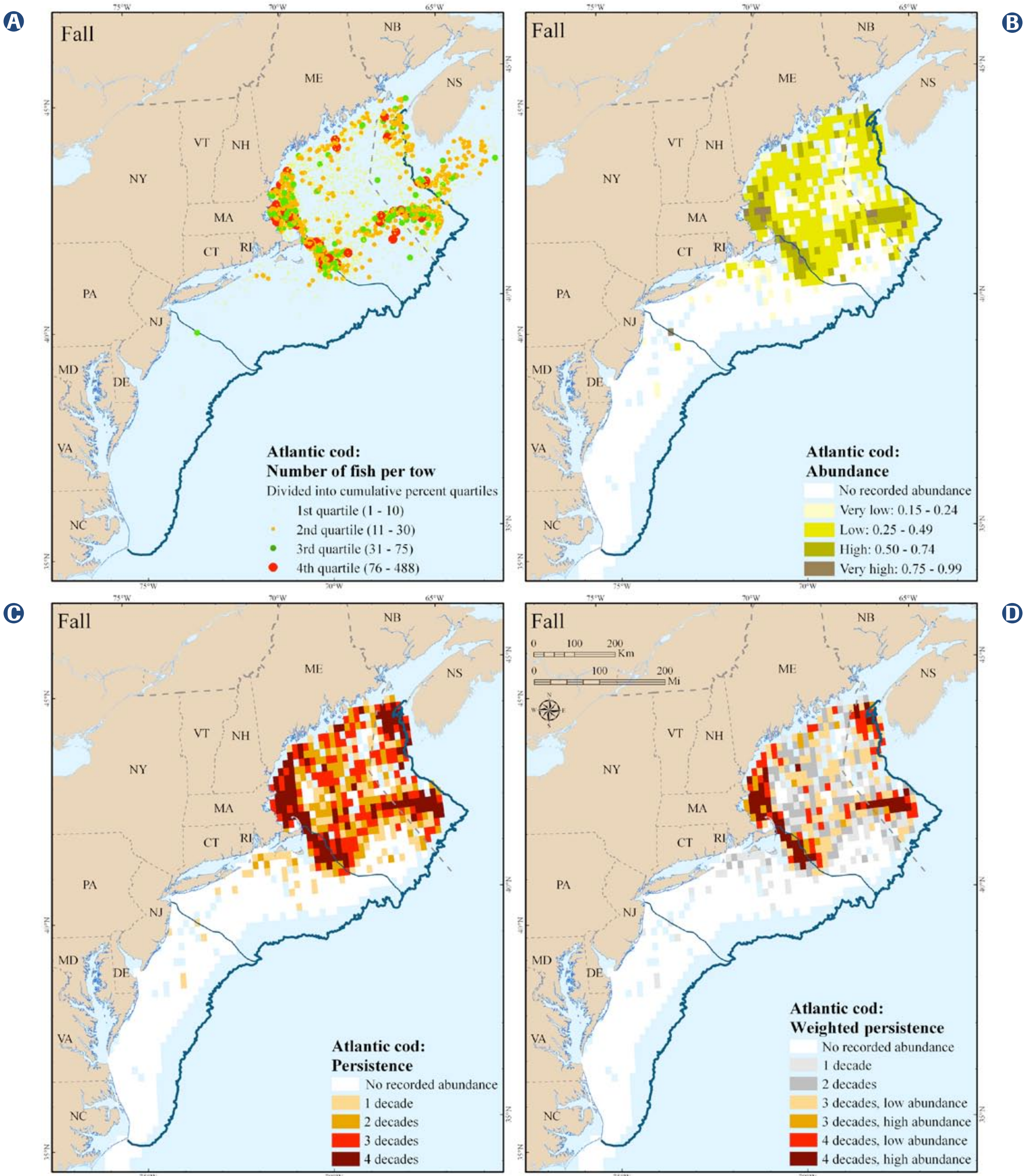

Figure 5-2. a. Point distribution map of Atlantic cod, b. Abundance map of Atlantic cod binned by ten minute squares, c. persistence map of Atlantic cod, d. weighted persistence map of Atlantic cod.

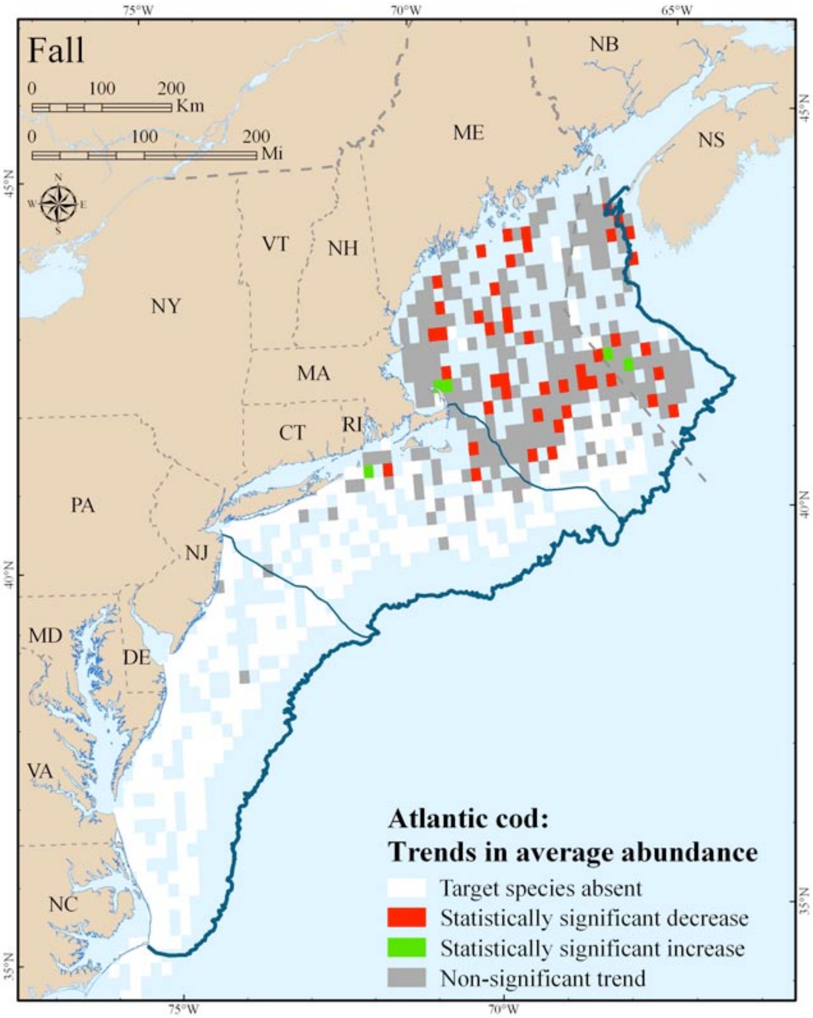

Figure 5-3. Maps showing trend in average abundance for Atlantic cod.

The weighted persistence score was calculated by adding the persistence and relative average abundance. In the resulting metric, the integer part of the score is the persistence score while the decimal part of the score is the relative grand average abundance value (Figure 5-2d)

Limitations to the persistence maps

The use of the ten minute squares (TMS) to bin the trawl data smoothed out some of the noise in the data to provide a straightforward picture of obvious robust trends in persistence. A species had only to be caught once per decade to be tagged as present. However there is variability in how many times a particular square was sampled per decade, with samples per decade ranging from 1 to 36 depending on the TMS. Squares that were sparsely sampled may have failed to catch a species that was actually present. This distribution of these sparsely sampled TMS is centered on the deep central region of the Gulf of Maine (Figure 5-4). In consequence, the results are valid for detecting persistent areas (true positives) in all TMS but may underestimate actual persistence values in areas of sparse sampling (false negatives).

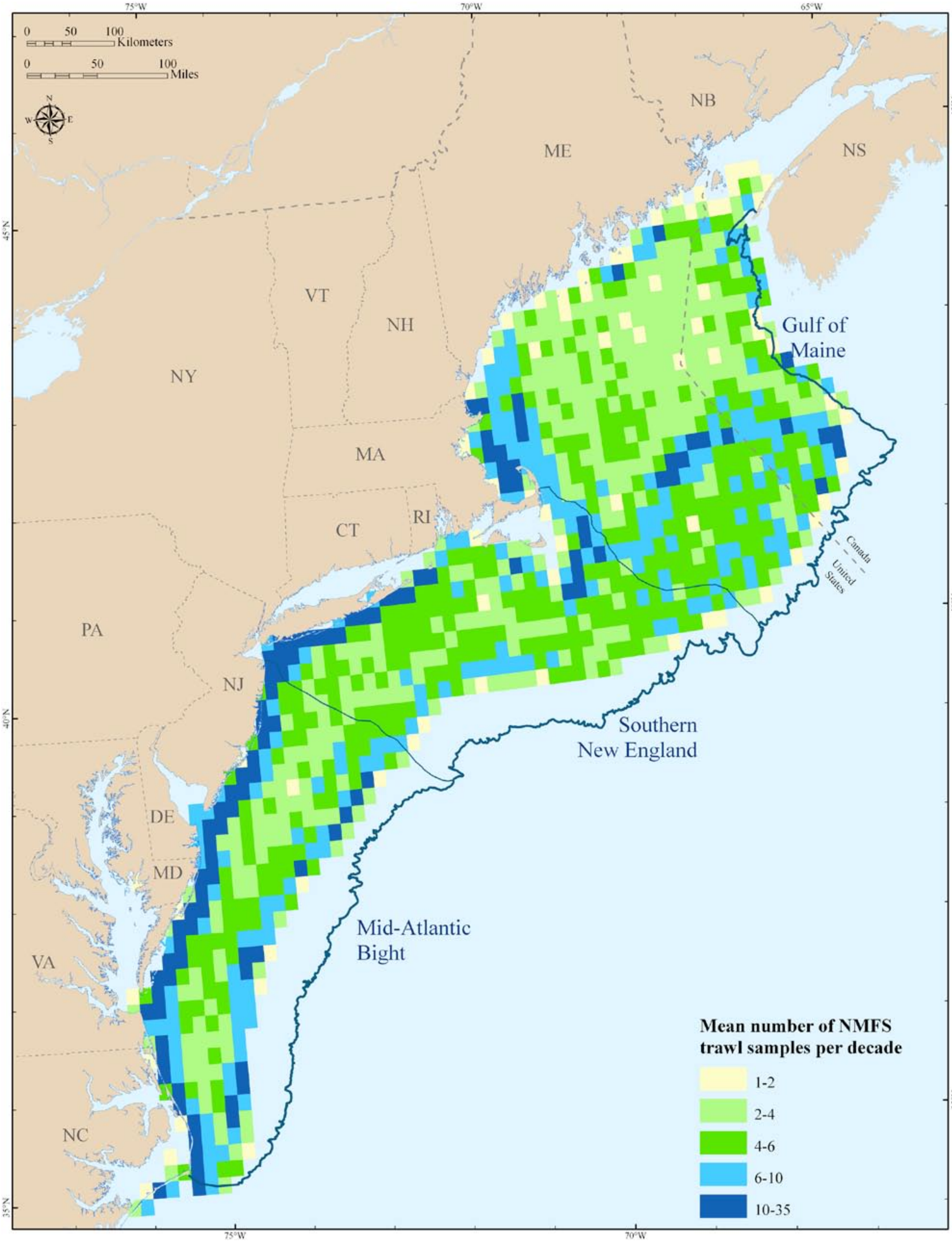

Figure 5-4. Combined mean sampling effort for spring and fall. Ten minute squares shown in yellow were sampled on average only once or twice per decade. Actual persistence may be underestimated in these areas.

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CHAPTER

6

Diadromous Fish

Alison Bowden

Introduction

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Diadromous fish share one major attribute. They exploit both freshwater and saltwater habitats during distinct phases of their life cycles. The distance they travel in order to do this varies widely among species, from the rainbow smelt that lives its entire life within about a mile of the coast up to the head of tide in rivers, to the Atlantic salmon that travels thousands of miles from the ocean waters off Greenland to headwater streams hundreds of miles inland. Because their life histories link terrestrial, freshwater, and marine ecosystems, they are an ideal conservation target for ecosystem-scale initiatives. The stress and depletion of energy stores required to transition between fresh and salt water render these species extremely vulnerable to habitat degradation within freshwater and marine migratory corridors, and much of their historic freshwater spawning habitat is no longer accessible, having been blocked by dams and other barriers. The combination of habitat impacts, excessive predation and fishing pressure, both from directed fisheries and bycatch, has caused significant declines in populations of these species. For example, American shad is estimated to occupy about half of its historic spawning rivers coastwide at 10% of historic abundance (ASMFC 2007). The cultural importance of these species is evident: Several of these species have been featured in popular literature, from Henry David Thoreau's lament of the loss of herring runs due to dam construction on the Concord River in 1839 to John McPhee's account (2002) of the natural and social history of American shad in *The Founding Fish.*

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Selection of Target Species

All diadromous fish species were initially considered for inclusion as targets, but those that are apparently stable or increasing in number were ultimately not included. The species included as primary targets show evidence of significant decline or are already recognized as globally rare. Based on these criteria, eleven species of diadromous fish were selected as primary targets for this assessment:

- Alewife *(Alosa pseudoharengus)*
- American eel *(Anguilla rostrata)*
- American shad *(Alosa sapidissima)*
- Atlantic salmon (Salmo salar)
- Atlantic sturgeon *(Acipencer oxyrhinchus)*
- Atlantic tomcod *(Microgadus tomcod)*
- Blueback herring *(Alosa aestivalis)*
- Hickory shad *(Alosa mediocris)*
- Rainbow smelt *(Osmerus mordax)*
- Sea-run brook trout *(Salvelinus fontinalis)*
- Shortnose sturgeon *(Acipencer brevirostrum)*

Population Status and the Importance of Northwest Atlantic region

The Northwest Atlantic populations of some of these species are particularly important because the global range of seven of the 11 target diadromous species is limited to the Atlantic coast of the United States and Canada.

The conservation status of each of these species varies among conservation programs (including among the International Union for the Conservation of Nature (IUCN), FishBase, and Natureserve programs; Table D1). The two species of sturgeon have a Natureserve global rank of G3, considered "globally rare." The sturgeons are consistently recognized as highly threatened or vulnerable; shortnose sturgeon is listed as Threatened under the Endangered Species Act (ESA), and Atlantic sturgeon is a candidate for listing (currently a National Oceanic and Atmospheric Administration (NOAA) Species of Concern, defined as a species about which the agency has concerns regarding status and threats but for which insufficient information is available to list the species under the ESA). This designation does not carry any procedural or substantive protections under the Endangered Species Act (NMFS OPR 2009).

Because of their complex history of extirpation and restocking, Atlantic salmon have a variety of legal statuses within the region, but they are generally regarded as imperiled. Atlantic salmon is considered stable in the northern portions of its global range in Canada and Europe, and is ranked G5, of "least concern." However, the status of populations within the Northwest Atlantic region in southern Canada and the United States is poor. The only remaining wild Atlantic salmon populations in the U.S are found in Maine. In 2000, all naturally reproducing remnant populations of Atlantic salmon from the Kennebec River downstream of the former Edwards Dam site northward to the mouth of the St. Croix River were added to the Federal endangered species list as a Distinct Population Segment (DPS) (NMFS USFWS 2005). In 2009 the Gulf of Maine DPS was expanded to include fish in the Penobscot, Kennebec, and Androscoggin rivers and their tributaries (NMFS OPR 2009). The Gulf of Maine DPS has a global rank of G5T1Q, denoting that this population segment of the species is critically imperiled. Inner Bay of Fundy populations in New Brunswick and Nova Scotia are ranked G5TNR (not yet ranked), but they were listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada in April 2001 (COSEWIC 2008).

The remaining species are all ranked G5, or "globally secure" by Natureserve, but Fishbase vulnerability ranks vary from moderate to very high. Like Atlantic sturgeon, alewife, blueback herring, and rainbow smelt are listed by NOAA as Species of Concern. A 2004 petition to list the American eel under the ESA was found to be "not warranted" but noted numerous stressors in declines; ASMFC is currently conducting a stock assessment, due in 2010 (ASMFC 2005). The American shad stock assessment found that stocks are currently at all-time lows and do not appear to be recovering (ASMFC 2007). Recent declines of American shad were reported for Maine, New Hampshire, Rhode Island, and Georgia stocks, and for the Hudson (New York), Susquehanna (Pennsylvania), James (Virginia), and Edisto (South Carolina) rivers. Low and stable stock abundance was indicated for Massachusetts, Connecticut, Delaware, the Chesapeake Bay, the Rappahannock River (Virginia), and some South Carolina and Florida stocks. Stocks in the Potomac and York Rivers (Virginia) have shown some signs of recovery in recent years.

Other important Atlantic coast diadromous species like striped bass and sea lamprey play an important role in the ecosystem of the northwest Atlantic, but populations appear to be stable, therefore were not included in this Assessment. They are also likely to benefit from efforts to protect target species with similar life histories. More detail on the individual life histories of target species may be found in the species accounts in Appendix XX.

Ecosystem Interactions and Ecological Dependencies

Riverine habitats and communities may be strongly influenced by migratory fauna that provide a significant source of energy input. Pacific salmon have been recognized as key elements of riparian (streamside) and terrestrial as well as freshwater systems (Gende et al. 2002); Atlantic coast species like alewife appear to play an equally important role in their freshwater spawning habitats, providing nutrients that assist microbes in the breakdown of leaf litter and the resulting release of that stored energy to consumers (Durbin et al. 1979). Specific associations between diadromous fish and other species also exist. For example, many freshwater mussels are dependent upon migratory fishes as hosts for their parasitic larvae (Neves et al. 1997; Vaughn and Taylor 1999), such that loss of upstream migratory fish habitat is a major cause of mussel population declines (Williams et al. 1992; Watters 1996).

These historically abundant species serve as prey in rivers and estuaries for larger predatory fish such as bluefish and striped bass, gulls, osprey, cormorants, river otter, and mink, and at sea for seals, sea birds, and a wide range of piscivorous (fish-eating) marine fish. In one study tomcod accounted for 59% of the diet by weight of young-of-year bluefish, along with juvenile shad, blueback herring, and similar species (Juanes et al. 1993). Clupeids (shad and river herring) are an important food source for striped bass, making up a majority of their diet in late spring and early summer (Dovel 1968).

The 2005 Recovery Plan for Gulf of Maine Atlantic salmon identified diminished runs of clupeids and sea lamprey as factors impacting recovery of salmon. The authors suggest that an abundance of other diadromous species provided three categories of ecosystem services to salmon: prey buffering (providing an alternative forage base such that no individual prey species becomes overly depleted), marine derived nutrient cycling (all sea lamprey and 20% or more of clupeids die after spawning, enriching freshwater habitats), and habitat modification and enhancement (sea lamprey build nests that are used preferentially as spawning sites for salmon).

Northwest Atlantic Distribution and Important Areas

Methods

Marine Distribution

See methods overview in Chapter 5.

Data Limitations of Marine Data

It is important to note that using trawl data from bottom surveys to determine distributions of pelagic fish, e.g. river herring, could underestimate numbers or biomass of fish that are expected to be distributed throughout the water column. However, the National Marine Fisheries Service (NMFS) trawl data is the only long term fishery-independent data set available for examining marine distributions of these species. This information is necessary, but it must be interpreted with caution and results must be compared with other sources. In order to address this issue with the data set, marine distributions were mapped and analyzed only for species that occurred in at least 5% of trawls: alewife, American shad, and blueback herring. More than 3,000 individuals of each of these species were recorded in the database.

Freshwater Distribution

Freshwater/estuarine distributions were determined from several data sources including NatureServe (2007) data based on occurrences at the coarse, HUC-8 watershed level and Estuarine Living Marine Resources (ELMR) data for estuaries (NOAA 1994). Both datasets were mapped for presence/absence only. The ELMR dataset includes qualitative abundance data for multiple life stages of several species, but the team concluded that presence/absence offered the greatest confidence and clarity of information. Eastern Brook Trout Joint Venture (2006) data were used to map brook trout distribution and status. Sea-run brook trout were not mapped separately for that effort, but the coastal distribution of the species corresponds with the United States range of the sea-run form (note that resident and sea-run forms often occur in the same river).

More detailed information on status of runs from the Delaware River to mid-coast Maine is available in the North Atlantic Coast Ecoregional Plan (Anderson 2006). A variety of other sources is available for freshwater distributions of some species at multiple scales, including coastwide information on alosines compiled by ASMFC (2004). Some states, e.g. Maine, have detailed maps of habitat use for multiple species, but these have not been developed at the scale of this plan. The current effort focuses on developing a marine portfolio for the Northwest Atlantic marine region and thus river data sets compiled by others were utilized.

Maps, Analysis, and Areas of Importance

Because the fish included in this target are migratory, moving extensively from spawning to feeding to overwintering areas, critical areas for these species can vary in time and space, and maps of data for a few weeks of the year in spring and fall cannot provide a complete picture of habitat use. Surveys of striped bass, which have been the subject of intensive tagging, have indicated widely varying distribution and abundance patterns depending on when sampling was conducted relative to the fishes' seasonal coastal movements. The general pattern of movement, north in spring, south in fall, has long been understood, but with increasing information the complexities of fish abundance and distribution becomes clearer. Fish behavior varies depending on many factors that probably vary by year (Martha Mather, personal communication). It will be important to update these maps and conservation plans as more detailed data become available for the species discussed here. The following discussion is provided with these caveats in mind.

Alewife

Alewife spawn in coastal watersheds throughout the region (Figure 6-1), which represents most of their native range. Estuaries are used by adults prior to entering and after leaving spawning rivers in the spring, and by juveniles during seaward migration in later summer and fall and possibly as overwintering habitat. The species' range is apparently contracting northward: the southern limit of the range has changed from South Carolina to North Carolina, as surveys indicate no current spawning in South Carolina (ASMFC 2008). The 2008 status review also indicated historical and recent declines in abundance for alewife and blueback herring based on available run size estimates, declines in mean length-at-age of alewife and blueback herring, and decline in maximum age of male and female alewife by one to two years. A river herring stock assessment report is due in 2012 (because they are similar in appearance and life history, alewife and blueback herring are often referred to collectively as river herring).

In spring, alewife are concentrated in a wide band off Long Island and Rhode Island, and in two smaller areas in the Gulf of Maine near Cape Ann and the Kennebec River (Figure 6-2a). Catches occurred all along the coast and out to the shelf edge. In fall, alewife are tightly clustered along the Massachusetts coast from Cape Cod to Cape Ann, and in a small area around Block Island (Figure 6-2b). This pattern seems to indicate a northward movement in summer in order to utilize the Gulf of Maine as a feeding area, and a southward movement in fall to overwinter. It also approximates the observed areas of bycatch of river herring from 2005-2007 (Cieri et al. 2008).

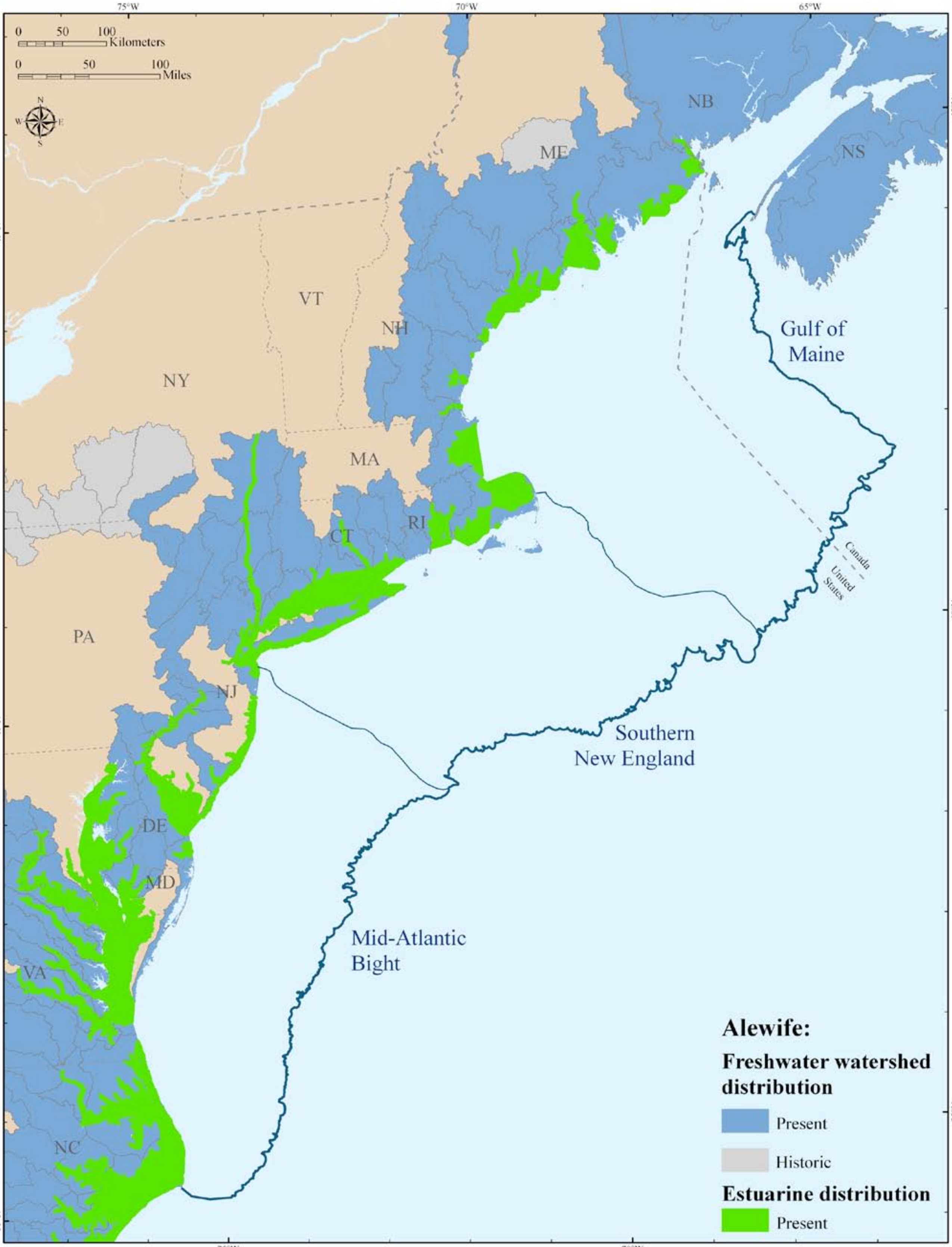

Figure 6-1. Freshwater and estuarine distribution for alewife.

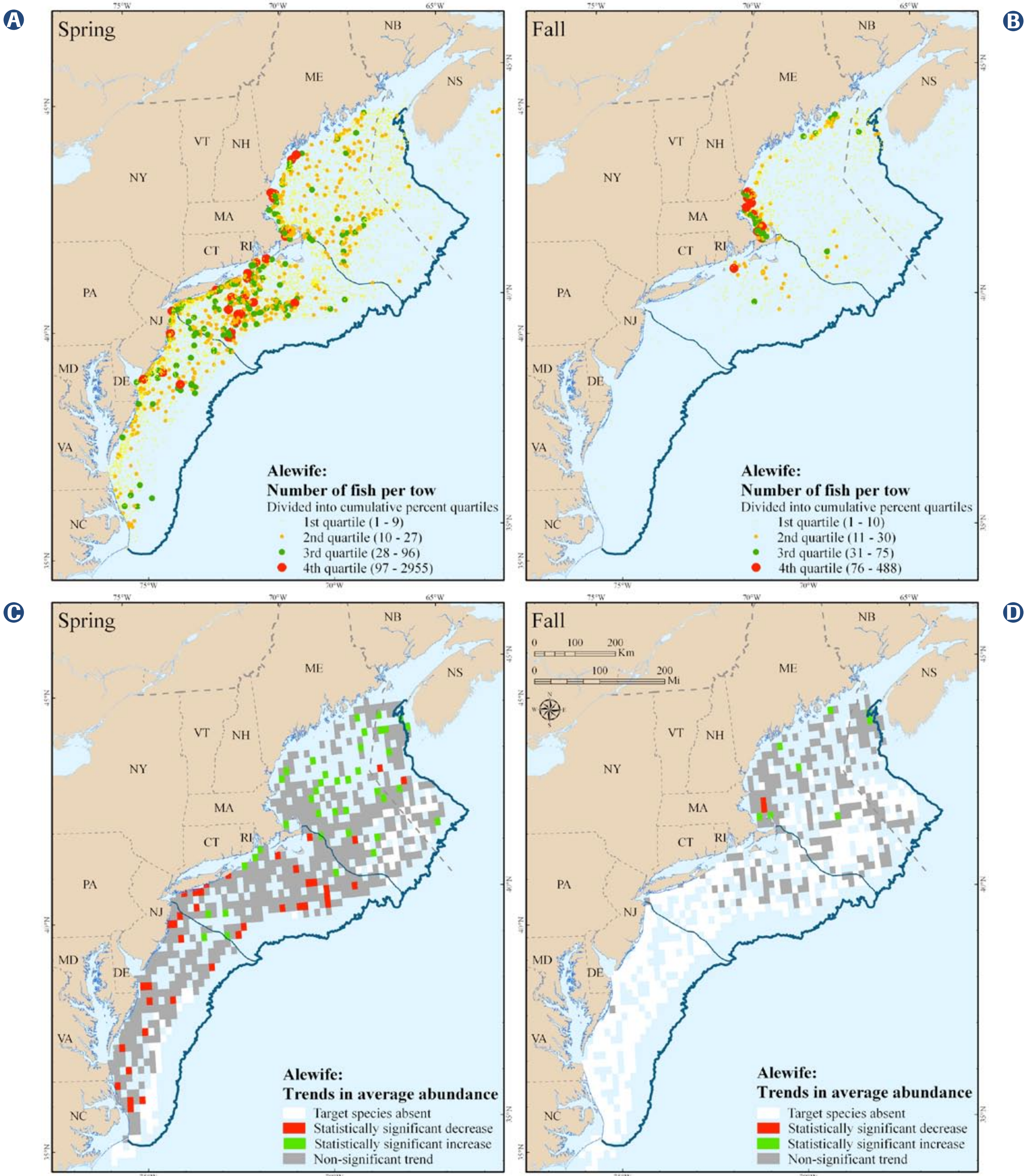

Figure 6-2. Trends in average abundance over 40 years for alewife during the spring and fall seasons.

No trend in abundance in spring or fall was observed for the majority of sampled ten minute squares (Figures 6-2c, 6-2d). There is evidence of a declining trend in spring in the southern portion of the region, and an increasing trend in the Gulf of Maine. Spring distributions at least partially reflect fish aligning themselves with natal watersheds for spawning runs so this pattern is consistent with observed declines in the southern range. In the fall, in a small area north of Cape Cod alewife increased in some TMS and decreased in some TMS. Since alewife is a northern species that is believed to respond to temperature cues by moving or migrating, these trends could be related to changes in ocean temperature, i.e., preferred temperature zones might be shifting in a way that makes alewife more or less likely to be captured by bottom-tending gear.

Alewife were highly persistent along the entire coast in spring, and consistently found in greatest abundances across southern New England, Georges Bank, and Cape Ann (Figure 6-3a). In fall, strongest persistence and abundance were in coastal waters along the Massachusetts coast north of Cape Cod and off downeast Maine and the mouth of the Bay of Fundy (Figure 6-3b). The combination of habitats represented by these maps is a reasonable representation of important habitat areas for alewife in three seasons; it may miss areas further south or offshore that are used for overwintering.

Important Marine Areas for Alewife

Spring: Southern New England, Georges Bank, and Cape Ann

Fall: Massachusetts coast north of Cape Cod, Downeast Maine, mouth of the Bay of Fundy

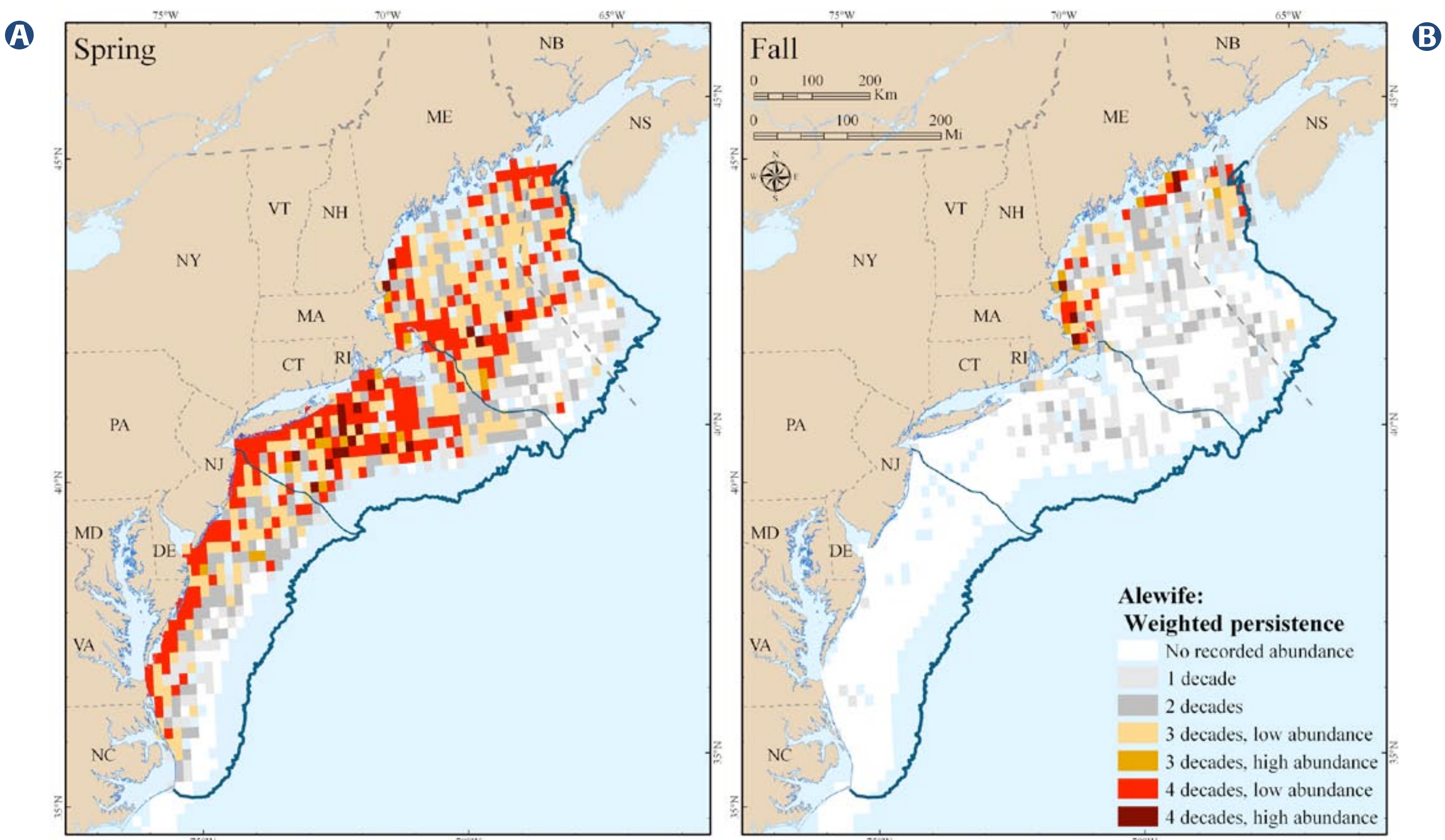

Figure 6-3. Areas with high persistence and abundance over 40 years for alewife during the spring and fall seasons.

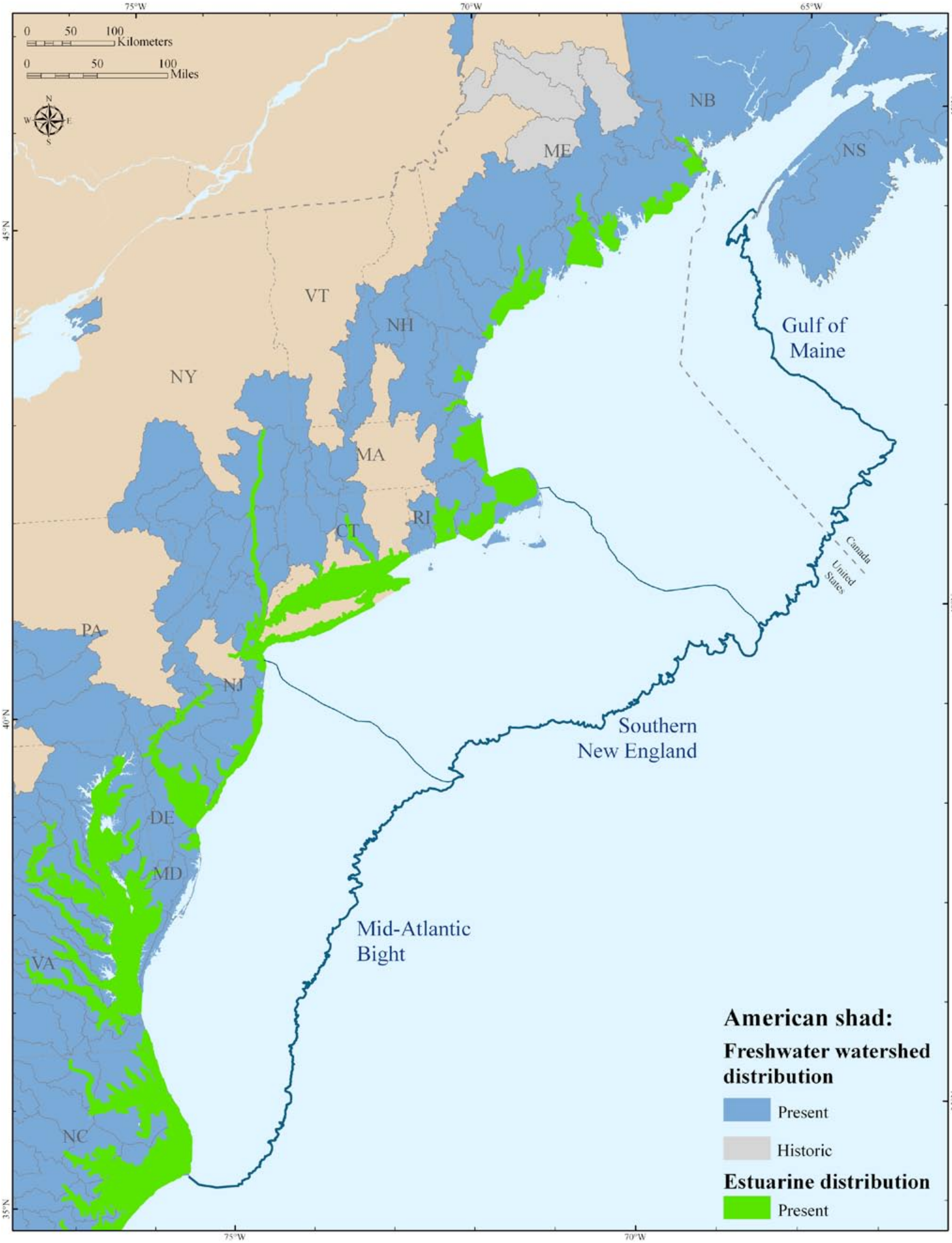

Figure 6-4. Freshwater and estuarine distribution for American shad.

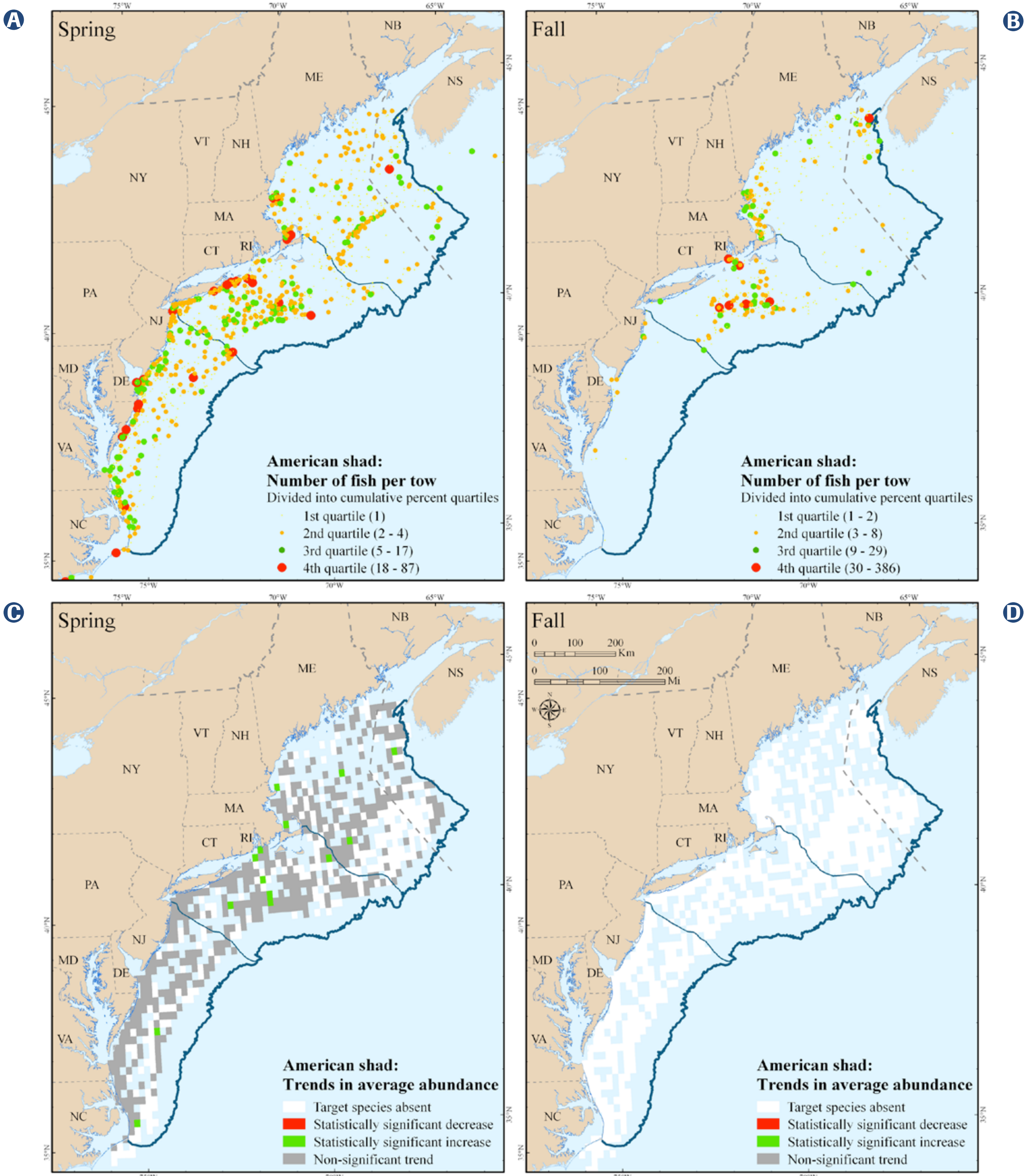

Figure 6-5. Trends in average abundance over 40 years for American shad during the spring and fall seasons.

American Shad

American shad may still occur in each of the drainages represented (Figure 6-4), but it is important to note that accessible, suitable spawning habitat is greatly reduced. For example, in the Merrimack River watershed in Massachusetts and New Hampshire, dams with ineffective fish ladders prevent shad from accessing habitats beyond the second dam at Lowell, Massachusetts.

In spring American shad abundances were greatest in coastal waters near Chesapeake and Delaware Bays, Hudson River, Long Island, and Massachusetts Bay (Figure 6-5a), and in fall in small areas off Rhode Island and near the mouth of the Bay of Fundy (Figure 6-5b). Trends in shad abundance exhibit only a weak spatial signature, despite evidence from surveys of spawning runs that shad have suffered huge declines. In spring where there is a trend at all it is generally increasing (Figure 6-5c); in fall the few places with a trend are evenly split between increases and decreases (Figure 6-5d). These data are clearly not informative with regard to overall abundance of shad; it is also possible that the number of shad caught overall may be too small to represent trends in shad distribution.

The spring persistence pattern (Figure 6-6a) is consistent with spawning locations (Figure 6-4) in the Chesapeake, Delaware, and Hudson River for the Mid-Atlantic subsection, and it is likely that coastal waters near spawning rivers are important for staging of adults and/or overwintering for juveniles. In the two northern subsections, the areas of spring persistence are further offshore. In fall (Figure 6-6b), areas of persistence and abundance in the northern Gulf of Maine reflect the more northern summer distribution in the Bay of Fundy and Gulf of St. Lawrence indicated by tagging data (Dadswell et al. 1987). Additional important areas for shad not represented here include wintering areas in deeper offshore waters.

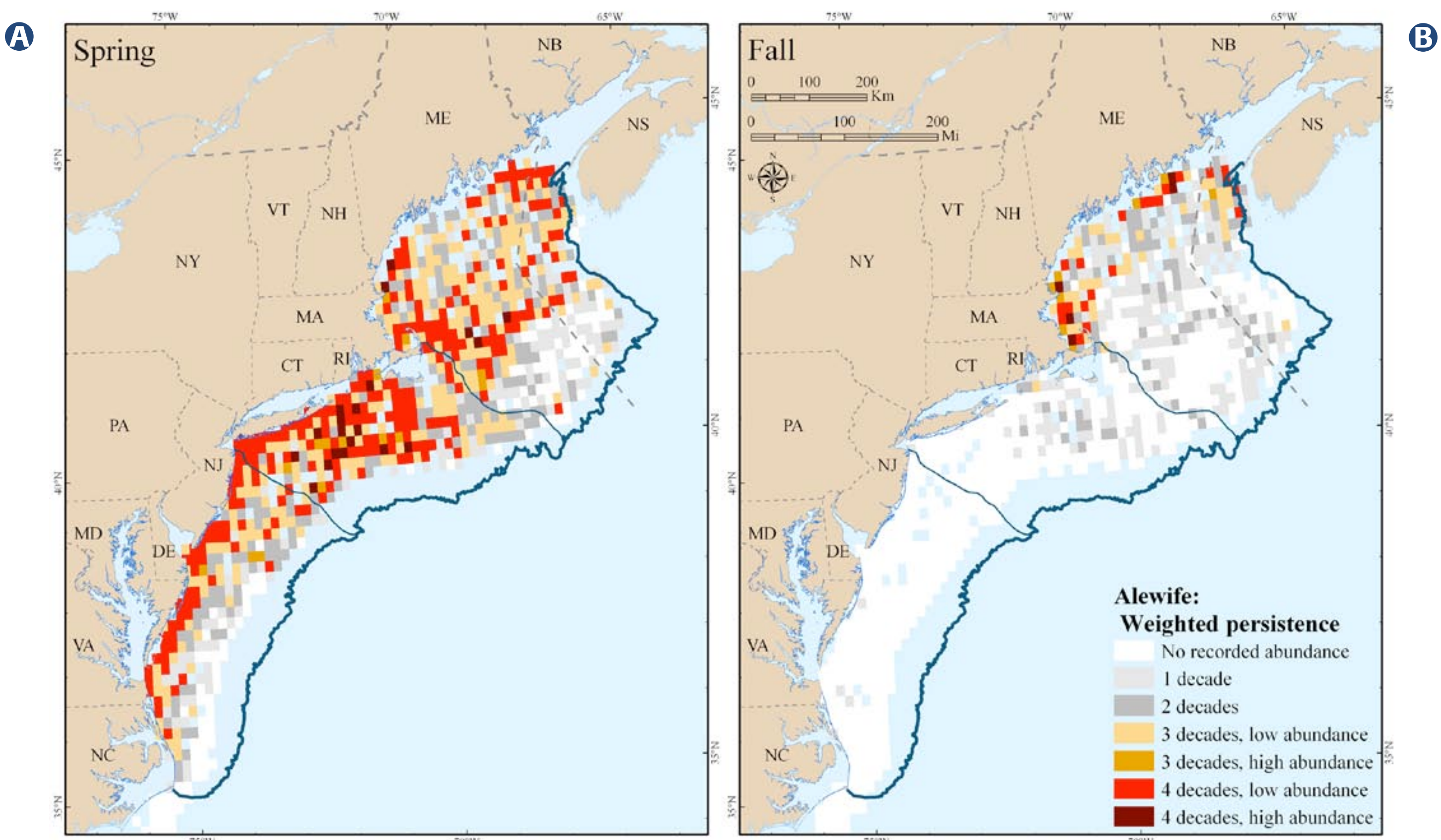

Figure 6-6. Areas with high persistence and abundance over 40 years for American shad during the spring and fall seasons.

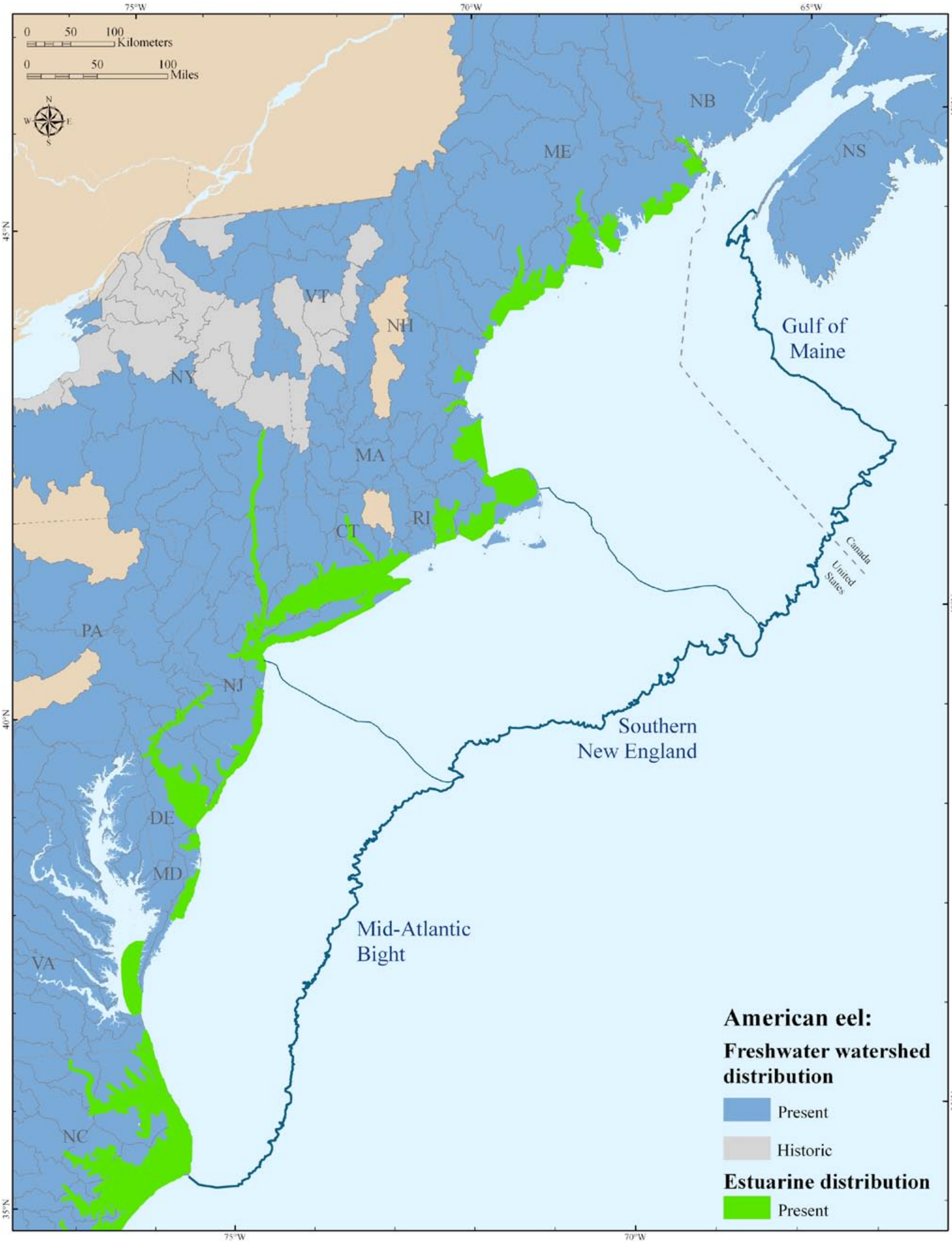

Figure 6-7. Freshwater and estuarine distribution for American eel.

Important Marine Areas for American Shad

Spring: Chesapeake, Delaware and Hudson rivers and adjacent coastal waters

Fall: Northern Gulf of Maine

American Eel

American eel occurs throughout the coastal drainages, up to hundreds of miles inland, as well as in all estuaries in the region (Figure 6-7). The Northwest Atlantic region represents a relatively small portion of the global range, from the St. Lawrence River, Canada to Venezuela. This species is greatly diminished at the northern limit of its range in Canada; no data are available from the southern limit of the range.

There are too few records of American eel in the NOAA trawl surveys to interpret. Adult eels presumably migrate quickly through this geography on their way to the Sargasso Sea and thus have low probability of being detected in a trawl survey. The listing finding (USFWS 2007) summarized available information on ocean distribution of larval (leptocephali) and silver eels. The majority of leptocephali enter the Florida Current just south of Cape Hatteras directly from the Sargasso Sea. The remainder may enter the Florida Current by a more southern route. Other than this likely current transport, little is known. Similarly, actual distances, routes, and depths of migration for adult eels are unknown.

Important Marine Areas for American Eel

Not enough data to determine

Atlantic Salmon

Long Island Sound and the Connecticut River are the southern limit of the range of Atlantic salmon in the United States (Figure 6-8). Salmon in New England rivers outside Maine (Connecticut, Pawcatuck, Merrimack) were extirpated and recovery efforts continue through stocking and passage improvements. Wild salmon still exist in the Gulf of Maine (Penobscot, Kennebec and eight eastern Maine rivers) and Bay of Fundy. A widespread collapse in Atlantic salmon abundance started around 1990. In the past decade, United States salmon returns across all rivers have averaged 1,600 fish; returns in 2005 were 1,320 fish. All stocks are extremely small, with only the Penobscot River population at a viable level. Most populations are still dependent on hatchery production and current marine survival regimes are compromising the long-term prospects of even these hatchery-supplemented populations (Kocik and Sheehan 2006).

For this Assessment, marine distribution of Atlantic salmon could not be mapped with NOAA data, but adults are known to congregate in the waters off Greenland and migrate to spawning rivers from the Connecticut River northward (NMFS USFWS 2005). Post smolt surveys have also tracked movements in coastal waters (Kocik and Sheehan 2006).

Important Marine Areas for Atlantic Salmon

Not enough data to determine

Atlantic Sturgeon

Atlantic sturgeon spawning populations occur in each sub-section of the region, but in only a handful of large rivers, e.g., Kennebec, Hudson, and Delaware Rivers (Atlantic Sturgeon Status Review Team 2007). Most watersheds where they occur (Figure 6-9) host only wandering juveniles, although occasionally in substantial numbers. All rivers and estuaries where they occur represent important habitat.

Some fishery-dependent data are available regarding Atlantic sturgeon habitat use. A 2007 ASMFC report shows concentrations of sturgeon bycatch in shallow waters in a few locations including Massachusetts Bay, off the east shore of Cape Cod, Rhode Island coastal waters, New York Bight, and the Delmarva Peninsula. The authors note that seasonal trends were confounded with fishery behavior, e.g. type of net used, but the data provides a useful indication of the locations and types of coastal habitats used by sturgeon.

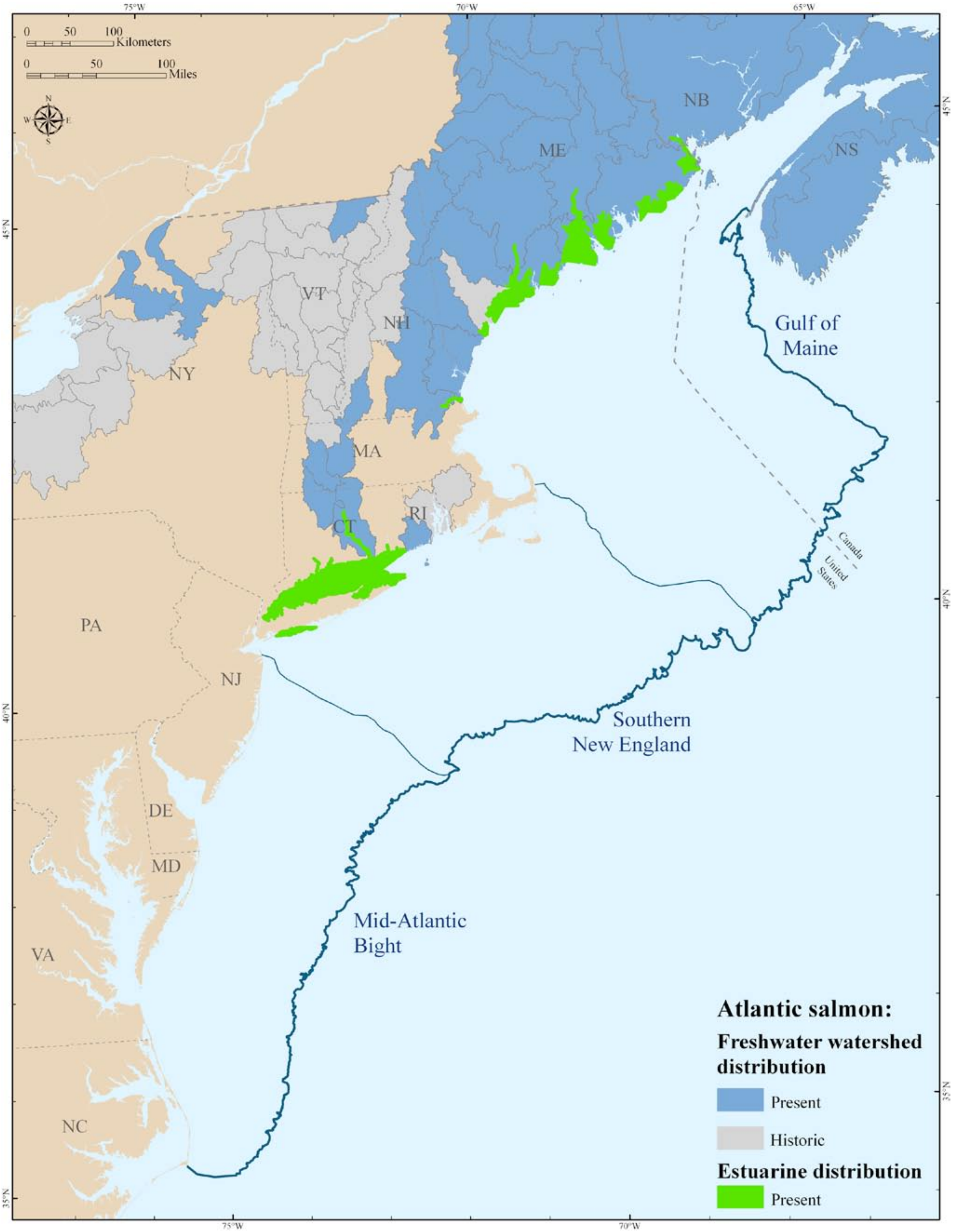

Figure 6-8. Freshwater and estuarine distribution for Atlantic salmon.

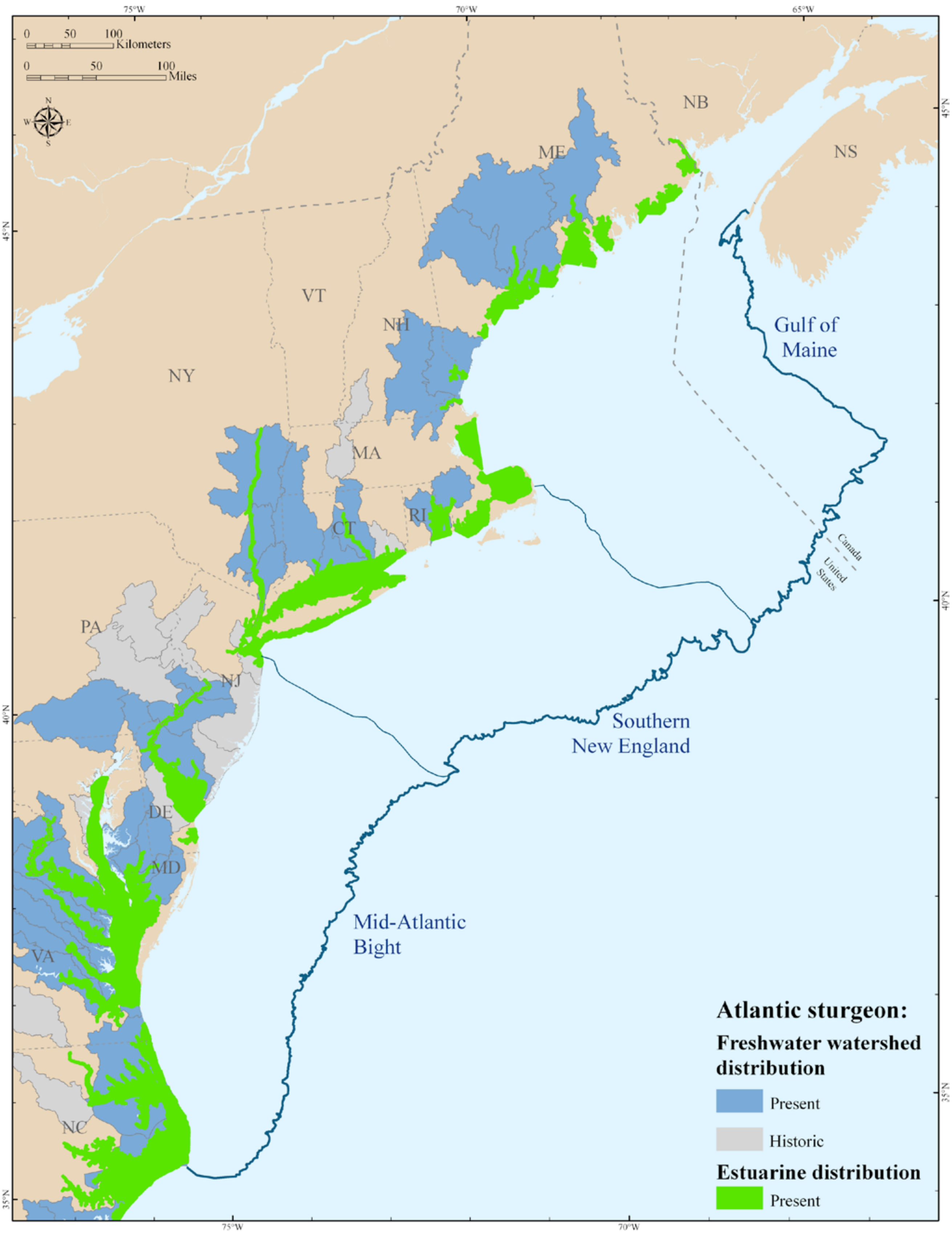

Figure 6-9. Freshwater and estuarine distribution for Atlantic sturgeon.

Important Marine Areas for Atlantic Sturgeon:

Coastal waters of Massachusetts Bay, east Cape Cod, Rhode Island, New York Bight, Delmarva peninsula

Atlantic Tomcod

Atlantic tomcod historically occurred in low numbers as far south as Chesapeake Bay (Figure 6-10), with the Hudson River being the southernmost major spawning area (Klauda et al. 1981). Levinton and Waldman (2006) report that tomcod has declined significantly in the Hudson River in recent years, suggesting that the species' range may be continuing to contract northward. Atlantic tomcod is primarily an inshore fish that does not usually travel to offshore waters, therefore was not sampled adequately in the NOAA trawl survey.

Important Marine Areas for Atlantic Tomcod

Not enough data to determine

Blueback Herring

Blueback herring occurs in coastal drainages, as well as in all estuaries in the region (Figure 6-11). Blueback herring were captured all along the coast in spring, with concentrations at several locations along the Mid-Atlantic coast and in Massachusetts Bay (Figure 6-12a); in the fall bluebacks were strongly concentrated in Massachusetts Bay (Figure 6-12b). Most TMS showed no trend, but in spring a number of TMS show decreasing trends, while all the northern TMS with trends are increasing (Figure 6-12c). The spring distribution seems consistent with other accounts and with the location of spawning rivers (Figure 6-12d). In spring there were a few areas of high persistence and abundance in each subsection, predominantly in the Mid-Atlantic (Figure 6-13a). In the fall, only Massachusetts Bay showed high persistence, with high abundance in three of the sampled decades (Figure 6-13b). In contrast, ASMFC (2008) reported that blueback herring populations have declined to extremely low levels in some places (e.g. fewer than 100 fish were counted at Holyoke Dam on the Connecticut River in 2006-2008, in contrast to ~500,000 in the 1980s) and there is evidence of coastwide decline.

Important Marine Areas for Blueback Herring

Spring: Individual areas in the Mid-Atlantic

Fall: Massachusetts Bay

Hickory Shad

Hickory shad (Figure 6-14) has a limited spawning distribution in the Gulf of Maine and southern New England. They are most common and widely distributed south of Delaware Bay. This species' estuarine distribution is not included in the Estuarine Living Marine Resources database. Levinton and Waldman (2006) observe that hickory shad abundance in New York Bight and Long Island Sound increased substantially through the 1990s, which they suggest is likely due to increased immigration from other sources rather than to local reproduction. Similarly, Gephard and McMenemy (AFS Monograph #9 2004) report these fish becoming increasingly more common in the Connecticut River, possibly reflecting a climate-driven northward range expansion.

The marine distribution and habits of hickory shad are often described as similar to other alosines. Collette and Klein-MacPhee (2002) report that hickory shad are caught off New England primarily in the fall, which might indicate southward movement from feeding grounds in the Gulf of Maine like American shad. Perhaps it is a result of their relative rarity that they are not often found at sea with the other species, or they could be less susceptible to certain gear types. There are some records of hickory shad in the NOAA trawl data but too few to interpret.

Important Marine Areas for Hickory Shad

Not enough data to determine

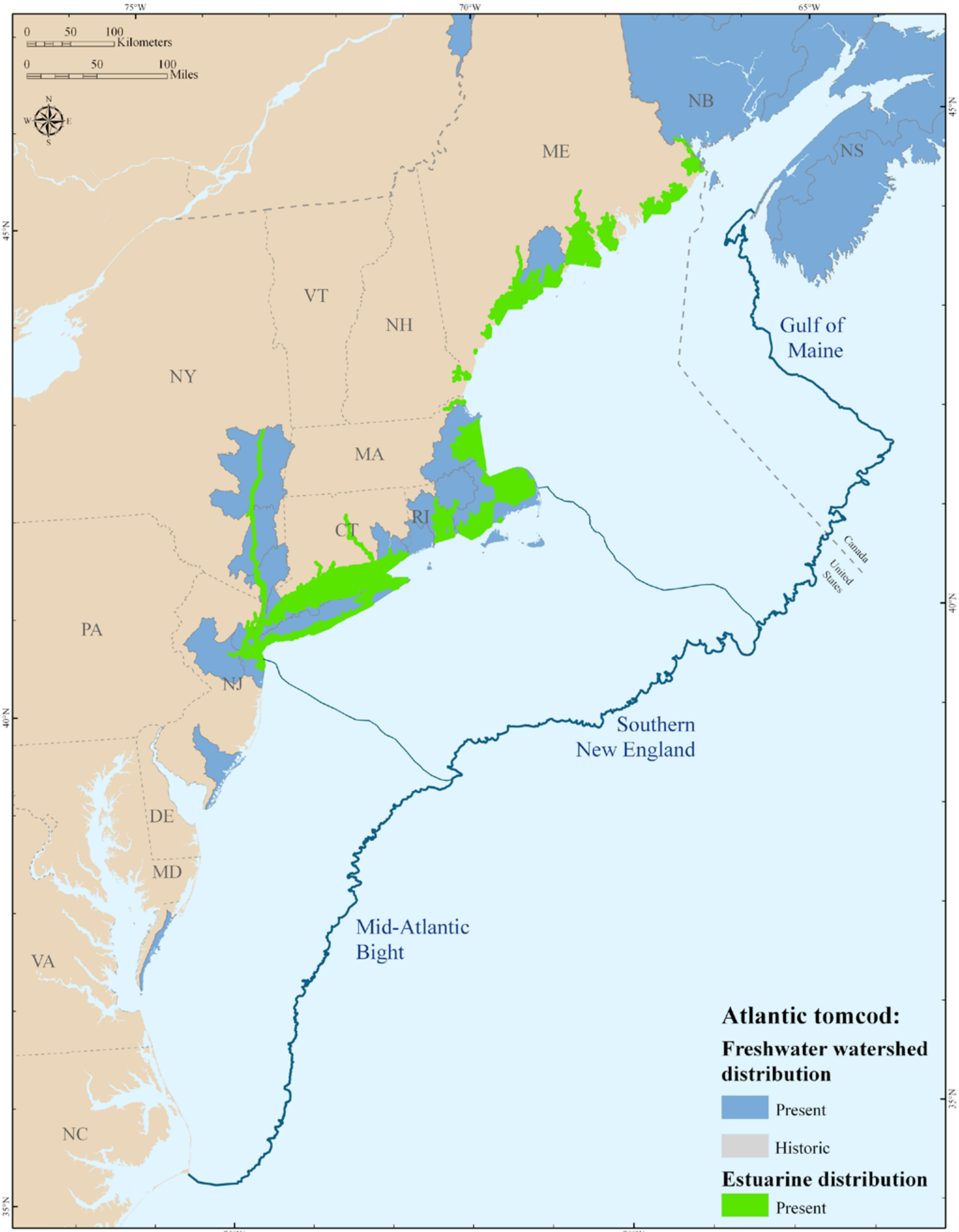

Figure 6-10. Freshwater and estuarine distribution for Atlantic tomcod.

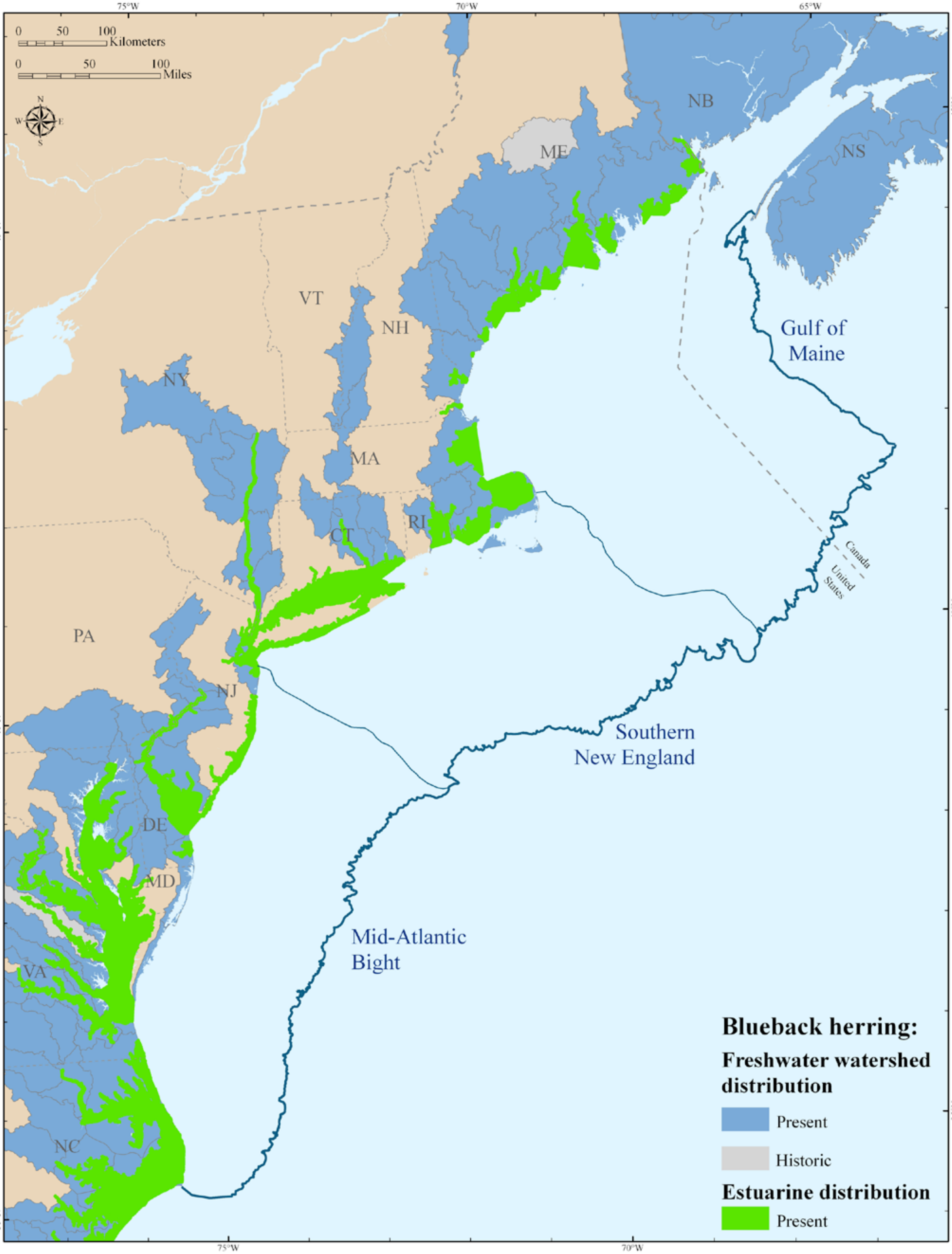

Figure 6-11. Freshwater and estuarine distribution for blueback herring.

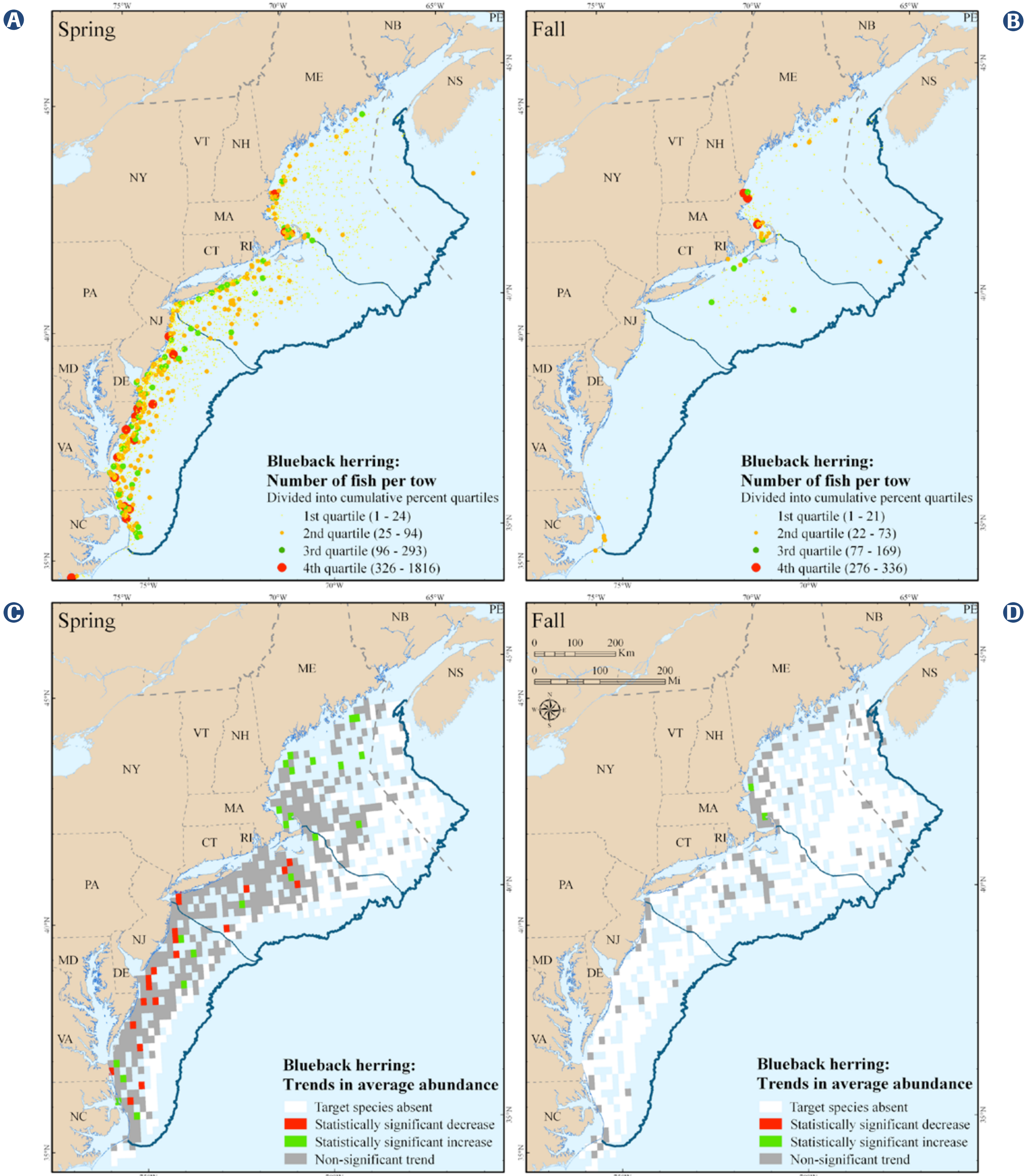

Figure 6-12. Trends in average abundance over 40 years for blueback herring during the spring and fall seasons.

Rainbow Smelt

Rainbow smelt spawning has been documented near the head of tide in rivers all along the coast from the Hudson River northward; the species becomes more widely distributed (Figure 6-15) and common north of Cape Cod. There is evidence of significant, recent range contraction. Levinton and Waldman (2006) report that rainbow smelt declined through the late 1900s and were extirpated from the Hudson River by 2000. A survey by a University of Connecticut graduate student in 2005 failed to document any smelt runs in Connecticut and the species is now listed by the state as "Threatened" (Gephard, not dated). Until the 1960s, there were many abundant runs of rainbow smelt in rivers across coastal Connecticut. Buchsbaum et al. (1994) also noted a marked decline in smelt between 1965 and 1994 samples taken in Plum Island Sound on the north shore of Massachusetts.

Rainbow smelt is primarily an inshore fish that does not usually travel to offshore waters, therefore was not sampled adequately in the NOAA trawl survey.

Important Marine Areas for Rainbow smelt

Not enough data to determine

Sea-run Brook Trout (eastern brook trout, sea-run form)

Coastal populations of eastern brook trout are limited to the two northern subsections of the region, with significant reductions in abundance and distribution at the southern limit of the range (Figure 6-16). The sea-run form is currently documented in very few locations in southern New England (Anderson et al. 2006), but becomes more common in small coastal streams northward through the Saint Lawrence River. Typically, anadromous

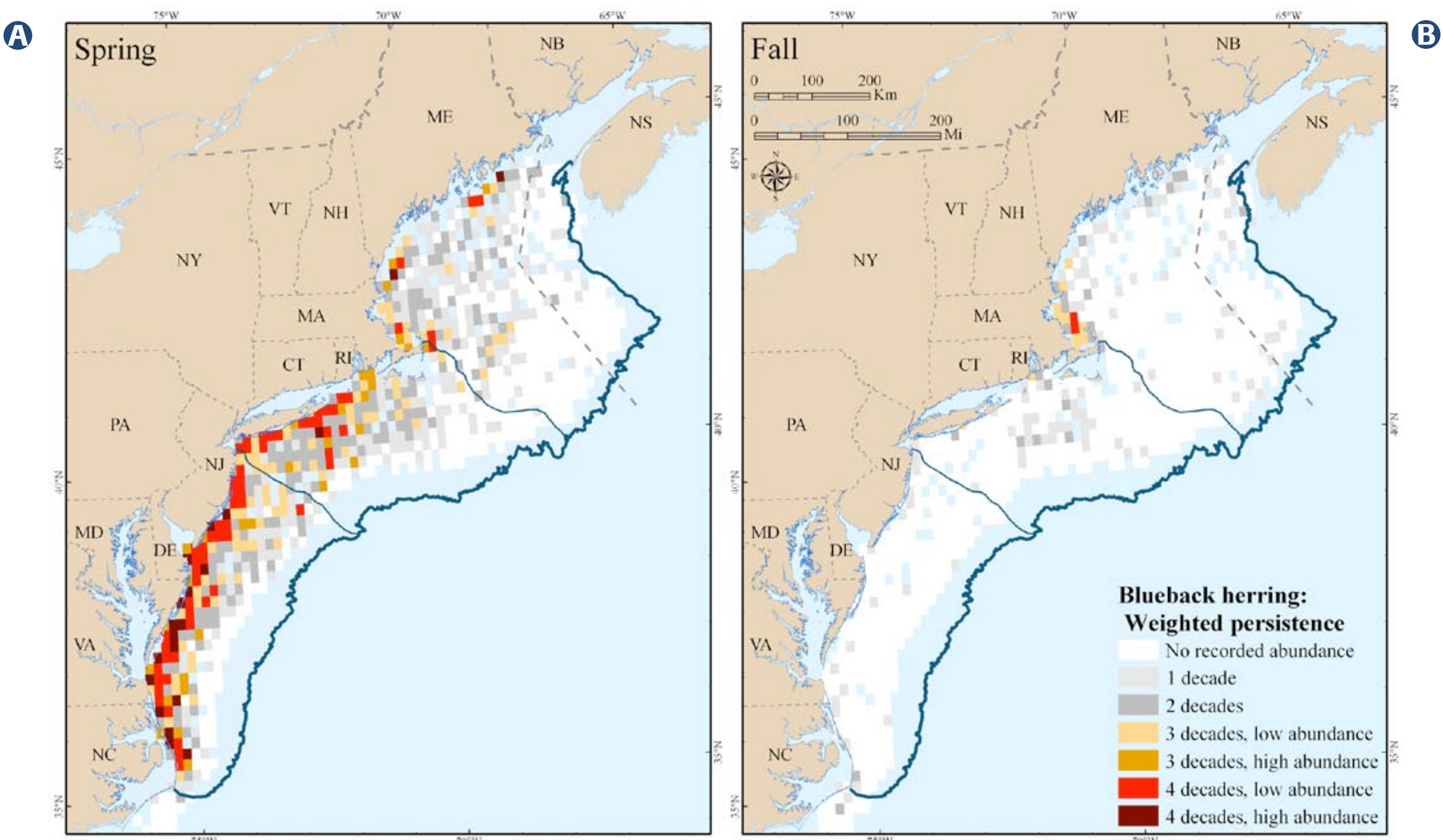

Figure 6-13. Areas with high persistence and abundance over 40 years for blueback herring during the spring and fall seasons.

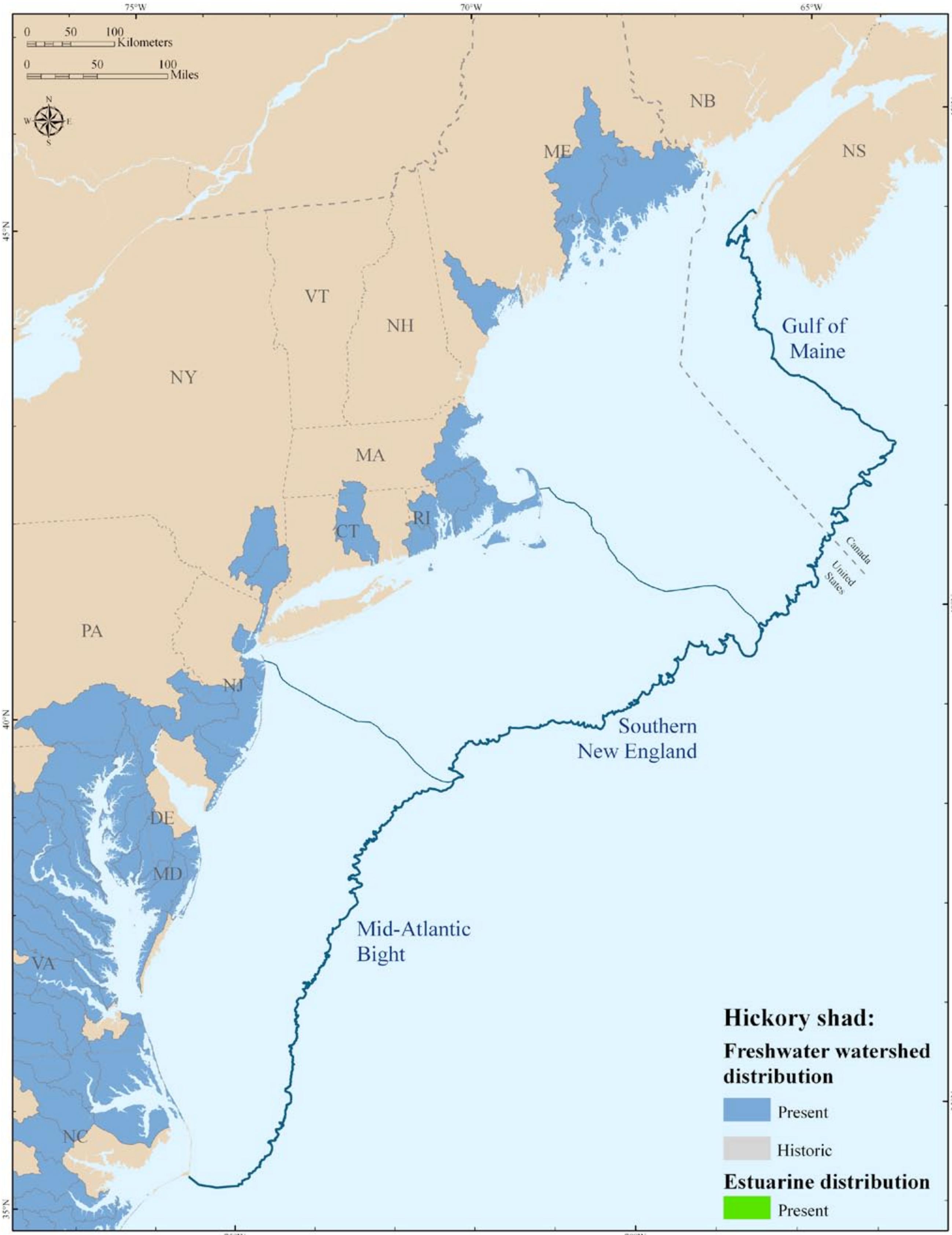

Figure 6-14. Freshwater and estuarine distribution for hickory shad.

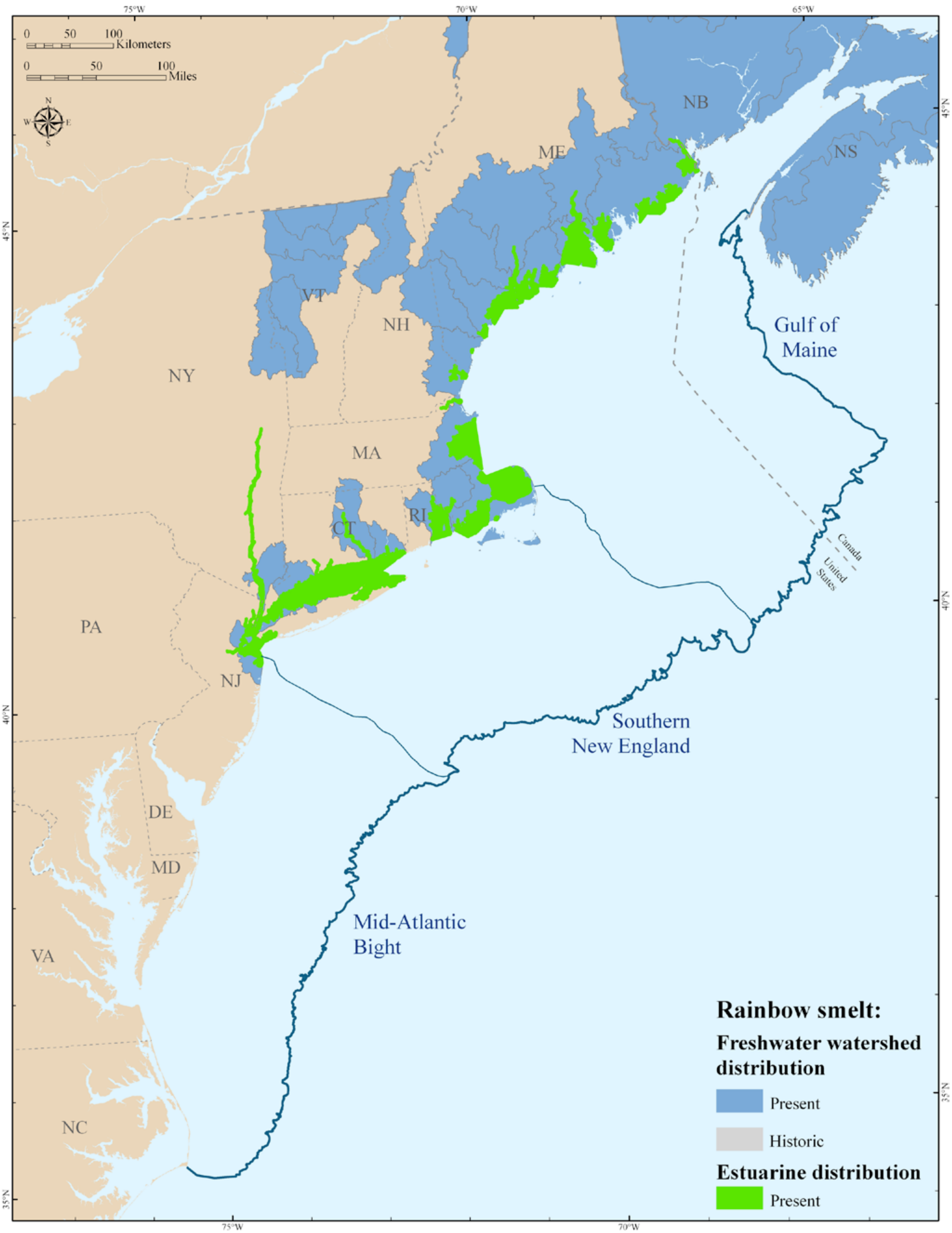

Figure 6-15. Freshwater and estuarine distribution for rainbow smelt.

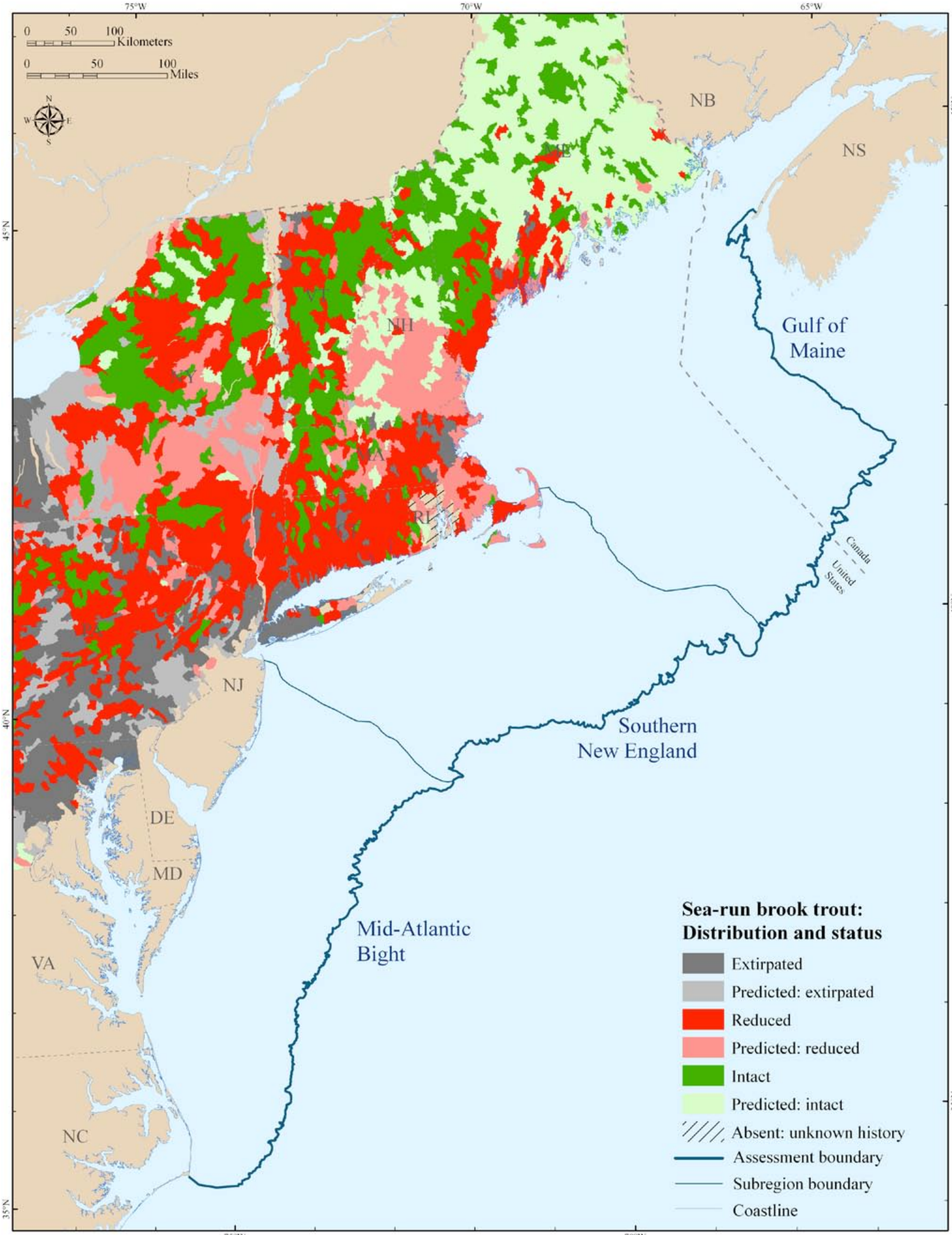

Figure 6-16. Distribution and status of sea-run brook trout.

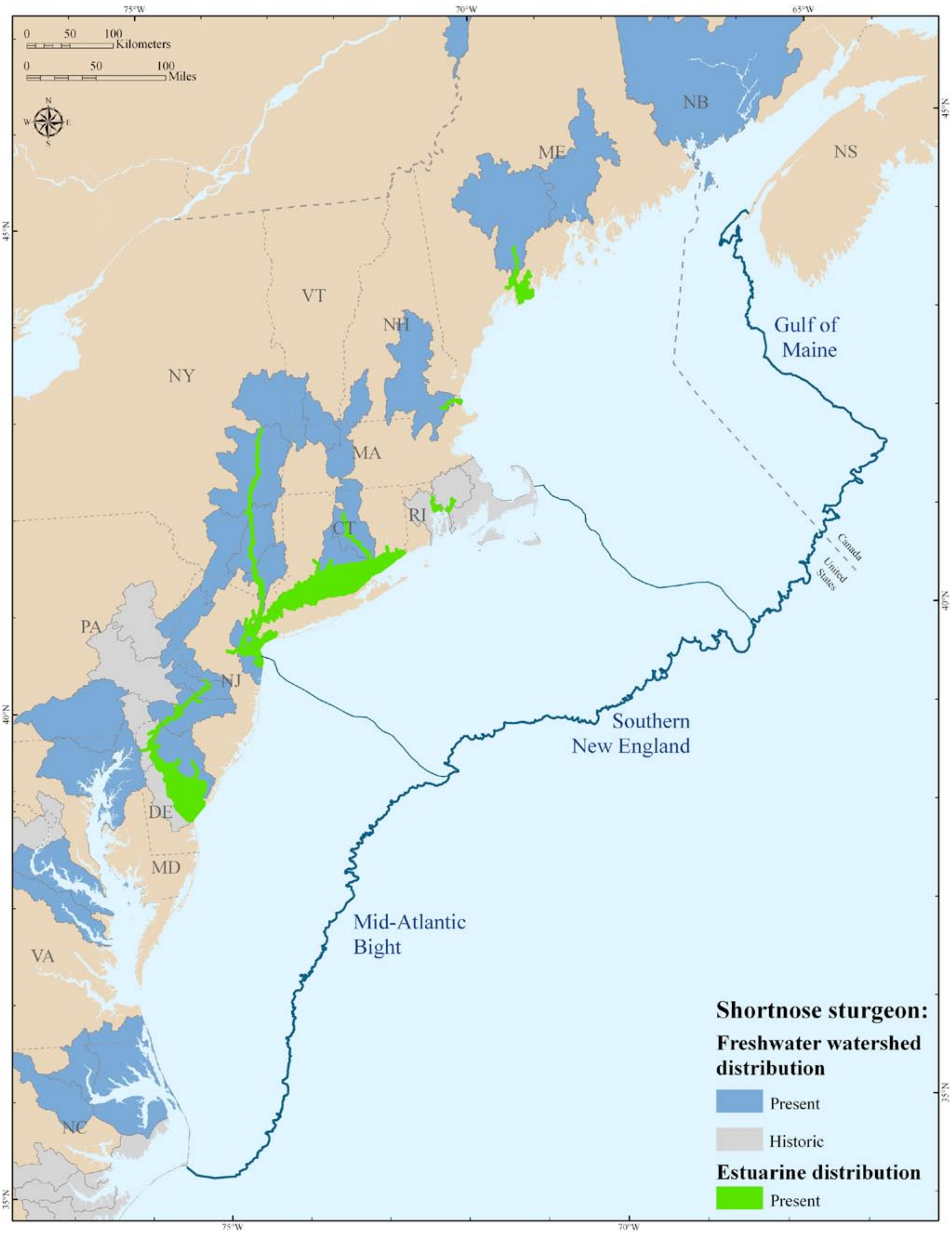

Figure 6-17. Freshwater and estuarine distribution of shortnose sturgeon.

behavior is most prevalent at northern latitudes because the ocean is more productive than adjacent freshwater habitats in temperate and Arctic zones. For a number of facultative anadromous species (e.g., Arctic char, Dolly Varden, brook trout, brown trout, and threespine stickleback) anadromous behavior declines in frequency or ceases toward the southern portion of the distributional range of the species (McDowall 1987). Sea-run trout have been caught up to 45 km away in open ocean or in other estuaries (Collette and Klein-MacPhee 2002).

Important Marine Areas for Sea-run brook trout

Not enough data to determine

Shortnose Sturgeon

Shortnose sturgeon currently have spawning populations in each of the three subsections (Figure 6-17). The global range of this species is limited to the Atlantic coast from the St. John River in New Brunswick to St. Johns River in Florida. About half of the extant populations are within the Northwest Atlantic region, including the two largest, in the Hudson and St. John Rivers (NMFS 1998).

Important Marine Areas for Shortnose Sturgeon

Not enough data to determine

Human Interactions

Historic and current threats to this group of species have been described at length in the literature and in various stock assessments and status reviews cited here. Because of variations in life history traits, such as distance traveled in freshwater and marine environments, feeding preferences, and geographic range, the most acute threats vary somewhat among species, but the general pattern appears to be the same: Excessive mortality of adults through overharvest and other direct impacts combined with reduced access to spawning grounds and impacts of pollution, power plant operations, and other factors on reproduction and recruitment have led to broad scale population declines.

Across all species, frequently cited threats include dams (lack of access to spawning habitat; flow alteration affecting cues and/or egg development; direct mortality due to passage through hydroelectric turbines; increased predation especially due to delays at inefficient fish passage facilities); impingement and entrainment due to operations that require cooling water; overharvest (directed and/or bycatch); and toxins and "emerging pollutants," e.g. endocrine disruptors (chemicals that interact with hormone receptors, thereby disrupting the endocrine system).

Invasive species probably also pose a threat. Introduction of fishes like catfish and snakeheads to freshwater habitats present new predators or competitors to which native diadromous species are not adapted. Non-native plants that create infestations in rivers or ponds can degrade spawning/nursery habitat or restrict migratory pathways.

Climate change (warming waters) is implicated in the documented range contractions of the species adapted to cool waters: alewife, Atlantic salmon, Atlantic tomcod, rainbow smelt, and sea-run trout. Shifts in the North Atlantic Oscillation, also linked to climate change, have been hypothesized to be one cause of the decline of American eel at the northern edge of its range.

Case Study: Atlantic sturgeon

Atlantic sturgeon provides a useful case study of the historic impacts humans have had on diadromous fish in the region. This species' status changed rapidly from abundant to globally rare. Historical records from Massachusetts and Maine indicate an important and abundant sturgeon fishery dating to the 1600s. After a caviar market was established in 1870, fishing intensity increased greatly, with record landings from Atlantic coastal rivers of 3350 metric tons reported in 1890. The fishery collapsed in 1901, when less than 10% (295 mt) of its 1890 peak landings were reported (Atlantic Sturgeon Status Review Team 2007). Fishing continued, however, until the fishery was closed by ASMFC in 1998, when a coastwide fishing moratorium was imposed for 20-40 years, or at least until 20 year classes of mature female Atlantic sturgeon were present (ASMFC 1998). The Hudson and Altamaha Rivers are presumed to be the healthiest populations within the United States and are the only rivers with abundance estimates: for the Hudson, approximately 870 spawning adults/yr and for the Altamaha, approximately 343 spawning adults/yr. Populations in the St. John and St. Lawrence Rivers in Canada still support fisheries.

Because sturgeon are a long-lived, slow growing fish with a late age of first reproduction, they rely on high survival of adults to maintain the population. Today, though protected from directed fishing, a greatly reduced number of adults face a variety of ongoing threats. All of the habitats (oceanic, estuarine, and riverine) used by various life

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stages of Atlantic sturgeon are necessary for species survival. However, riverine habitat where spawning occurs may be the most critical to maintenance of the species. The 2007 status review concluded that the principal threats to the survival of Atlantic sturgeon are modifications to or loss of spawning and nursery habitat, poor water quality, and contaminants. Dredging causes physical alteration of habitat, increases siltation, and may reduce food availability. The dams on most major river systems have severely restricted the amount of spawning habitat available to Atlantic sturgeon; dams close to the river mouth are the most problematic because they preclude nearly all-upriver movement and can create unsuitable conditions for egg hatching and survival. To date, fish passage devices for Atlantic sturgeon have been unsuccessful.

In addition to these habitat impacts, direct mortality from dredging activities, ship strikes, and bycatch in estuaries and coastal waters were cited. A 2007 ASMFC report on bycatch in coastal fisheries for 2001-2006 found concentrations of sturgeon bycatch in sink gillnet fisheries in a few locations including Massachusetts Bay, off the east shore of Cape Cod, Rhode Island coastal waters, New York Bight, and the Delmarva Peninsula at depths less than 50 m. As a result of the population status and multiple ongoing threats, Atlantic sturgeon is a candidate for listing under the Endangered Species Act.

Please see the historical chapter beginning on page xx for additional information.

Management and Conservation

Regulatory Authorities

ASMFC is an interstate compact of the fifteen Atlantic coast states formed in 1942. Since 1994, ASMFC has been responsible for implementing fishery management requirements for all Atlantic coast interjurisdictional fisheries under the Atlantic Coastal Fisheries Act, which established cooperative management among ASMFC, NMFS and the United States Fish and Wildlife Service (USFWS). There are 22 species regulated under this program, including the diadromous species American eel, American shad, hickory shad, blueback herring, alewife, Atlantic sturgeon, and striped bass.

For species that have significant fisheries in both state and federal waters, e.g., Atlantic herring, the Commission works cooperatively with the East Coast Regional Fishery Management Councils to develop fishery management plans. The Commission also works with NMFS to develop compatible regulations for the federal waters of the exclusive economic zone (from three miles to 200 miles offshore; from the shoreline to three miles offshore is the jurisdiction of the individual coastal states). The 1988 fisheries management plan (FMP) for Atlantic salmon established explicit United States management authority over all Atlantic salmon of United States origin to complement state management programs in coastal and inland waters and federal management authority over salmon on the high seas conferred as a signatory nation to the North Atlantic Salmon Conservation Organization. An extensive hatchery program initiated in the 1960s sustains re-introduced runs in New England from the Connecticut River northward. Shortnose sturgeon was listed as an endangered species by the USFWS in 1967; NMFS assumed jurisdiction in 1974. The species is managed under a 1998 recovery plan.

Rainbow smelt, Atlantic tomcod and sea-run trout, species that live mostly within the three mile limit of state waters and are not federally protected, are managed by fisheries agencies within states. Freshwater fisheries for migratory fish may be managed by state marine fisheries agencies, state inland fisheries agencies, and/or local commissions.

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Across all species there is a dizzying array of additional federal, state and local entities with jurisdiction over different aspects of habitat, water quality and fish passage, e.g. Federal Energy Regulatory Commission, Army Corps of Engineers, Environmental Protection Agency, state fisheries agencies. And town herring wardens). There is increasing recognition of the need to coordinate fisheries management with these other authorities across all life stages and habitats in order to meet recovery goals. For example, ASMFC recently passed a resolution on the importance of fish passage.

Current Conservation Efforts

Diadromous fish have been the subject of many conservation and recovery efforts, and there appears to be a strong and growing interest in coordination across habitats and political boundaries in recognition of both the importance and stressed condition of many of these species. ASMFC and its member institutions and partners have played a critical leadership role in these interjurisdictional efforts. In winter 2009 ASMFC published *Atlantic Coast Diadromous Fish Habitat: A Review of Utilization, Threats, Recommendations for Conservation, and Research Needs,* a comprehensive compilation of habitat information for the seven diadromous species it manages. In addition, the Atlantic Coast Fish Habitat Partnership, an entity that grew out of the ASMFC Habitat Committee, and individual Commission species technical committees have undertaken efforts to characterize the amount, location, and gear involved in bycatch of managed species, and a fish passage working group has been convened.

Fishing impacts are being addressed for many of these species. In United States waters, fishing for Atlantic sturgeon, shortnose sturgeon, and Atlantic salmon is prohibited, and the ocean-intercept fishery for American shad was closed in 2004. In May 2009, Amendment 2 to the FMP for American shad and river herring established a coastwide moratorium for river herring with exceptions for sustainable fisheries. Draft Amendment 3offers the same provision for shad, among other alternatives, was released for public comment in August 2009, and will likely be finalized in 2010.

Several states have included diadromous fish in State Wildlife Action Plans, and some have opted to work together on specific projects to promote species recovery. For example, in 2006, Maine, New Hampshire, and Massachusetts received a NMFS Proactive Conservation Program grant to develop a comprehensive conservation program for Atlantic sturgeon, Atlantic salmon, and rainbow smelt in the Gulf of Maine.

Private conservation organizations also play an important role in conservation of these species. The Nature Conservancy has conservation programs in all 15 coastal states, and has identified diadromous fish as conservation priorities coastwide. TNC programs are working on a wide variety of site-based and policy efforts, from dam removal and stormwater management projects to serving on the ASMFC Habitat Committee and Shad and River Herring Advisory Panel. Environmental Defense Fund serves on the Habitat Committee and American Eel Advisory Panel. American Rivers works coastwide on barrier removal projects and policies to enable river restoration. Additional groups such as Trout Unlimited, Cape Cod Commercial Hook Fishermen's Association, and local watershed associations also play important roles in raising awareness of the conservation needs of these species, collecting data, and improving their management.

Species Accounts

Alewife *(Alosa pseudoharengus)*

Alewife spawn in rivers from northeastern Newfoundland to South Carolina, but are most abundant in the Mid-Atlantic and northeastern states. A wide range of habitats and substrates is utilized, including large rivers, small streams, ponds, and lakes with substrates of gravel, sand, detritus, or submerged vegetation. The distance traveled to spawn also varies widely, from a few meters to reach back-barrier ponds to hundreds of kilometers as on the Saint John River (Collette and Klein-Macphee 2002). Most alewife are believed to return to their natal river or pond after about three or four years at sea.

After the eggs hatch, the young-of-the-year spend two to six months in freshwater nursery areas before they begin to migrate to sea. Adult and juvenile alewives are planktivorous, although they occasionally eat insects and fish larvae, including larval alewives. Seasonal migrations in the ocean may be related to zooplankton abundance and water temperature (Neves 1981). Winter catches in the northwest Atlantic are made between 40 and 43oN latitude; in spring alewife move inshore and northward and occur most frequently over the continental shelf between Nova Scotia and North Carolina. During summer and fall catches are concentrated in three areas north of 40o latitude: Nantucket Shoals, Georges Bank, and the perimeter of the Gulf of Maine. At sea, alewife congregate in schools of thousands of fish, sometimes mixing with other herring species (Collette and Klein-Macphee 2002).

American eel *(Anguilla rostrata)*

Adult eel migrate to spawning grounds located in the Sargasso Sea, a large portion of the western Atlantic Ocean east of The Bahamas and south of Bermuda. The Gulf Stream then transports and disperses fertilized eggs and larval eel, called leptocephali, along the entire United States East Coast and into Canadian waters. Bigelow and Schroeder (1953) described the distribution of eels in Gulf of Maine tributaries as universal — occurring in every stream, estuary, and tidal marsh and sometimes the open coast. American eel is classified as catadromous (living in freshwater and migrating to marine waters to spawn), but it has been suggested recently that this may be a facultative trait, that is, rather than having its growth phase restricted to fresh water, some eels complete their life cycle in brackish or marine waters without ever entering fresh water (USFWS 2007).

American eel life history is complex. The species exhibits a multitude of life stages including leptocephalus, glass eel, elver, yellow eel, and silver eel stages. Leptocephali metamorphose into glass eel as they migrate toward land and freshwater bodies. Glass eel develop into the pigmented elver stage as they move into brackish or freshwater. Usually by age two, elvers make the transition into the yellow eel stage. Yellow eel inhabit bays, estuaries, rivers, streams, lakes, and ponds where they feed primarily on invertebrates and smaller fishes. Sexual maturity of yellow eel can occur any time between eight and 24 years of age according to data in the Mid-Atlantic region. When yellow eel reach sexual maturity they begin a downstream migration toward the Sargasso Sea spawning grounds. During this migration yellow eel metamorphose into the adult silver eel phase, undergoing several physiological changes that enable the animals to move from a freshwater to a saltwater environment. Adult silver eel are believed to spawn in the Sargasso Sea during winter and early spring (USFWS 2007), although spawning has never been observed.

American shad *(Alosa sapidissima)*

The spawning range of American shad is from Florida to the St. Lawrence River. Shad ascend tributaries in the spring when water temperatures reach 16.5oC to 19oC and spawn preferentially in shallow water over gravel or rubble substrates (Collette and Klein-MacPhee 2002). Pelagic shad eggs are carried downstream by the current. Larvae and early juveniles use natal rivers during summer and begin downstream migration to the sea in response to decreasing water temperatures in the fall (Weiss-Glanz et al. 1986). In the northern part of their range, shad may spawn up to five times. The percentage of adults that live to be repeat spawners decreases with decreasing latitude; south of Cape Hatteras shad are semelparous (reproduce only once during their lifetime; Collette and Klein-MacPhee 2002).

Shad form seasonal aggregations and undertake extensive oceanic migrations; fish tagged in the summer in the Bay of Fundy have been recaptured in rivers all along the coast, up to 3,000 km from the tagging location (Dadswell et al. 1987). By late June immature shad are in coastal waters of the inner Bay of Fundy, the Gulf of St. Lawrence, and north to Newfoundland while the spawning fish are upstream in coastal rivers. In late fall and winter shad move to deeper waters further offshore, up to 175 km from the nearest land. Young of the year are thought to overwinter near the mouths of their natal streams (Collette and Klein-MacPhee 2002). At sea they eat zooplankton, small benthic crustaceans, and occasionally, small fish.

Atlantic salmon *(Salmo salar)*

Atlantic salmon are found in coastal waters on both sides of the North Atlantic, from Spain to the Arctic circle, Long Island Sound to Labrador, and a few rivers in western Greenland (Collette and Klein-McPhee 2002). Atlantic salmon spend their first few years in small streams and rivers feeding primarily on aquatic insects. These young, mostly solitary fish are called "parr." After reaching a size of about four inches, the fish become "smolts" in the spring and begin migrating to the ocean. It takes two to five years to become a smolt, less in the southern portion of the range and more in the north where growing seasons are short. During their downstream migration smolts begin schooling and develop the salinity tolerance needed to survive in the ocean. Fish becomes a larger proportion of their diet as they grow.

Feeding while they migrate, the salmon move toward their major feeding grounds in the North Atlantic near Greenland and Iceland. After spending one or two years at sea, salmon begin their journey back to their natal rivers. Salmon may reenter fresh water in spring, summer, or fall, but spawning occurs in the fall. Unlike Pacific salmon, Atlantic salmon typically do not die after spawning.

Interestingly, a small group of salmon native to Nova Scotia, New Brunswick streams in the inner Bay of Fundy region are thought to utilize Gulf of Maine waters most of the year and don't undertake long ocean migrations. These "resident" salmon stocks, like the long-distance migrants, are impacted by degradation of freshwater habitat by flow alteration and acid precipitation. Atlantic salmon are among a small group of diadromous fish that require access into remote upstream tributaries up to hundreds of miles from the sea. The extent of habitats required to support a salmon throughout its life cycle led to the species' extirpation from all but a few of its native rivers in the United States by the time of the Industrial Revolution.

Atlantic sturgeon *(Acipenser oxyrinchus)*

Historically, Atlantic sturgeon were present in approximately 38 rivers in the United States from St. Croix, Maine to the Saint Johns River, FL, 35 of which have been confirmed to have had a historical spawning population. Atlantic sturgeon are currently present in the same 35 rivers, and spawning occurs in at least 20 of these rivers (Atlantic Sturgeon Status Review Team 2007).

Sturgeons are members of the ancient family Acipenseridae, large, slow-growing, and late maturing anadromous fish that migrate from the ocean into coastal estuaries and rivers to spawn. Adhesive eggs are attached to firm substrates in oligohaline (brackish) and tidal fresh waters (Collette and Klein-MacPhee 2002). Juveniles may spend several years in fresh water in some rivers, but in others fish move to brackish water in the fall. The lower portions of rivers and estuaries are important for growth. The distribution and residence times of larval, post-larval, and young juveniles in upstream areas are unknown, but aggregations of juveniles at the freshwater/saltwater interface suggest that this is a nursery area. Juveniles remain within riverine estuarine systems for periods of about one to six years before migrating to the coast and onto the continental shelf where they grow to maturity. Tagging and genetic data indicate that subadult and adult Atlantic sturgeon may travel widely once they emigrate from rivers, wandering among shallow coastal and estuarine habitats. Coastal features or shorelines where migratory Atlantic sturgeon commonly aggregate include the Bay of Fundy, Massachusetts Bay, Rhode Island, New Jersey, Delaware, Delaware Bay, Chesapeake Bay, and North Carolina (Atlantic Sturgeon Status Review Team 2007).

Sturgeons are benthic feeders, with a subterminal mouth (located on the underside of the head) and barbels (fleshy feelers) well designed for sensing and capturing benthic invertebrates. Historically, abundant and widely distributed, the combination of slow rates of population growth and high economic demand for flesh and roe made Atlantic sturgeon especially vulnerable to over-harvesting.

Atlantic tomcod *(Microgadus tomcod)*

Atlantic tomcod are distributed in shallow, inshore waters along the Atlantic coast from southern Labrador to Chesapeake Bay, spawning in brackish or fresh areas of rivers from November to February (Collette and Klein-MacPhee 2002). Atlantic tomcod are not truly anadromous but amphidromous (utilizing both fresh and marine habitats but not necessarily requiring both habitats). Tomcod can survive and reproduce with access only to brackish water. Eggs sink and stick to gravel, stones, or plants, hatching after 24-30 days. Larvae and juveniles eat mostly copepods; as they grow they eat a variety of crustaceans, worms, and larval fishes. Tomcod are benthic, estuarine residents, and as a result are subject to stress from a variety of pollutants. Detailed studies from the Hudson River show elevated levels of PCBs, metals, and pesticides in tomcod tissues as well as high rates of liver cancer and shortened life spans (Collette and Klein-MacPhee 2002). Data on distribution and abundance of tomcod are limited but anecdotal reports indicate that these fish were ubiquitous in coastal waters a century ago and supported some substantial fisheries, but today they are less plentiful.

Blueback herring *(Alosa aestivalis)*

Blueback herring spawn from Nova Scotia to northern Florida, but are most numerous in warmer waters from Chesapeake Bay south. Blueback herring prefer to spawn in swift flowing sections of freshwater tributaries, channel sections of fresh and brackish tidal rivers, and Atlantic coastal ponds, over gravel and clean sand substrates (ASMFC 1999). Similar in appearance, alewife and blueback herring are collectively known as river herring. Mature river herring broadcast their eggs and sperm simultaneously into the water column and over the substrate. Immediately after spawning, adults migrate downstream. Juveniles remain in freshwater nursery areas in spring and early summer, feeding mainly on zooplankton, but larvae are tolerant of salinity early in life and may utilize both freshwater and marine nurseries (Collette and Klein-MacPhee 2002). As water temperatures decline in the fall, juveniles move downstream to more saline waters. Little information is available on the life history of subadult and adult blueback herring after they emigrate to the sea as young-of-year or yearlings, and before they mature and return to spawn. In summer and fall bluebacks are concentrated in shelf areas north of 40oN latitude, along Georges Bank and the perimeter of the Gulf of Maine; in winter between 40o N and 43o N, and in spring across the continental shelf from Cape Hatteras to Nova Scotia as migration toward spawning rivers begins (Neves 1981). Recruitment to the spawning population takes place between ages 3 and 6, usually age 5 (Collette and Klein-MacPhee 2002).

Hickory shad *(Alosa mediocris)*

Hickory shad occur along the Atlantic coast from the Bay of Fundy, Canada to the Saint John's River, Florida (Levinton and Waldman 2006), but spawning is reported in rivers from Maryland to Florida (Harris et al. 2007). Adult hickory shad appear to spawn in a diversity of physical habitats ranging from backwaters and sloughs, to tributaries, to mainstem portions of large rivers in tidal and non-tidal freshwater areas (AMSFC 1999). In Chesapeake Bay, hickory shad spawning runs usually precede American shad runs, typically beginning in March and April. Repeat spawning in hickory shad appears to be common, but tends to vary among river systems. Spawning hickory shad females (ages 3 and 4) broadcast a large quantity of eggs into the water column which are fertilized by males (ages 2 and 3). After spawning, adults return to the sea, but their distribution and movements in the ocean are essentially unknown. It is believed that they are highly migratory and follow a pattern similar to the coastal migrations of American shad, moving northward from the Mid-Atlantic and southeast after spawning. Hickory shad are predators, consuming small fishes, crabs, and squid.

Rainbow smelt *(Osmerus mordax)*

Smelt occur on the Atlantic coast from Labrador to New Jersey, but are most abundant from the southern Canadian Maritime Provinces to Maine. Their range, which formerly extended to the Delaware River, appears to be contracting northward; state status ranks vary from SH or "possibly extirpated" in Pennsylvania; to S1 in Connecticut and Rhode Island; to S3 in Massachusetts and S4-S5 northward (Natureserve 2008). Coastal smelt stocks throughout New England declined markedly by the 20th century, due to the construction of dams and reduction in water quality. Two concerns identified for many rivers in Massachusetts Bay are structural impediments to spawning habitat and chronic degradation of spawning habitat from stormwater inputs (Chase and Childs 2001).

Smelt are a pelagic, schooling species that spends most of its time in shallow nearshore waters and may make ocean migrations, but little is known about this part of its life history. Their movement patterns are associated with seasonal changes in water temperatures. In summer, schools move to deeper, cooler, waters; in the fall they enter bays and estuaries where they actively feed until the onset of winter. Most spawning occurs in fast flowing, turbulent water in stream sections dominated by rocks, boulders, and aquatic vegetation, about the time ice breaks up in late winter. After hatching, larvae move passively downstream in freshwater currents until reaching estuarine waters (Collette and Klein-MacPhee 2002). By mid-summer, juveniles reside in the deeper waters of estuaries, particularly during daylight hours. Larvae and juveniles feed upon zooplankton, particularly microscopic crustaceans. Adult smelt feed primarily on small crustaceans and fish. Smelt in turn are an important prey for a variety of predatory fish, including, striped bass and bluefish, and several bird and marine mammal species.

Sea-run brook trout *(Salvelinus fontinalis)*

Brook trout are native to eastern North America from Labrador southward to Georgia along the Appalachian chain (Natureserve 2008). Like many other salmonids, including brown trout and rainbow trout introduced to the East Coast as sport fish, brook trout life histories are highly variable. Brook trout once exhibited anadromous behavior in many streams of eastern Canada southward to Long Island, but few sea run populations remain and most continue to decline (Doucet et al. 1999). Historical accounts suggest that sea-run brook trout were common prior to the 1700s, and that they suffered the same fate as other anadromous fish when subjected to damming and pollution of rivers. They are now documented in a handful of sites in Massachusetts, Maine, and maritime Canada but may still persist as far south as Long Island.

Sea-run trout typically remain near the mouth of their natal stream, but have been found up to 45 km away in open ocean habitats or in other estuaries (Collette and Klein-MacPhee 2002). Technically most of these fish are amphidromous, spending substantial time feeding and growing in freshwater but frequently visiting saltwater. Few authors agree on the specific mechanism that initiates anadromy or on the relatedness of resident and sea-run brook trout in mixed populations; possible factors include environmental conditions, food availability, and density-dependent behavior (Doucet et al. 1999).

Shortnose sturgeon *(Acipenser brevirostrum)*

Shortnose sturgeon are found in rivers and estuaries from the Saint John River in New Brunswick to the Saint John's River in Florida (Collette and Klein-Macphee 2002). There are currently 19 spawning populations that are considered to be viable; the largest known population is the Hudson River with 38,000 individuals, the second largest is 18,000 in the Saint John River (NMFS 1998). Adult shortnose sturgeon exhibit freshwater amphidromy (i.e., adults spawn in freshwater but regularly enter salt-water habitats) in some rivers in the northern part of their range but are generally estuarine anadromous in southern rivers (Kieffer and Kynard 1993). At least one population, in the Connecticut River, is landlocked above the Holyoke Dam 128.7 km upstream and never enters salt water (Hartel et al. 2002). Fish move upriver to spawning grounds in the spring, then return to lower freshwater or brackish reaches. Spawning occurs in deep, fast currents over rocky substrate at or above the fall line (Collette and Klein-Macphee 2002). Shortnose sturgeon have recently been found to travel moderate distances between river systems; in 2006 a sturgeon tagged in the Savannah River in Georgia was found 300 miles (483 km) away in the Santee-Cooper River system in South Carolina (Amanda Wrona, personal communication).

Shortnose sturgeon reach maturity at progressively later ages from south to north, and females mature two to three years later than males. In Georgia, males mature at age 2-3, while females in New Brunswick may not reproduce until age 13. After maturity, males spawn every one to two years and females every three years. Shortnose sturgeon are opportunistic benthic foragers, feeding on crustaceans, mollusks, insects, and worms (Collette and Klein-Macphee 2002).

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CHAPTER

7

Demersal Fish

Geoffrey Smith

Introduction

The high rates of productivity within the Northwest Atlantic region provide an abundant food source for planktivores in the water column, while still allowing significant energy to reach the ocean floor to support benthic communities. As a result, demersal fish species, i.e., fish that live on or near the seafloor, are able to thrive on the abundance of available prey items. These demersal species (which include Atlantic cod, haddock, flounders, monkfish, sea bass, skates, tilefish, and several estuarine-dependent species) are characterized by their close association with the seafloor for critical life stages including feeding, juvenile nursery areas, and spawning. Historically, demersal fish in the region played a critical role as a dominant predator, heavily influencing lower trophic levels in the system (Steneck 1997).

The list of demersal fish species included in this assessment is comprised of teleosts (ray-finned fishes) and elasmobranchs (cartilaginous fishes) that utilize a variety of benthic habitats to complete various phases of their life histories. While the species within the group share the common attribute of close association with sea floor habitats, individual species utilize a variety of different habitats throughout the region. Atlantic cod and haddock demonstrate an affinity for more complex substrates including gravel, pebbles, and cobbles, while flounders and skates show a preference for finer-grained substrates such as sands and mud. In addition, many species within the group make distinct seasonal migrations, occupying shallower habitats in the spring and summer months, then moving offshore to deeper water habitats in the winter in response to changes in water temperature.

Demersal fish have also played a critical economic and cultural role in the region for centuries. Fisheries for cod, haddock, hake, and halibut are believed to be largely responsible for European settlement in North America some 500 years ago (Kurlansky 1997). Since then, demersal fish populations have helped support fishing communities up and down the east coast, providing a source of income, food, and community identity. Even today, demersal fisheries are important to the economies in many parts of the region despite significant declines in many commercially exploited demersal fishes.

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Selection of Target Species

The selection of target species was an iterative process undertaken by the TNC Team Lead and team members. Several factors were considered when selecting target species for this assessment, including: 1) distribution over a range of depths and substrate types, 2) variations in life history, including reproduction and food habits, 3) availability and quality of species-specific information, 4) current population status, and 5) distinct ecological roles within the Northwest Atlantic. Team members agreed it was important to develop a more inclusive suite of species representing the broad ecological role of demersal fish, rather than focusing more narrowly on those species in need of immediate conservation attention. As such, the species analyzed in this assessment range from those whose population status is of concern because of significant depletion relative to historic levels (e.g., cod, halibut, some flounders, and wolffish) to species that are relatively abundant and show signs of continued improvement (e.g., haddock, redfish, and summer flounder).

The 32 species chosen for this assessment were:

Gadids

- Atlantic cod *(Gadus morhua)*
- Cusk *(Brosme brosme)*
- Haddock *(Melanogrammus aeglefinus)*
- Pollock *(Pollachius pollachius)*
- Red hake *(Urophycis chuss)*
- Silver hake *(Merluccius bilinearis)*
- White hake *(Urophycis tenuis)*

Pleuronectids

- American plaice *(Hippoglossoides platessoides)*
- Winter flounder *(Pseudopleuronectes americanus)*
- Witch flounder (Glyptocephalus cynoglossus)
- Yellowtail flounder (Pleuronectes ferruginea)

Elasmobranchs

- Barndoor skate (Dipturus laevis)
- Clearnose skate (Raja eglanteria)
- Little skate *(Raja erinacea)*
- Rosette skate *(Leucoraja garmani)*
- Spiny dogfish (*Squalus acanthias*
- Thorny skate (*Amblyraja radiata*)

Offshore Wintering Guild

- Black sea bass (*Centropristis striata*)
- Northern sea robin (*Prionotus carolinus*
- Scup (*Stenotomus chrysops*)
- Summer flounder (*Paralichthys dentatus*)

Mid-Atlantic Estuarine

- Atlantic croaker (*Micropogonias undulatus*)
- Spot (*Leiostomus xanthurus*)
- Weakfish (*Cynoscion regalis*)

Other Species of Interest

- Acadian redfish *(Sebastes fasciatus)*
- Atlantic halibut *(Hippoglossus hippoglossus)*
- Atlantic wolffish *(Anarhichas lupus)*
- Golden tilefish *(Lopholatilus chamaeleonticeps)*
- Longhorn sculpin *(Myoxocephalus octodecimspinosus)*
- Monkfish *(Lophius americanus)*
- Ocean pout *(Zoarces americanus)*
- Tautog *(Tautoga onitis)*

Population Status and Importance of Northwest Atlantic Region

The global distribution of the demersal fish species included in the group is limited to the Atlantic Ocean, with the exception of spiny dogfish which are distributed throughout many of the world's oceans. Distributions are limited primarily to nearshore coastal waters and along the Continental Shelf and are controlled by a variety of factors, with water temperature among the most important. Variations in water temperature are especially important because thermal extremes have a greater effect on the distribution of most organisms than mean annual temperatures. Density and biomass are highest in areas with broad annual ranges in temperature, and lowest in areas with low annual ranges, although this distribution is probably influenced also by other chemical and physical properties of water masses (Cook and Auster 2007). Several species in the group occur in both the Northwest and Northeast Atlantic, with the Northwest Atlantic representing an important center of distribution. These species include Acadian redfish, Atlantic cod, Atlantic halibut, Atlantic wolfish, American plaice, cusk, haddock, and pollock. Distribution of all other species within the assemblage is limited to the western side of the Atlantic, with the exception of spiny dogfish noted above (Collette and MacPhee 2002).

Analysis of species distribution using National Marine Fisheries Service (NMFS) bottom trawl survey data and other sources reveals distinct differences in species abundance, distribution, and composition within the Northwest Atlantic region itself, with Georges Bank representing a significant transition zone between colder-water species to the north in the Gulf of Maine and more temperate species in Southern New England and the Mid-Atlantic. According to Cook and Auster (2007), there appears to be a reasonably strong consensus about the existence of five distinct biogeographic regions on the Continental Shelf of the eastern United States and Nova Scotia, including the Scotian Shelf/Grand Banks, Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight. Each is characterized by a unique combination of oceanographic conditions, fish species assemblages, and a wide variety of invertebrate taxa. The boundary at Cape Cod appears to be so strong that some authorities consider it to be a break between two major provinces, the Eastern Temperate and Warm Temperate (Cook and Auster 2007). This transition zone at Georges Bank was also recognized by researchers studying benthic macroinvertebrates in the Northwest Atlantic, south of the Scotian Shelf. They found that the large majority of species off Nova Scotia and in the Gulf of Maine consists of boreal forms, whereas a significant component of the Georges Bank assemblage is temperate transitional or Virginian species because of the area's higher seasonal maximum temperatures (which preclude reproduction and/or growth of many subarctic or boreal species) (Theroux and Grosslein 1987).

The most recent peer reviewed stock assessments found that ten of the demersal species included in the stock assessment are overfished (less than half of biological goals for population size) and eight are subject to overfishing

(fishing mortality rates exceed target levels) (NEFSC 2008). However, several species that were once severely depleted are successfully rebuilding, including Acadian redfish, haddock, and summer flounder (NEFSC 2008; ASMFC 2009). Trends in relative abundance for each of the 32 species varied. While many species in the assemblage are declining, some are holding steady and others are increasing. These trends are often specific to different portions of the species' ranges.

A number of demersal fish species included in this assessment have been identified as Species of Concern. NMFS defines these as species about which they have some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act. Species of Concern included in the assemblage are Atlantic halibut, Atlantic wolfish, barndoor skate, cusk, and thorny skate. Of these five species, Atlantic halibut and barndoor skate are considered endangered by the IUCN and Atlantic wolffish and cusk are under status review by NMFS for potential Endangered Species Act listing (NMFS 2009a).

Ecosystem Interactions and Ecological Dependencies
The demersal species included in this assemblage are characterized by their close association with the seafloor for critical life stages and activities including feeding, usage of juvenile nursery areas, and spawning. High rates of productivity in the region provide an abundant food source for planktivores in the water column, while still allowing significant energy to reach the ocean floor to support benthic communities.

The trophic ecology of demersal fish species in the Northwest Atlantic is well studied. Many species are characterized as opportunistic generalists, feeding on a variety of prey items ranging from plankton to benthic macroinvertebrates or fishes depending on life stage (Link and Garrison 2002). Larval and juvenile life stages of many demersal fish are a significant food source for adult life stages of species, and cannibalism is not uncommon. Many demersal fishes exhibit ontogenetic (size-specific) shifts in diet, switch among prey items according to their availability, and exhibit dietary preference for small pelagic fish.

In contrast to other ecosystems, the food web of the northeast United States Continental Shelf ecosystem is highly connected and complex, consisting of weak species interactions (Link and Garrison 2002). It has been inferred that production in this region is tightly bound, with most of the fish production being consumed by other fish species (Sissenwine et al. 1982). These apparent energetic constraints can result in relatively stable levels of overall biomass and production of fish, although dramatic fluctuations at the individual species level are routinely observed. Such fluctuations were observed on Georges Bank in the mid- to late 1980s as populations of elasmobranchs (skates and dogfish) increased in response to significant declines in cod, haddock, and flounder populations due to fishing pressure (Fogarty and Murawski 1998). Similar changes in trophic dynamics were observed in coastal portions of the Gulf of Maine when depletion of cod and other large predatory fishes fundamentally altered the food web, leading to significant increases in lobsters, crabs, and sea urchins in the coastal zone (Steneck 1997). These studies and others demonstrate the degree to which populations of some species in the assemblage (and other marine species) are directly influenced by changes in the relative abundance of others.

In addition to species-specific trophic interactions, many demersal species in the assemblage display strong associations with a range of benthic habitats during various life stages. For example, survivorship of juvenile cod is known to be higher in substrates with greater structural complexity, and it has been suggested that gravel substrate may represent a limiting resource for the early life stages of cod and haddock (Fogarty and Murawski 1998). Nearshore coastal and estuarine habitats are especially important for a number of the Southern New England and mid-Atlantic species in the group. Atlantic croaker, summer flounder, spot, tautog, and winter flounder display obligate utilization of these habitats (they use them by necessity), and many others, including black sea bass and displaying facultative (non-obligatory) use. Golden tilefish are known to be important modifiers and creators of habitat on the outer Continental Shelf and along the slopes and walls of submarine canyons, creating elaborate “pueblo villages” of burrows within clay substrates, presumably to avoid predation (Able et al. 1982; Grimes et al. 1986). Tilefish burrows provide habitat for a variety of other species, including crustaceans, lobster, conger eel, cusk, hake, and ocean pout.

Northwest Atlantic Distribution and Important Areas

Methods

See methods overview in Chapter 5.

Data Limitations

Relative distribution, weighted persistence, and trends analyses for the demersal fish group were based upon data from the NMFS bottom trawl survey database. Otter trawl systems like the one utilized to conduct survey sampling are specifically designed to capture a variety of demersal fish species, including many of the species analyzed in this assessment. It is important to note, however, that the catch rates for various species within the group are variable. Catchability coefficients are generally higher for demersal, round-bodied species including Atlantic cod, haddock, pollock and hake and lower for flat-bodied fish and pelagic species. In additional, catch rates at any given location can be heavily influenced by day/night differences in species distribution within in the water column, and by seasonal variations in species distribution within their geographic range. As such, it should be recognized that while analyses derived from the bottom trawl survey database are indeed informative, results obtained from other data sources should also be considered.

Maps, Analysis, and Areas of Importance

Gadids

Atlantic cod (Figure 7-1a, b), haddock (Figure 7-3a, b), and pollock (Figure 5a, b) were distributed across the Gulf of Maine, Georges Bank and Southern New England, occurring in high numbers along the northern edge and Northeast Peak of Georges Bank. High numbers of Atlantic cod and pollock were also found to occur along the 50 fathom curve in the western Gulf of Maine. Statistical analyses indicated a declining trend for Atlantic cod (Figure 7-1c, d) and pollock (Figure 7-5c, d) across much of their range, though increasing trends were observed for Atlantic cod in parts of the Jeffreys Ledge and Stellwagen Bank area and in discrete areas around the perimeter of Georges Bank. Statistical analyses for haddock did not reveal significant trends across much of their range, though increasing trends were observed on parts of Georges Bank, in the Great South Channel, and shelf waters off the coast of New Jersey (Figure 7-3c, d). Haddock declined in the Gulf of Maine in small portions of the Jeffreys Ledge and Stellwagen Bank area and along the coastal shelf in eastern Maine off of Penobscot Bay.

Weighted persistence analyses identified the Northern Edge and Northeast Peak of Georges Bank, and the Great South Channel as important areas for Atlantic cod (Figure 7-2), haddock (Figure 7-4), and pollock (Figure 7-6). The southern flank of Georges Bank was also important for haddock. In the Gulf of Maine, nearshore waters of Massachusetts Bay, Jeffreys Ledge, and Stellwagen Bank were identified as important for these three species, as were the Cashes Ledge area, the coastal shelf off Penobscot Bay in eastern Maine, and the area between Grand Manan Banks and German Bank off of Nova Scotia.

Cusk were widely dispersed throughout the Gulf of Maine and along the northern perimeter of Georges Bank (Figure 7-7a, b). High numbers occurred in the deeper waters of the central Gulf of Maine, including waters extending from Cashes Ledge through the Jordan Basin and onto the Scotian Shelf in Canadian waters. Statistical analyses for cusk generally found no significant trend across much of their range, though declining trends were observed in portions of the Gulf of Maine, including near Franklin Swell, the northern tip of Jeffreys Ledge, off the southern coast of Nova Scotia near Grand Manan Banks and German Bank, and along the Northeast Peak of Georges Bank (Figure 7c, d). Weighted persistence analyses for cusk identified Jeffreys Ledge, waters west of Cashes Ledge to Sewell Ridge, the Northeast Channel, and the Northern Edge/Northeast Peak of Georges Bank as important areas (Figure 7-8).

High numbers of red hake were found on Jeffreys Ledge and Stellwagen Bank in the Gulf of Maine, along the perimeter of Georges Bank, along the Continental Shelf and Slope break in Southern New England as far south as

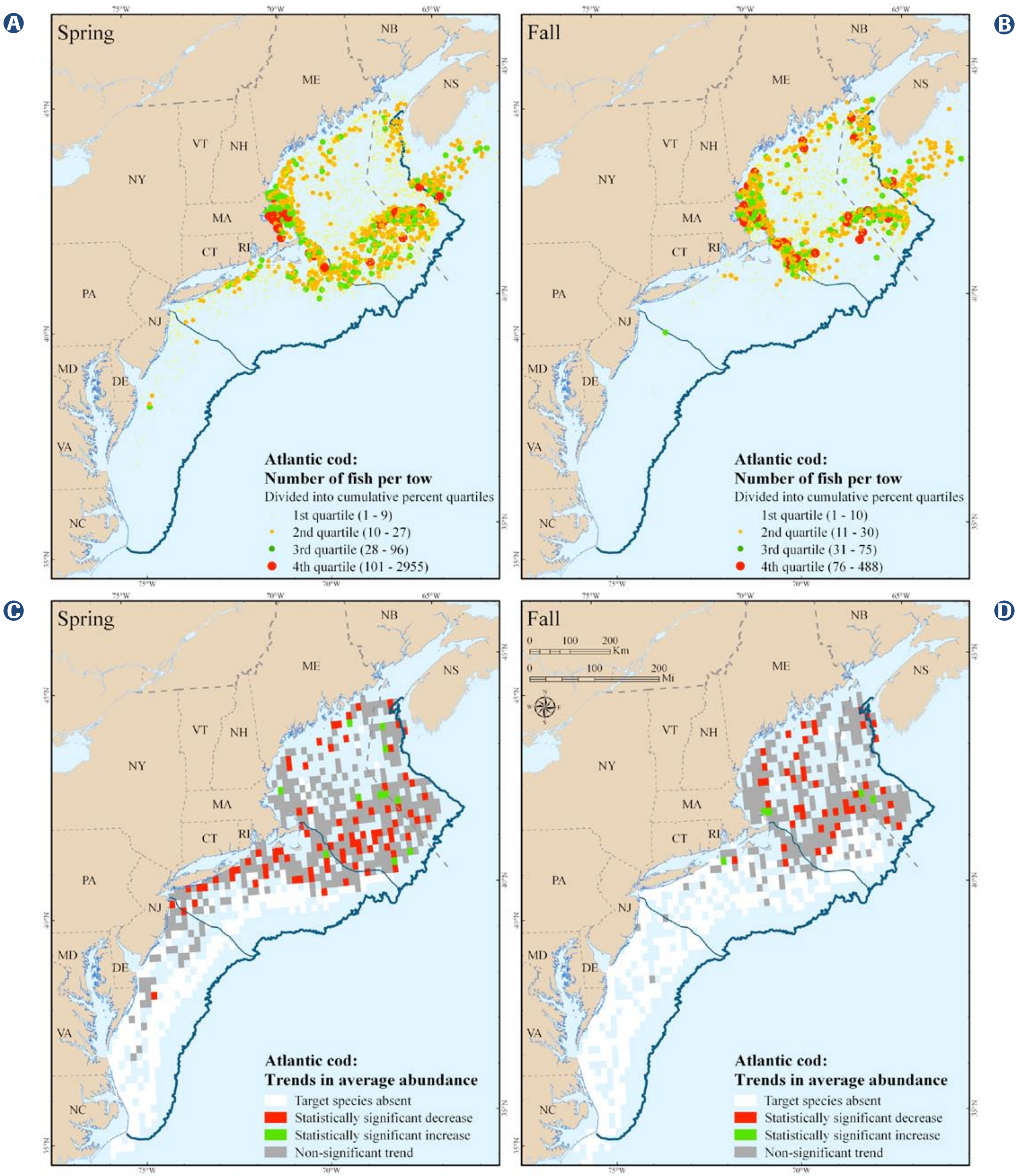


Figure 7-1. Trends in average abundance over 40 years for Atlantic cod during the spring and fall seasons.

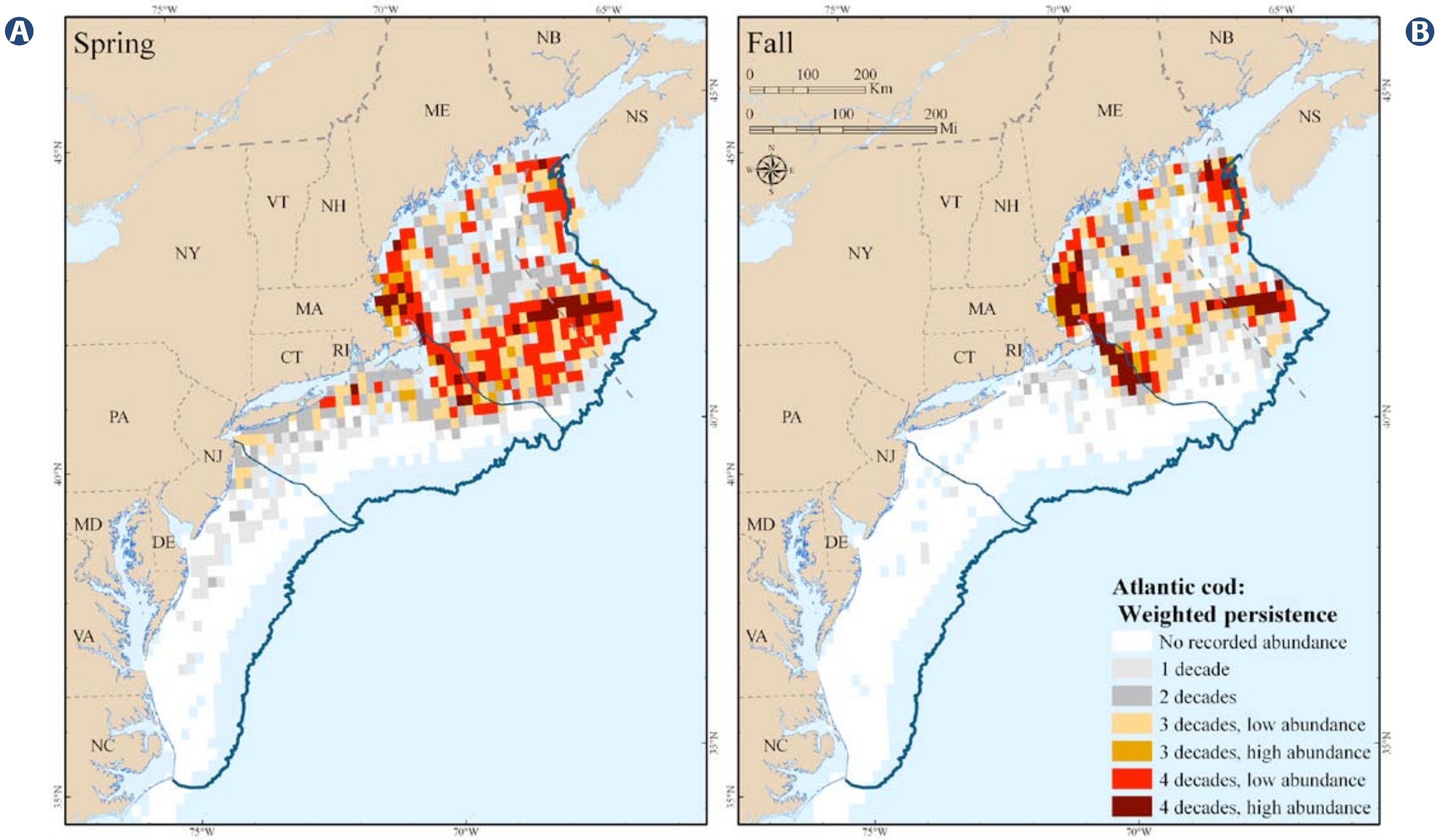


Figure 7-2. Areas with high persistence and abundance over 40 years for Atlantic cod during the spring and fall seasons.

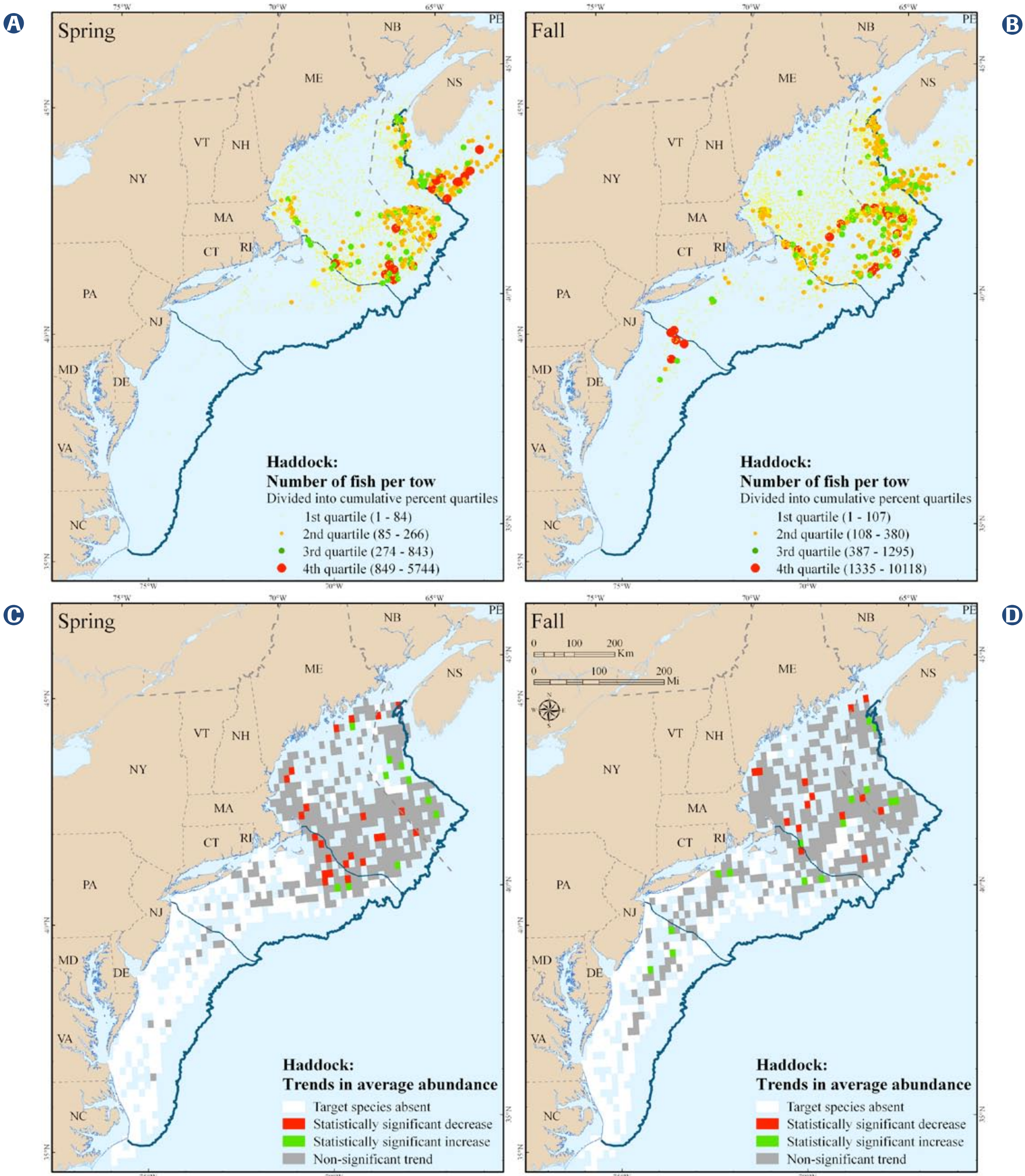


Figure 7-3. Trends in average abundance over 40 years for haddock during the spring and fall seasons.

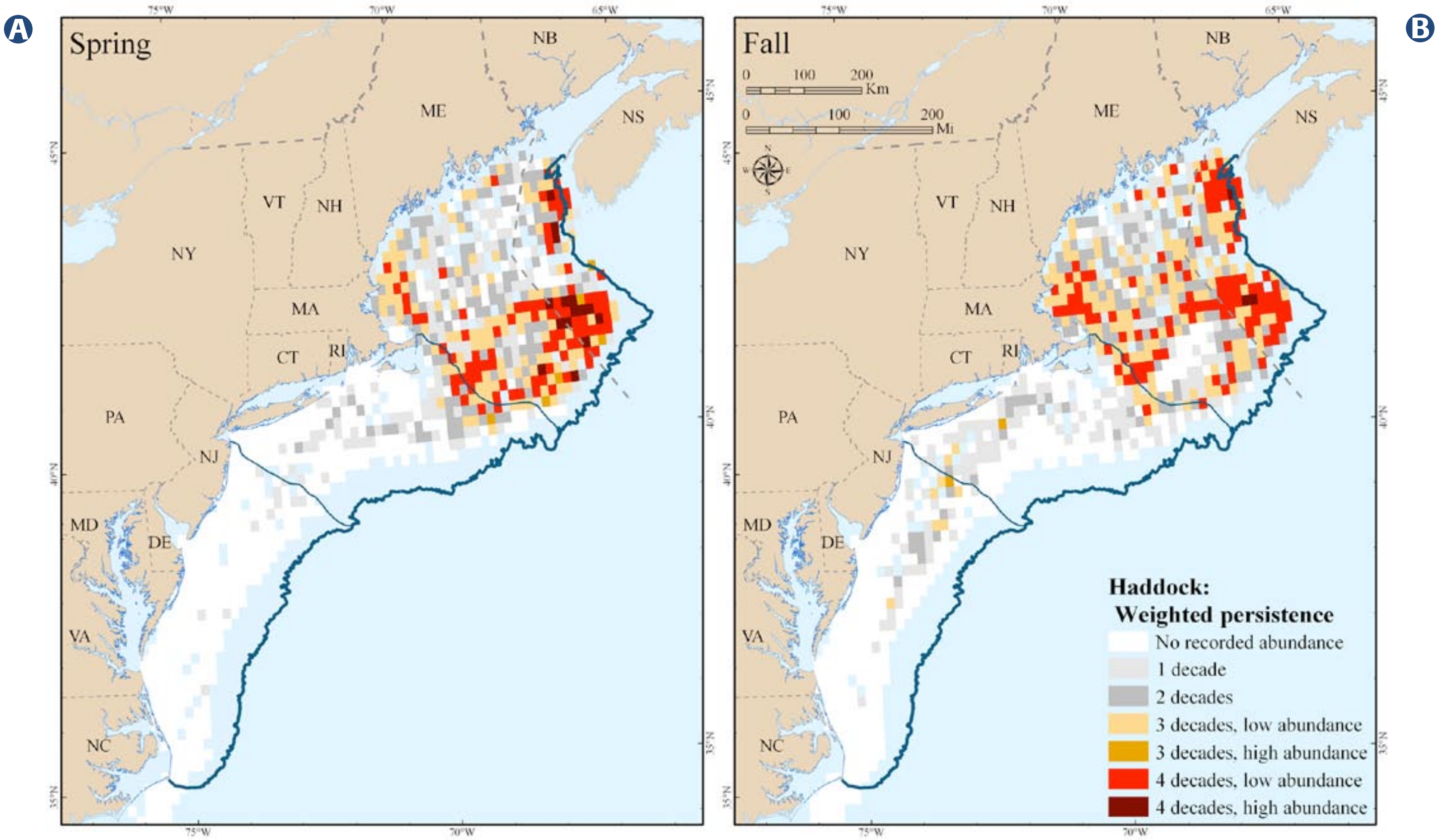


Figure 7-4. Areas with high persistence and abundance over 40 years for haddock during the spring and fall seasons.

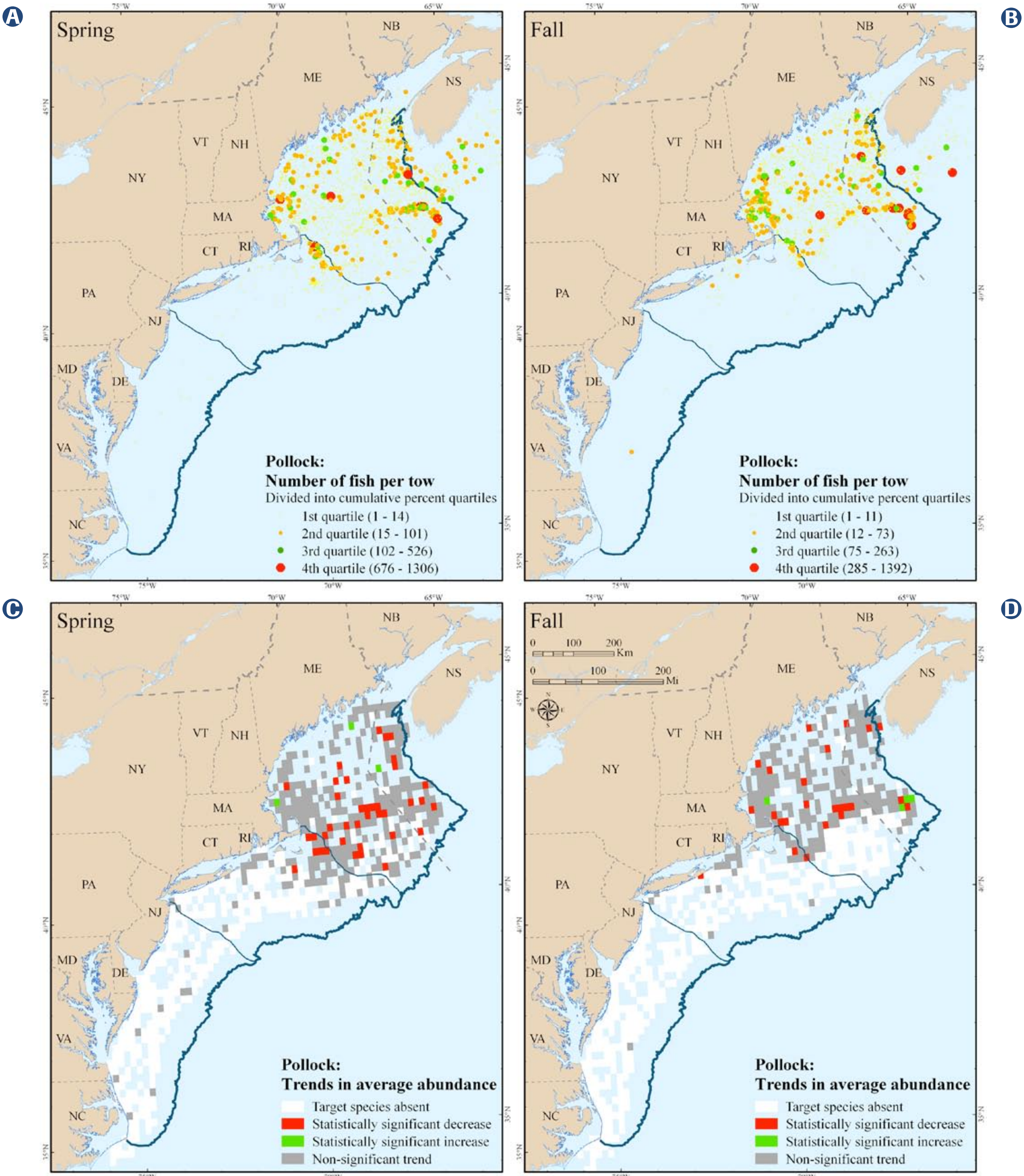


Figure 7-5. Trends in average abundance over 40 years for pollock during the spring and fall seasons.

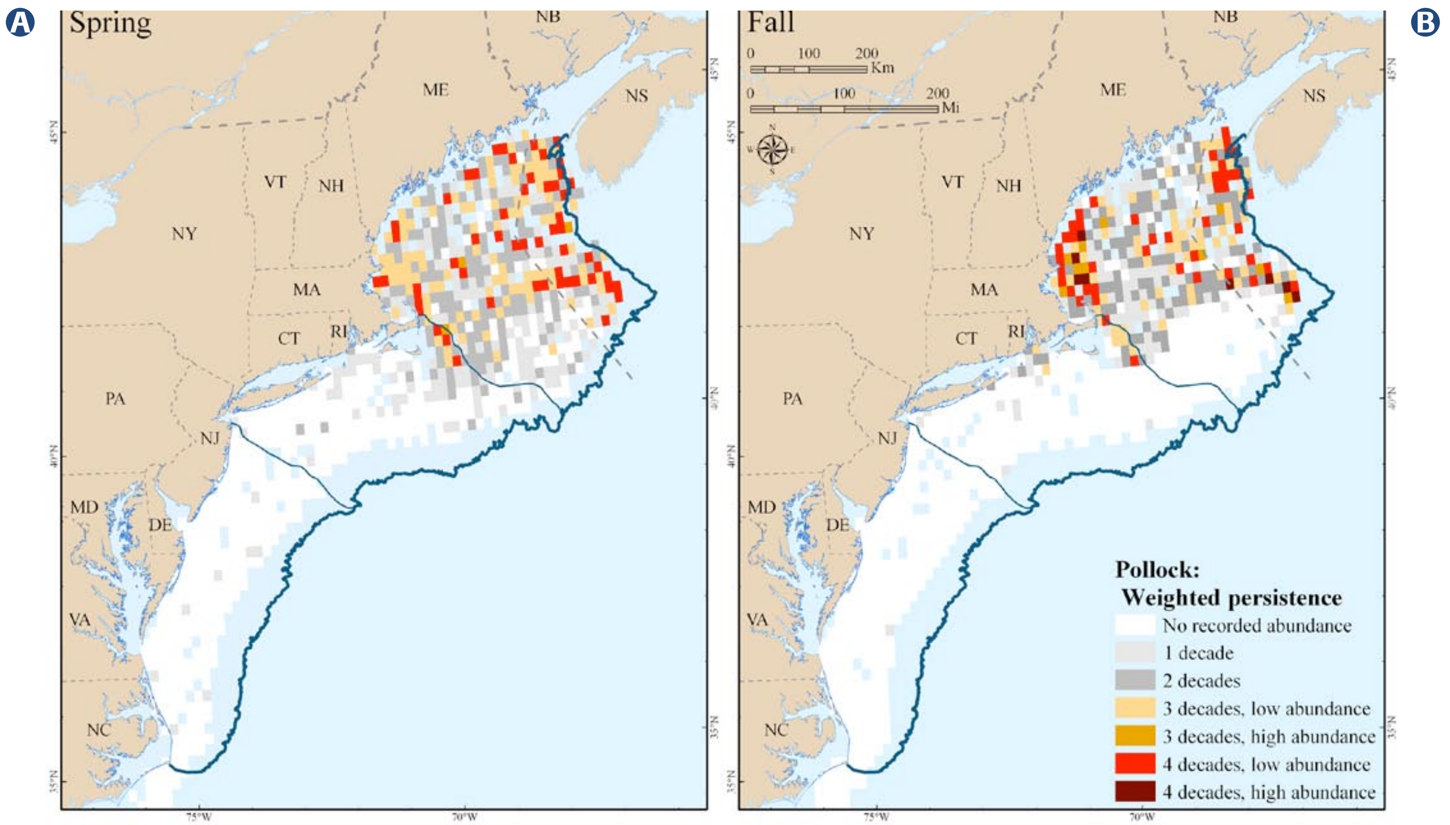


Figure 7-6. Areas with high persistence and abundance over 40 years for pollock during the spring and fall seasons.

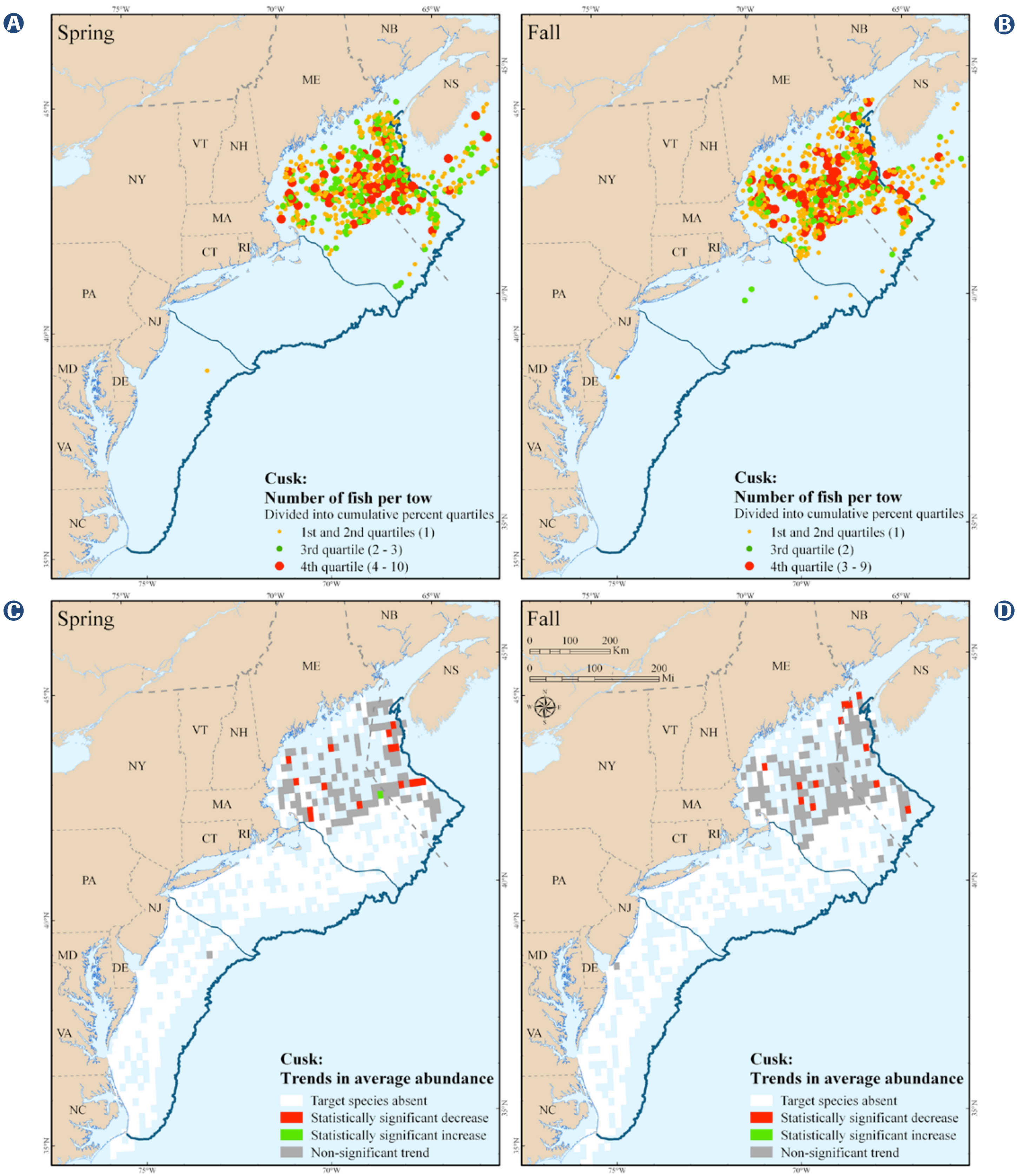


Figure 7-7. Trends in average abundance over 40 years for cusk during the spring and fall seasons.

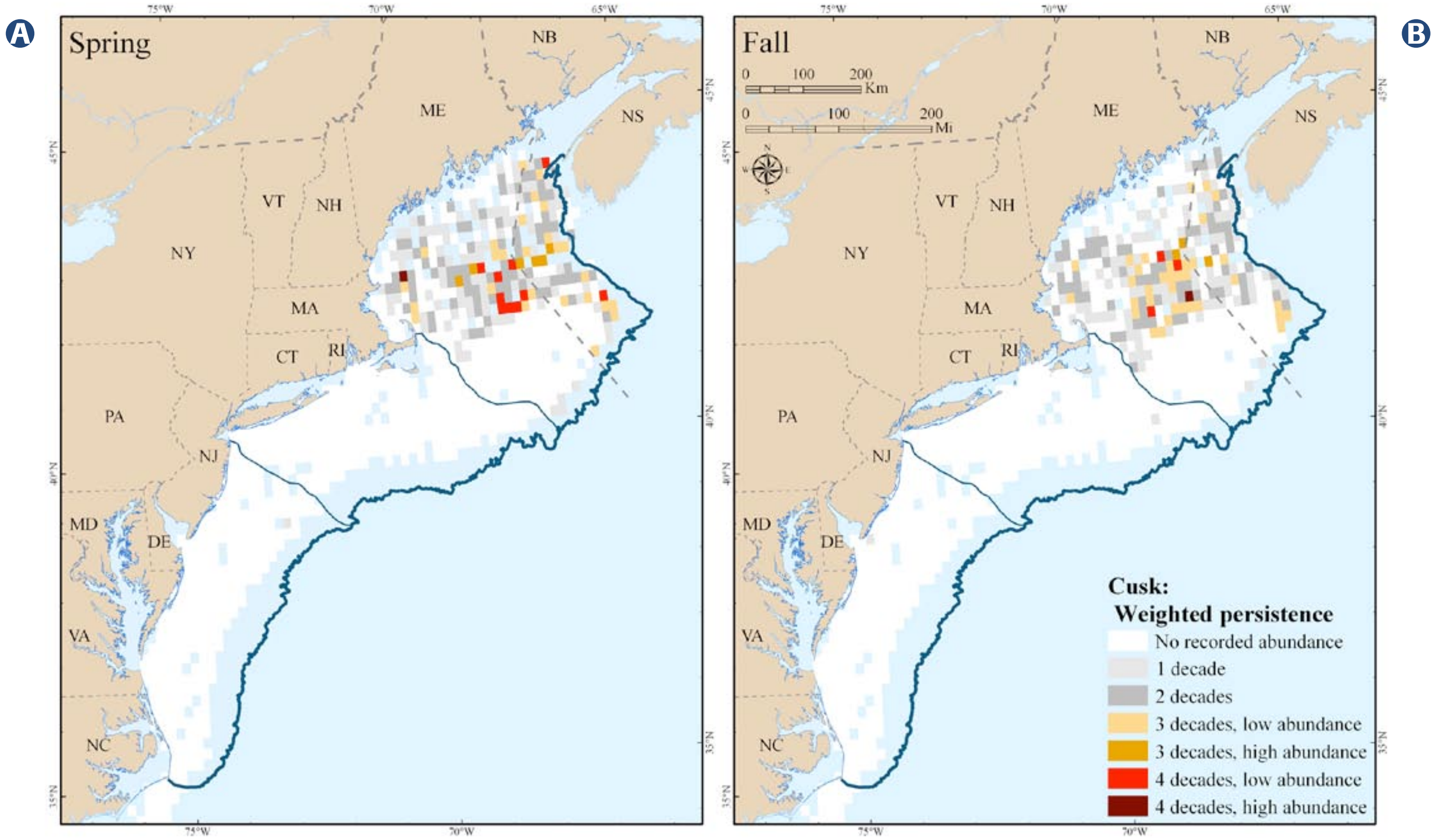


Figure 7-8. Areas with high persistence and abundance over 40 years for cusk during the spring and fall seasons.

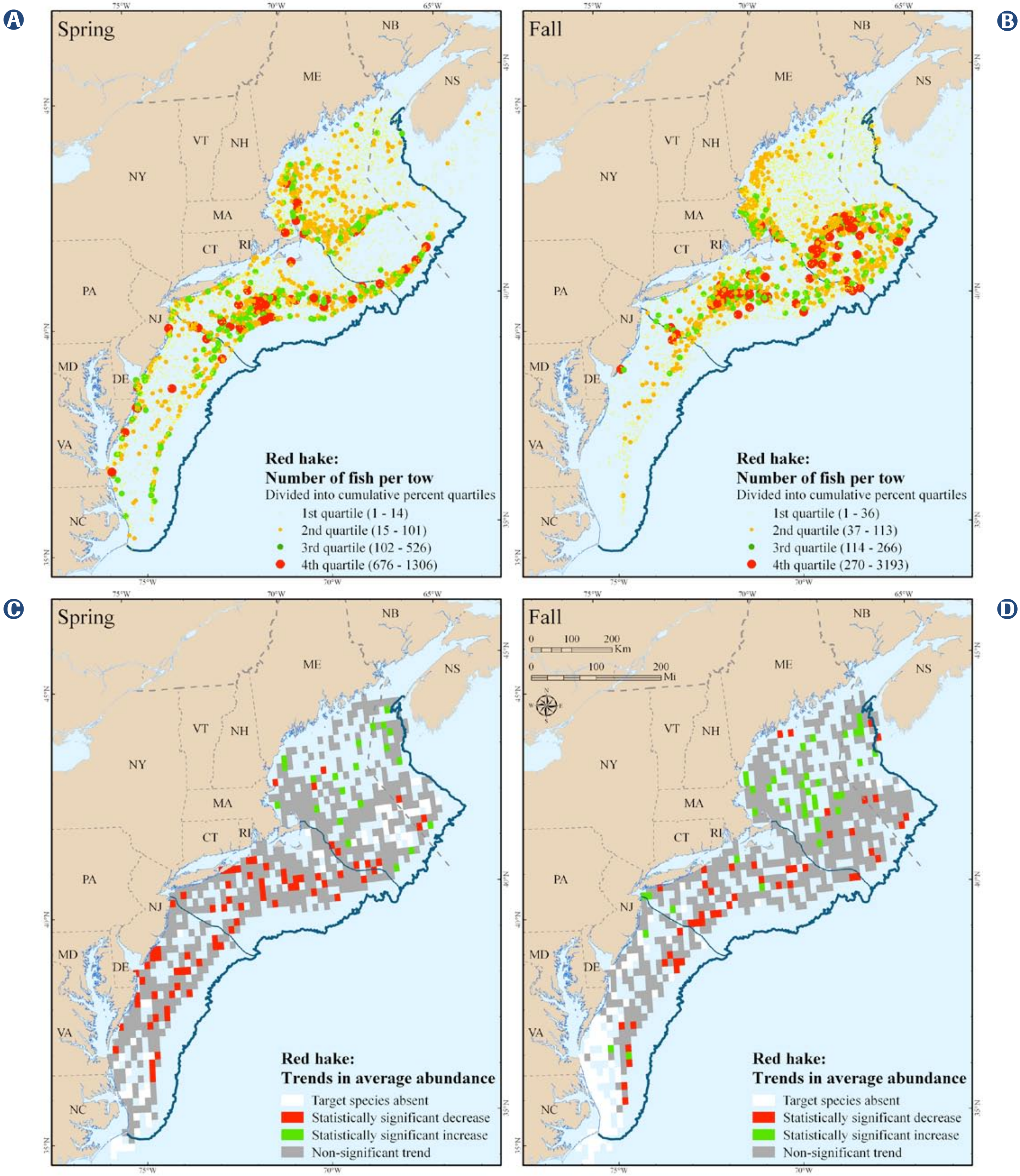


Figure 7-9. Trends in average abundance over 40 years for red hake during the spring and fall seasons.

Delaware Bay (Figure 7-9a, b). Statistical analyses indicated generally increasing trends for red hake in the Gulf of Maine and decreasing trends in much of Southern New England and the Mid-Atlantic Bight area, particularly along the shelf/slope break (Figure 7-9c, d). Weighted persistence analyses for red hake identified the 50 fathom curve from Jeffreys Ledge through the Great South Channel to the Northern Edge of Georges Bank, and a large area along the Continental Shelf extending from Long Island to Great Bay, New Jersey as important areas (Figure 7-10). In the spring, coastal waters from Delaware Bay to Cape Henry, Virginia were also important.

High numbers of silver hake were found in the deeper waters of the Gulf of Maine and along the coastal shelf from Jeffreys Ledge to Outer Schoodic Ridge and in shelf waters of Southern New England from Nantucket Shoals to Barnegat Bay, New Jersey (Figure 11a, b). Statistical analyses for silver hake revealed a pattern similar to red hake, with increasing trends observed in the Gulf of Maine and

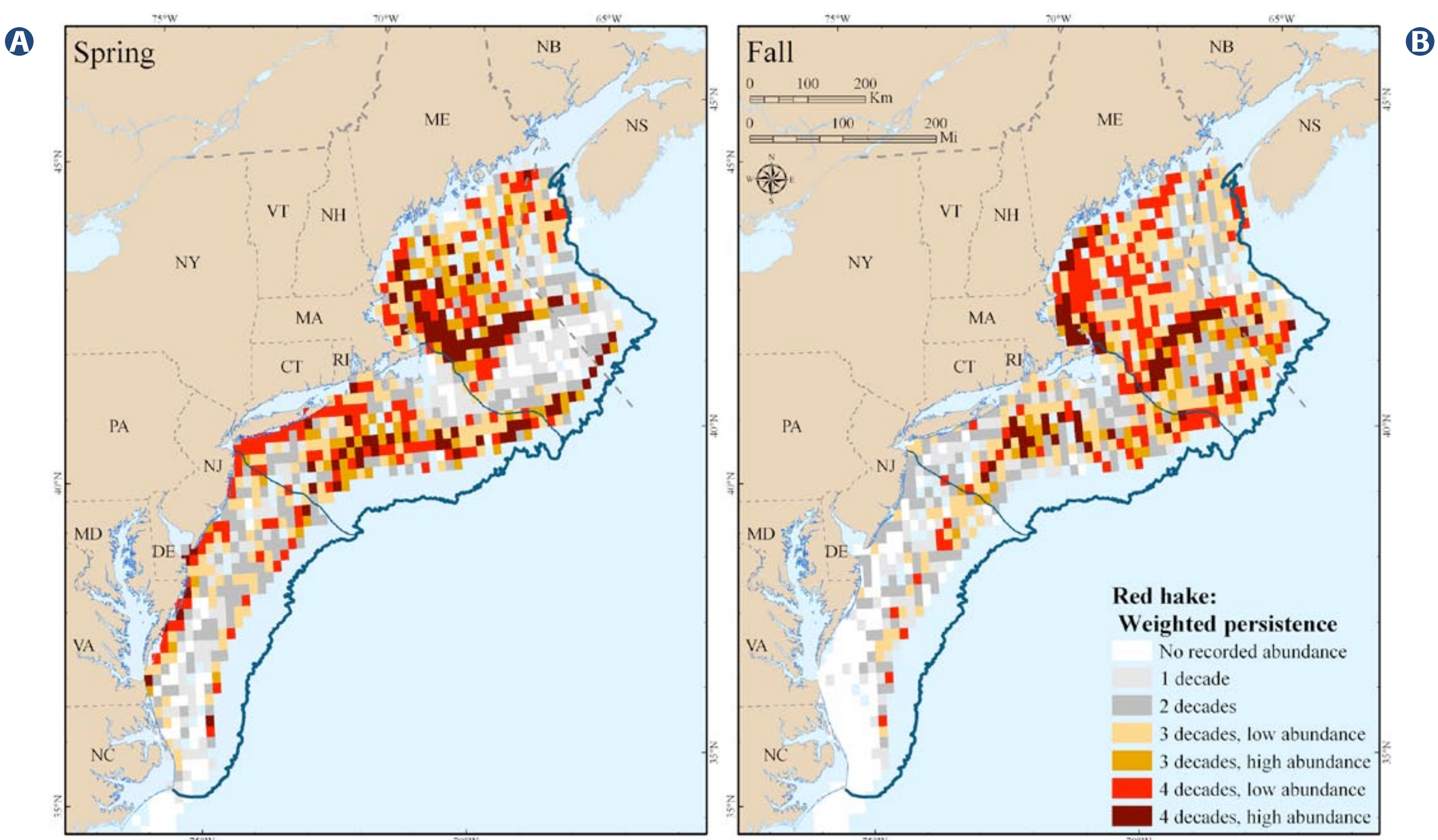


Figure 7-10. Areas with high persistence and abundance over 40 years for red hake during the spring and fall seasons.

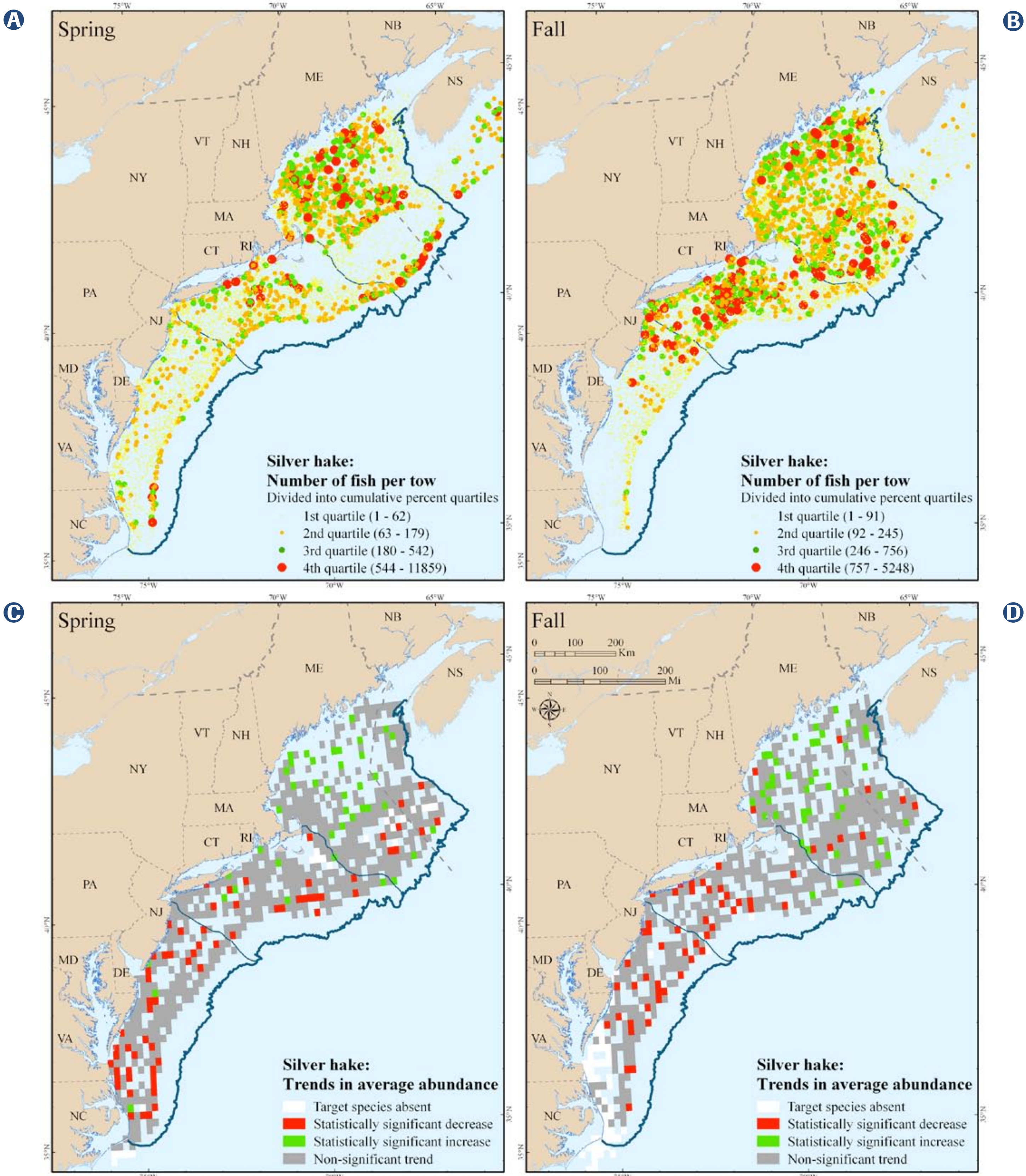


Figure 7-11. Trends in average abundance over 40 years for silver hake during the spring and fall seasons.

decreasing trends observed across much of the Southern New England/Mid-Atlantic Bight area (Figure 7-11c, d). Weighted persistence analyses for silver hake identified the coastal shelf and deeper basin waters in the Gulf of Maine, the Cultivator Shoals area on Georges Bank, and a large area along the Continental Shelf from the coast of Long Island to the Nantucket Lightship as areas of importance (Figure 7-12).

High numbers of white hake were found predominantly in the deep basins of the Gulf of Maine and along the perimeter of Georges Bank into Southern New England (Figure 7-13a, b). Statistical analyses for white hake generally found no significant trend across much of their range, though decreasing trends were observed at discrete locations along the 50 fathom curve in the Gulf of Maine, along the perimeter of Georges Bank, and along the shelf/slope break off of Long Island Sound (Figure 7-13c, d). Weighted persistence analyses for white hake identified Wilkinson Basin, Jordan Basin, Georges Basin, and shelf waters from Grand Manan Banks to German Bank as important areas (Figure 7-14).

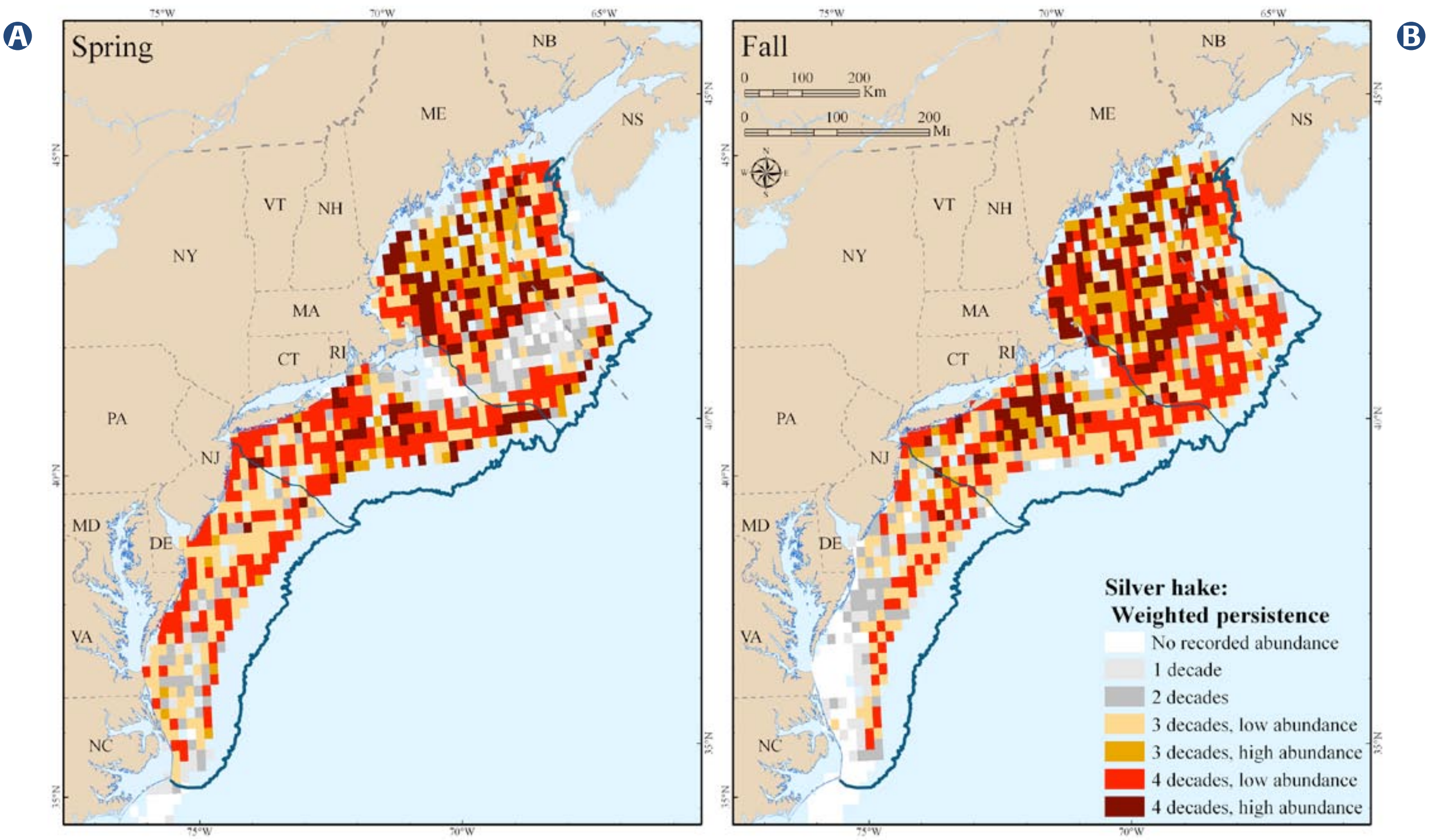


Figure 7-12. Areas with high persistence and abundance over 40 years for silver hake during the spring and fall seasons.

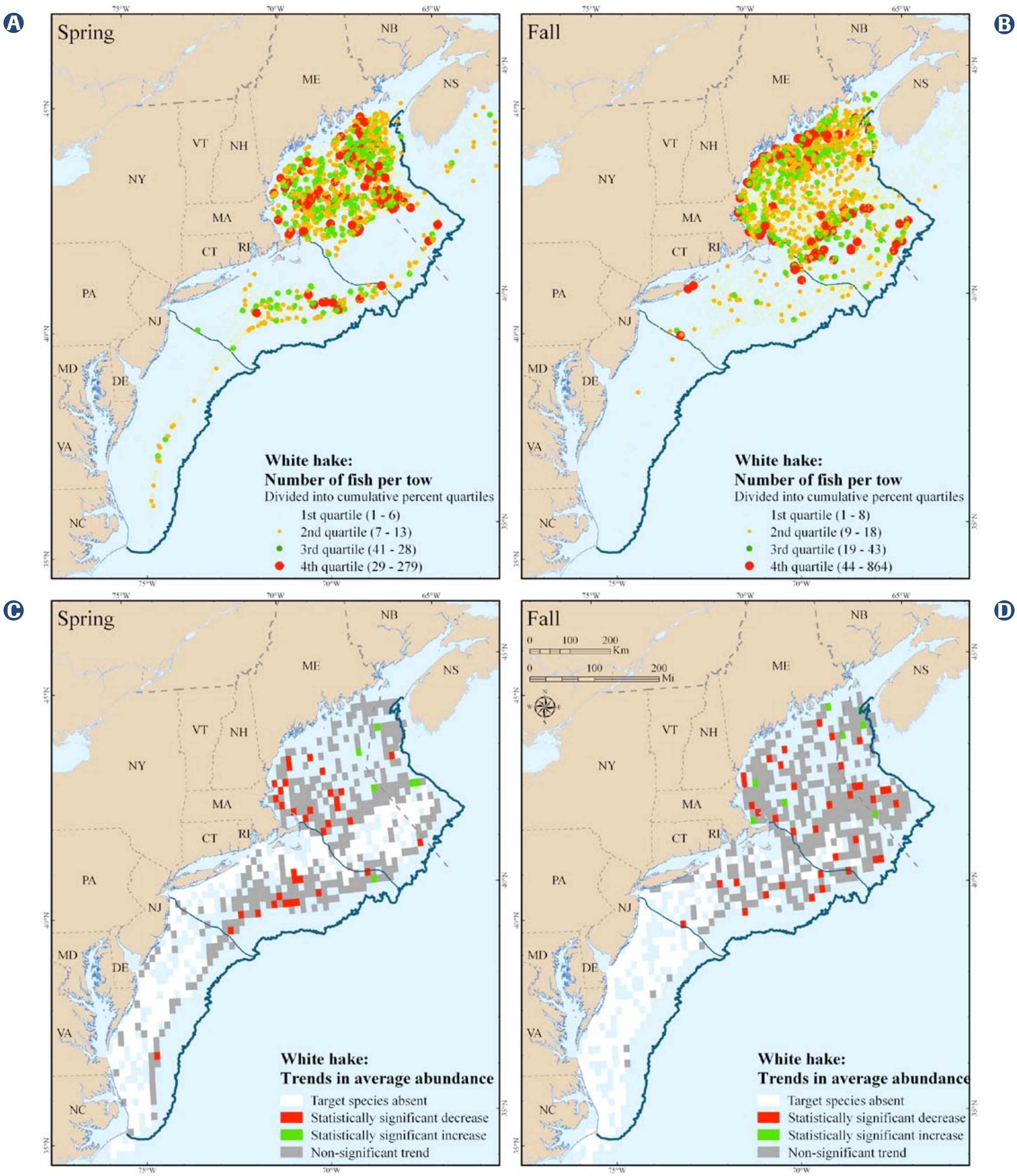


Figure 7-13. Trends in average abundance over 40 years for white hake during the spring and fall seasons.

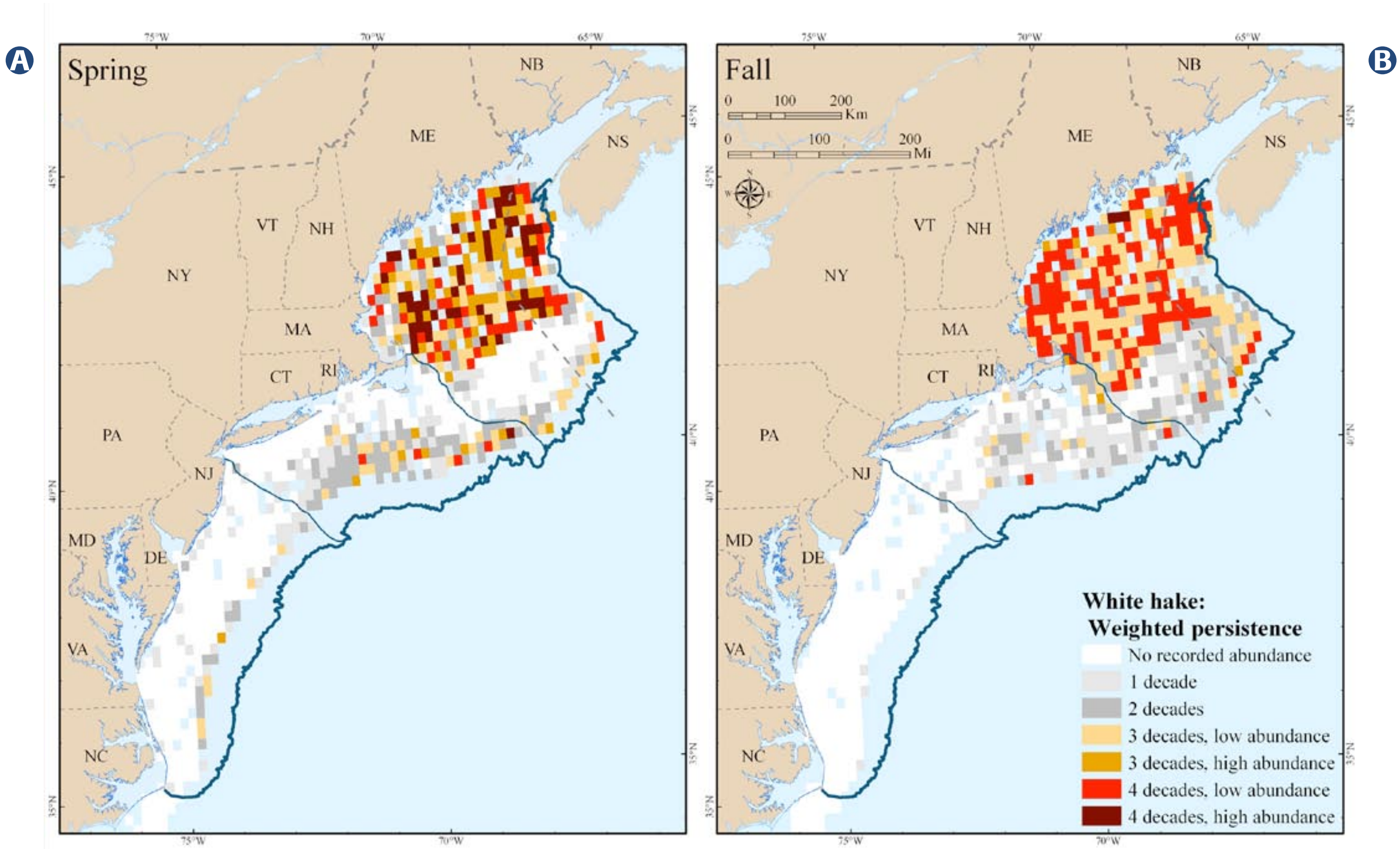


Figure 7-14. Areas with high persistence and abundance over 40 years for white hake during the spring and fall seasons.

A B C D

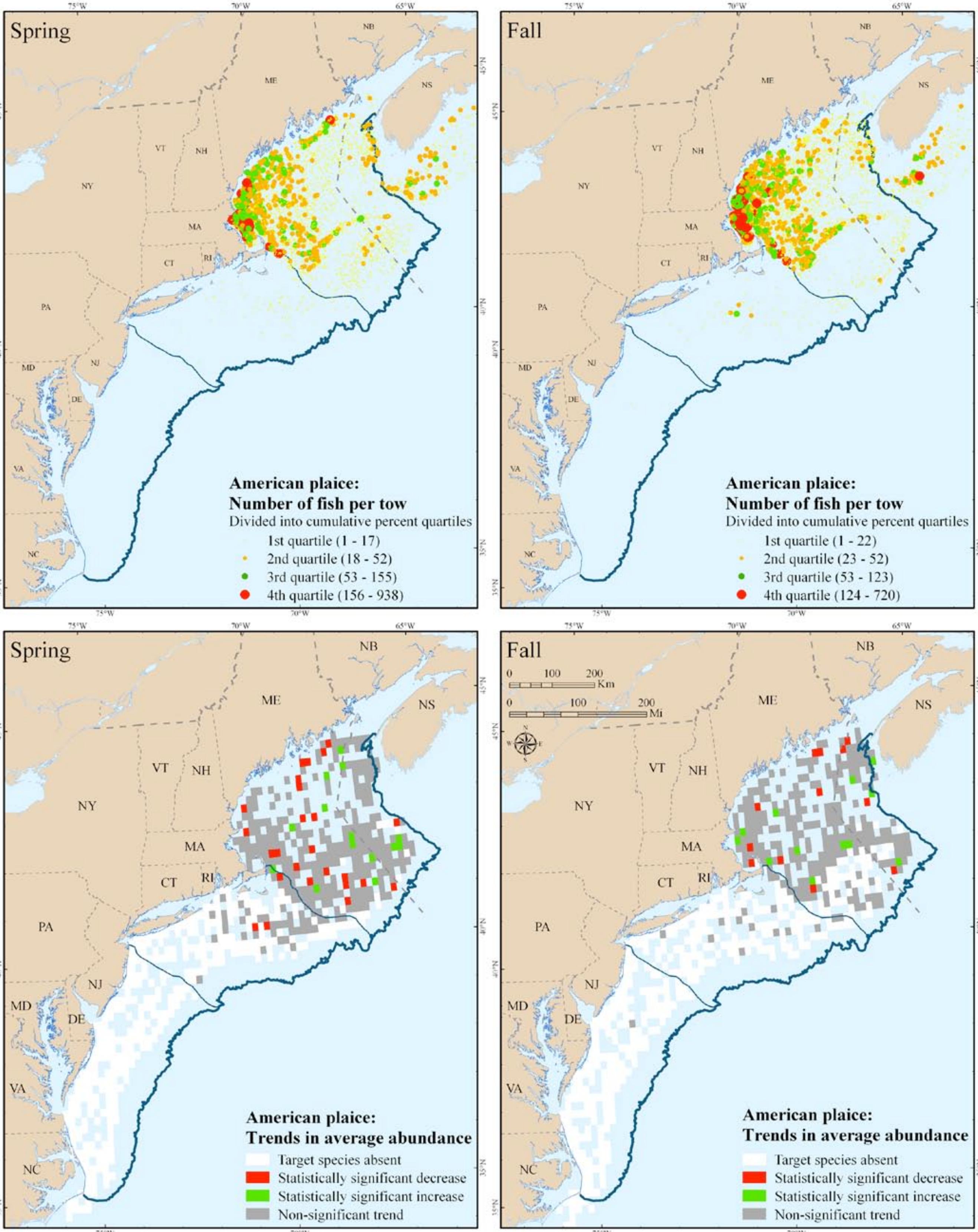


Figure 7-15. Trends in average abundance over 40 years for American plaice during the spring and fall seasons.

Plueronectids

The pluronectid (or flatfish) group was found across much of the Northwest Atlantic, although distinct differences in distributions within the region were apparent. American plaice were distributed across much of the Gulf of Maine and Georges Bank, with highest numbers occurring along the 50 fathom curve from Cape Cod to the northern tip of Jeffreys Ledge and in the northern portions of Wilkinson Basin (Figure7-15a, b). Very few were found south of Cape Cod. Statistical analyses did not identify any significant trends over the range during the time series, though decreasing trends were observed in the spring across many parts of the Gulf of Maine (Figure 7-15c, d). Weighted persistence analyses for American plaice identified waters along the 50 fathom curve in the western Gulf of Maine from Cape Cod Bay to Casco Bay, portions of the central Gulf of Maine including Wilkinson Basin and the Cashes Ledge area, and the eastern side of the Great South Channel and Cultivator Shoals as important areas (Figure 7-16).

Winter flounder were distributed from the Gulf of Maine south to Delaware Bay, with highest numbers occurring in nearshore waters in the western Gulf of Maine through the Great South Channel and into Southern New England as far south as Barnegat Bay, New Jersey (Figure 7-17a, b). Statistical analyses generally did not find significant trends over the time series, though declining trends were observed along the southern flank of Georges Bank to nearshore waters from Long Island Sound to Chesapeake Bay, while increasing trends were observed around Massachusetts Bay in the western Gulf of Maine and off the southwest coast of Nova Scotia (Figure 7-17c, d). Weighted persistence analyses for winter flounder identified waters from Grand Manan Banks to German Bank off the southwest coast of Nova Scotia, nearshore waters from Massachusetts Bay to Nantucket Shoals, and nearshore waters from Block Island to Sandy Hook, New Jersey as important areas (Figure 7-18).

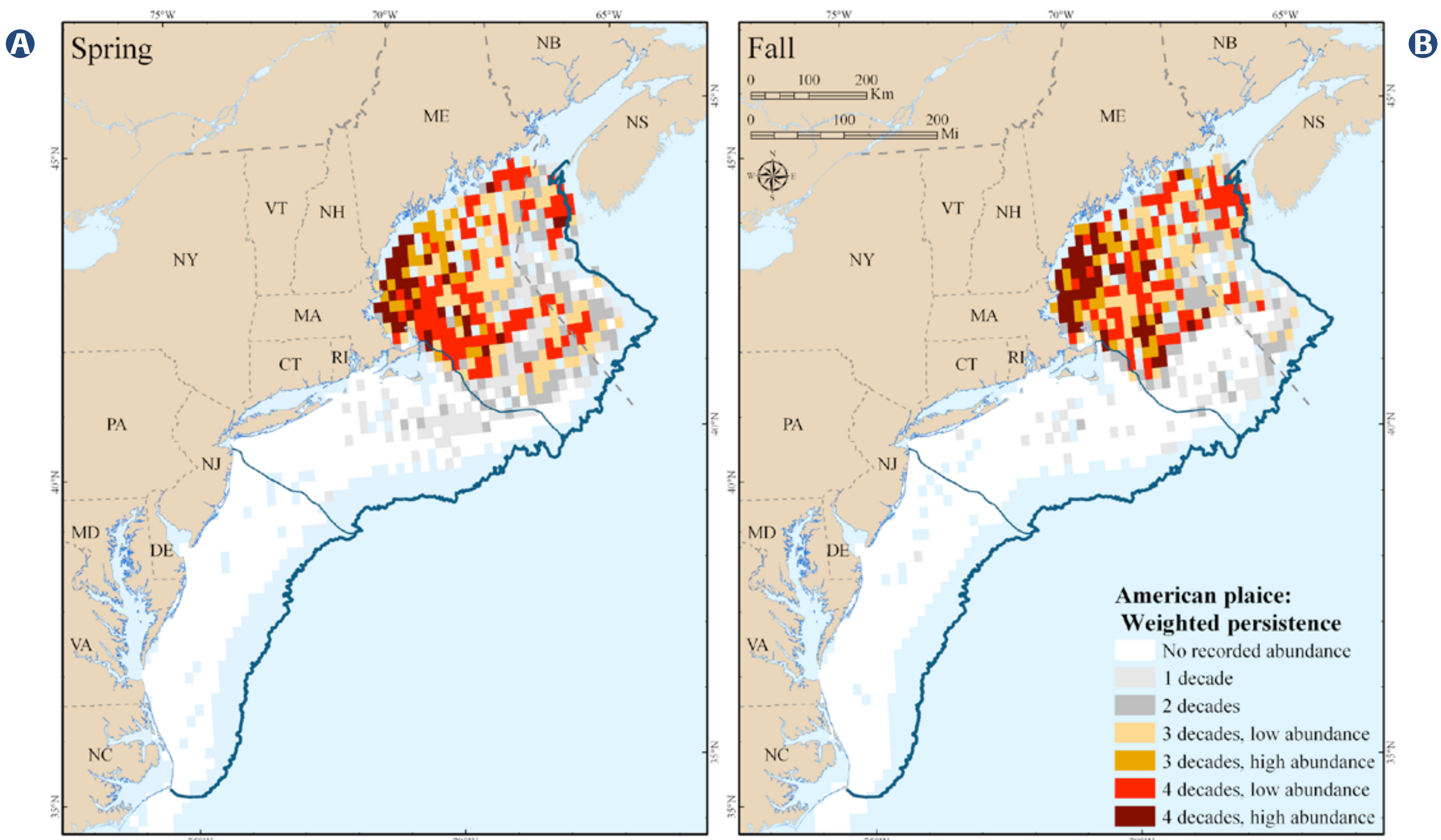


Figure 7-16. Areas with high persistence and abundance over 40 years for American plaice during the spring and fall seasons.

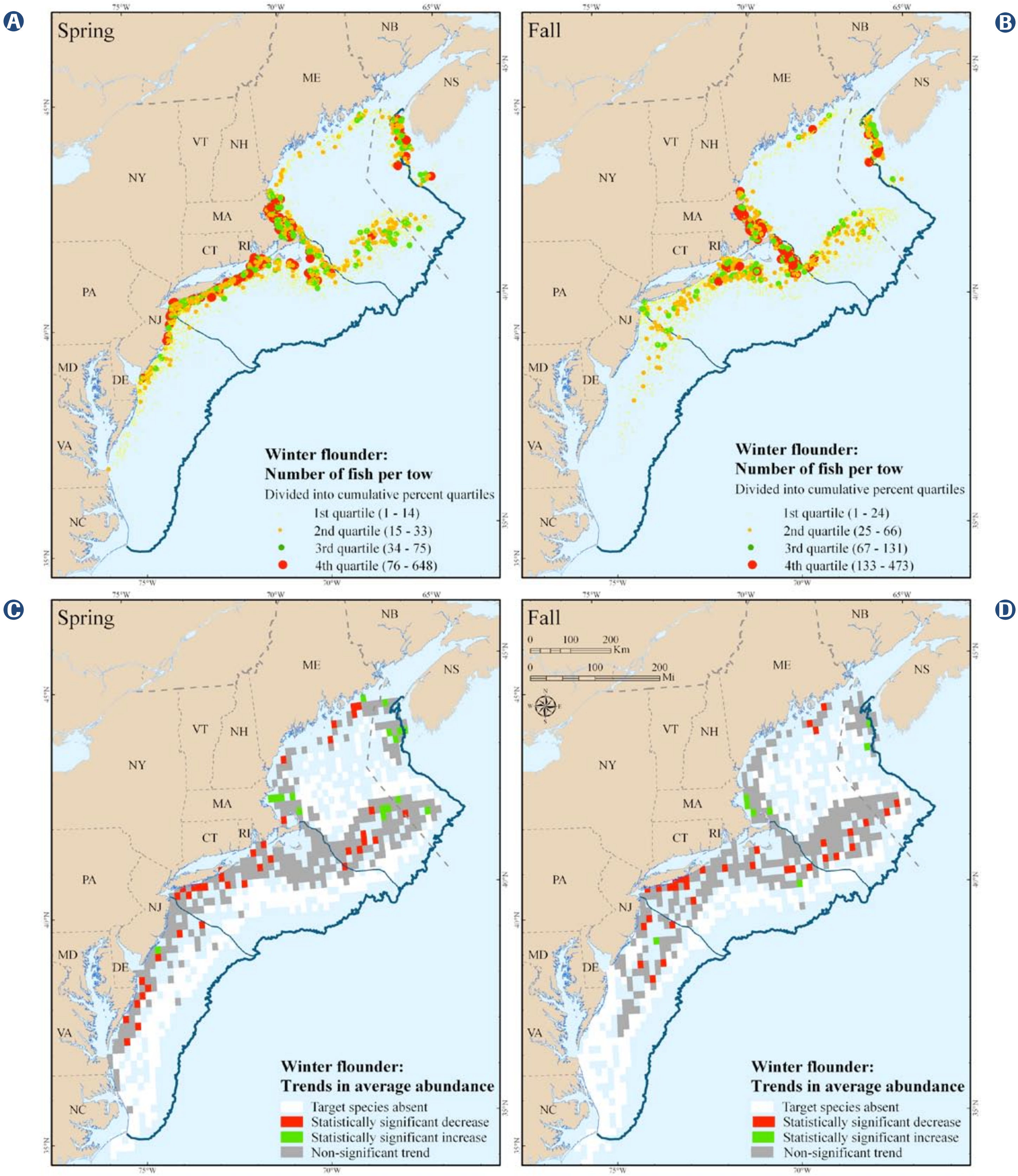


Figure 7-17. Trends in average abundance over 40 years for winter flounder during the spring and fall seasons.

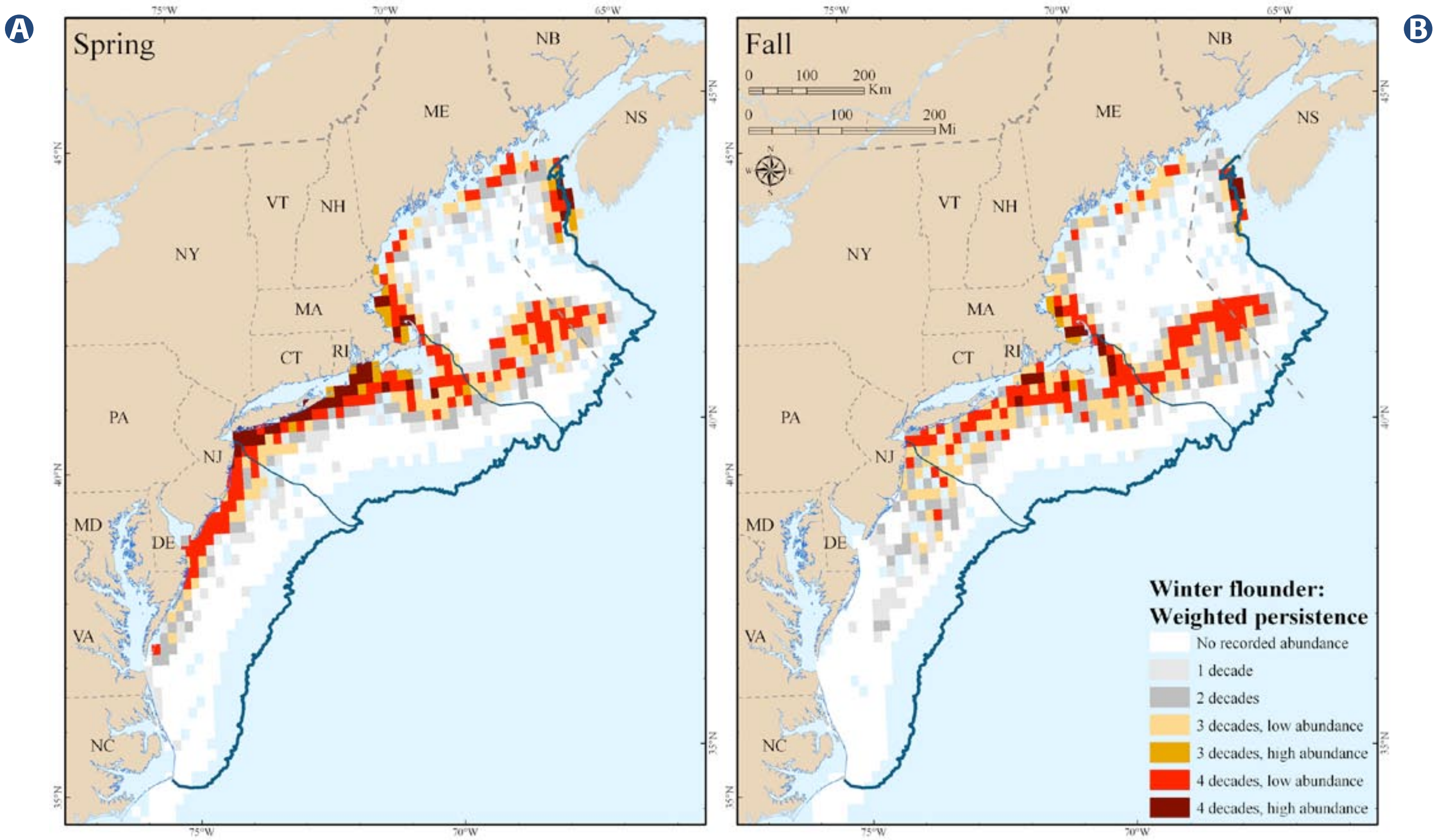


Figure 7-18. Areas with high persistence and abundance over 40 years for winter flounder during the spring and fall seasons.

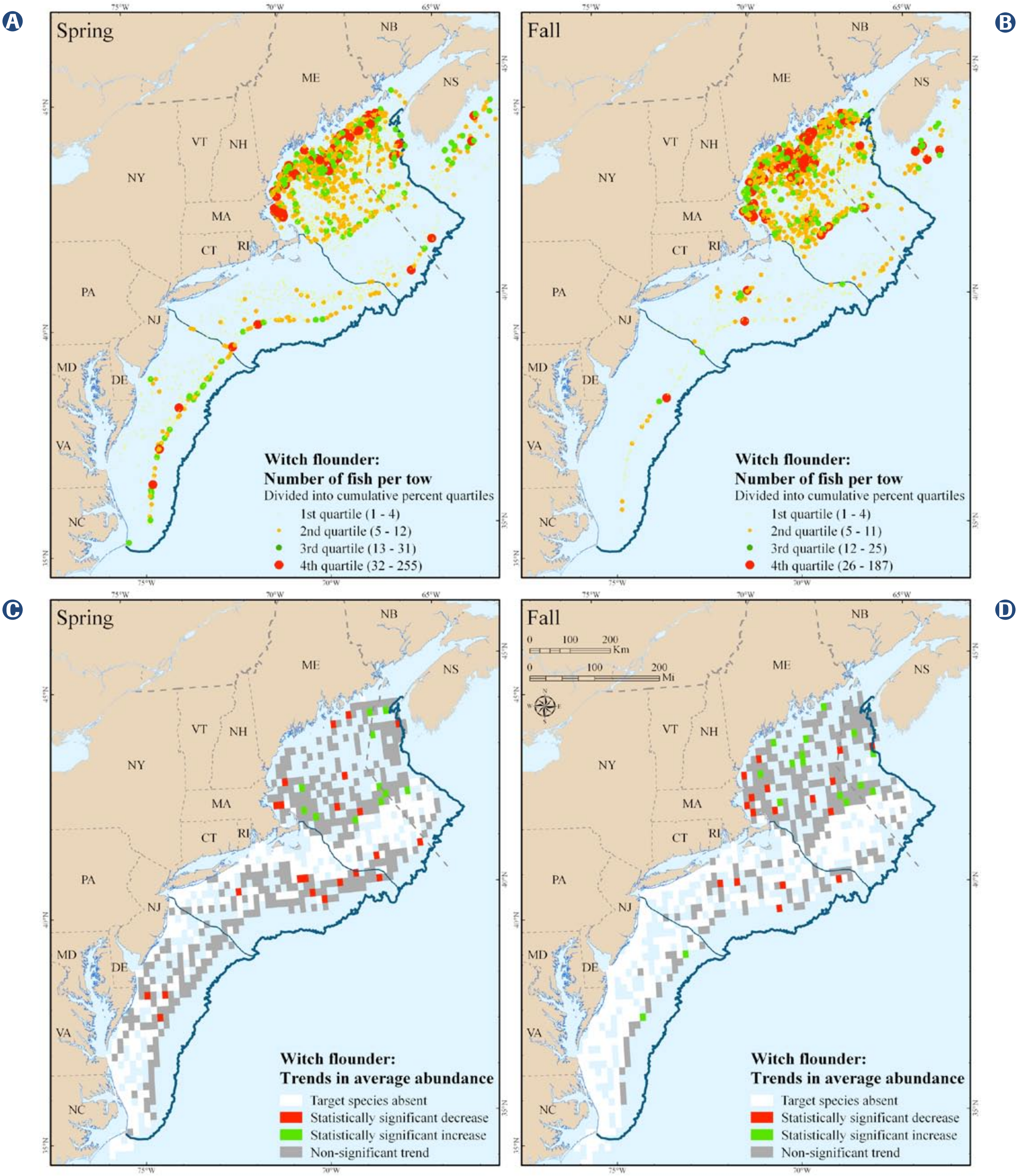


Figure 7-19. Trends in average abundance over 40 years for witch flounder during the spring and fall seasons.

Witch flounder were distributed throughout much of the Gulf of Maine and Georges Bank, although their range does extend south along the Continental Shelf to Albemarle Sound (Figure 7-19a, b). Highest numbers were found along the coastal shelf in the Gulf of Maine from Cape Cod to the Grand Manan Banks, in deeper waters near Jeffreys Bank and Jordan Basin, along the northern perimeter of Georges Bank, and along the shelf/slope break from Sandy Hook, New Jersey to Albemarle Sound. Statistical analyses generally did not identify any significant trend over the range during the time series, though increasing trends were observed in some portions of the central Gulf of Maine and decreasing trends were found in inshore areas from Massachusetts Bay to Casco Bay, Maine and in shelf waters of Southern New England south to Delaware Bay (Figure 7-19c, d). Weighted persistence analyses for witch flounder identified coastal shelf waters from Massachusetts Bay to Platts Bank, the area around Jeffreys Bank into Jordan Basin, and the mouth of the Bay of Fundy in eastern Maine as important (Figure 7-20).

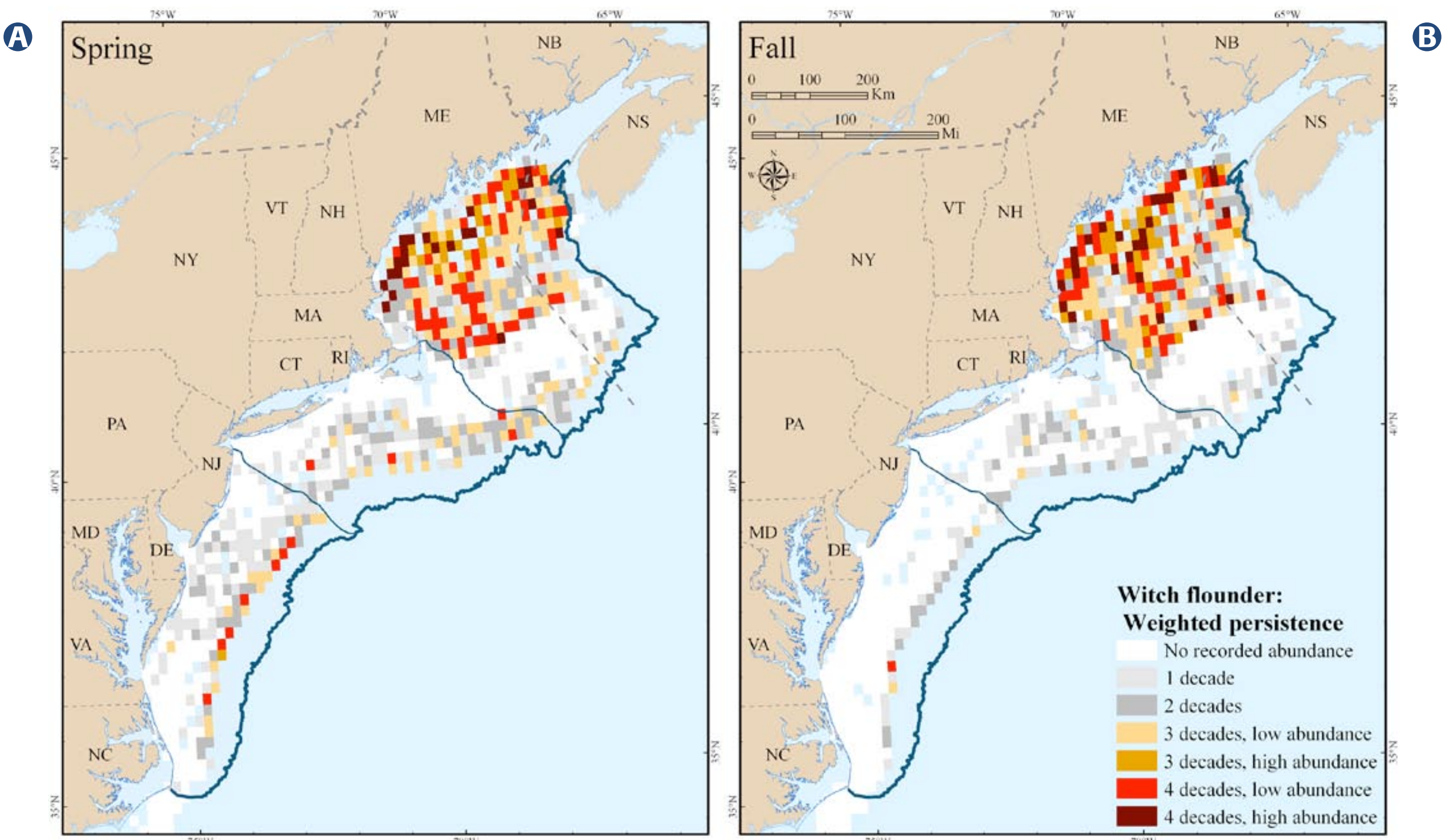


Figure 7-20. Areas with high persistence and abundance over 40 years for witch flounder during the spring and fall seasons.

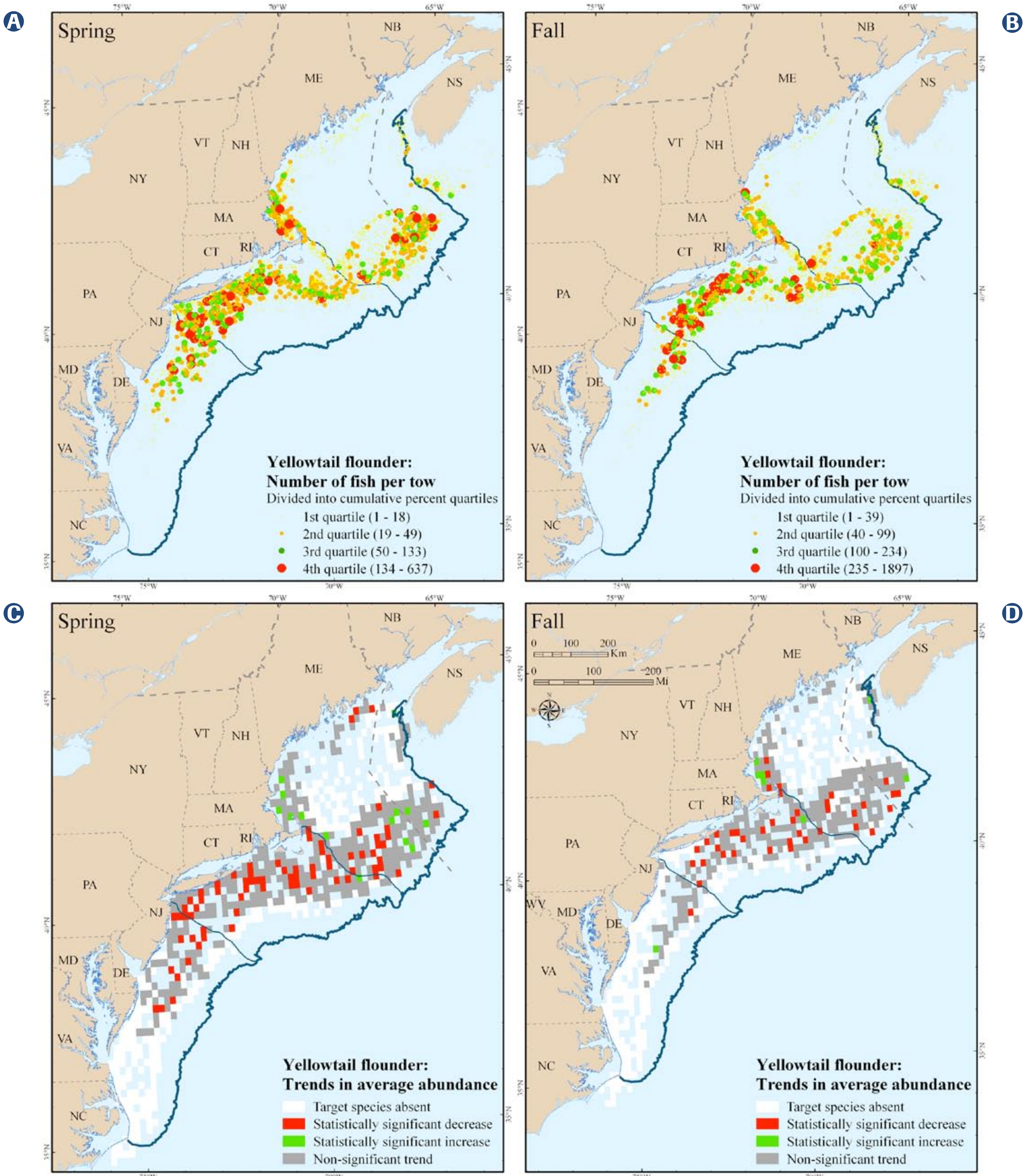


Figure 7-21. Trends in average abundance over 40 years for yellowtail flounder during the spring and fall seasons.

Yellowtail flounder were distributed throughout much of the region, with highest numbers occurring along the eastern part of Georges Bank and through Southern New England to shelf waters as far south as Delaware Bay (Figure 7-21a, b). High numbers were also found within the nearshore water of the Gulf of Maine, primarily around Massachusetts Bay and the Stellwagen Bank/Jeffreys Ledge area. Statistical analyses identified a declining trend over the time series over much of the Southern New England area and western Georges Bank, while trends were mixed on eastern Georges Bank and in the Gulf of Maine (Figure 7-21c, d). Weighted persistence analyses for yellowtail flounder identified nearshore waters from Massachusetts Bay to Chatham, Massachusetts, and the Northern Edge, Northeast Peak, and southern flank of Georges Bank, and a narrow band at 30-40 fathoms extending from the Great South Channel and Nantucket Shoals to Sandy Hook, New Jersey as important areas (Figure 7-22).

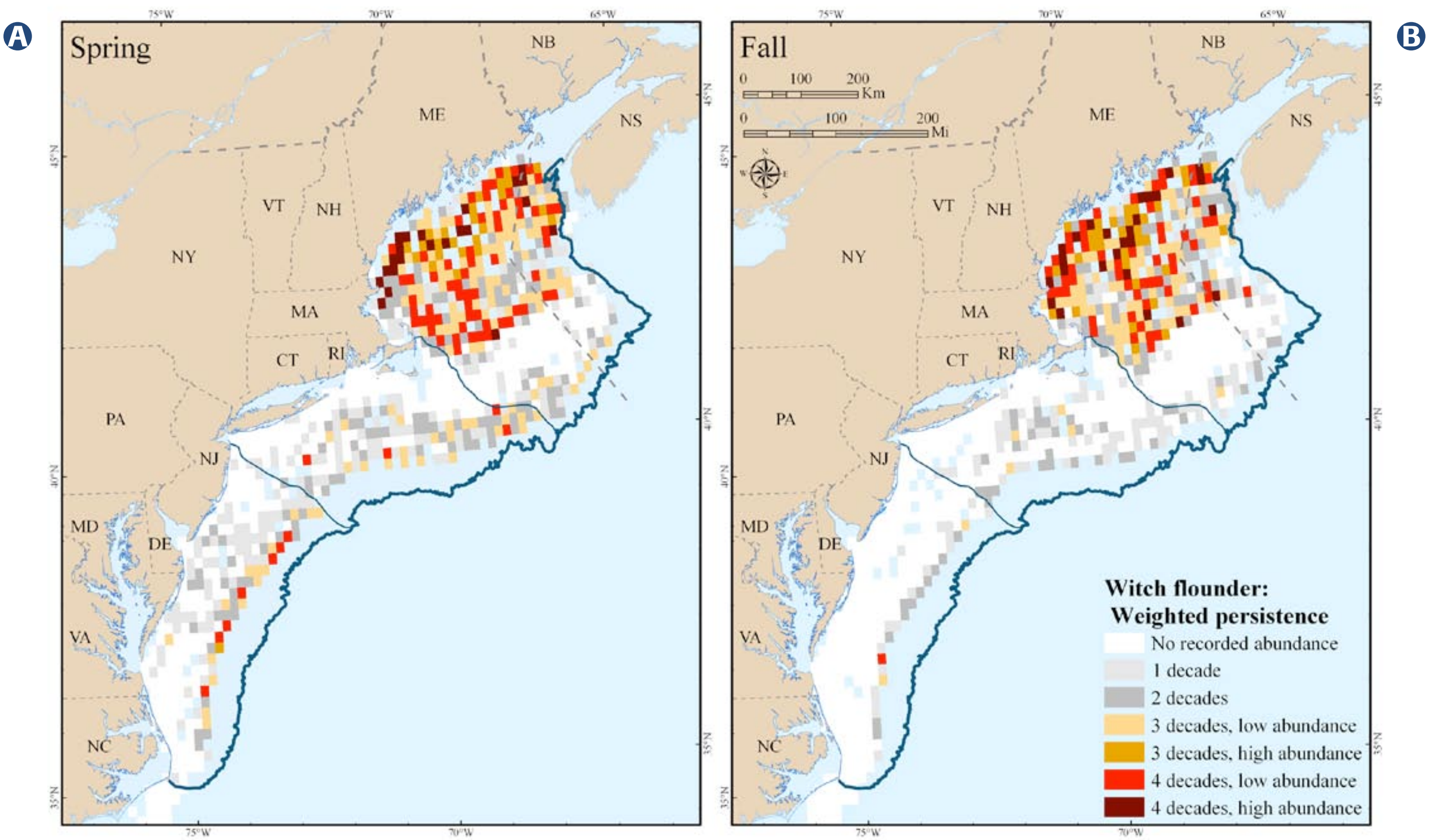


Figure 7-22. Areas with high persistence and abundance over 40 years for yellowtail flounder during the spring and fall seasons.

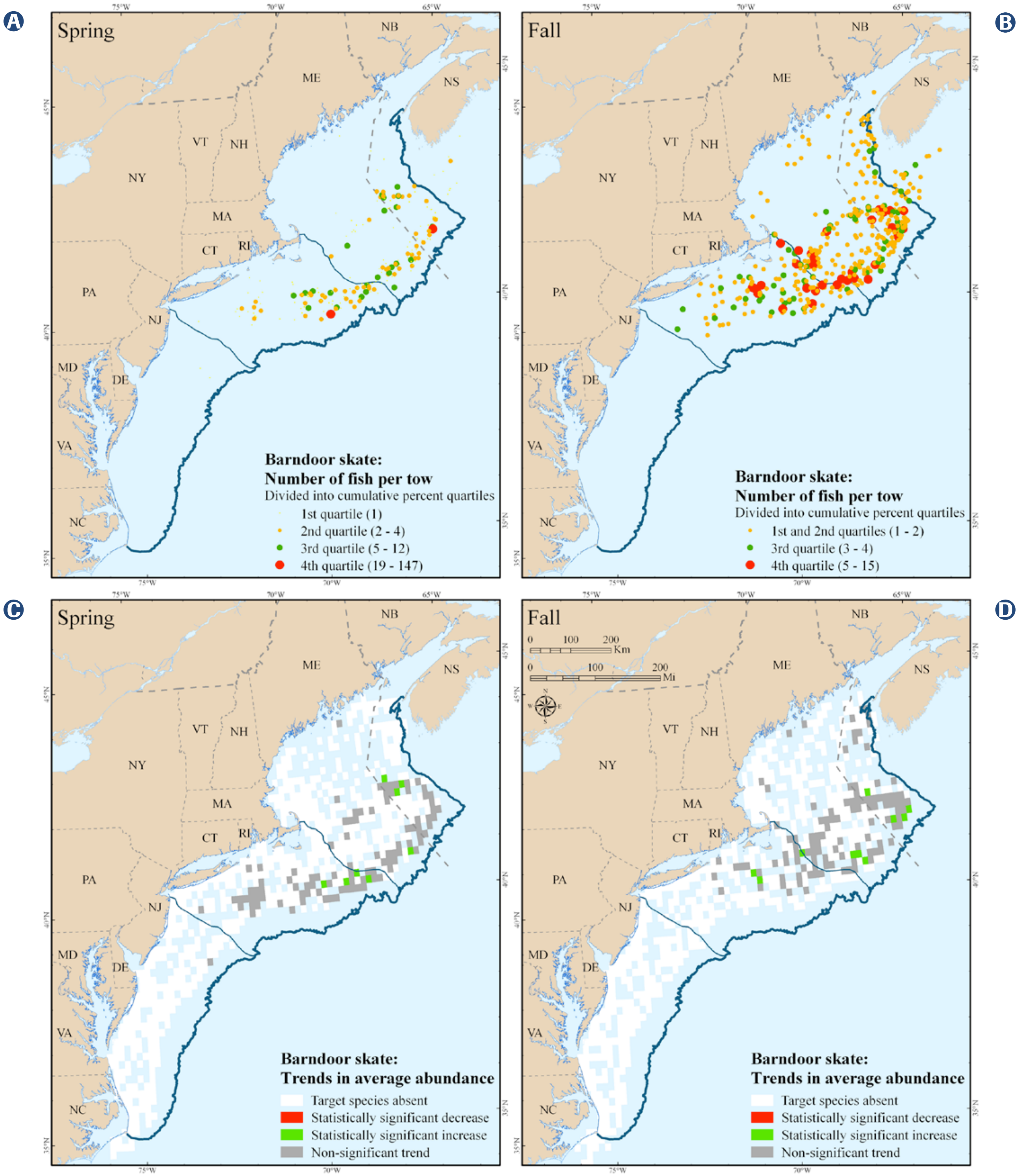


Figure 7-23. Trends in average abundance over 40 years for barndoor skate during the spring and fall seasons.

Elasmobranchs

Elasmobranchs were distributed across much of the Northwest Atlantic, displaying distinct differences in distributions depending on species. Within the region, barndoor skate occurred along the coastal shelf off the Gulf of Maine from the Bay of Fundy to Massachusetts Bay and along the southern flank of Georges Bank (Figure 7-23a, b). Highest numbers occurred around the perimeter of Georges Bank, particularly along the southern flank, in the Great South Channel, south of Nantucket Shoals, and in Continental Shelf waters off of Long Island in Southern New England. Statistical analyses identified increasing trends for barndoor skate in discrete locations from the Northeast Peak to the southern flank of Georges Bank, as well as offshore waters of Southern New England (Figure 7-23c, d). Weighted persistence analyses for barndoor skate identified an area extending from the Northeast Peak and southern flank of Georges Bank as important (Figure 7-24).

Clearnose skate occurred primarily in the southern portion of the region from Long Island to Pamlico Sound,

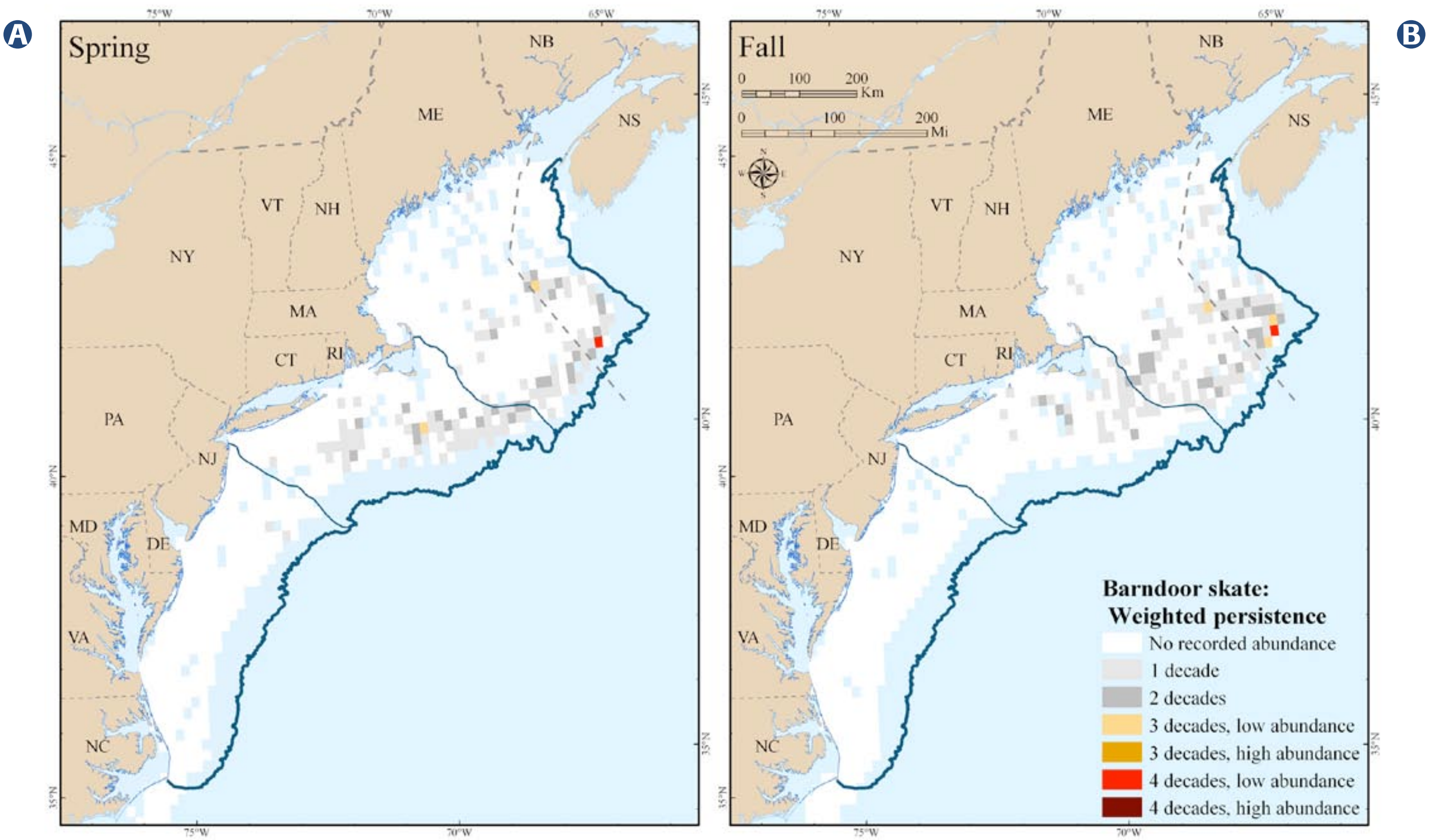


Figure 7-24. Areas with high persistence and abundance over 40 years for barndoor skate during the spring and fall seasons.

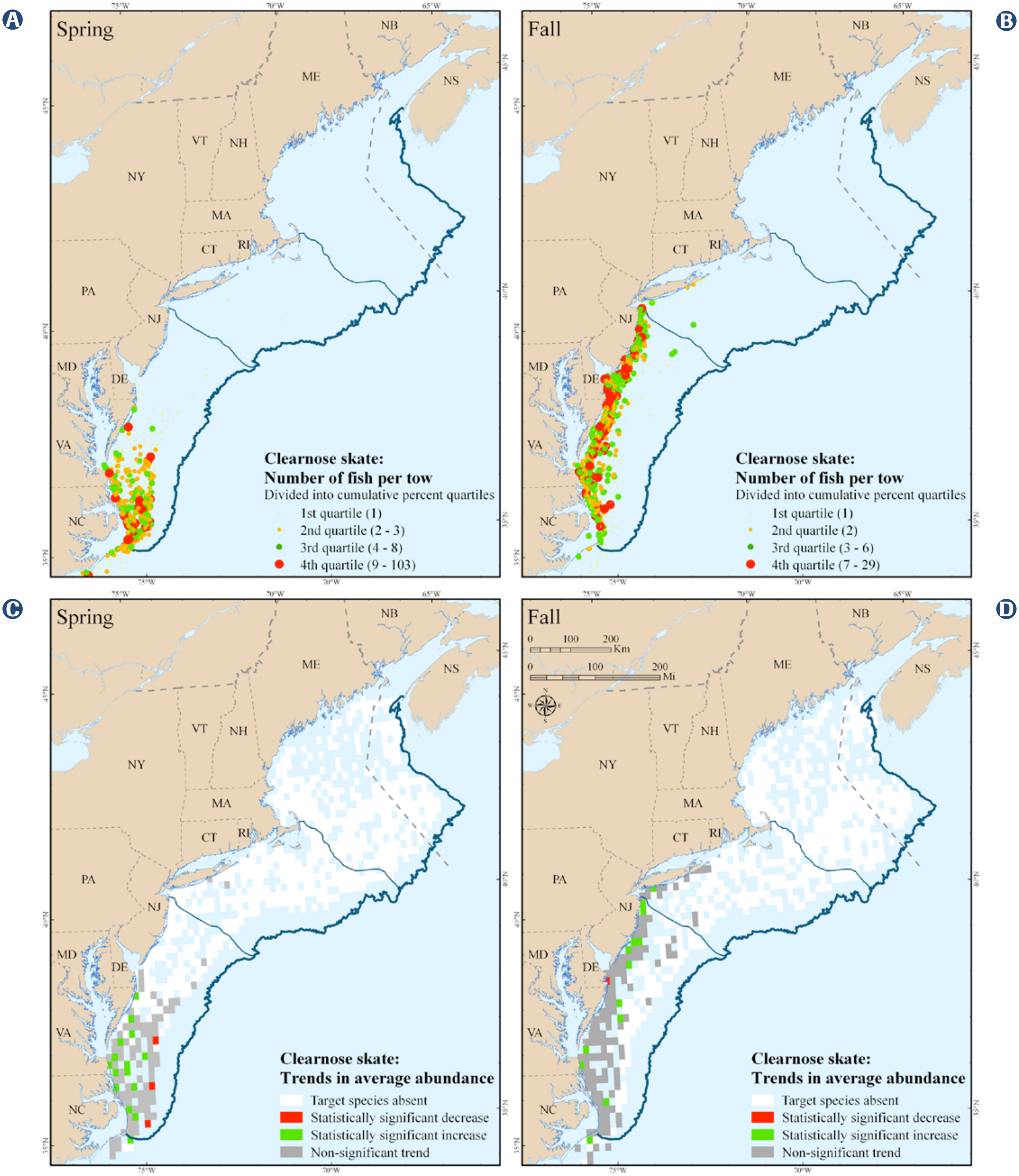


Figure 7-25. Trends in average abundance over 40 years for clearnose skate during the spring and fall seasons.

with highest numbers found in nearshore areas of the Mid-Atlantic from Sandy Hook, New Jersey to Pamlico Sound (Figure 7-25a, b). Statistical analyses did not identify significant trends over much of the range. Increasing trends were observed in some parts of the southern end of the range from the mouth of the Hudson River/Raritan Bay estuary to Cape Hatteras, while decreasing trends were observed in the spring at discrete locations along the shelf/slope break off Virginia and North Carolina (Figure 7-25c, d). Weighted persistence analyses for clearnose skate identified nearshore waters from the mouth of the Hudson River to Pamlico Sound as important. Seasonal differences were also observed; important areas were concentrated south of Chesapeake Bay and extended out to the shelf/slope break in the spring (Figure 26).

Little skate occurred throughout much of the region from Georges Bank to the Chesapeake Bay, with highest numbers occurring on the western part of Georges Bank and in Southern New England from Nantucket Shoals to Cape May, New Jersey (Figure 7-27a, b). Statistical analyses identified increasing trends in discrete areas from

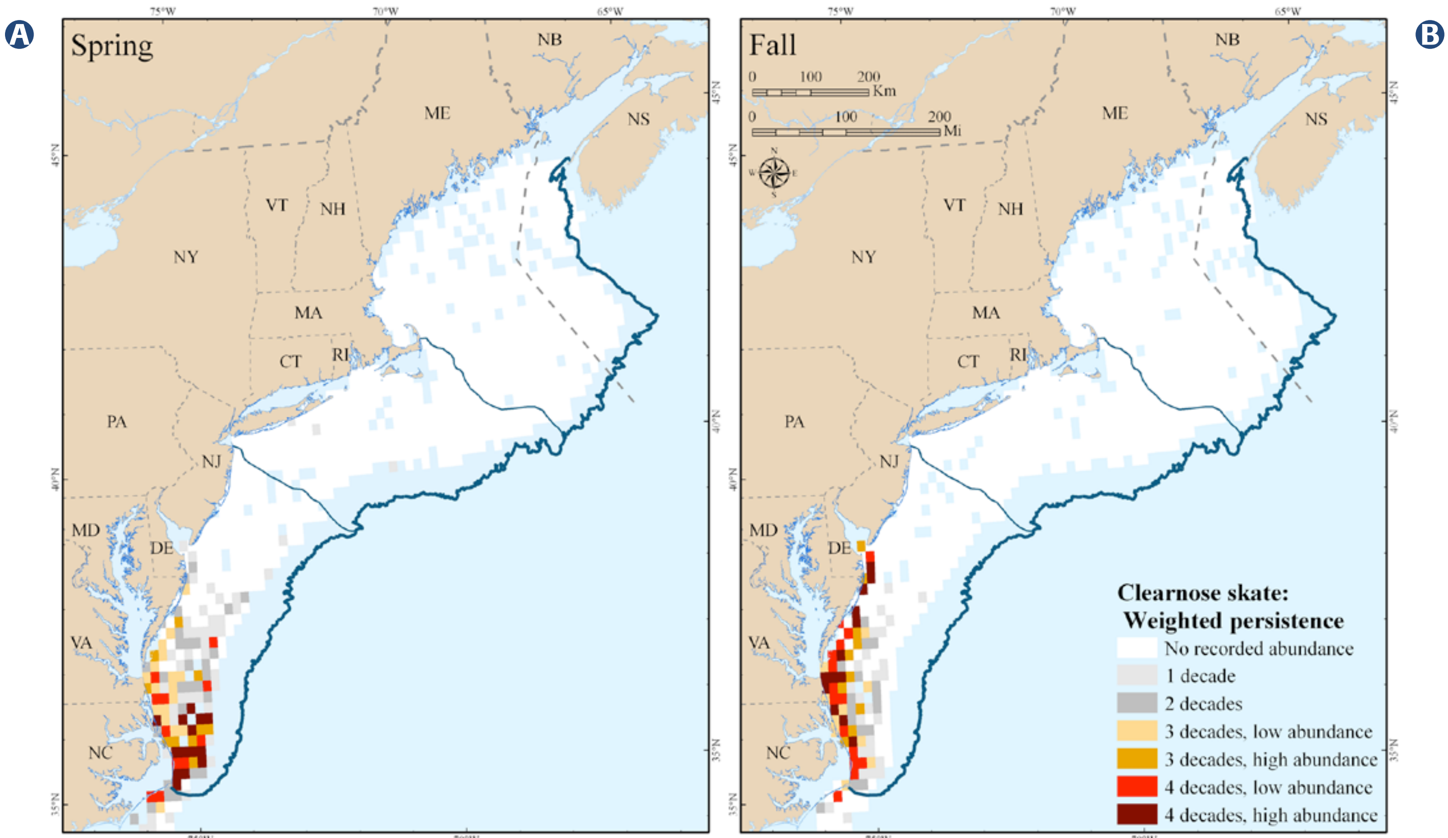


Figure 7-26. Areas with high persistence and abundance over 40 years for clearnose skate during the spring and fall seasons.

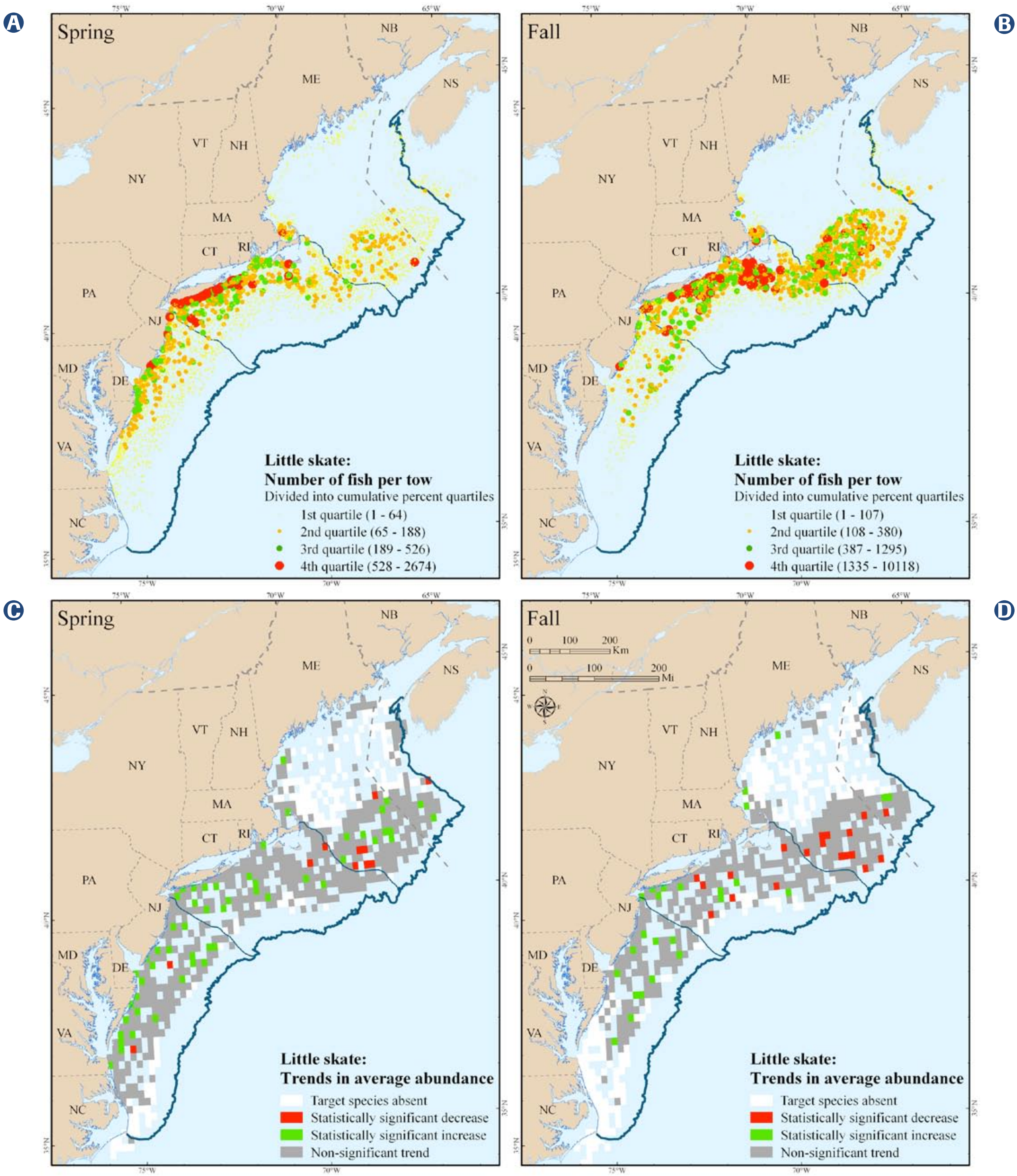


Figure 7-27. Trends in average abundance over 40 years for little skate during the spring and fall seasons.

Georges Bank to Chesapeake Bay over the time series during the spring, and more mixed results during the fall (Figure 7-27c, d). Weighted persistence analyses for little skate identified central portions of Georges Bank and the Great South Channel, waters south of Nantucket and Martha's Vineyard, nearshore waters along the southern shore of Long Island, and waters off the New Jersey shore and Delaware Bay as important. Seasonal shifts were also observed, with waters from Barnegat Bay to Chincoteague Inlet becoming important in the spring (Figure 7-28).

Rosette skate occurred primarily in the Mid-Atlantic from New Jersey to Pamlico Sound, with highest numbers observed in offshore waters along the Continental Shelf and Slope break from Delaware Bay to Albemarle Sound (Figure 7-29a, b). Statistical analyses did not identify significant trends over the time series (Figure 7-29c, d). Weighted persistence analyses for rosette skate clearly identified offshore waters along the shelf/slope break from Chincoteague Bay to Albemarle Sound as important areas (Figure 7-30).

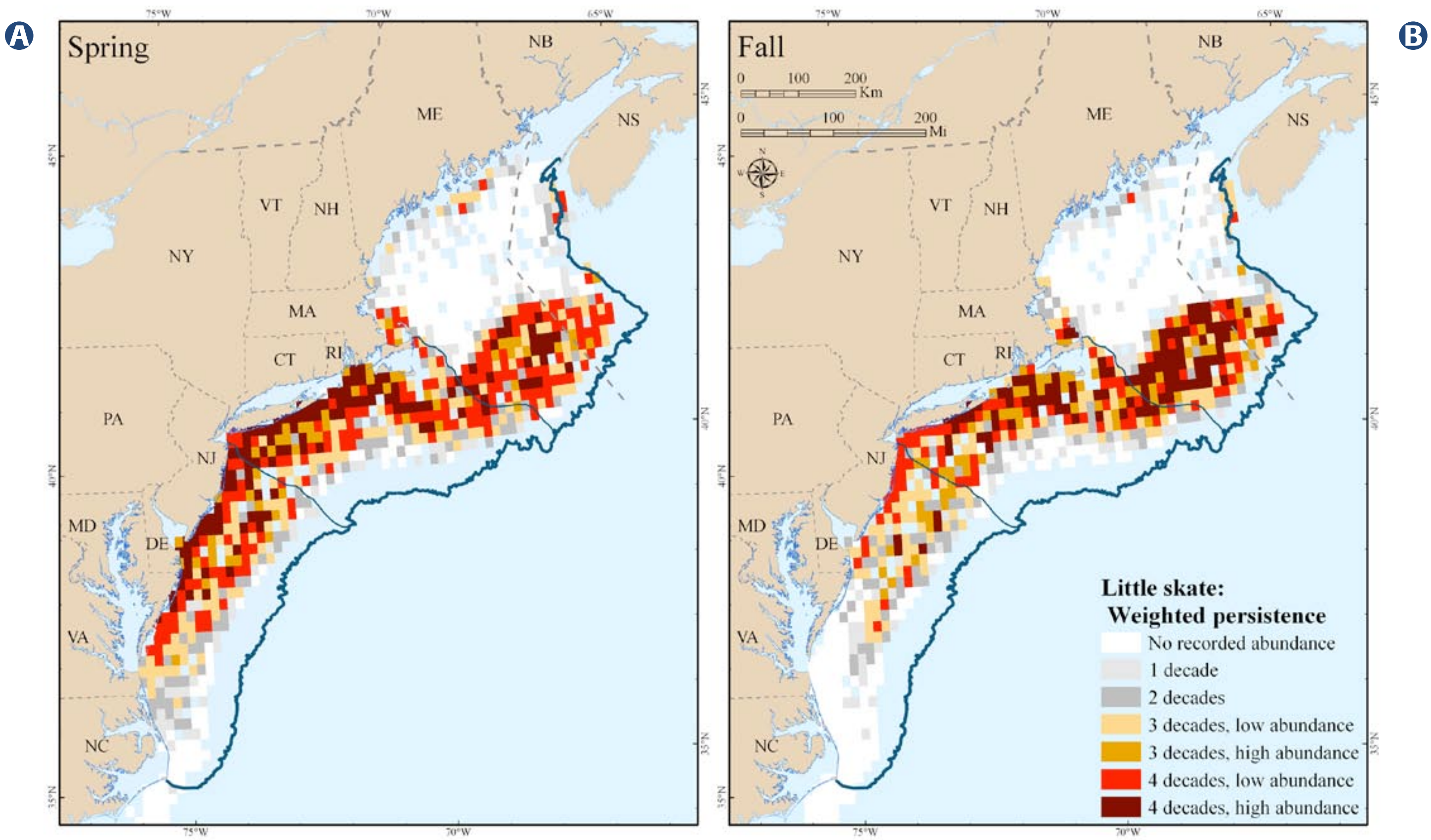


Figure 7-28. Areas with high persistence and abundance over 40 years for little skate during the spring and fall seasons.

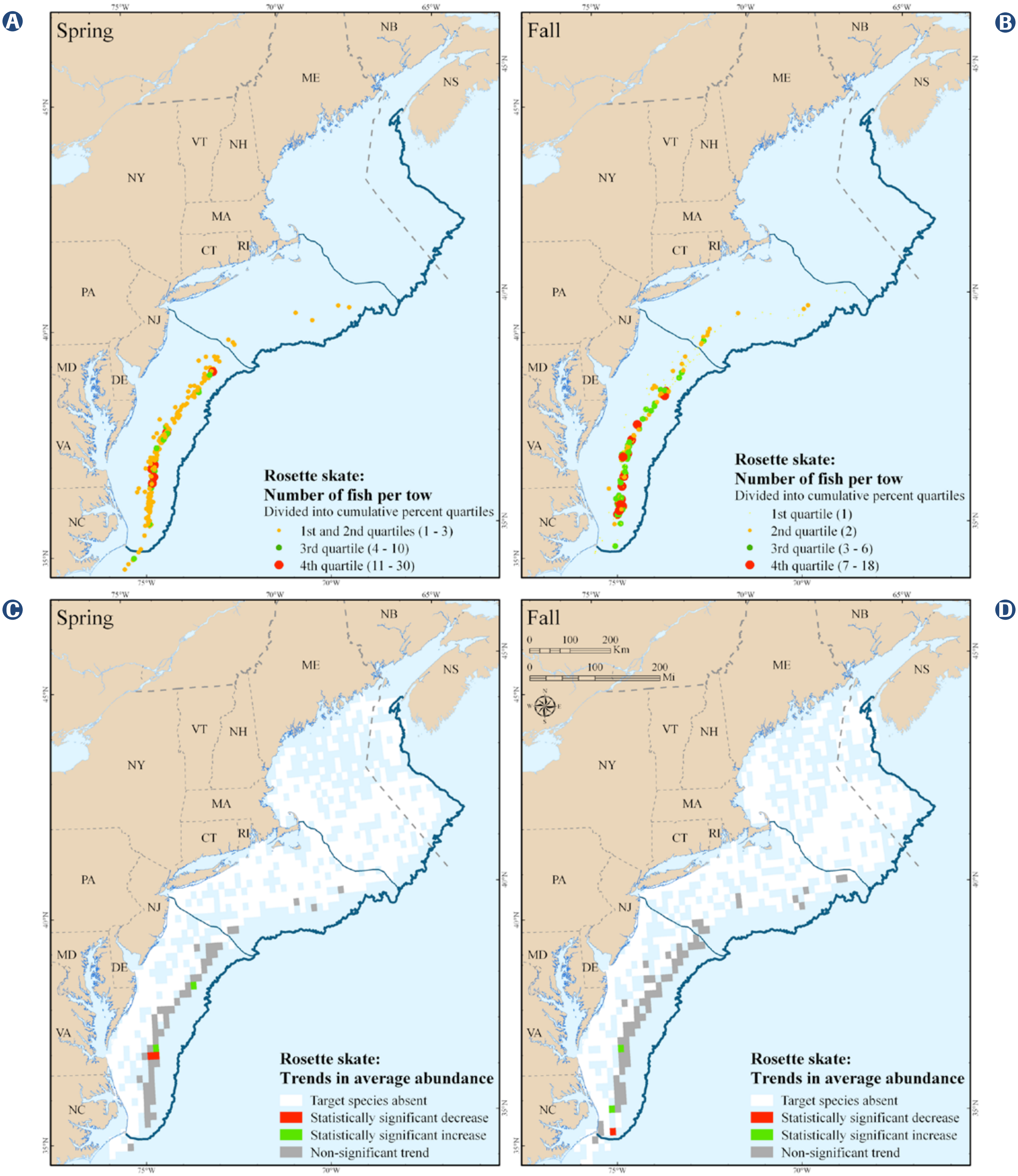


Figure 7-29. Trends in average abundance over 40 years for rosette skate during the spring and fall seasons.

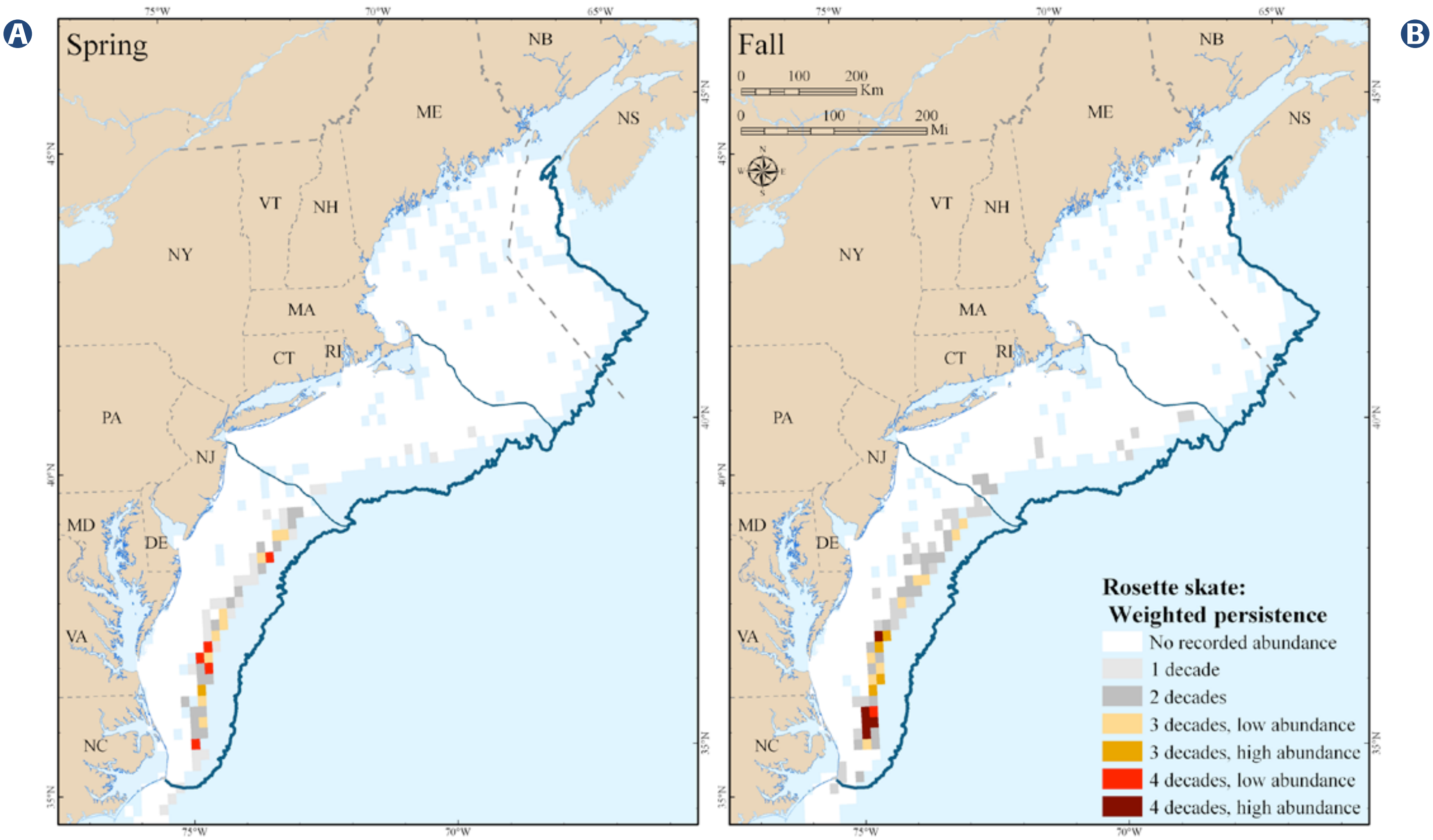


Figure 7-30. Areas with high persistence and abundance over 40 years for rosette skate during the spring and fall seasons.

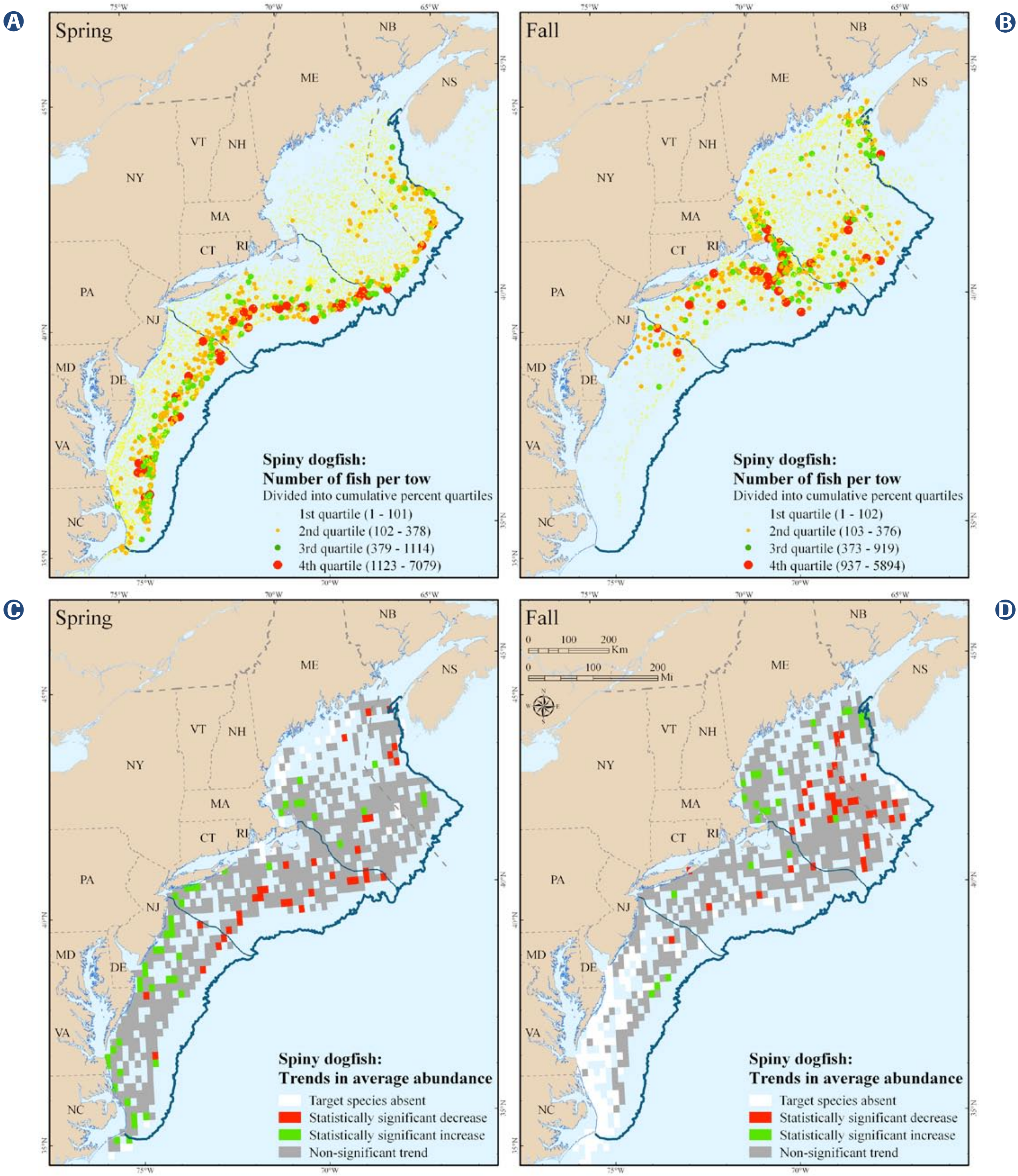


Figure 7-31. Trends in average abundance over 40 years for spiny dogfish during the spring and fall seasons.

Spiny dogfish occurred throughout the region, with highest numbers dependent on the time of year because of distinct seasonal migrations (Figure 7-31a, b). Highest numbers were found in the southern portion of the range offshore along the shelf/slope break in the spring and further north and nearshore in the fall. Increasing trends were observed in nearshore areas while decreasing trends were observed further offshore, although neither of these trends was statistically significant. Statistical analyses identified variable trends, with increases generally occurring in nearshore waters in the Gulf of Maine, Southern New England, and Mid-Atlantic and decreases observed in offshore waters of the Gulf of Maine, Georges Bank, and Southern New England (Figure 7-31c, d). Weighted persistence maps for spiny dogfish identified Massachusetts Bay, the Great South Channel, Georges Bank, Nantucket Shoals to Block Island Sound, and offshore waters along the shelf/slope break from the Hudson River/Raritan Bay estuary to Pamlico Sound as important. Distinct seasonal patterns were observed. Important areas were concentrated in the southern and offshore portions of the range in the spring and further north and nearshore during the fall (Figure 7-32).

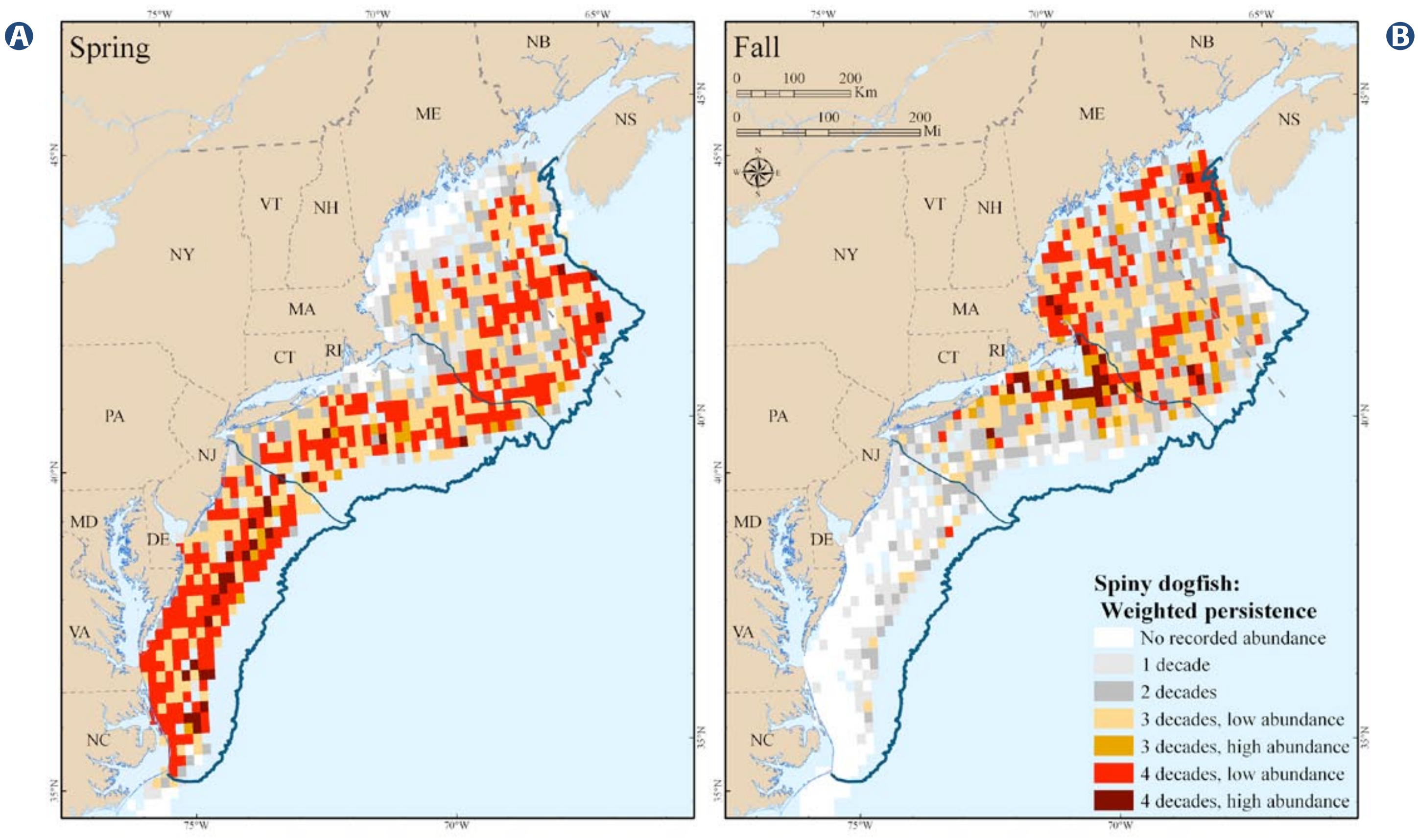


Figure 7-32. Areas with high persistence and abundance over 40 years for spiny dogfish during the spring and fall seasons.

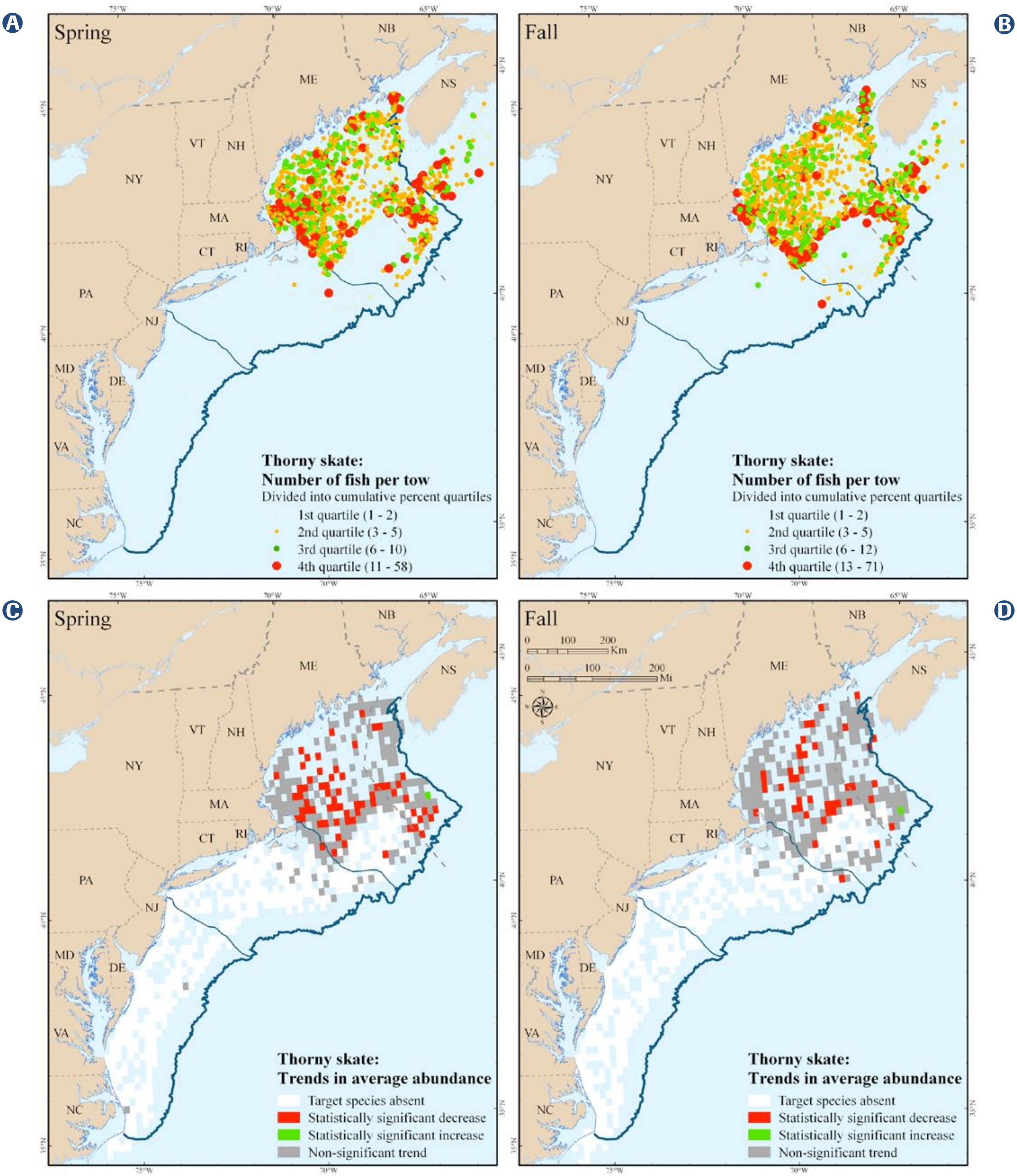


Figure 7-33. Trends in average abundance over 40 years for thorny skate during the spring and fall seasons.

Thorny skate occurred primarily in the Gulf of Maine and Georges Bank, with highest numbers found in the southern and central portions of the Gulf of Maine, east of Grand Manan Island, along Browns Bank and the Northeast Channel, in and around the Great South Channel, and along the northern edge and southern flank of Georges Bank (Figure 7-33a, b). Statistical analyses identified a declining trend in the time series across much of the range, including central and eastern portions of the Gulf of Maine and along much of the perimeter of Georges Bank (Figure 7-33c, d). Weighted persistence analyses for thorny skate identified waters north of the Great South Channel and Northeast Peak of Georges Bank, nearshore waters from Massachusetts Bay to Casco Bay, and Grand Manan Banks as important, with no distinct seasonal differences observed (Figure 7-34).

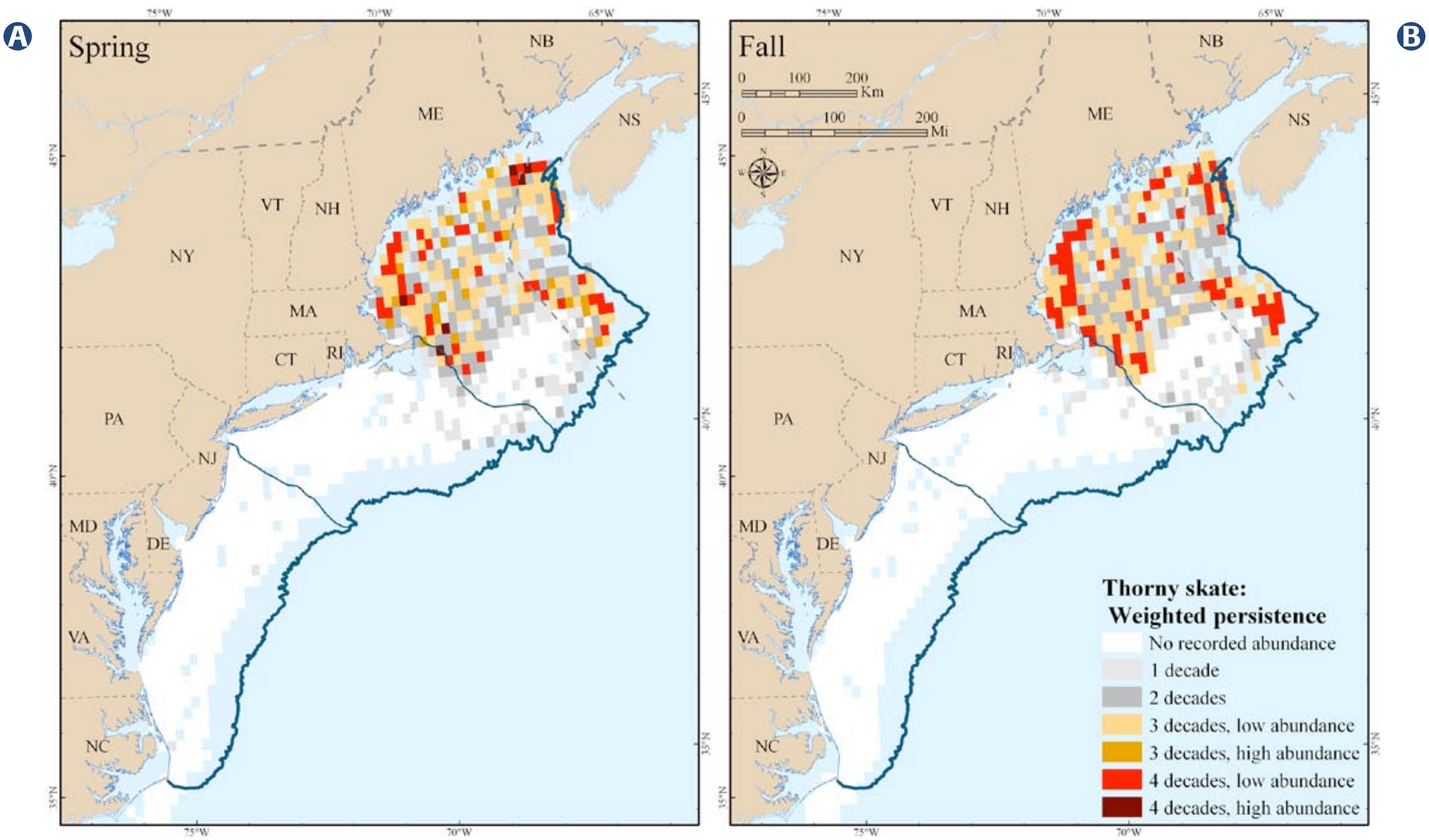


Figure 7-34. Areas with high persistence and abundance over 40 years for thorny skate during the spring and fall seasons.

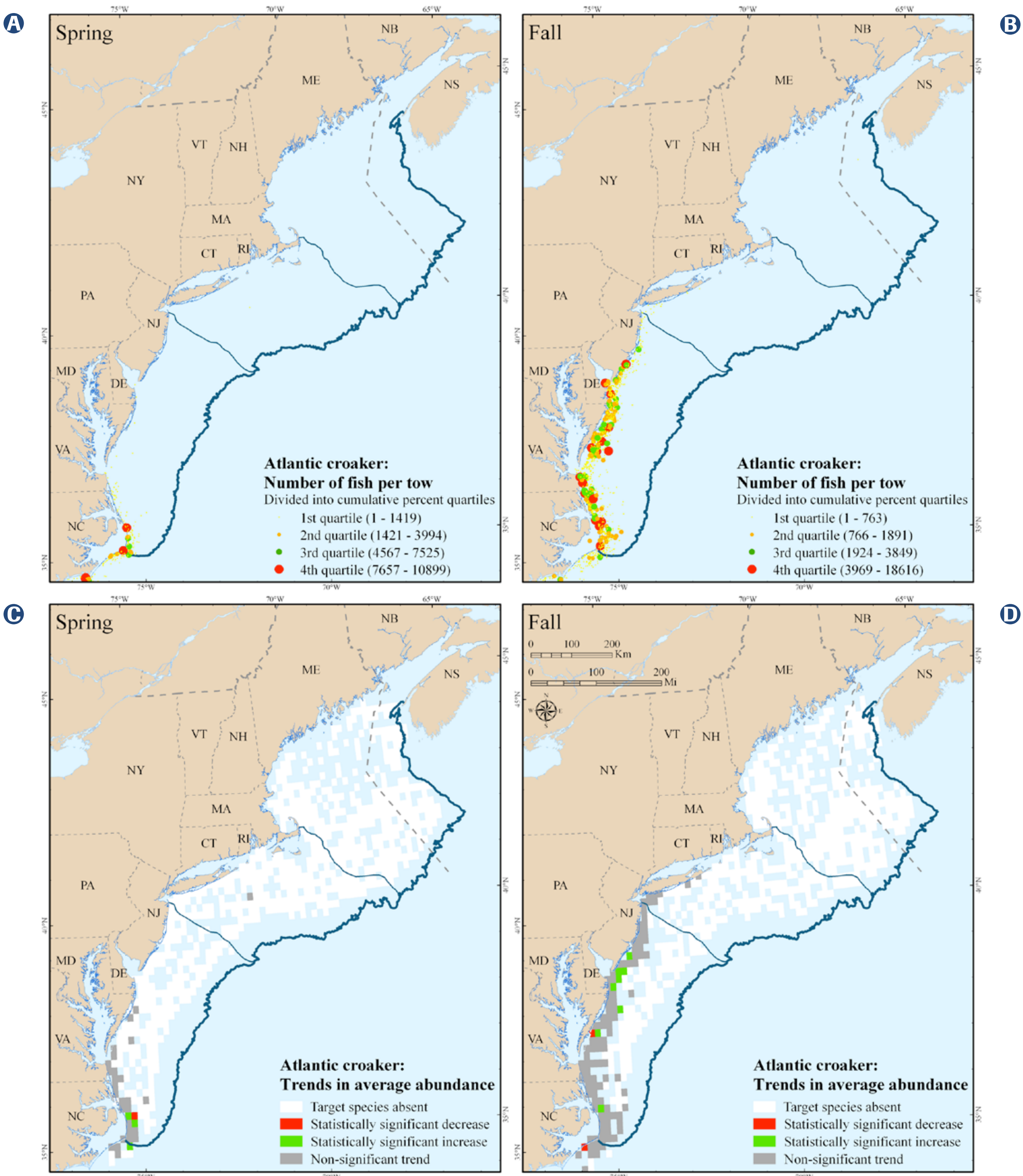


Figure 7-35. Trends in average abundance over 40 years for Atlantic croaker during the spring and fall seasons.

Mid-Atlantic Estuarine

Within the region, these species were predominantly found from Long Island Sound to Cape Hatteras, North Carolina with highest numbers of Atlantic croaker, spot, and weakfish occurring from Delaware Bay south to Chesapeake Bay. However, all species do occur along the perimeter of Georges Bank and the Great South Channel. They have occasionally been observed in the Gulf of Maine in and around Massachusetts Bay and the Jeffreys Ledge and Stellwagen Bank area. Highest numbers of croaker (Figure 7-35a, b), spot (Figure 7-37a, b), and weakfish (Figure 7-39a, b) occurred south of Delaware Bay to Pamlico Sound. Distinct seasonal patterns in distribution were also apparent for spot, croaker, and weakfish with higher numbers occurring in nearshore coastal waters during the fall.

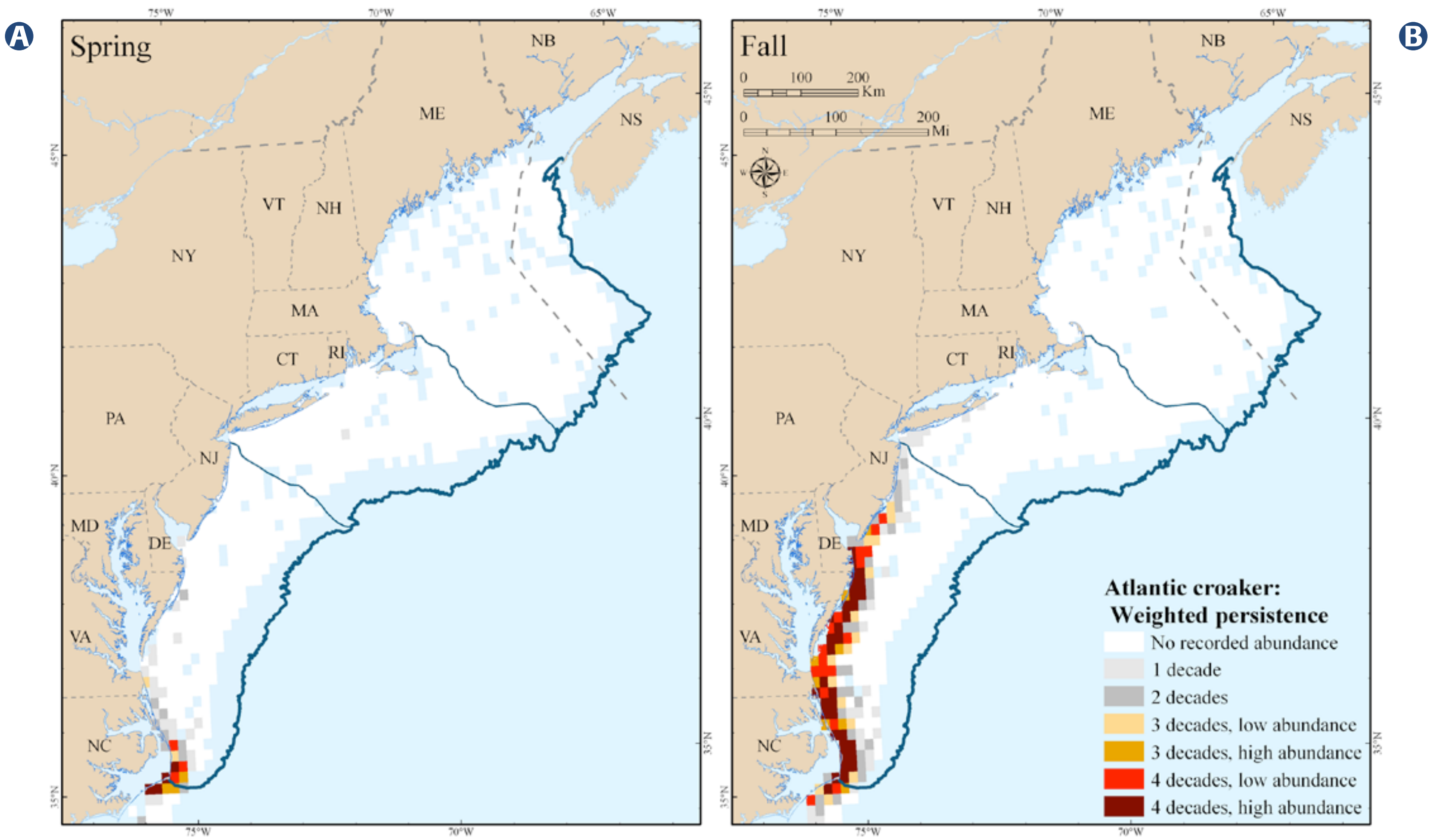


Figure 7-36. Areas with high persistence and abundance over 40 years for Atlantic croaker during the spring and fall seasons.

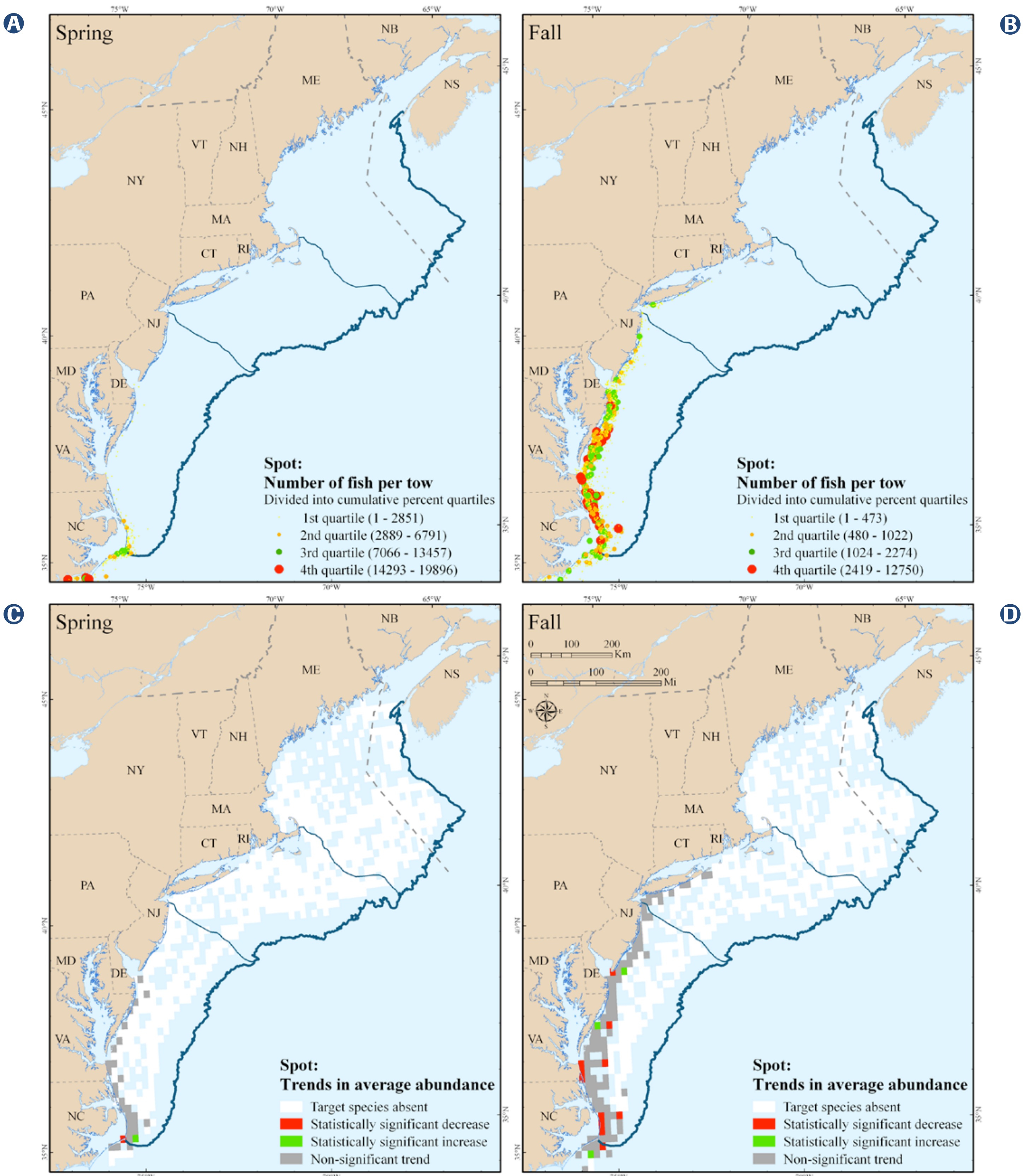
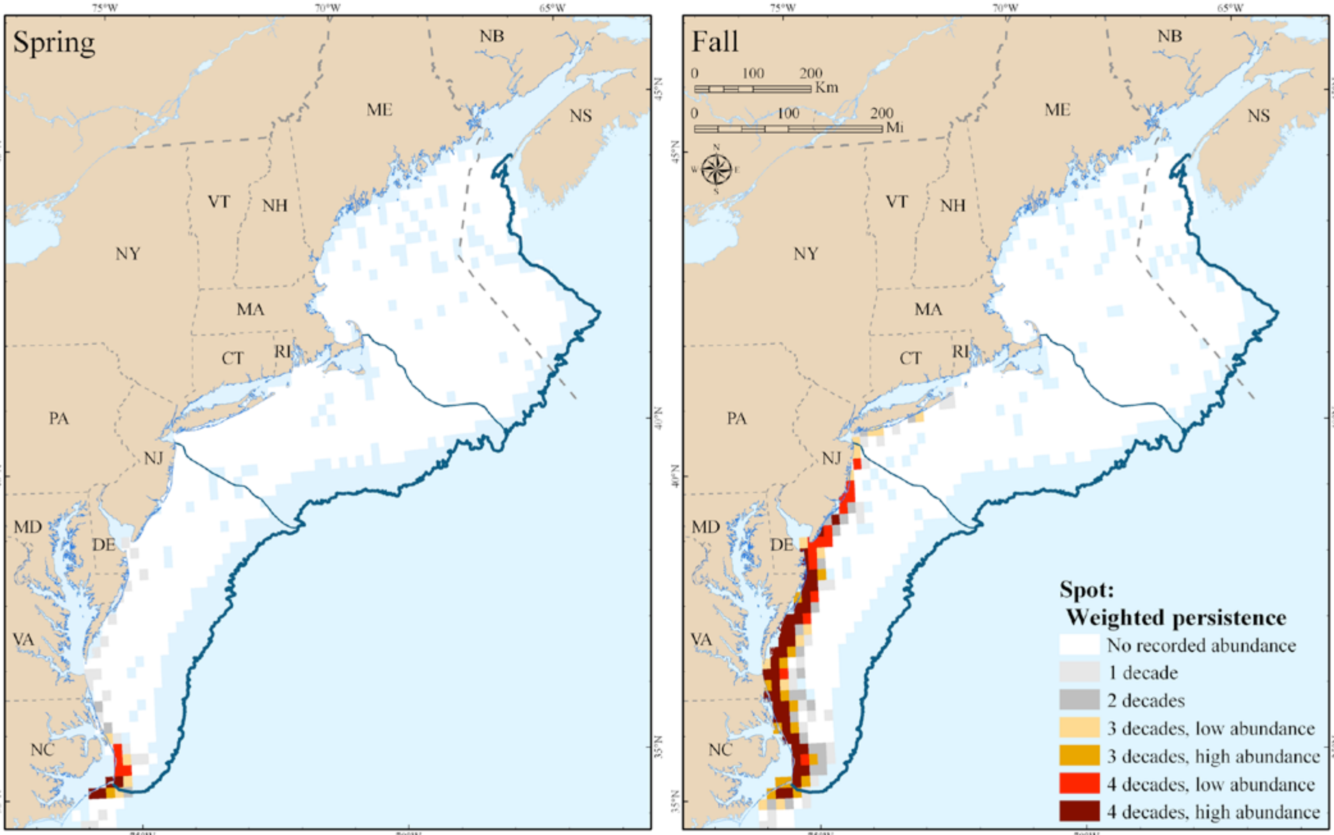


Figure 7-37. Trends in average abundance over 40 years for spot during the spring and fall seasons.

A



B

Figure 7-38. Areas with high persistence and abundance over 40 years for spot during the spring and fall seasons.

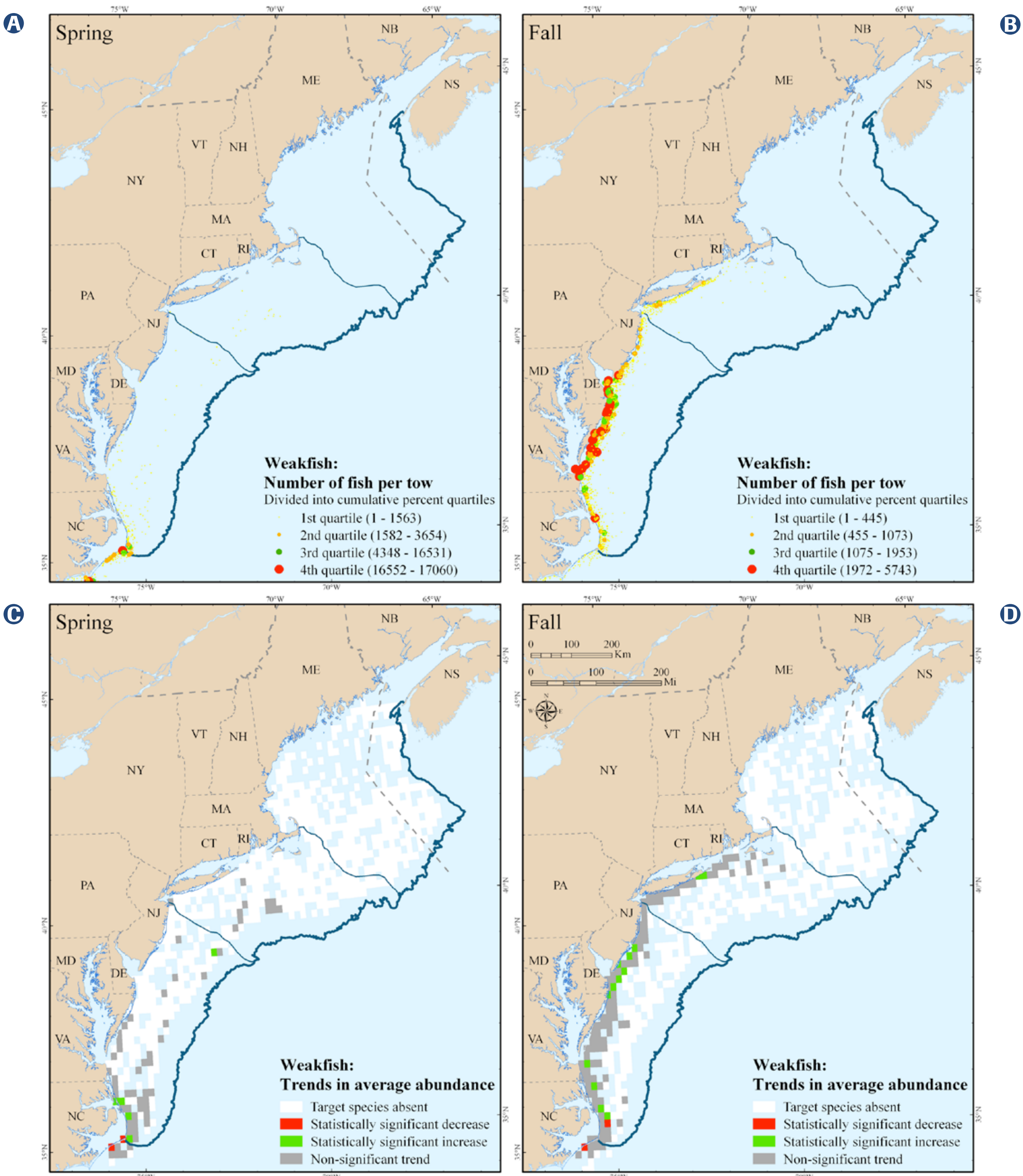


Figure 7-39. Trends in average abundance over 40 years for weakfish during the spring and fall seasons.

Statistical analyses did not identify significant trends in croaker abundance over much of the range, though increasing trends were observed in the fall in nearshore waters from Delaware Bay to Cape Charles, Virginia (Figure 7-35c, d). Statistical analyses did not identify significant trends for spot over much of the range, though decreasing trends were observed in nearshore waters from Delaware Bay south during the fall (Figure 7-37c, d). Statistical analyses did not identify significant trends in abundance over much of the range, though increasing trends were observed at discrete locations in nearshore waters from Great Bay, New Jersey south to Pamlico Sound (Figure 7-39c, d). Weighted persistence analyses for croaker (Figure 7-36) and spot (Figure 7-38) identified discrete locations in nearshore waters from Delaware Bay south to Pamlico Sound as important, particularly in the fall. Weighted persistence analyses for weakfish identified nearshore waters near Albemarle and Pamlico Sound as important in the spring and from Long Island south, especially from Delaware Bay to Pamlico Sound, as important in the fall (Figure 7-40).

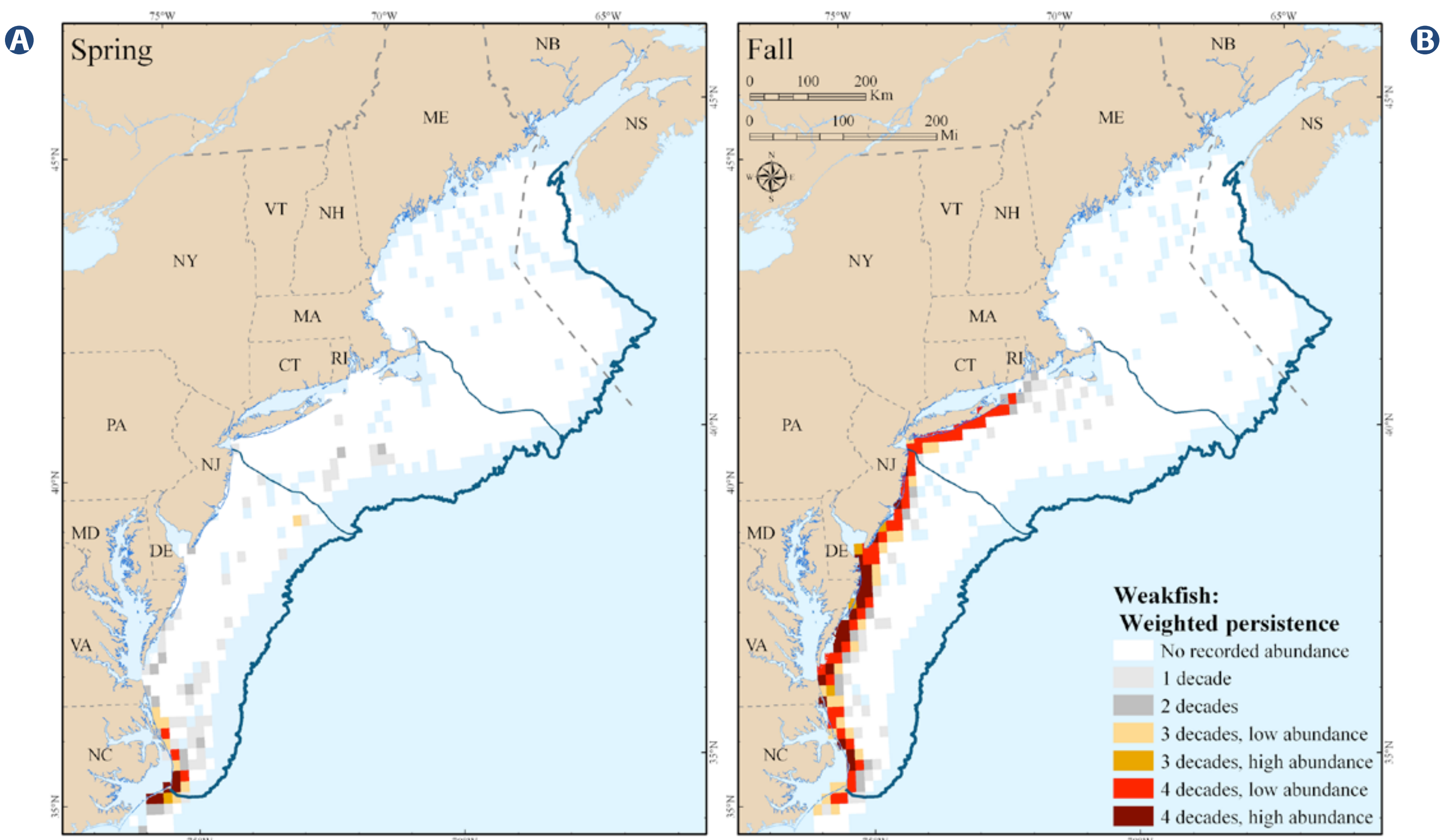


Figure 7-40. Areas with high persistence and abundance over 40 years for weakfish during the spring and fall seasons.

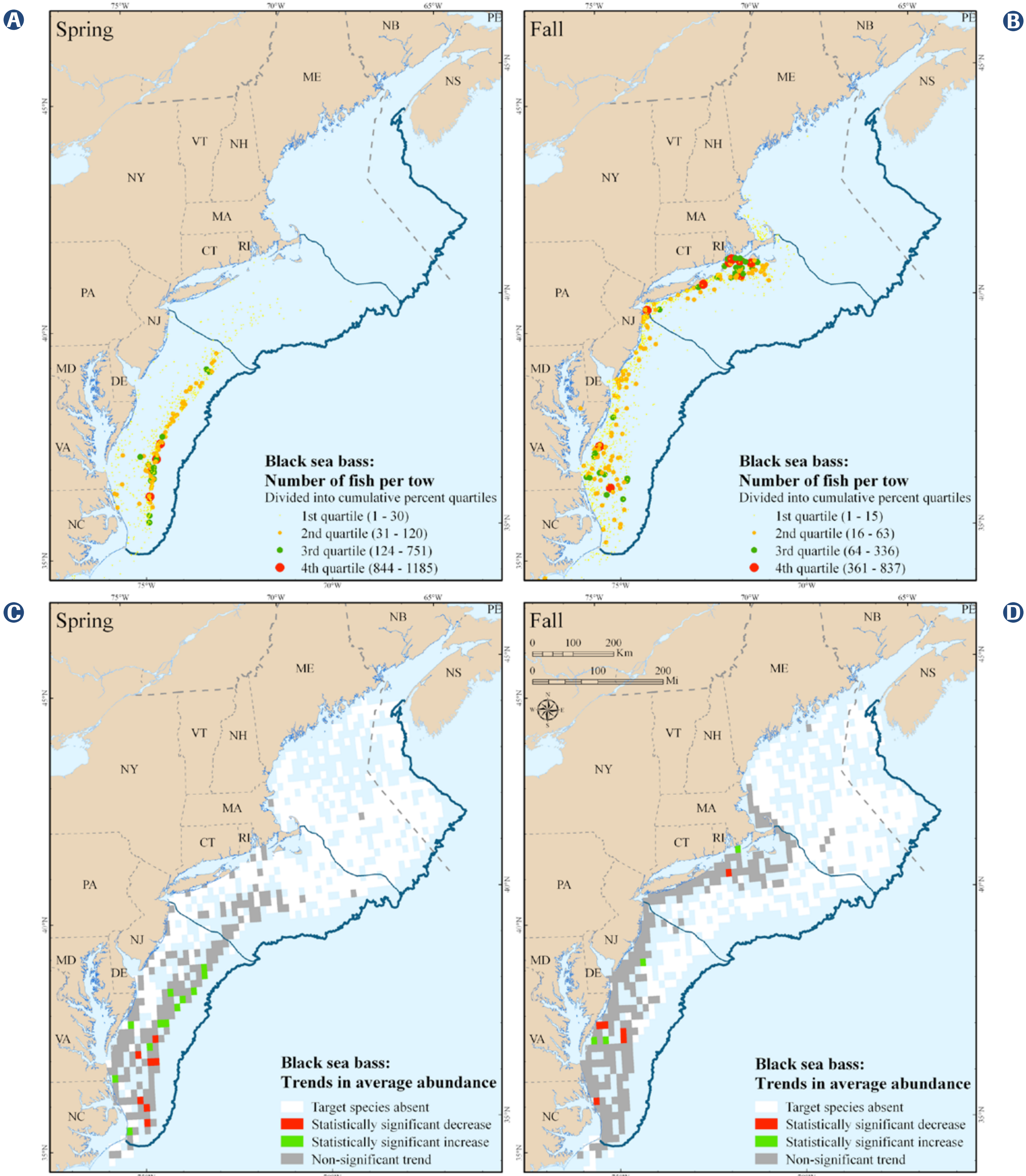


Figure 7-41. Trends in average abundance over 40 years for black sea bass during the spring and fall seasons.

Offshore Wintering Guild

Within the region, the highest numbers of species in this guild were found from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. However, all species also occurred along the 50 fathom curve of Georges Bank and the Great South Channel and in the Gulf of Maine, particularly in and around Massachusetts Bay and the Jeffreys Ledge and Stellwagen Bank area.

Highest numbers of black sea bass were found from Vineyard Sound and Narragansett Bay to the Hudson/Raritan Estuary and Cape Charles, Virginia to Albemarle Sound (Figure 7-41a, b). Distinct seasonal patterns were also observed, with highest numbers found in coastal waters in the fall and along the shelf/slope break in the spring. Statistical analyses did not identify significant trends across much of the species' range, though variable increasing trends were observed along the southern flank of Georges Bank in fall and from Cape May, New Jersey to Chincoteague Bay in the spring, while decreasing trends were observed in offshore waters from Chincoteague Bay to Pamlico Sound in the spring (Figure 7-41c, d). Weighted persistence analyses for black sea bass identified the shelf/slope break from Delaware Bay to Chesapeake Bay as important during the spring and nearshore waters from Martha's Vineyard to Albemarle/Pamlico Sound as important in the fall (Figure 7-42).

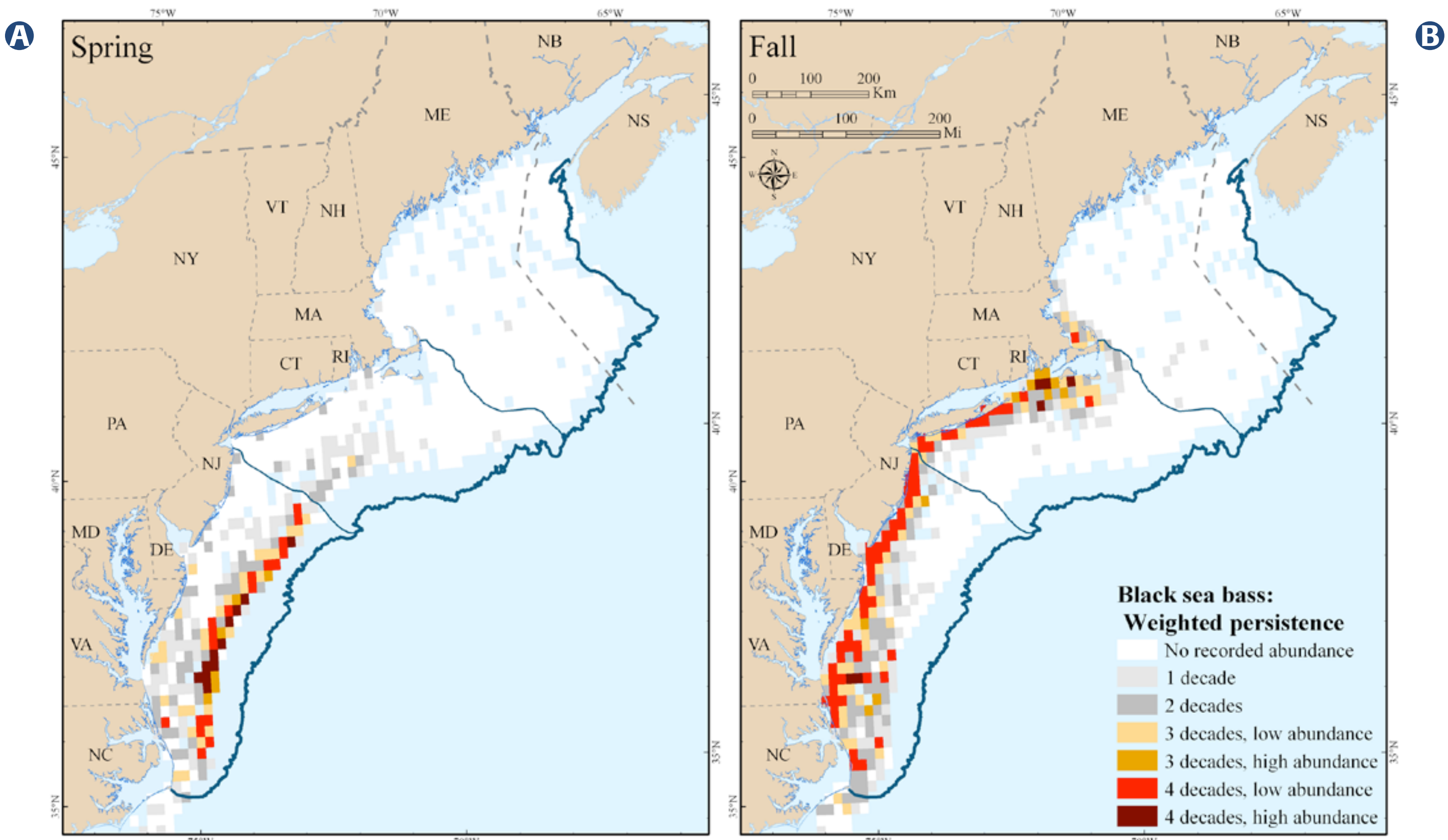


Figure 7-42. Areas with high persistence and abundance over 40 years for black sea bass during the spring and fall seasons.

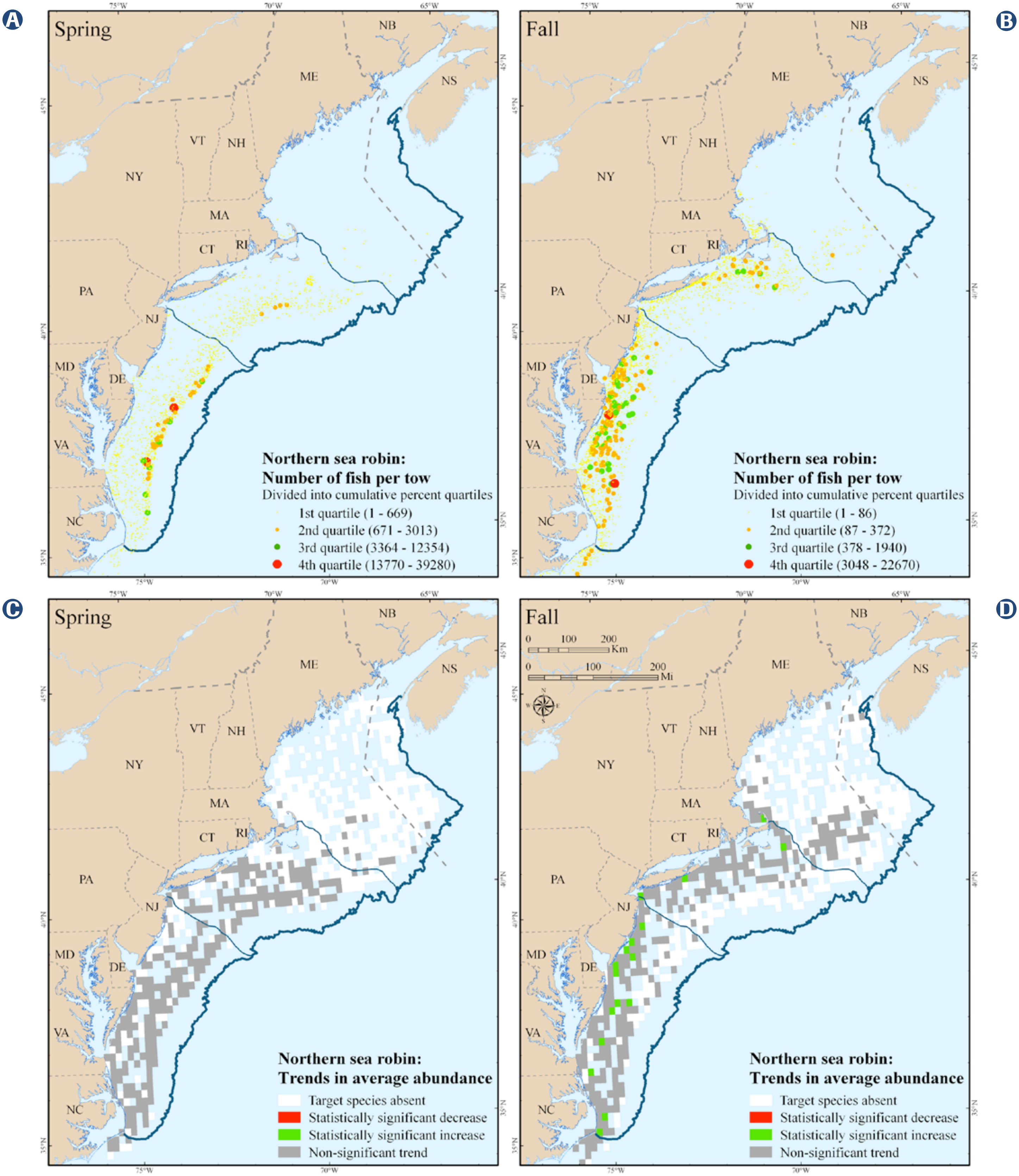


Figure 7-43. Trends in average abundance over 40 years for northern sea robin during the spring and fall seasons.

Highest numbers of northern sea robin were found from Great Bay, New Jersey to Cape Henry, Virginia (Figure 7-43a, b). Distinct seasonal patterns were also observed, with highest numbers found in nearshore coastal waters in the fall and along the shelf/slope break in the spring. Statistical analyses did not identify significant trends across much of the species' range. However, decreasing trends were observed in Southern New England from Long Island Sound to the Great South Channel, while a mix of increasing and decreasing trends were observed at discrete locations in the Mid-Atlantic from Great Bay, New Jersey to Pamlico Sound (Figure 7-43c, d). Weighted persistence analyses for northern sea robin identified offshore waters along the shelf/slope break extending from east of the Hudson /Raritan Estuary to Virginia Beach as important in the spring and nearshore waters from Vineyard Sound to Long Island and from Barnegat Bay, New Jersey to Pamlico Sound as important in the fall (Figure 7-44).

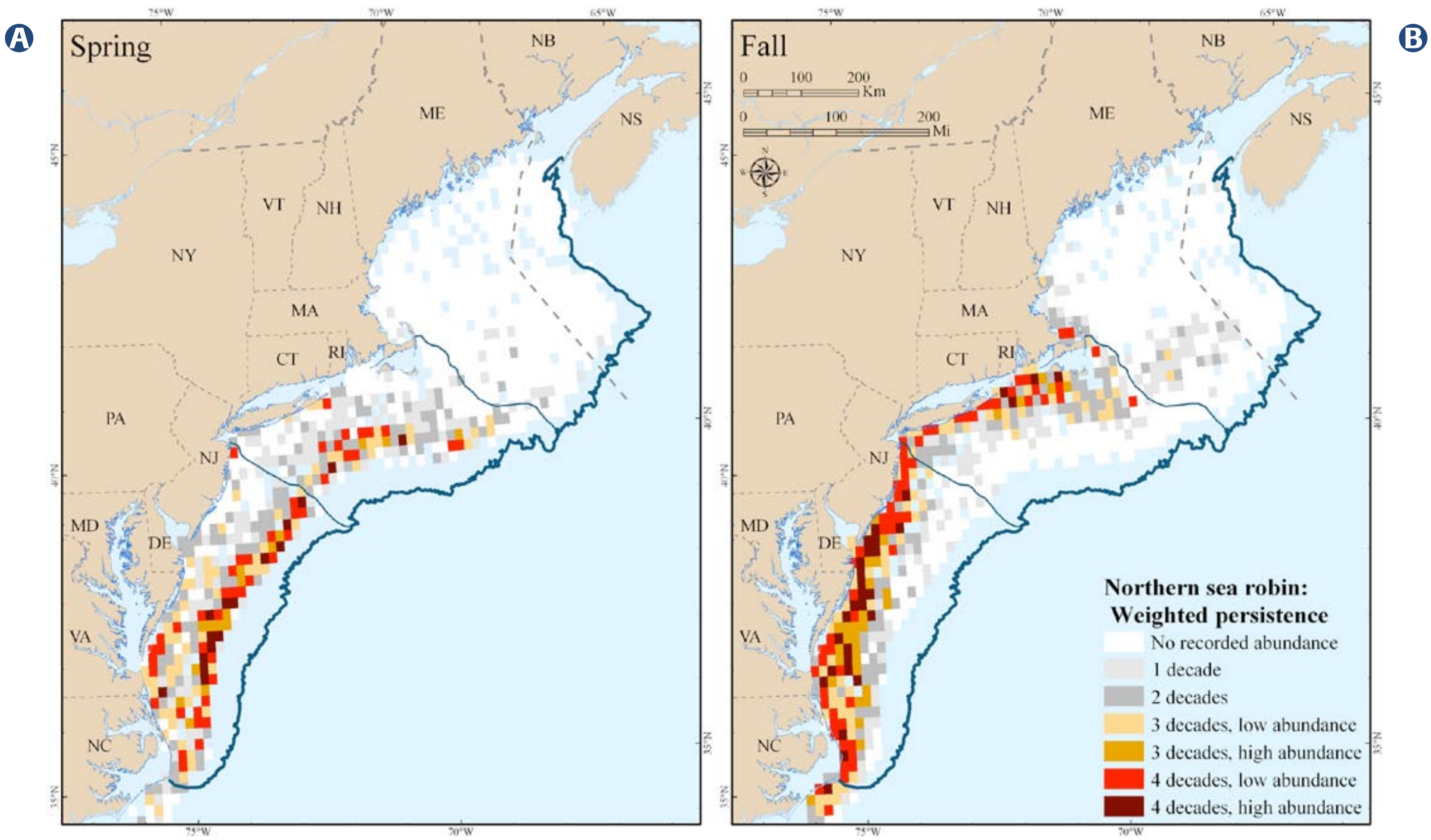


Figure 7-44. Areas with high persistence and abundance over 40 years for northern sea robin during the spring and fall seasons.

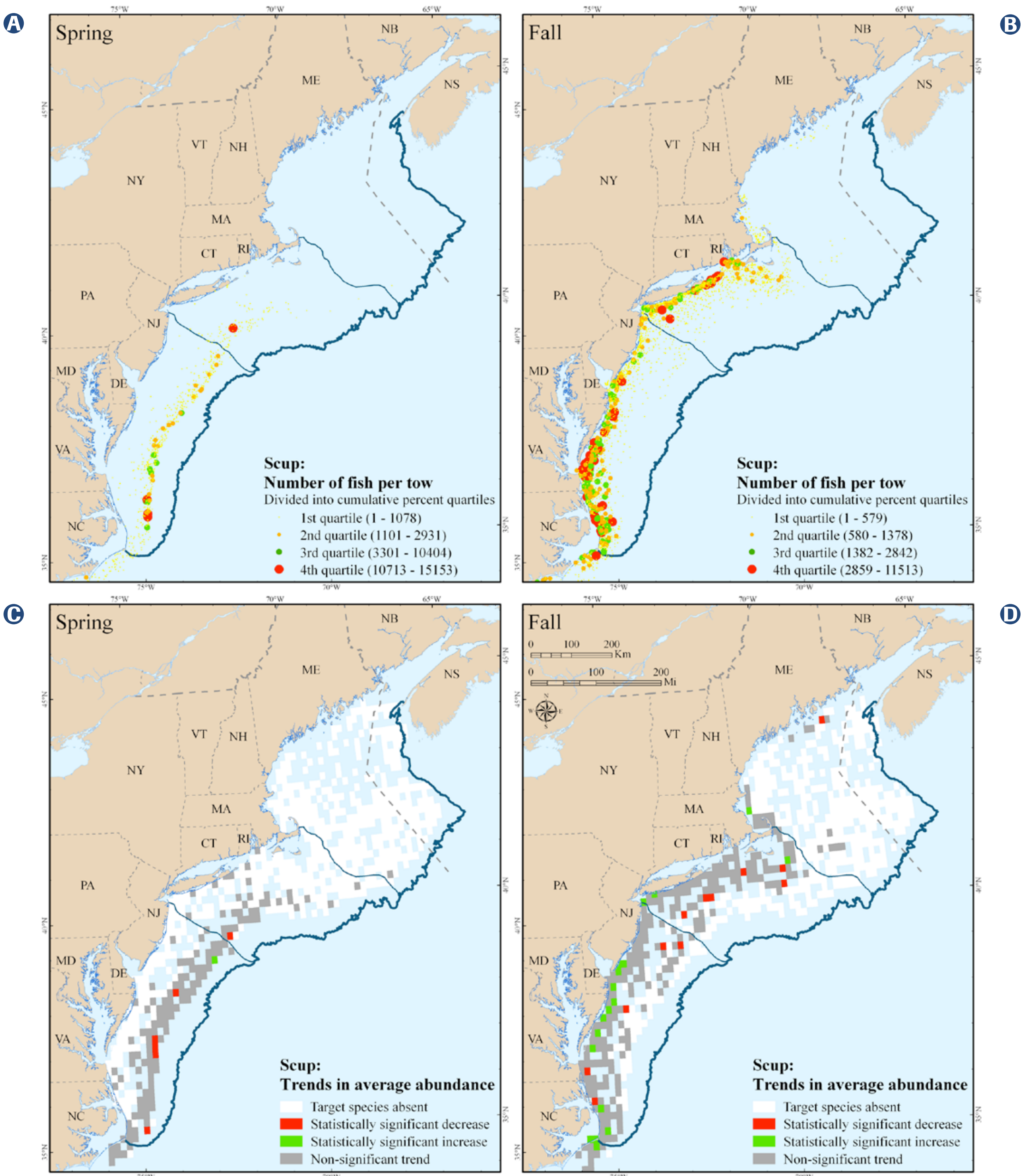


Figure 7-45. Trends in average abundance over 40 years for scup during the spring and fall seasons.

Highest numbers of scup were found in Southern New England and the Mid-Atlantic Bight from Cape Cod, Massachusetts to Pamlico Sound (Figure 7-45a, b). Distinct seasonal patterns were also observed, with highest numbers found in nearshore coastal waters in the fall and along the shelf/slope break in the spring. Statistical analyses did not identify significant trends in abundance across the species' range, though increasing trends were observed in some nearshore waters of Southern New England and the Mid-Atlantic Bight, while decreasing trends were observed further offshore (Figure 7-45c, d).

Weighted persistence analyses for scup identified offshore waters along the shelf/slope break from Cape May, New Jersey to Albemarle/Pamlico Sound as important in the spring and nearshore waters from Vineyard Sound to Sandy Hook, New Jersey, the mouth of Delaware Bay, and Cape Charles, Virginia to Pamlico Sound as important in the fall (Figure 7-46).

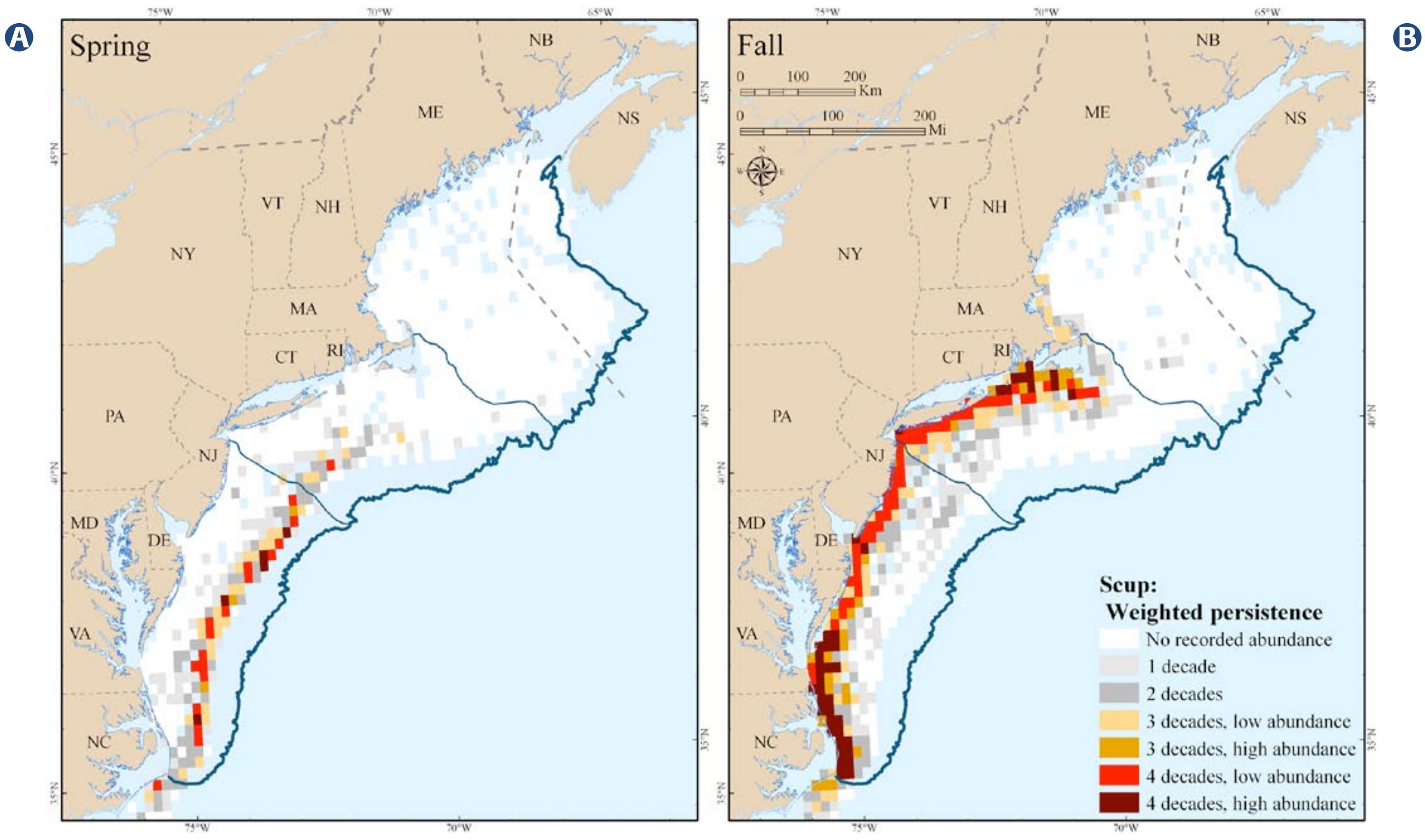


Figure 7-46. Areas with high persistence and abundance over 40 years for scup during the spring and fall seasons.

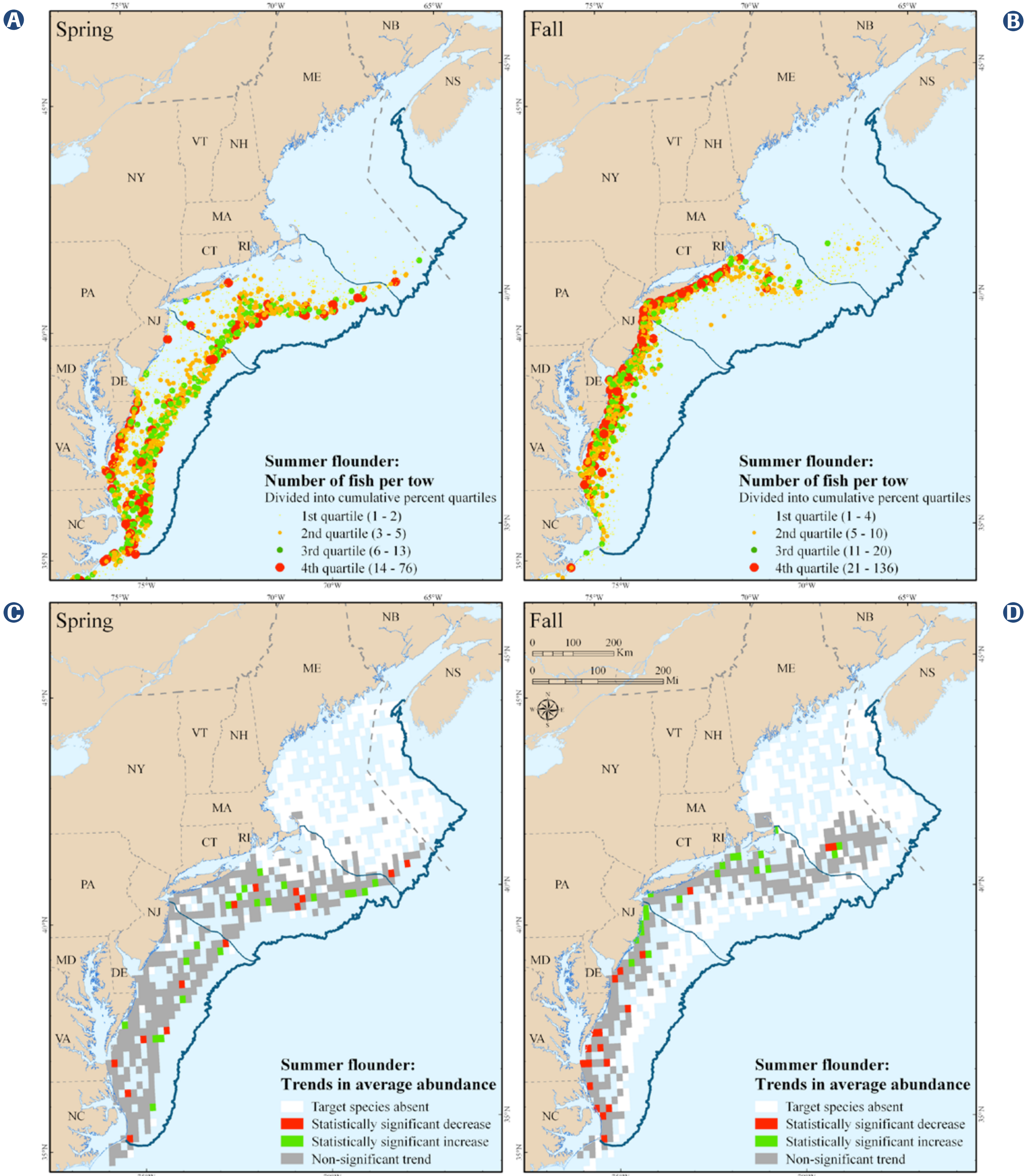


Figure 7-47. Trends in average abundance over 40 years for summer flounder during the spring and fall seasons.

Highest numbers of summer flounder were found from the southern flank of Georges Bank through Southern New England and the Mid-Atlantic as far south as Pamlico Sound (Figure 7-47a, b). Distinct seasonal patterns were also observed, with highest numbers found in nearshore coastal waters in the fall and a broader distribution out to the shelf/slope break in the spring. Statistical analyses did not identify significant trends across the species' range, though decreasing trends were observed across parts of the Mid-Atlantic while increasing trends were observed in portions of Southern New England (Figure 7-47c, d). Weighted persistence analyses for summer flounder identified offshore waters along the shelf/slope break extending from east of the Hudson/Raritan Estuary to Pamlico Sound and nearshore waters from south of Delaware Bay to Pamlico Sound as important in the spring, and nearshore waters from Cape cod, Massachusetts and to Cape Henry, Virginia as important in the fall (Figure 7-48).

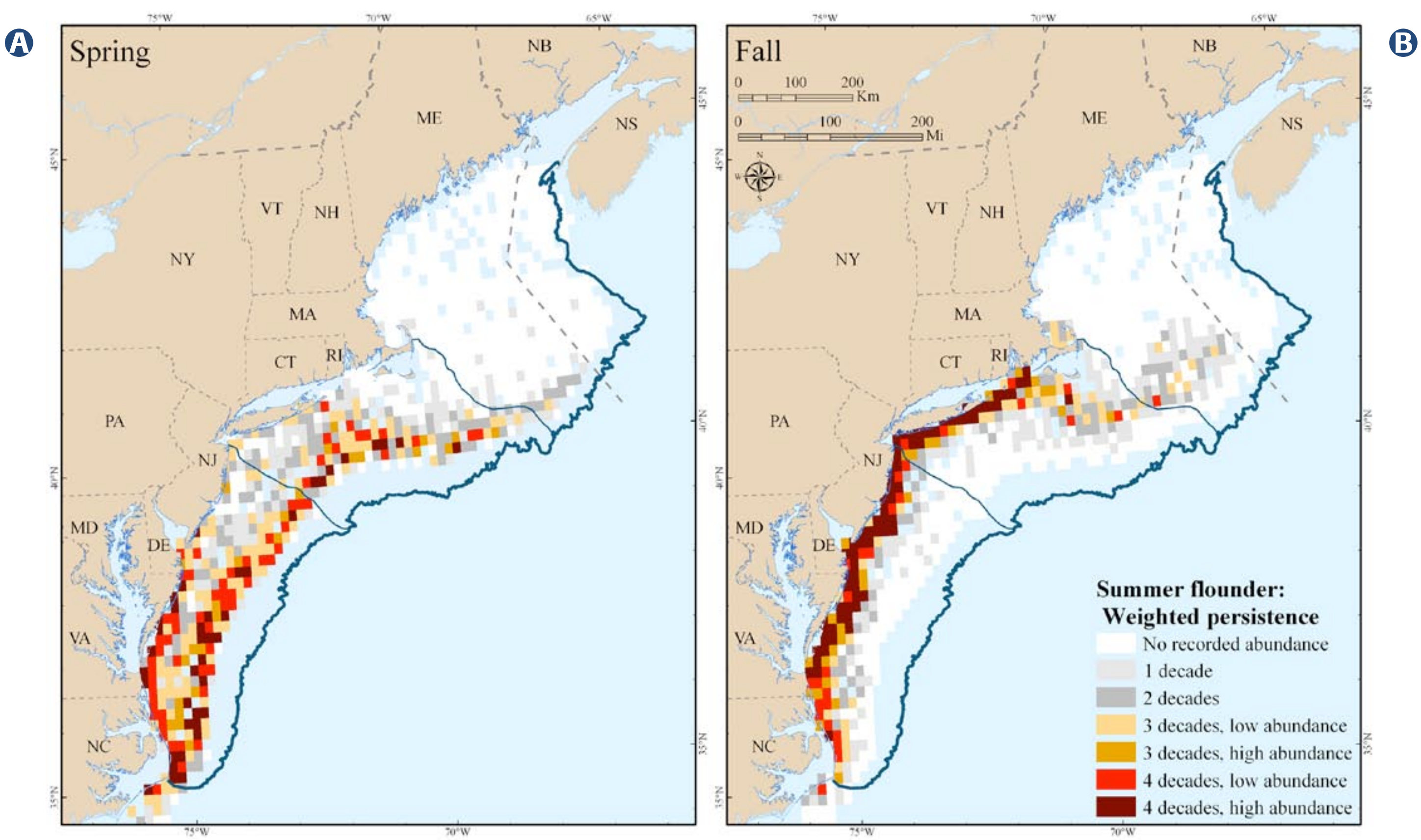


Figure 7-48. Areas with high persistence and abundance over 40 years for summer flounder during the spring and fall seasons.

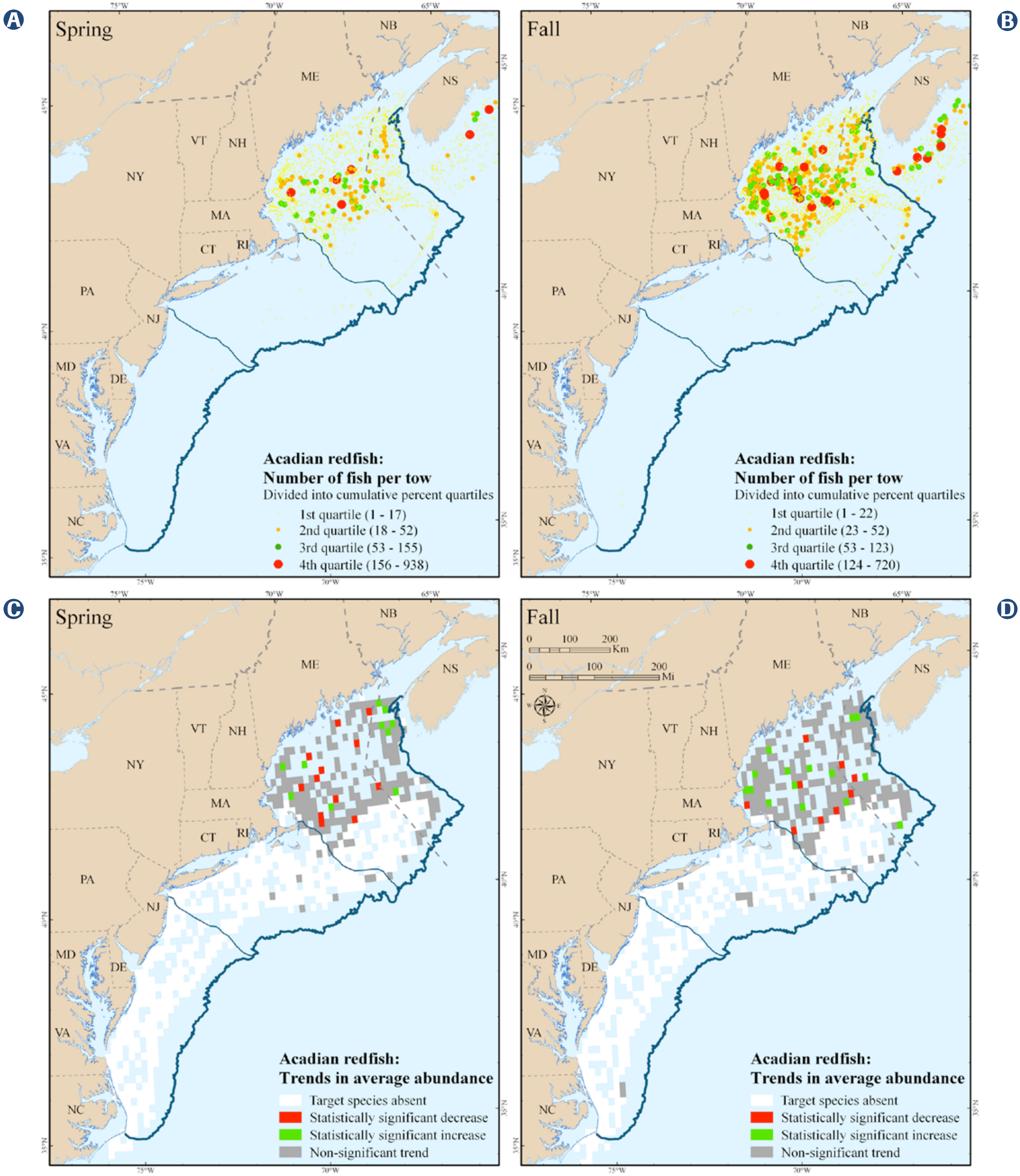


Figure 7-49. Trends in average abundance over 40 years for Acadian redfish during the spring and fall seasons.

Other Species of Interest

Acadian Redfish

Within the region, highest numbers of redfish occurred in the western and central portions of the Gulf of Maine and along the northern perimeter of Georges Bank and the Great South Channel (Figure 7-49a, b). Statistical analyses did not find significant trends across much of the range, though variable increasing and decreasing trends were observed at discrete locations within the Gulf of Maine in both United States and Canadian waters (Figure 7-49c, d). Weighted persistence analyses identified discrete and patchy locations scattered across much of the western and central portions of the Gulf of Maine including Jordan and Georges Basins, waters south of Digby, Nova Scotia, and the northern perimeter of Georges Bank as important (Figure 7-50).

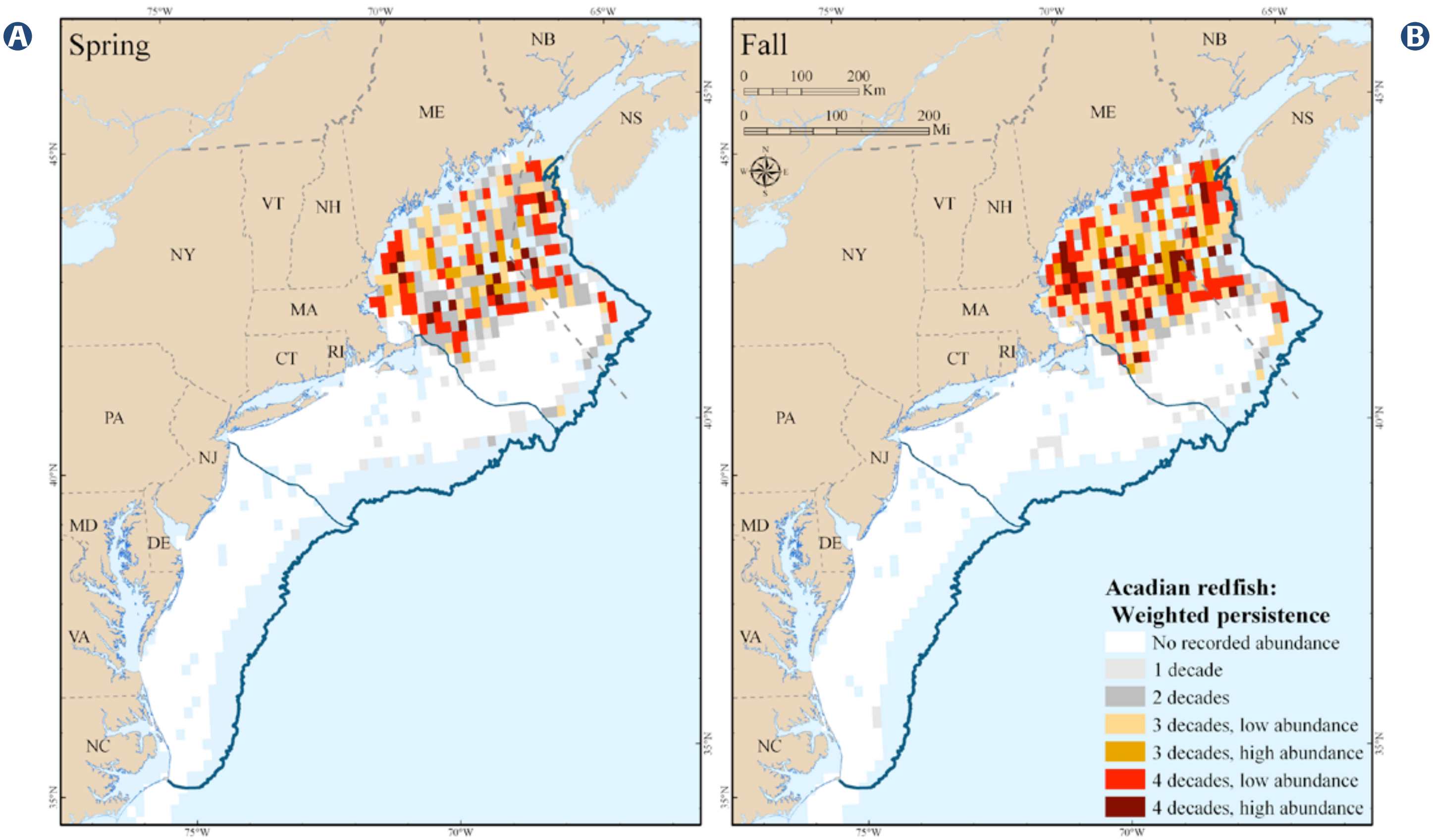


Figure 7-50. Areas with high persistence and abundance over 40 years for Acadian redfish during the spring and fall seasons.

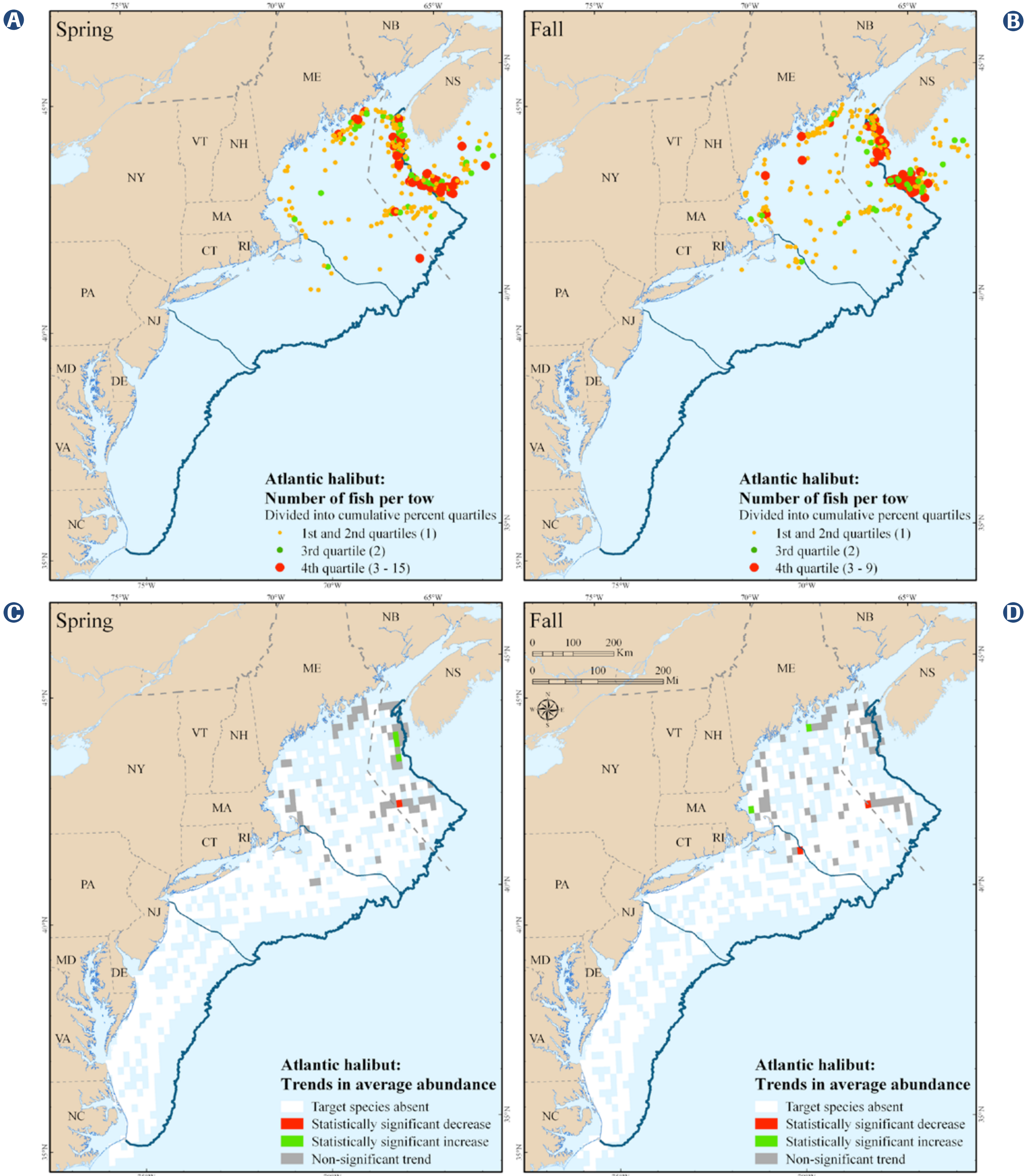


Figure 7-51. Trends in average abundance over 40 years for Atlantic halibut during the spring and fall seasons.

Atlantic Halibut

Within the region, the highest numbers of Atlantic halibut occurred along the coastal shelf in eastern Maine from Penobscot Bay to Grand Manan Banks, in Canadian waters from Digby, Nova Scotia to Browns Bank, and along the northern edge to the Northeast Peak of Georges Bank (Figure 7-51a, b). Statistical analyses did not identify significant trends across the species' range in the Gulf of Maine in either United States or Canadian waters (Figure 7-51c, d). Weighted persistence analyses for halibut identified coastal shelf waters in eastern Maine from Penobscot Bay to Jonesport, and Canadian waters from Digby, Nova Scotia to German Bank as important (Figure 7-52).

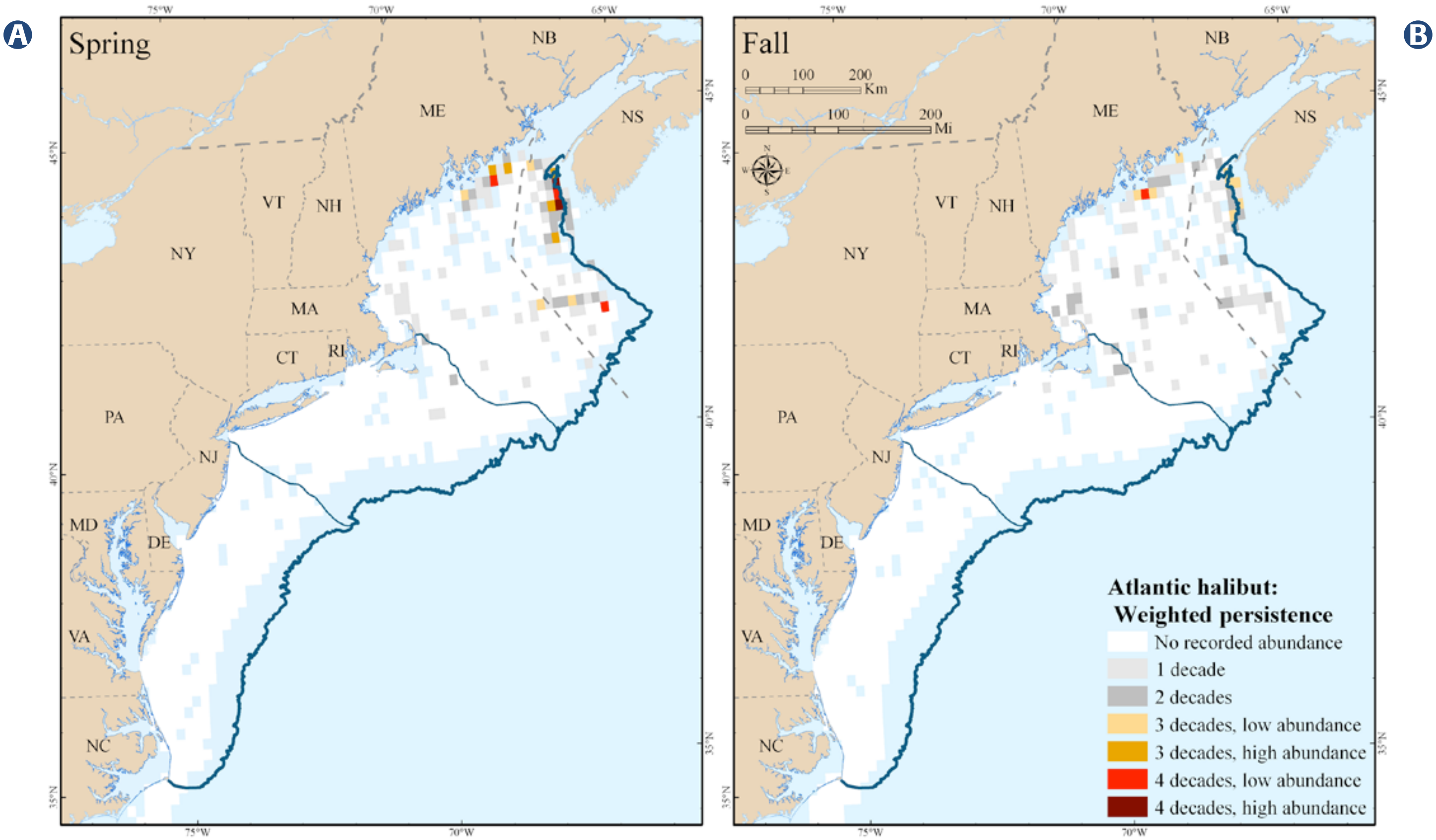


Figure 7-52. Areas with high persistence and abundance over 40 years for Atlantic halibut during the spring and fall seasons.

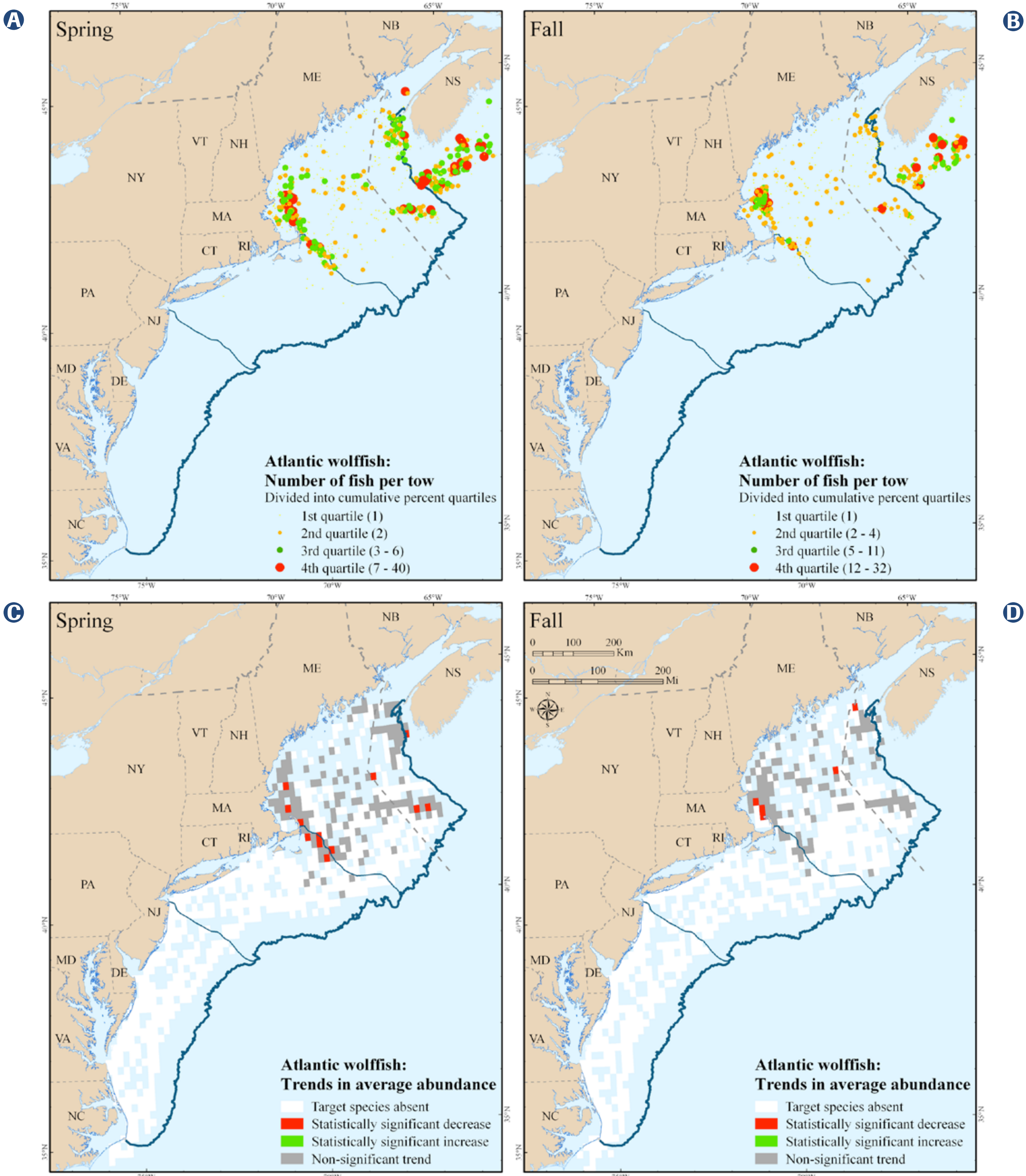


Figure 7-53. Trends in average abundance over 40 years for Atlantic wolffish during the spring and fall seasons.

Atlantic Wolffish

Within the region, highest numbers of Atlantic wolffish were found from the Great South Channel to the Jeffreys Ledge and Stellwagen Bank area, select locations in the central Gulf of Maine, Canadian waters from Digby, Nova Scotia to Browns Bank and along the Scotian Shelf, and the Northeast Peak of Georges Bank (Figure 7-53a, b). Statistical analyses identified declining trends for wolffish in the areas where they are still present in the Gulf of Maine and Georges Bank, most notably from the Great south Channel to the Stellwagen Bank/Jeffreys Ledge area (Figure 7-53c, d). Weighted persistence analyses for wolffish identified the area from Provincetown, Massachusetts to the Jeffreys Ledge and Stellwagen Bank area in the Gulf of Maine, waters off the southern tip of Nova Scotia including German Bank, and along the northern edge and Northeast Peak of Georges Bank as important (Figure 7-54).

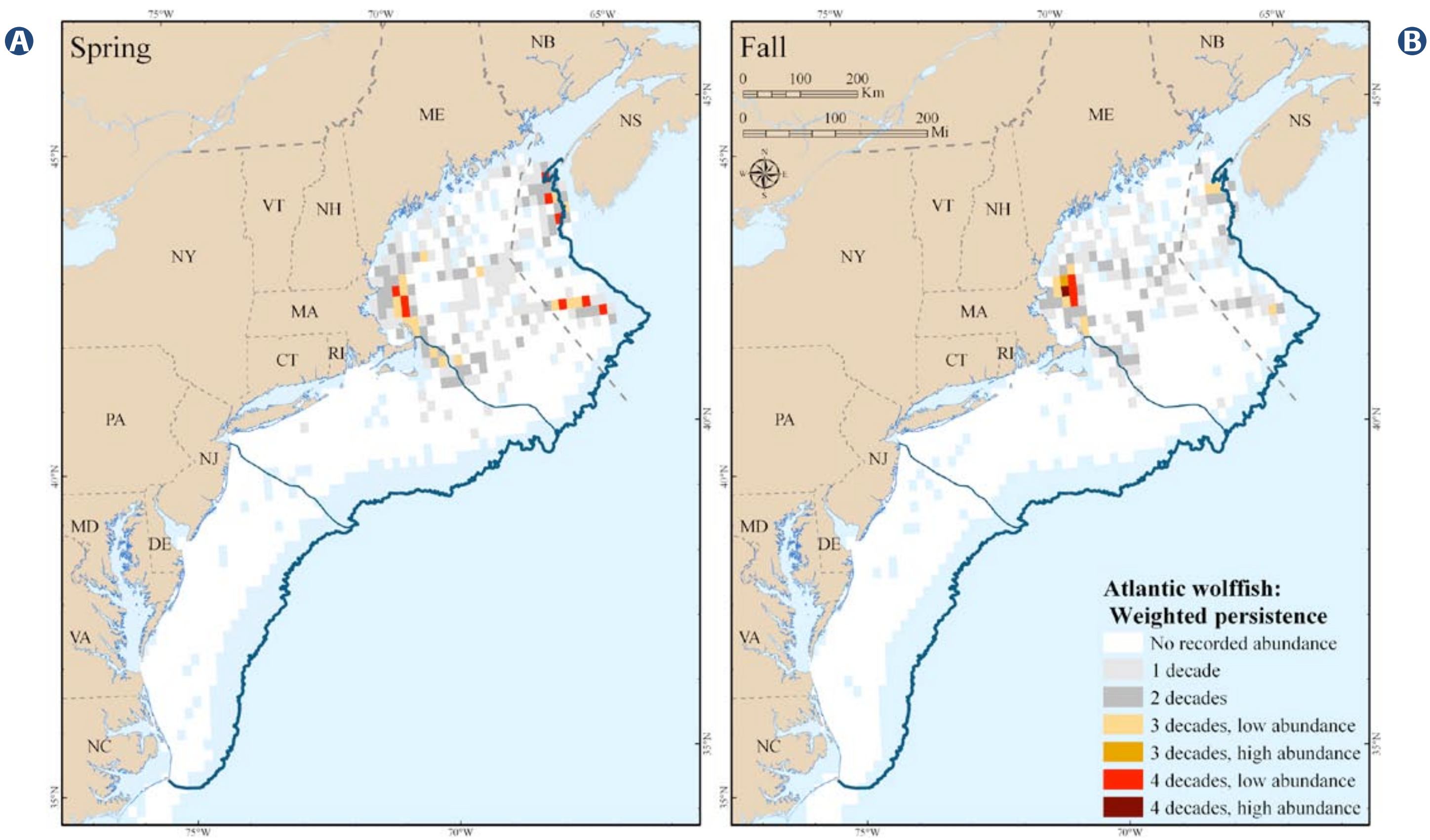


Figure 7-54. Areas with high persistence and abundance over 40 years for Atlantic wolffish during the spring and fall seasons.

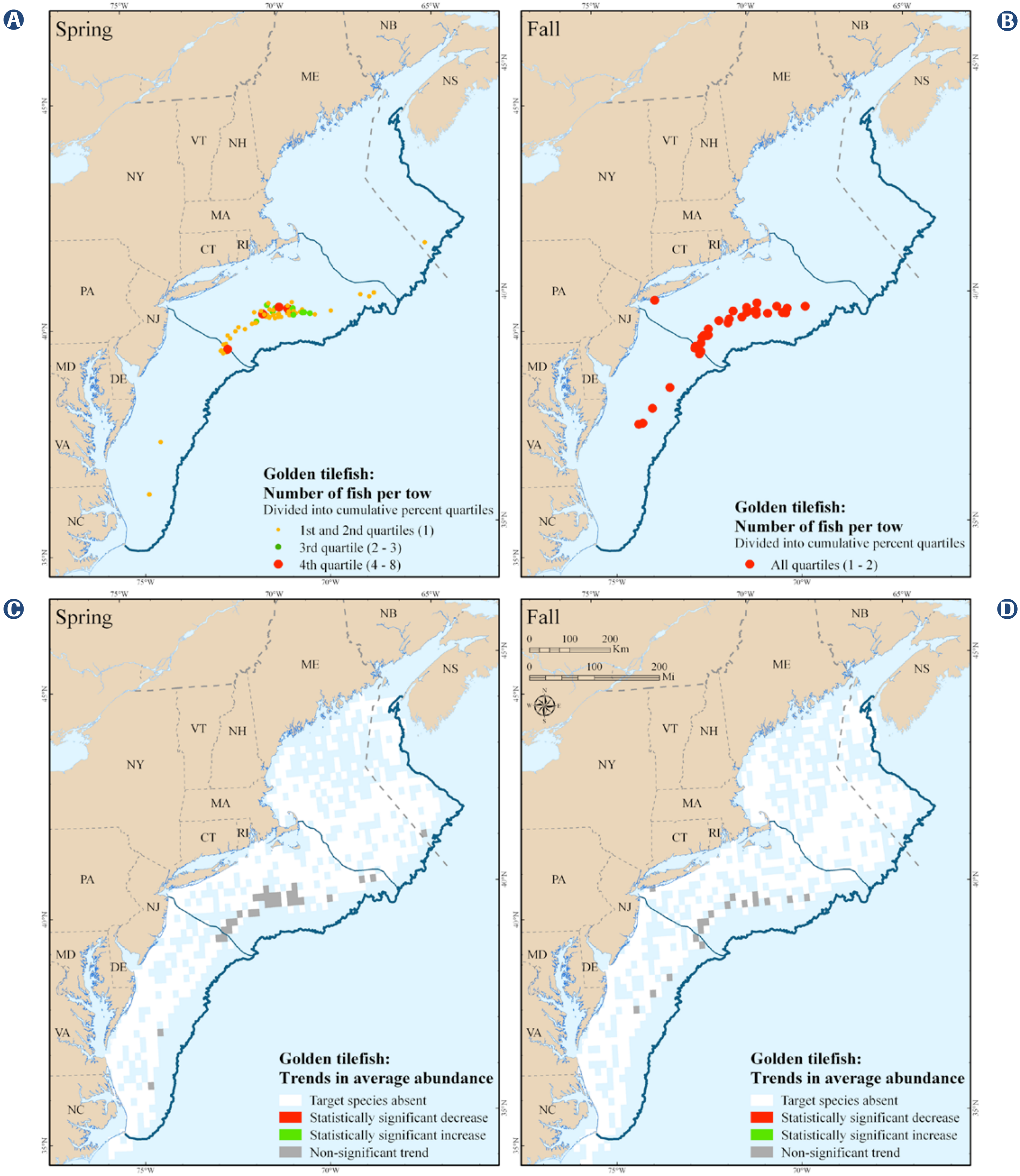


Figure 7-55. Trends in average abundance over 40 years for golden tilefish during the spring and fall seasons.

Golden Tilefish

Within the region, golden tilefish occurred along the Continental Shelf in the Southern New England and mid-Atlantic areas, with highest numbers found in deeper waters along the shelf/slope break off Long Island Sound to Chincoteague Bay, Virginia (Figure 7-55a, b). Statistical analyses did not identify significant trends for tilefish (Figure 7-55c, d). Weighted persistence analyses identified a narrow band of waters along the shelf/slope break from Long Island to the Hudson/Raritan Estuary as important (Figure 7-56). This area is consistent with the location of the tilefish Habitat Area of Particular Concern designated by MAFMC and NMFS.

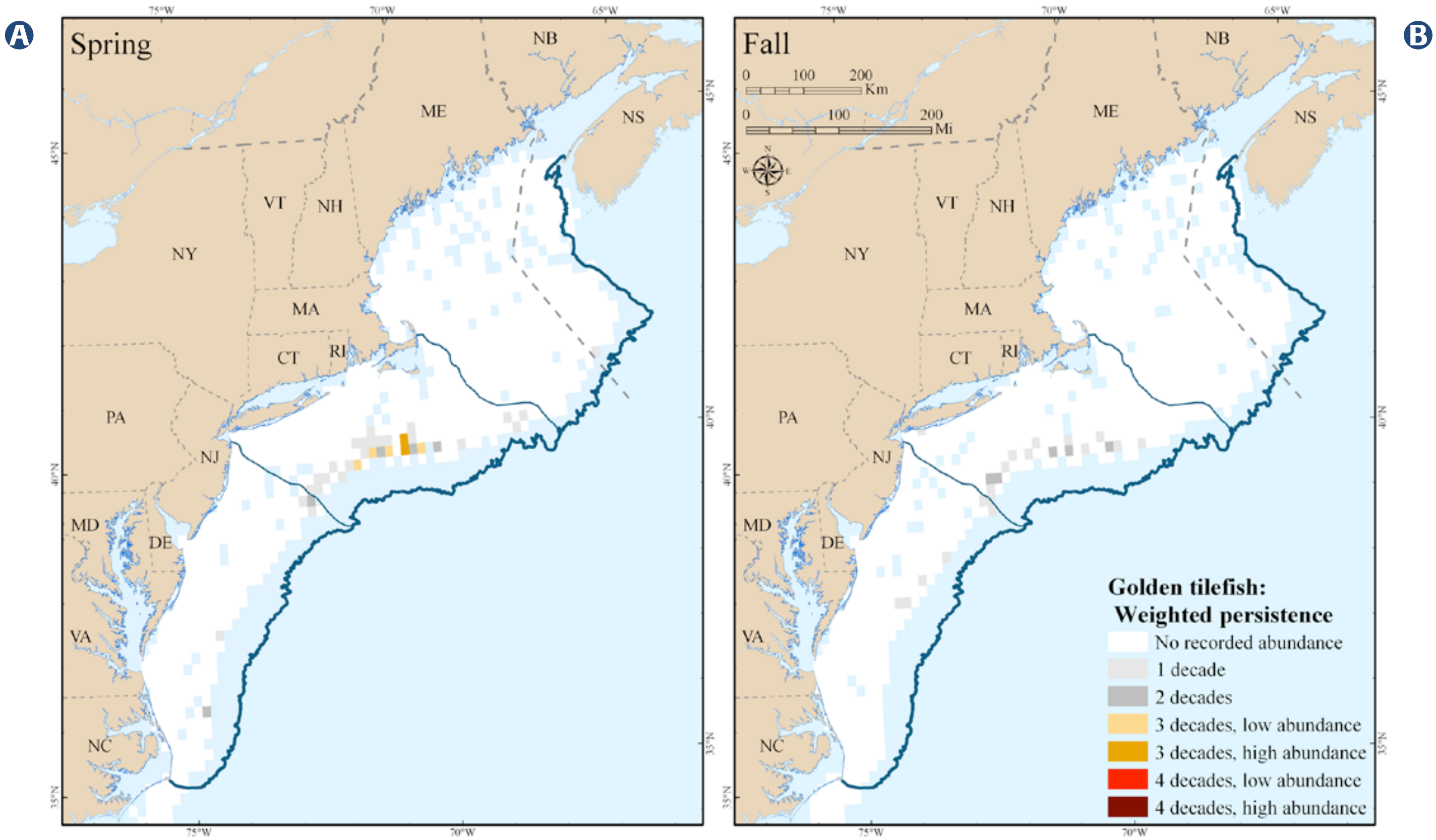


Figure 7-56. Areas with high persistence and abundance over 40 years for golden tilefish during the spring and fall seasons.

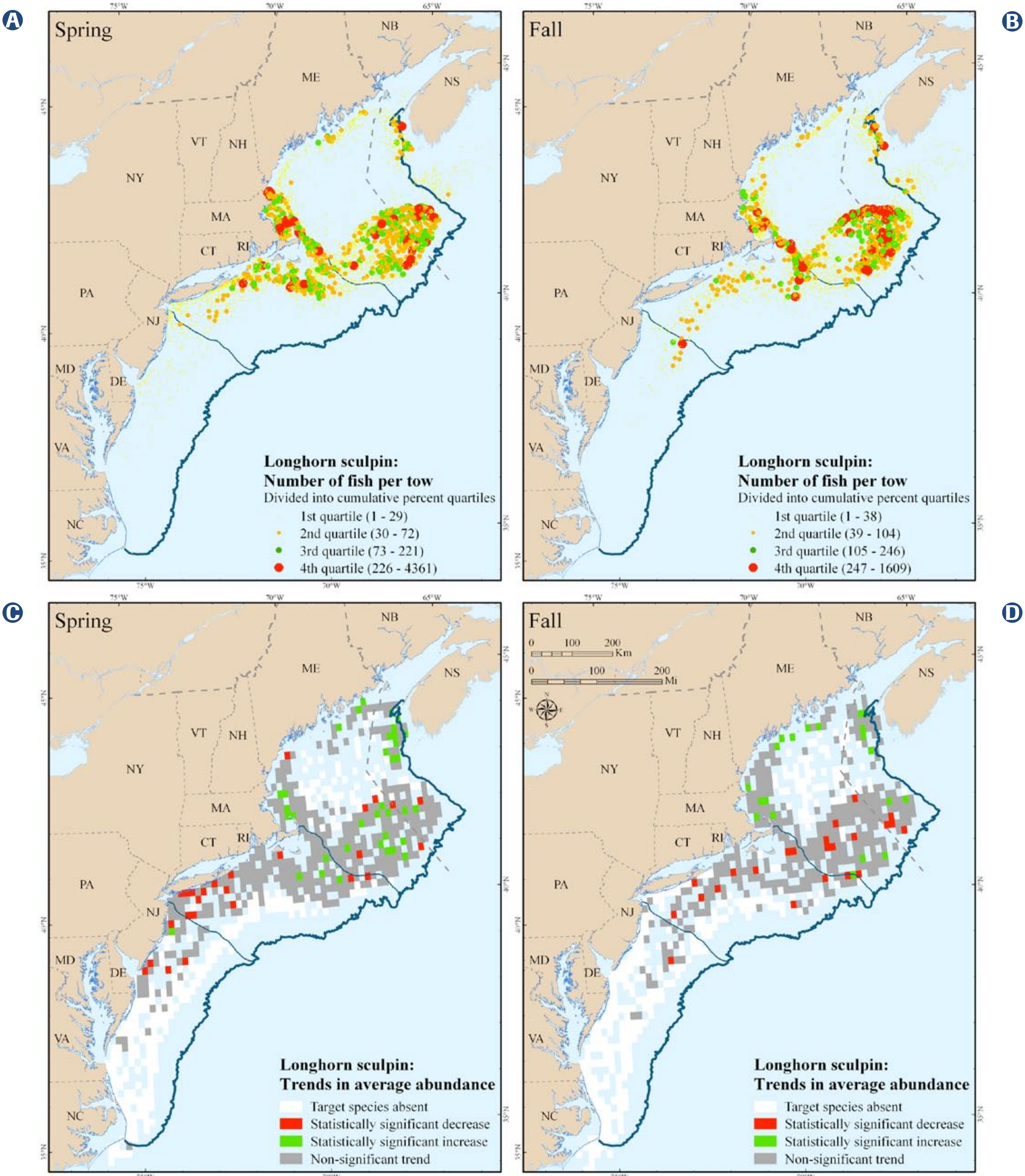


Figure 7-57. Trends in average abundance over 40 years for longhorn sculpin during the spring and fall seasons.

Longhorn Sculpin

Within the region, longhorn sculpin occurred from the Bay of Fundy and off the southern tip of Nova Scotia south to Virginia, with highest numbers found in the western Gulf of Maine, along the flanks of Georges Bank, and south to Barnegat Bay, New Jersey (Figure 7-57a, b). Statistical analyses identified generally increasing trends in the Gulf of Maine, a mix of increasing and decreasing trends on Georges Bank, and decreasing trends across much of the Southern New England/Mid-Atlantic (Figure 7-57c, d). Weighted persistence analyses identified Massachusetts Bay, the Great South Channel and the eastern portions of Georges Bank including the Northeast Peak and Northeast Channel, and waters off the southern tip of Nova Scotia as important (Figure 7-58).

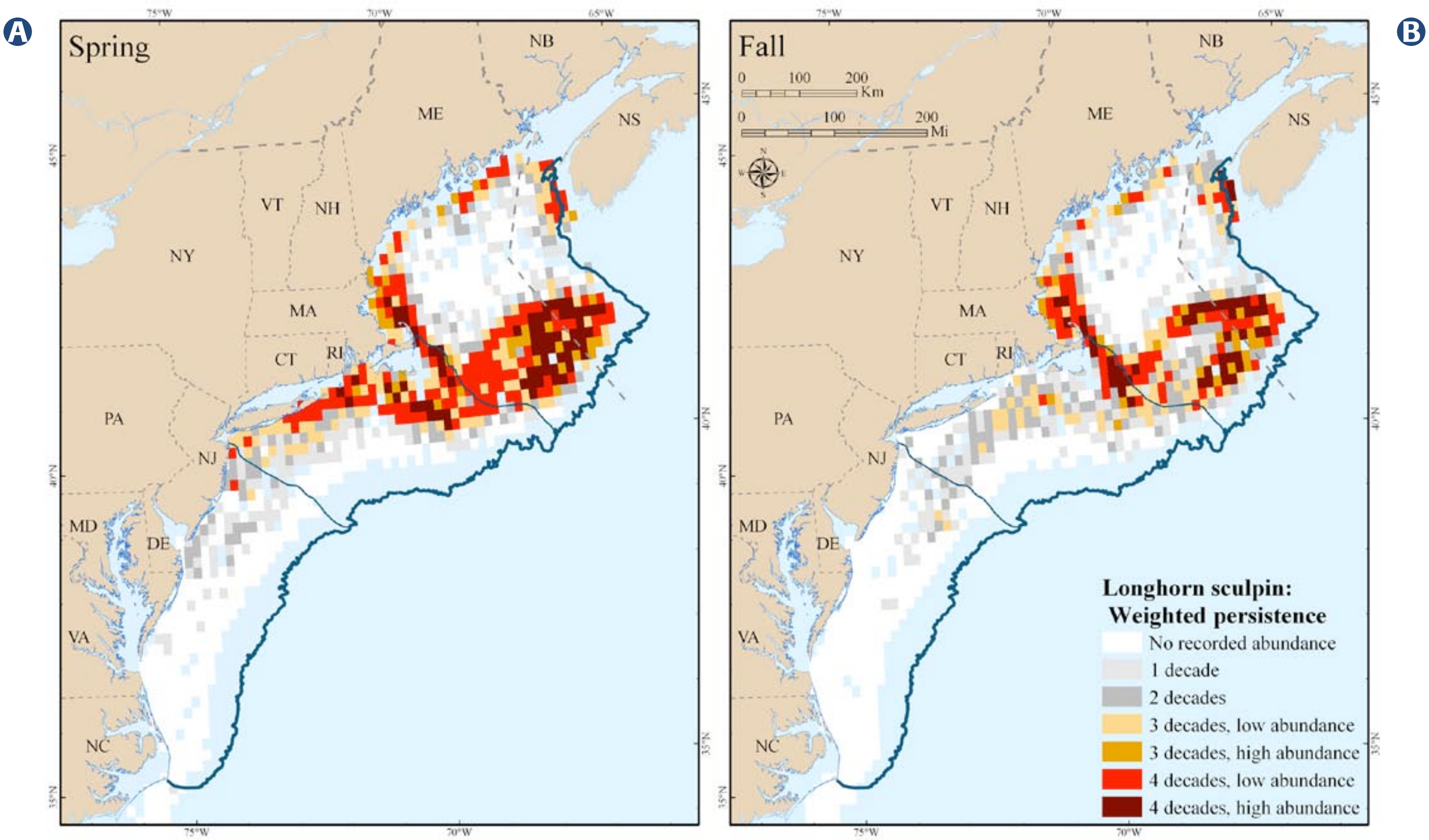


Figure 7-58. Areas with high persistence and abundance over 40 years for longhorn sculpin during the spring and fall seasons.

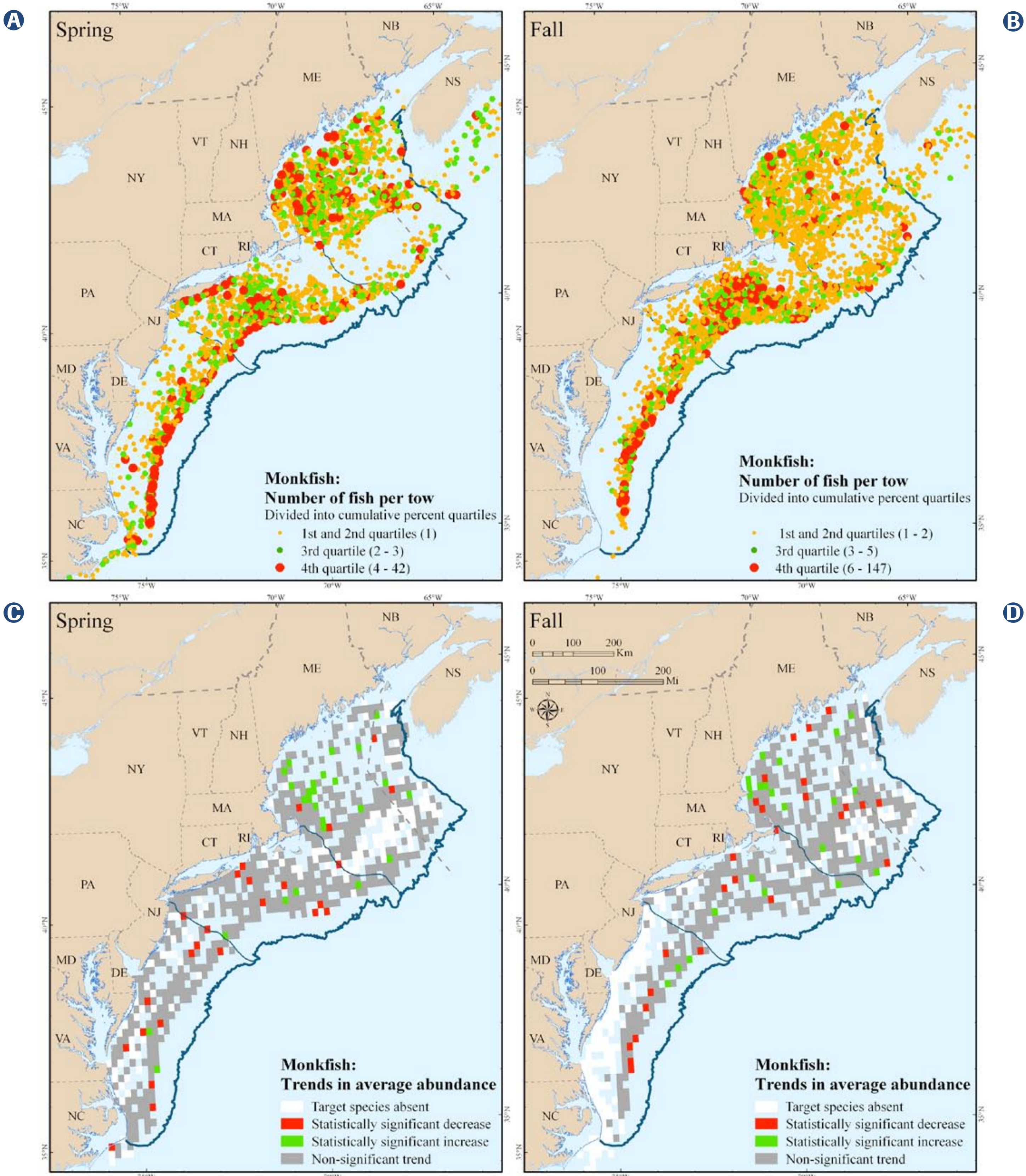


Figure 7-59. Trends in average abundance over 40 years for monkfish during the spring and fall seasons.

Monkfish

Within the region, monkfish was common in both inshore and offshore areas of the Gulf of Maine and ubiquitous across the Continental Shelf in the Mid-Atlantic Bight (Figure 7-59a, b). Highest numbers occurred throughout the Gulf of Maine, off Long Island Sound in Southern New England, and along the shelf/slope break from New Jersey to Pamlico Sound. Statistical analyses identified variable trends for monkfish, with a mix of increasing and decreasing trends observed throughout the range depending on location (Figure 7-59c, d). Weighted persistence analyses identified deeper waters in the Gulf of Maine from Jeffreys Ledge to the Cashes Ledge area extending to Franklin Swell, shelf waters south of Nantucket and east of the Hudson/Raritan Estuary, and waters along the shelf/slope break from Chincoteague Bay to Albemarle Sound as important (Figure 7-60).

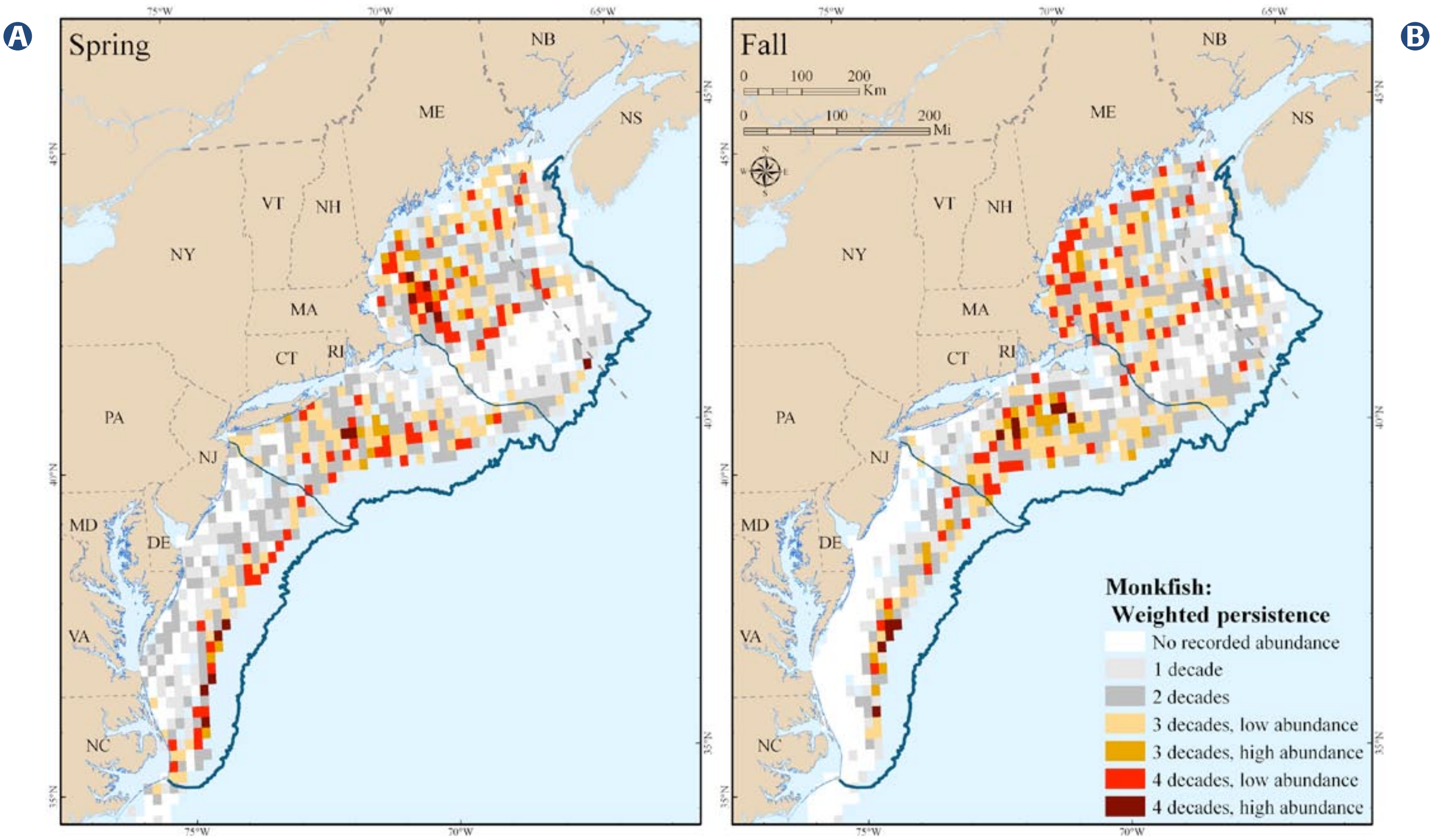


Figure 7-60. Areas with high persistence and abundance over 40 years for monkfish during the spring and fall seasons.

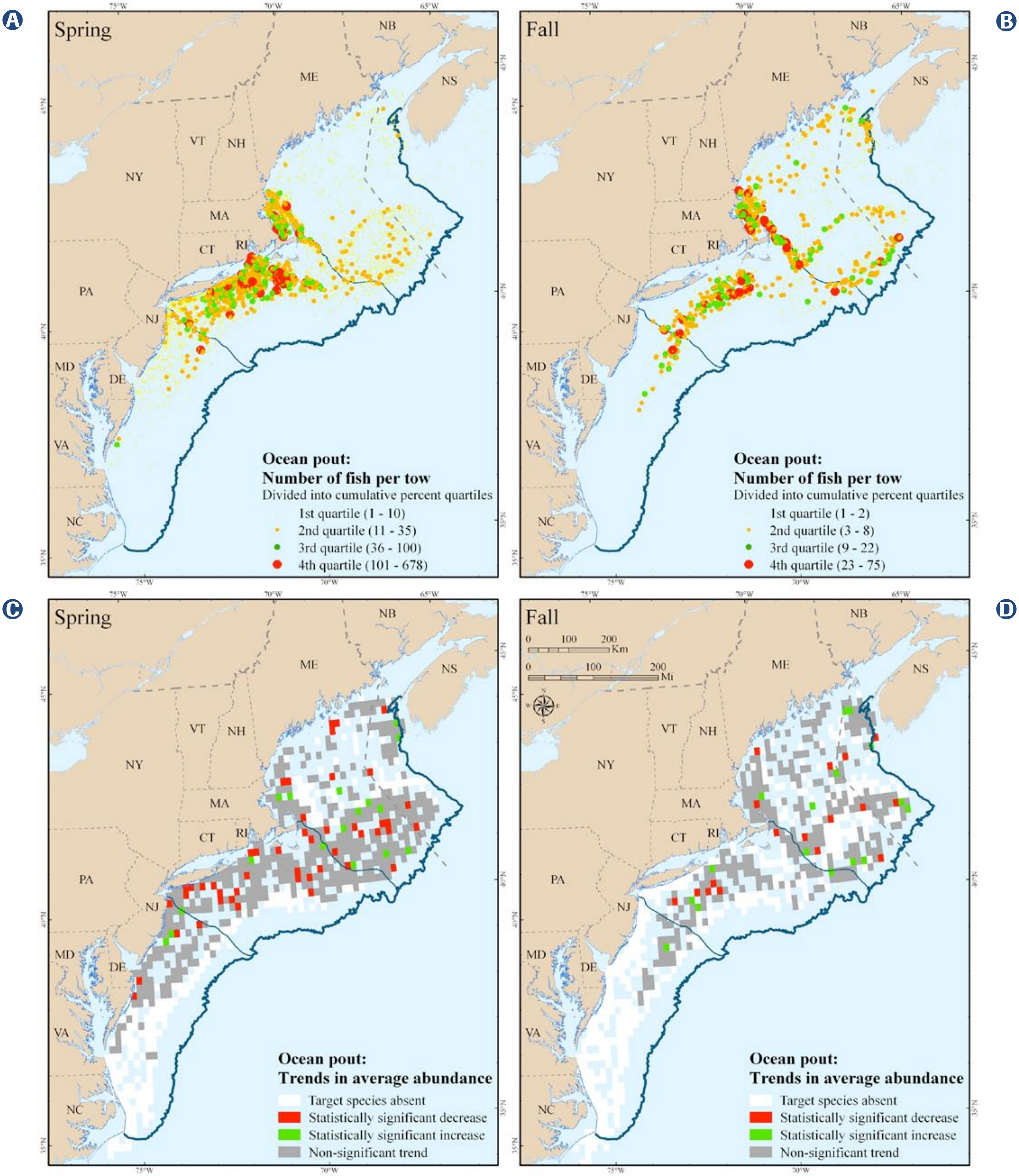


Figure 7-61. Trends in average abundance over 40 years for ocean pout during the spring and fall seasons.

Ocean Pout

Within the region, ocean pout were found in highest numbers along a narrow band from Barnegat Bay, New Jersey through Narragansett Bay to south of Nantucket in Southern New England; in Cape Cod Bay, Massachusetts Bay, and Stellwagen Bank in the western Gulf of Maine; and along the southern flank of Georges Bank (Figure 7-61a, b). Statistical analyses identified variable trends across the species' range, with declining trends generally observed in Southern New England and a mix of declining and increasing trends in the Gulf of Maine and Georges Bank depending on location (Figure 7-61c, d). Weighted persistence analyses identified nearshore waters in Massachusetts Bay from Stellwagen Bank to the Great South Channel and waters south of Narragansett Bay to Sandy Hook, New Jersey as important (Figure 7-62).

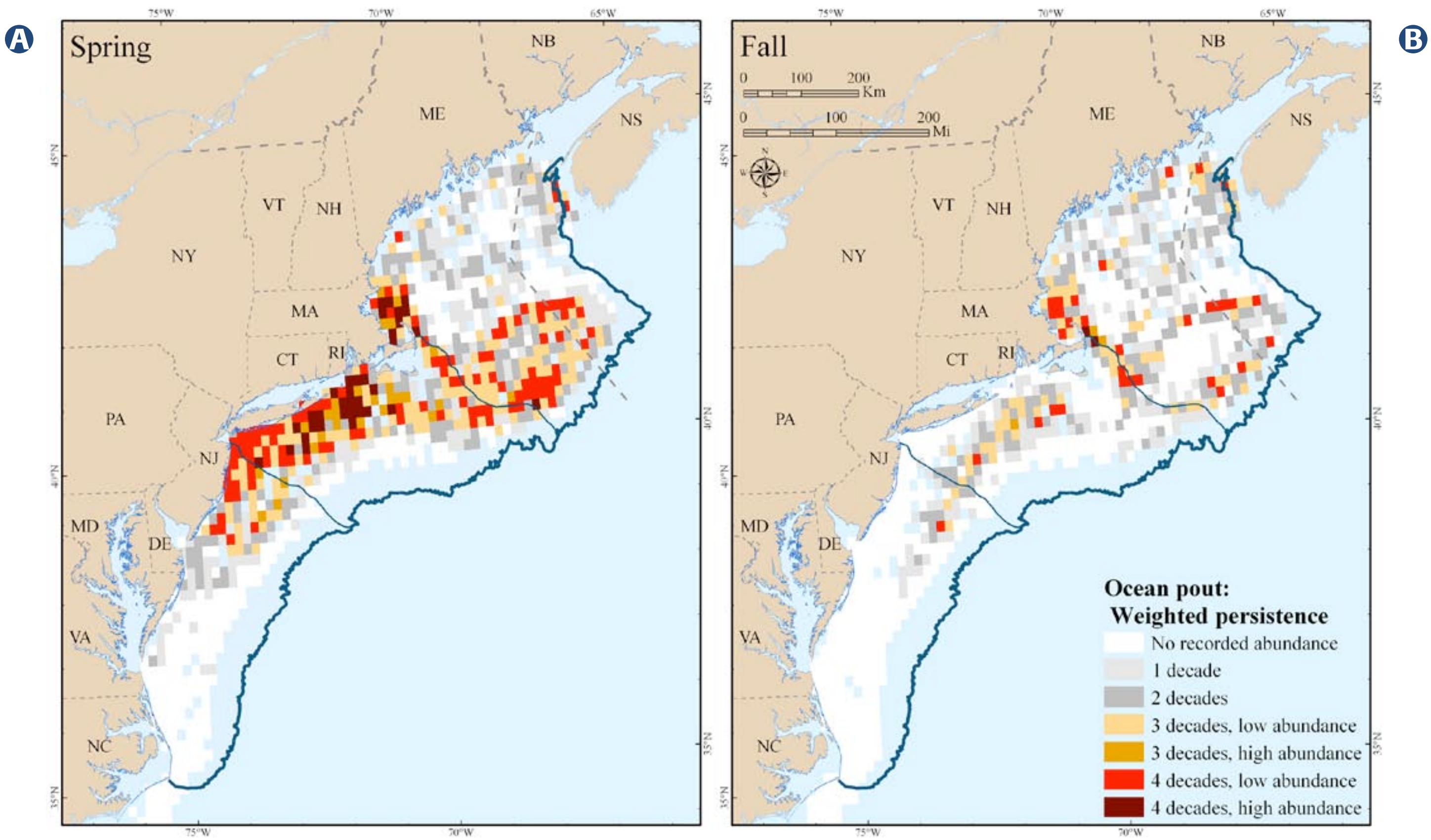


Figure 7-62. Areas with high persistence and abundance over 40 years for ocean pout during the spring and fall seasons.

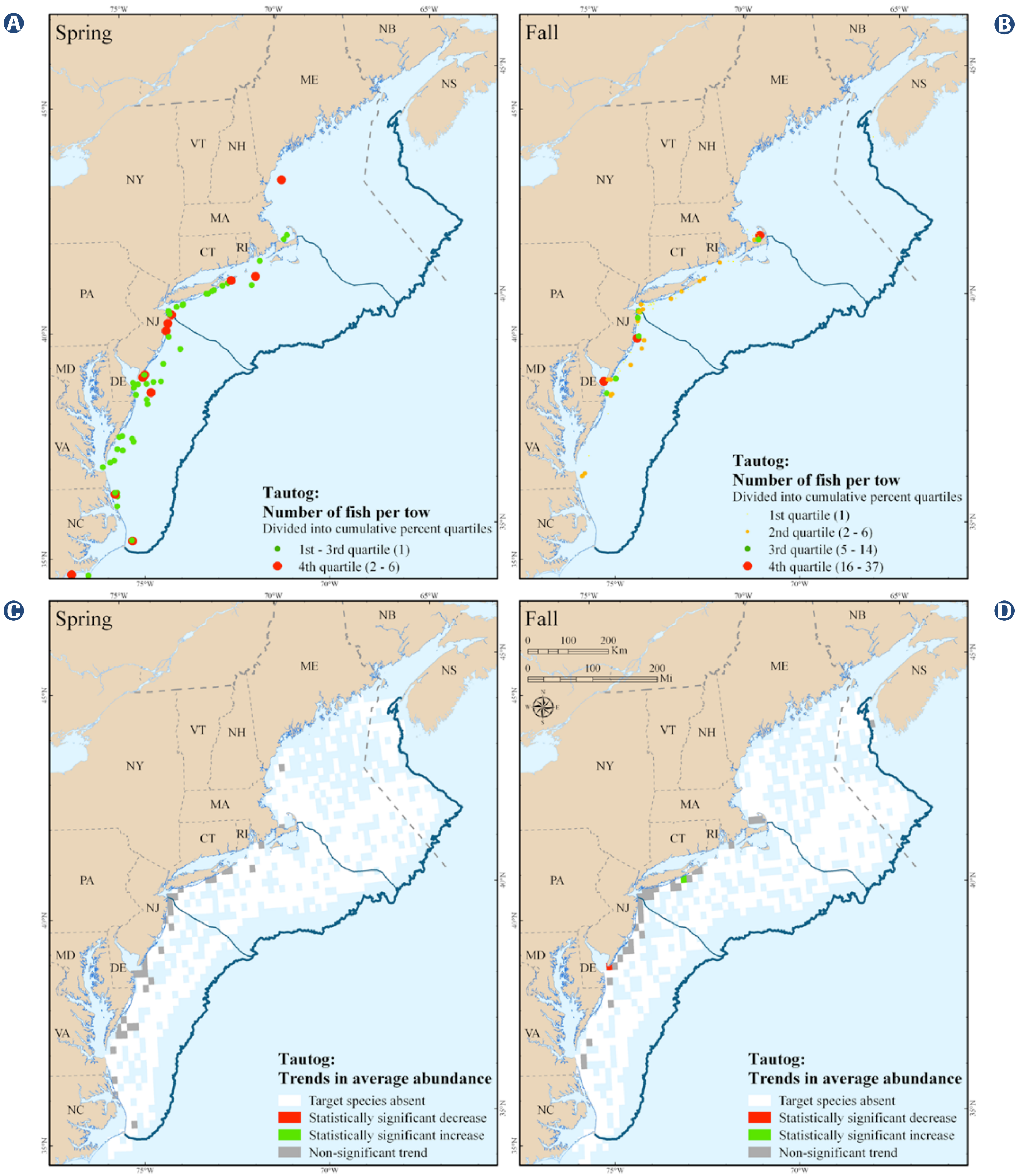


Figure 7-63. Trends in average abundance over 40 years for tautog during the spring and fall seasons.

Tautog

Within the region, highest numbers of tautog were found from Chesapeake Bay to Cape Cod, with lesser numbers observed in the Gulf of Maine in and around Massachusetts Bay and the Jeffreys Ledge/Stellwagen Bank area (Figure 7-63a, b). Statistical analyses did not identify significant trends in abundance over the species' range (Figure 7-63c, d).Weighted persistence analyses for tautog identified nearshore waters from the Hudson/ Raritan Estuary to the mouth of Delaware Bay as important (Figure 7-64).

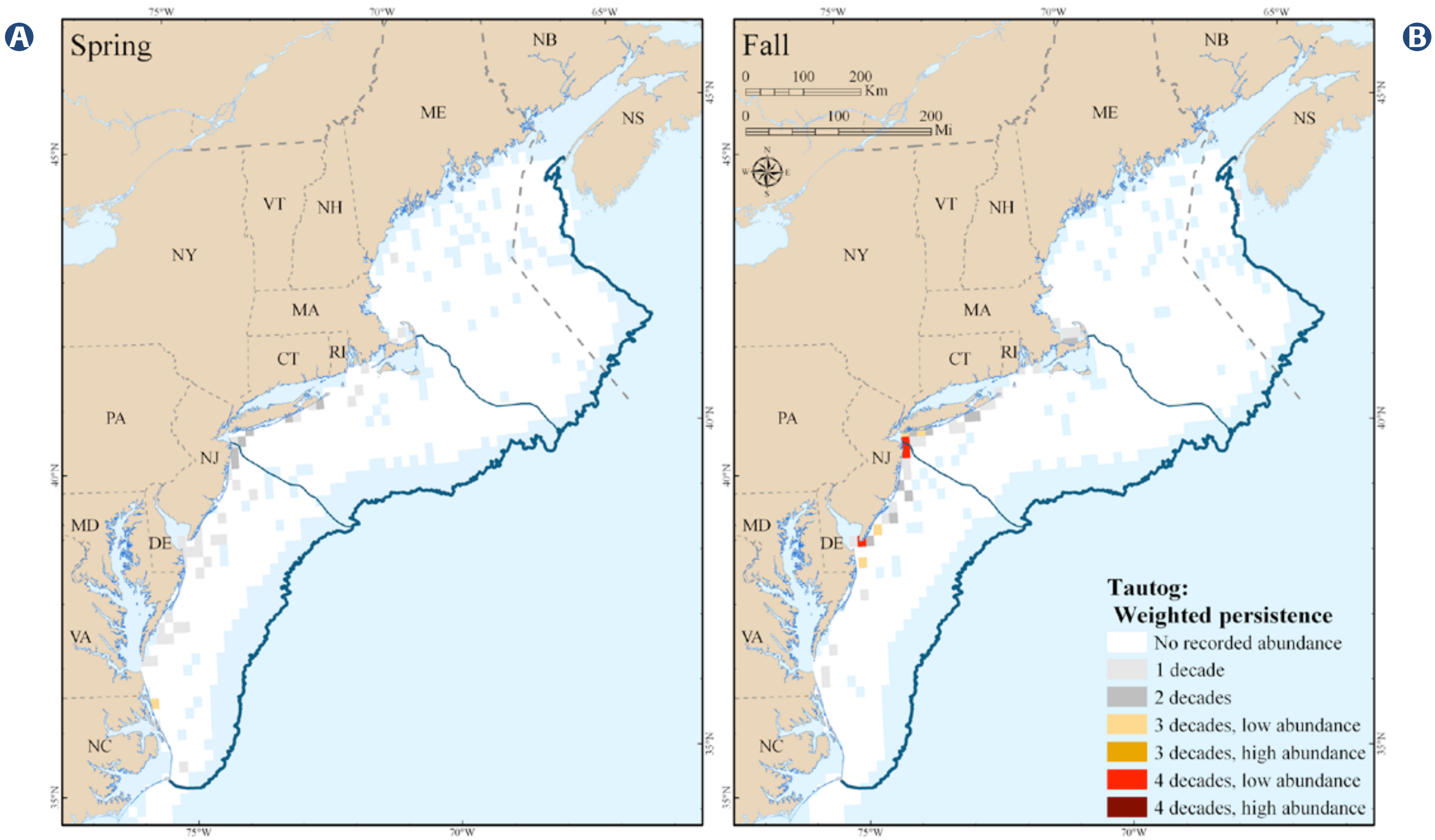


Figure 7-64. Areas with high persistence and abundance over 40 years for tautog during the spring and fall seasons.

Human Interactions

Humans interact with the species included in the demersal fish assemblage in a number of ways that either directly or indirectly influences their relative abundance and distribution within the region. While the degree and intensity of interaction varies significantly depending on species and location, the following human interactions have been identified as important within the region: 1) fisheries-related interactions, 2) climate change, 3) nearshore habitat loss and degradation, 4) energy development, 5) power plants, and 6) invasive species.

Fishing-related interactions

Ecosystem level effects of fishing are well documented in the scientific literature, including changes in food web interactions and fluctuations in ecosystem productivity. Stock biomass and abundance have been reduced by fishing pressure, and the size structure of populations has been altered (NRC 2006). Within the region, species included in the demersal fish assemblage have been directly and indirectly impacted by both commercial and recreational fisheries for well over a century. In fact, many were fished by natives before colonists arrived hundreds of years ago. The most recent peer-reviewed stock assessments identified twelve stocks of demersal species in the assemblage as overfished (population size is less than one half of the current scientific estimate of a "healthy" population) and ten as subject to overfishing (fishing mortality rates are higher than current estimates of "sustainable" levels) (NMFS 2009b). Directed fisheries on a number of demersal fish have resulted in significant changes in overall abundance, distribution, and life history characteristics. Impacts include decreases in overall spawning stock biomass, truncated age structure (removal of the oldest individuals from the population), and changes in age and length at sexual maturity. Truncated age structures in which there are relatively few older fish have been observed for several species, including witch flounder, Georges Bank Atlantic cod, and Georges Bank yellowtail flounder most recently (NEFSC 2008; TRAC 2009a; TRAC 2009b). In addition, significant reductions in age and length at sexual maturity have been observed for many species including Atlantic cod, black sea bass, golden tilefish, pollock, witch flounder (Lough 2005; Cargnelli et al. 1999a; Steimle et al. 1999a; Cargnelli et al. 1999b; Drohan. et al. 2007). Reduction in age and length at sexual maturity is of particular concern in light of the growing body of scientific evidence that larger, older fish produce more eggs and viable offspring than younger smaller fish (Berkeley et al. 2004). Recreational fishing is also a significant source of mortality, comprising a significant portion of the overall take for many of the demersal species, including Atlantic cod in the Gulf of Maine, black sea bass, scup, spot, summer flounder, tautog, weakfish, and winter flounder (NEFSC 2008; ASMFC 2009).

Benthic habitats for many species included in the assessment are known to be vulnerable to impacts from fishing gear, particularly bottom-tending mobile gear such as trawls and dredges. Numerous studies have documented a variety of impacts that trawls and dredges can have on sensitive marine habitats, including loss of physical features, loss of structure-forming organisms, reduction of overall habitat complexity, and alteration of the detailed physical structure of the seafloor (NRC 2002). The New England Fisheries Management Council (NEFSC) found that habitats for juvenile and/or adult life stages of 23 of the demersal fish species included in this assessment are moderately or highly vulnerable to impacts from otter trawls and dredges (NEFMC 2004). In addition, Atlantic States Marine Fisheries Commission (ASMFC) identified trawling and dredging as threats to habitats for tautog, black sea bass, and summer flounder (ASMFC 2009).

Climate change (water temperatures, currents, and primary production)

Another anthropogenic (human-caused) impact of increasing concern is the set of long-term effects resulting from global climate change, including increasing water temperatures, ocean acidification, and changes in currents, circulation patterns, and overall ocean productivity. The geographic distribution of many of the demersal species included in this assessment is heavily influenced by bottom water temperatures. In addition, spawning events, seasonal migrations, transformation from egg to larval phases, and juvenile survival rates are also temperature-dependent (NMFS 2009c). While the degree to which climate change will influence these critical life stages is unclear, the topic is of growing concern in the region and beyond.

Several studies have been conducted which document shifts in species range in response to temperature changes, while others have been undertaken to predict potential future shifts. For example, Mountain and Murawski (1992) observed latitudinal shifts in Gulf of Maine groundfish distributions in response to temperature changes. University of Rhode Island researchers have also observed long-term shifts in species composition (from vertebrates to invertebrates and from benthic to pelagic species) within Narragansett Bay and surrounding waters over the past 50 years (Collie et al. 2008). Smaller warm-water species have increased while cool-water species have decreased; these changes were attributed to a variety of factors, including climate change and increasing water temperatures. Lastly, Fogarty et al. (2008) looked at potential shifts in the range of Atlantic cod and concluded that the probability of catching cod decreases markedly with increasing bottom water temperatures. They also noted that reduced juvenile Atlantic cod survival caused by increasing water temperatures could significantly impact long-term recruitment trends.

Energy development

As interest in alternative and renewable energy production grows in the United States, energy development in marine water, including oil and gas exploration and extraction, wind and tidal energy facilities, and liquefied natural gas (LNG) terminals, are emerging as an important human interaction. Impacts from oil and gas activities include direct habitat disturbance from exploration and development activities and oil spills during production and transportation. Impacts from wind and tidal energy include direct habitat disturbance during construction, alteration of hydrologic regimes, and noise. Impacts from LNG development include direct habitat impacts from the construction of offloading facilities and entrainment in water withdrawals associated with LNG conversion from liquid to a gaseous state (Johnson et al. 2008).

Potential impacts from oil and gas development are most likely to occur on Georges Bank and along the Continental Shelf in the Mid-Atlantic because these areas are richest in these resources, and proposals for extraction have already been made for these areas. Several wind farms and tidal energy facilities have been proposed within the region, though very few facilities have actually been permitted and constructed. Two LNG terminals were recently sited in the waters of Massachusetts Bay near Gloucester.

Power plants

Coastal power plants have the potential to impact demersal fish species in a number of ways, including by increasing water temperatures as a result of discharging cooling water and increasing direct mortality through entrainment and impingement in cooling water intake systems (Johnson et al. 2008). Interactions will be dependent on the location and design of cooling intake and discharge facilities, and the degree to which individual species utilize nearshore coastal waters. The ASMFC has raised concerns about increased water temperatures, and impingement in cooling water intakes has been specifically identified as a problem for a number of species including winter flounder, tautog, and weakfish.

Nearshore habitat degradation

Nearshore habitat degradation is a pervasive problem throughout much of the region, particularly in the central and southern portions. Habitat degradation takes a number of forms, including direct habitat loss due to coastal development and conversion, water quality degradation from point and non-point source pollution, dredging and dredge spoil placement, dredging for beach nourishment projects, and hydrological modifications resulting from ditching and channelization. The ASMFC has identified these types of nearshore habitat degradation as significant threats to many of the species they manage, including spot, weakfish, tautog, scup, black sea bass, summer flounder, and winter flounder (ASMFC 2009).

Invasive species

Introduction and transportation of non-native invasive species is another human impact of growing concern. Invasive species have altered benthic habitats and food web dynamics at a number of locations within the region. Two species of particular recent concern are Codium and Didemnum. Codium is an invasive green alga (commonly known as dead man's fingers) that has taken hold in many nearshore coastal waters within the region from the Gulf of St. Lawrence to North Carolina. Codium is a dominant species in some subtidal zones and can radically alter subtidal community composition, structure, and function (Levin et al. 2002). The rapid growth of this species and its ability to regenerate from broken fragments assist in its ability to outcompete native plant species like kelp beds, the primary shelter for many finfish and invertebrates.

Didemnum is an invasive tunicate that smothers benthic organisms; it has been found in many parts of the region, causing particular concern by its recent spread across a significant portion of prime fishing grounds on Georges Bank. While extensive studies on the effect of *Didemnum* invasion of seafloor habitats have not been completed to date, evidence suggests it can overgrow scallops, mussels, other sessile species, and gravel potentially creating a barrier between demersal fish and prey items including worms and bivalves (Bullard et al. 2007). In addition, mat surfaces may reduce the area of the seabed suitable for settlement of larvae of other benthic species, including sea scallops (Valentine 2007).

Management and Conservation

Regulatory Authorities

Most of the species included in the demersal fish group are formally managed by one of three fishery management entities: the NEFMC, the Mid-Atlantic Fisheries Management Council (MAFMC), or the ASMFC. Regulatory authority for the NEFMC and the MAFMC is provided by the Magnuson Stevens Fishery Conservation and Management Act as amended in 2006. The Magnuson Stevens Act delegates responsibility for developing fishery management plans (FMP) to the regional councils, but those plans must be approved by the NMFS. Prior to approval and promulgation of implementing regulations, NMFS must review the plans submitted by the regional council and ensure they comply with ten National Standards included in the Magnuson Stevens Act. These standards require that regulations achieve optimum yield while preventing overfishing, rebuild overfished populations, minimize adverse impacts to essential fish habitat caused by fishing activities, minimize bycatch and discard of non-target species, and minimize adverse socio-economic impacts on fishing dependent communities consistent with the other requirements mentioned above.

Regulatory authority for the ASMFC is provided by the Atlantic Coast Fisheries Cooperative Management Act as amended in 1993. First created in 1943, the ASMFC includes representatives from the 15 coastal states on the Atlantic seaboard. Each state appoints three commissioners, representing state fisheries management agencies, state legislators and a member of the public. The ASMFC is responsible for developing management plans for fisheries occurring primarily in state waters (from 0-3 miles offshore). The ASMFC focuses on five major areas interest: 1) Interstate Fishery Management Plans, 2) Research and Statistics, 3) Fisheries Science, 4) Habitat Conservation, and 5) Law Enforcement.

Current Conservation Efforts

Eleven of the species included in the demersal fish group are managed by the NEFMC under the Northeast Multispecies Fisheries Management Plan (Acadian redfish, American plaice, Atlantic cod, Atlantic halibut, haddock, ocean pout, pollock, white hake, winter flounder, witch flounder, and yellowtail flounder). In 2004, the NEFMC and NMFS implemented a formal rebuilding program for many of these species through Amendment 13 to the Multispecies FMP. The rebuilding plan includes implementation of target fishing mortality rates, biomass targets, measures to minimize fishing-related impacts to Essential Fish Habitat, and rebuilding schedules. Most species are scheduled to be rebuilt by 2014, though some have longer rebuilding schedules based on stock conditions and biological constraints (NEFMC 2004). The NEFMC and NMFS have implemented a suite of management measures as part of the rebuilding plans, including restrictions on days at sea, closed areas, gear requirements, and trip limits. Major revisions to the groundfish management plan, including a transition away from days at sea management to "catch shares" and community sectors, are scheduled to take effect in May 2010.

NEFMC implemented the Skate Fishery Management Plan in 2003, which includes all five skate species that are part of this assessment. The FMP includes provisions for mandatory reporting by species; possession prohibitions on barndoor, thorny, and smooth skates; trip limits for winter skate; and a suite of measures in other FMPs to aid the recovery of overfished skate species. Barndoor and thorny skate have also been identified as Species of Concern by NMFS. This designation raises the profile of management concerns for the species but does not mandate additional regulations beyond those implemented through the NEFMC management plan.

Commercial and recreational fisheries for summer flounder, scup, and black sea bass have been jointly managed by the ASMFC and the MAFMC since 1997. The FMP contains several major regulatory provisions, including a total annual quota, minimum size limits, bag limits, and quotas for recreational fisheries, and annual quotas, minimum fish size limits, minimum mesh requirements for trawls, and pot and trap specifications for commercial fisheries.

Spot, croaker, weakfish, and tautog are managed under individual fishery management plans administered by the ASMFC. The Atlantic croaker FMP (last amended 2005) includes goals related to spawning stock biomass and habitat protection, fishing mortality targets, and provisions for regional management, but does not include specific measures restricting commercial or recreational harvest. The tautog FMP (last amended 2007) is focused on reducing fishing mortality by both commercial and recreational fisheries and includes minimum fish sizes, possession limits, gear restrictions, and closed seasons.

The weakfish FMP (last amended 2002) includes overfishing definitions, a goal to restore weakfish population age structure, and a goal to expand geographic range of the species. Management measures include size and possession limits for the recreational fishery and a combination of size limits, gear restrictions for bycatch reduction, and possible seasonal and/or year-round closed areas for the commercial fishery. The spot FMP (last amended 2002) seeks to improve the quality of information on species distribution and abundance and does not include mandatory management measures.

Golden tilefish are managed as two distinct stocks in the United States, one encompassing the Mid-Atlantic Bight south to Cape Hatteras, and the other from Cape Hatteras to the Gulf of Mexico. Implemented by the MAFMC in November of 2001, the tilefish FMP includes provisions for limited entry in the commercial fishery and a system for dividing total allowable landings among three categories.

Monkfish are jointly managed by the NEFMC and the MAFMC. Regional differences in prosecution of the monkfish fishery resulted in management of the species as two stocks (northern and southern), with the northern stock encompassing the Gulf of Maine to northern Georges Bank and the southern stock encompassing central Georges Bank to the Mid-Atlantic Bight. The primary goals of the Monkfish FMP are to end and prevent overfishing and to optimize yield and economic benefits to various sectors involved in the fishery. Current regulatory measures vary with permit type, but include limited access, days at sea limits, mesh size restrictions, trip limits, and minimum size limits.

Spiny dogfish in federal waters are jointly managed by the NEFMC and the MAFMC. The spiny dogfish FMP was first adopted in 1998 and currently includes a female spawning biomass rebuilding target, target fishing mortality rate, and annual quotas on overall catch. Spiny dogfish in state waters are managed by the ASFMC.

Red hake and silver hake are managed under the Small Mesh Multispecies FMP administered by NEFMC. Amendment 12 to this FMP established limited access in the fishery and retention limits based on net mesh size, adopted overfishing definitions for northern and southern stocks, identified essential fish habitat for all life stages, and set requirements for fishing gear.

Northern sea robin, longhorn sculpin, Atlantic wolffish, and cusk are not included in any regional fishery management plan, although the NEFMC is currently considering adding wolffish and cusk to the Northeast Multispecies FMP.

Species Accounts

Gadids

Inhabiting circumpolar to temperate waters mainly in the northern hemisphere, gadids are primarily marine fishes, but a few inhabit estuaries and one is restricted to freshwater (Collette and MacPhee 2002). Gadids are characterized by the presence of three dorsal fins and two anal fins and, sometimes, barbels on their chin used in locating food. Gadid species included in this assessment are Atlantic cod (*Gadus morhua*), cusk (*Brosme brosme*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius pollachius*), red hake (*Urophycis chuss*), silver hake (*Merluccius bilinearis*), and white hake (*Urophycis tenuis*).

Species included in the gadid group are distributed across much of the North Atlantic, with Atlantic cod, haddock, pollock, and cusk occurring in both the Northeast and Northwest Atlantic, and white, silver, and red hake limited to the Northwest Atlantic. Within the Northwest Atlantic, gadids generally occur from the Gulf of St. Lawrence to the Mid-Atlantic Bight, with highest densities found in the Gulf of Maine and along Georges Bank and the Great South Channel.

A number of the species in the gadid group make distinct inshore/offshore migrations in response to seasonal changes in water temperature. Atlantic cod in the Gulf of Maine typically move into coastal waters during the fall and over-winter for their peak spawning season, then return to deeper waters in the spring. In the Great South Channel area, cod move southwest in the fall, over-winter in Southern New England and along the mid- Atlantic coast and return to the Great South Channel in the spring (Lough 2005). Haddock do not make extensive migrations, however, adults undertake seasonal movements in the western Gulf of Maine, the Great South Channel, and on the Northeast Peak of Georges Bank, spending much of winter in deeper waters and moving to shoaler waters in spring to spawn (Brodziak 2005).

Juvenile and adult white hake distribution patterns indicate a pronounced inshore movement in warmer months, dispersing to deeper water in winter months (Chang et al. 1999). Red and silver hake also migrate seasonally in response to changes in water temperature. During the spring and summer months, they move into shallower, warmer waters where spawning occurs during late spring and early summer. During the winter months, red hake move offshore to deep waters in the Gulf of Maine and the edge of the Continental Shelf along Southern New England and Georges Bank. Silver hake from the northern stock move to deep basins of the Gulf of Maine in the winter months, while fish in the southern stock move to the outer Continental Shelf slope waters (Lock and Packer 2004; Steimle et al. 1999b).

Species included in the gadid group utilize a variety of benthic, pelagic, and nearshore habitats within the region during various stages of their life history. Adult cod are found inshore and offshore on a variety of bottom habitats, especially along rocky slopes, ledges, and other hard bottom substrates (Lough 2005; Stevenson 2008). Adult haddock are found on offshore bottom habitats composed of gravel, pebbles, clay, broken shells, and smooth, hard sand between rocky patches. They are not common on rocks, ledges, kelp, or soft mud (Stevenson 2008). Substantial areas of suitable substrate for haddock are found on Georges Bank while fewer suitable areas are found within the Gulf of Maine (Brodziak 2005). Adult pollock show little strong preference for particular bottom types and are commonly found in a variety of pelagic and benthic habitats, including areas with a substrate of mud, sand, gravel, and rocky bottom (Stevenson 2008). Adults tend to inhabit deeper waters in the spring and summer than in winter (Cargnelli et al. 1999a).

Adult white hake are found in inshore areas, on the coastal shelf, and along the continental slope. They prefer fine-grained substrates composed of mud and sandy mud (Chang et al. 1999; Stevenson 2008). Adult red hake occur on coastal marine and offshore shelf habitats composed of soft sand and mud. They are most common in soft sediments or shell beds in the Gulf of Maine and on hard bottom in the temperate reef areas of Maryland and northern Virginia. They occur in larger estuaries, including Chesapeake Bay, Delaware Bay, and the Hudson-Raritan Estuary, during cooler seasons and along coastal New England into Canadian waters from spring to fall (Steimle et al. 1999a; Stevenson 2008). Adult silver hake are found across a range of pelagic and benthic habitats, including mud, sand, and shell fragments in the Gulf of Maine and Georges Bank and on flat sand, sand waves, and shells/biogenic depressions in the Mid-Atlantic (Lock and Packer 2004; Stevenson 2008).

Spawning for Atlantic cod, haddock, and pollock generally occurs from November to May, with cod and haddock peaking from January to May and pollock peaking from November to February. Cod spawning is most intense along the Northeast Peak on Georges Bank and around the perimeter of the Gulf of Maine, including Massachusetts Bay, north of Cape Ann, and from Cape Elizabeth to Mt. Desert Isle in Maine (Lough 2005; Stevenson 2008). Georges Bank is the primary spawning area for haddock, with most spawning concentrated on the Northeast Peak. However, they do spawn in the Gulf of Maine, primarily on Jeffreys Ledge and Stellwagen Bank (Brodziak 2005; Stevenson 2008). Principal spawning sites for pollock are found in the western Gulf of Maine, the Great South Channel, and on Georges Bank, with spawning concentrated in Massachusetts Bay, Stellwagen Bank, and from Cape Ann to the Isle of Shoals in the Gulf of Maine (Cargnelli et al. 1999a; Stevenson 2008).

Spawning for white, silver, and red hake generally occurs in the summer months. White hake spawning occurs in April and May, generally in deeper waters along the continental slope from Georges Bank to the Mid-Atlantic Bight (Chang et al. 1999; Stevenson 2008). Red hake spawning peaks in May and June on Georges Bank, July and August in the Gulf of Maine, and occurs throughout the summer in the Southern New England/Mid-Atlantic Bight area. Red hake spawn on the southwestern part of Georges Bank and on the Continental Shelf off of Southern New England and Long Island. Spawning adults and eggs are also common in the marine parts of most bays between Narragansett Bay, RI and Massachusetts Bay (Steimle et al. 1999a; Stevenson 2008). Silver hake spawning peaks in May and June for the southern stock and July to August for the northern stock, and generally occurs on southwest Georges Bank and in Southern New England south of Montauk Point, Long Island (Lock and Packer 2004; Stevenson 2008).

Most of the gadids reach sexual maturity between 2 and 4 years, with the hakes reaching sexual maturity slightly earlier than Atlantic cod, haddock, and pollock. Cusk is the exception, reaching sexual maturity much later, as much as 10 years old (NMFS 2009a). Fertilized gadid eggs are pelagic and buoyant. Egg development occurs within the water column, with transition to the larval phase lasting from several days for silver, red, and white hake to several weeks for Atlantic cod, haddock, and pollock. Larval development also occurs in the water column, lasting for several months before juveniles settle to the bottom to begin their demersal life phase.

Young-of-the-year (YOY, or the young spawned in a particular year) cod settle in seagrass and macroalgae beds, on sand, and on structurally complex hard-bottom substrates with emergent epifauna (Stevenson 2008). On Georges Bank, juveniles are present predominantly in the gravel pavement habitat on the northeastern part of the bank, with gravel habitat appearing to favor the survival of recently-settled juveniles through predator avoidance and and/or increased food availability). Recent studies suggest nearshore nurseries, including grass beds, may be significantly more important to survival of juvenile fish than offshore habitats in the Gulf of Maine (Lough 2005). Juvenile haddock are found in similar habitats as adults, but appear to favor slightly shoaler waters (Stevenson 2008). YOY pollock are common in eel grass and macroalgae habitats in marsh creeks. Inshore and subtidal areas provide important nursery areas where juveniles spend much of the first two years of their lives before moving to deeper waters at age 2+ (Stevenson 2008).

Juvenile white hake are found on soft, muddy habitats in coastal estuarine nursery areas as well as on the Continental Shelf. Eel grass provides important habitat for juvenile white hake in nearshore areas, but they are not tied to eel grass, other vegetation, or structured habitats (Chang et al. 1999; Stevenson 2008). Juvenile red hake occur in estuarine, coastal, marine, and Continental Shelf benthic habitats on sand and mud substrates; physical structure for this species is particularly important for survival (Steimle et al. 1999a; Stevenson 2008). Juvenile silver hake are distributed across similar habitats, including mud, sand, and shell fragments in the Gulf of Maine and Georges Bank and on sand, silt, and amphipod tube mats in the Mid-Atlantic (Lock and Packer 2004; Stevenson 2008).

Ecosystem interactions are similar across the gadid species. Primary prey items include crustaceans, mollusks, euphausiids, and a variety of fishes including herring, mackerel, sand lance, and juvenile life stages of other gadid species. Principle predators include fishes, skates, dogfish, sharks, seals, and occasionally sea birds including puffins and terns.

Pleuronectids

Pleuronectids (or flatfish) are a relatively homogenous group, including in their morphology. They are characterized by their flat body shape, unique mouths, single long fins on each side, and eye position on the dorsal side of their flattened bodies. Flatfish can be "left-eyed" or "right-eyed" depending on which eye "migrated" during metamorphosis (Collette and MacPhee 2002). Summer flounder and halibut are flatfish species which are included in this assessment, but not in this particular grouping. Pleuronectids included in this grouping are American plaice (*Hippoglossoides platessoides*), winter flounder (*Pseudopleuronectes americanus*), witch flounder (*Glyptocephalus cynoglossus*), and yellowtail flounder (*Pleuronectes ferruginea*).

Species included in this group are distributed across much of the North Atlantic, with witch flounder and American plaice occurring in both the Northeast and Northwest Atlantic and winter and yellowtail flounder limited to the Northwest Atlantic. Within the Northwest Atlantic, these flounders generally occur from the Gulf of St. Lawrence to the Mid-Atlantic Bight, with highest densities found in the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic.

Species within the flounder group are relatively sedentary and are not known to make extensive migrations. However, adult winter flounder do make seasonal migrations in response to changes in water temperature, migrating inshore in the fall and early winter to spawn (Periera et al. 1999). Nearshore coastal bays and estuaries are of particular importance during this time of year. Mark and recapture studies on yellowtail flounder reveal that fish in Southern New England travel eastward during the spring and summer and back to the west in fall and winter in response to changes in water temperature (Johnson et al. 1999).

Adult stages of all four flounder species included in the group show a strong preference for finer-grained sediments, including sand, mud, and silts. American plaice generally prefer substrates of sand and sand/mud and inhabit a broad depth range of 1-500 m (Johnson 2004; Stevenson 2008). Adult winter flounder are found in coastal and estuarine benthic habitats comprised primarily of fine-grained sediments including sand, mud, and muddy sand. However, they are also found on sandy and coarser substrates including pebbles and gravels on Georges Bank and Nantucket Shoals (Periera et al. 1999; Stevenson 2008). Adult witch flounder are closely tied to substrate, preferring mud/silt, muddy sand, and clay substrates, and rarely occur on any other bottom type (Cargnelli et al. 1999b; Stevenson 2008). Adult yellowtail prefer sand or sand/mud sediments where they find their demersal prey, and appear to avoid rocks, stony ground, and very soft mud (Collette and MacPhee 2002).

Flounders in the group spawn throughout much of the year. Spawning season varies with species, but tends to occur later in the year along a south-north gradient. Spawning for American plaice occurs from February to June with a peak in April and May. Plaice generally spawn in shoaler waters less than 90 m over benthic habitats comprised of sand and muds. Highest spawning concentrations occur in the western Gulf of Maine on Jeffreys Ledge and Stellwagen Bank and along the Great South Channel and southern flank of Georges Bank (Johnson 2004; Stevenson 2008). Winter flounder spawning occurs during the winter and spring, peaking in February and March, in shoaler waters less than 72 m over benthic habitats. Coastal bays and estuaries are particularly important spawning sites (Periera et al. 1999; Stevenson 2008). Witch flounder spawn from March to November, with a peak occurring in the summer months, in deeper waters over benthic habitats comprised of sand and muds. The most active spawning sites are found in the western and northern portions of the Gulf of Maine (Cargnelli at al. 1999b; Stevenson 2008). Yellowtail flounder spawn from March to August, with a peak between April and June (Johnson et al. 1999; Stevenson 2008).

Most of the flounders reach sexual maturity by age 4; winter flounder reaches sexual maturity slightly earlier (Periera et al. 1999). Fertilized eggs of plaice, witch, and yellowtail flounder are pelagic and buoyant while winter flounder eggs are demersal, forming clusters that adhere to benthic substrates comprised mostly of sands, but also muds and gravel. The larval phase for plaice and yellowtail flounder occurs in the water column and persists for two to four months before settlement to the ocean floor (Johnson 2004; Johnson et al. 1999). Witch flounder demonstrate one of the longest pelagic larval development phases of all flounders, lasting more than 12 months (Cargnelli et al. 1999b). Larval development for winter flounder occurs in the water column and lasts about eight weeks before settling to the ocean floor (Periera et al. 1999). Juvenile life stages of all of these flounders are found predominantly on sandy substrates. Juvenile winter flounders are especially dependent on nearshore coastal bays and estuaries, spending more than a year in these shallow zones before moving off to deeper water as they mature (Periera et al. 1999, Stevenson 2008). Juvenile plaice are also known to utilize bays and estuarine river systems as nursery areas, though they do occur in the Gulf of Maine, along the Great South Channel, and along the northern edge of Georges Bank (Johnson 2004).

Primary prey items include crustaceans, mollusks, amphipods, and polychaete worms. Winter and yellowtail flounder are also known to eat a variety of fishes. Principal predators include fish, skates, dogfish, sharks, and seals.

Elasmobranchs

Elasmobranchs, the sharks, skates, and rays, are represented in this assessment by five skate species from the family Rajidae: barndoor skate (*Dipturus laevis*), clearnose skate (*Raja eglanteria*), little skate (*Raja erinacea*), rosette skate (*Leucoraja garmani*), and thorny skate (*Amblyraja radiata*). The spiny dogfish (*Squalus acanthias*) represents the family Squalidae. All six species are characterized by their relatively slow growth rates, late age at maturation, and internal egg fertilization and development. Given their unique life history, these species are particularly vulnerable to exploitation due to longer mean generation times and the relatively small number of offspring.

Species included in the elasmobranch group are distributed across much of the Northwest Atlantic, with thorny skate occurring in both the Northeast and Northwest Atlantic; barndoor, little, clearnose, and rosette skates limited to the Northwest Atlantic; and spiny dogfish distributed circumglobally. Within the Northwest Atlantic, barndoor, thorny and little skate generally occur from the Gulf of St. Lawrence to Cape Hatteras, while distributions of clearnose and rosette skates occur further south, from Southern New England to Florida. Highest densities are found on the Continental Shelf in the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic to Cape Hatteras.

Of the elasmobranchs included in this assessment, spiny dogfish and clearnose skate have the most distinct seasonal migration patterns. Spiny dogfish are known to make distinct north and south migrations along the Continental Shelf, as well as moving inshore and offshore seasonally in response to changes in water temperature. They primarily occur north of Cape Cod in summer, move southward to Long Island in the fall, and go as far south as North Carolina in the winter. In the spring, they migrate back north, reaching Georges Bank in March and April (Stehlik 2007). Clearnose skate also make distinct seasonal migrations north of Cape Hatteras, moving inshore and northward along the Continental Shelf during spring and early summer and offshore and southward during autumn and early winter when temperatures drop to 13-16° C (Packer et al 2003b).

Little skate are not known to migrate extensively, but they do make seasonal onshore and offshore migrations cued by temperature changes, generally moving into shallower waters in the spring and deeper waters in the winter. They also move north and south with seasonal temperature changes along the southern fringe of their range (Collette and MacPhee 2002). While several reports indicate that thorny skate undertake seasonal migrations in the summer and winter, others suggest they are a sedentary species. No seasonal migration patterns have been reported for rosette skate, although shoreward migrations during the summer have been suggested.

Adult and juvenile life stages of elasmobranchs included in this assessment generally utilize similar habitats within the region, but habitat preference varies with species. Adult and juvenile barndoor skate generally occupy similar habitats across the range. Adults are widely distributed on benthic habitats composed of soft muds, sand, and gravel. Adult and juvenile clearnose skates are found predominantly on soft bottom substrates along the Continental Shelf at depths less than 30 m. They have also been found on rocky and gravelly substrates (Packer et al. 2003b; Stevenson 2008). Adult and juvenile little skate are widely distributed across benthic habitats in coastal bays and estuaries along the Continental Shelf, generally on sandy or gravelly mud bottoms, but are also found in predominantly mud substrates (Packer et al. 2003c; Stevenson 2008). Adult and juvenile rosette skate occur on the outer Continental Shelf on benthic substrates of mud and sand, and also on substrates of mud and sand mixed with gravel (Packer et al. 2003d; Stevenson 2008). Adult and juvenile thorny skate occur on a variety of benthic substrates across the Continental Shelf and Slope, including sand, gravel, broken shells, pebbles, and soft mud (Packer et al. 2003e; Stevenson 2008). Spiny dogfish distributions are heavily influenced by depth, water temperature, and prey availability (Stehlik 2007).

All of the elasmobranchs included in this assessment share a similar life history, characterized by relatively slow growth rates, late age at maturity, and production of few offspring. The skate species reach sexual maturity at 5-7 years, while spiny dogfish do not reach sexual maturity until 10-12 years. Elasmobranchs mate throughout much of the year, with clearnose, thorny, and rosette skate having highest egg production in the summer, little skate producing eggs twice a year (spring and fall), barndoor skate mating in late-fall and winter, and spiny dogfish mating in the fall. Spiny dogfish are unique in that their egg fertilization and development is oviparous. Fertilized eggs develop within a tough, leathery egg casing which is deposited over a variety of substrates. Egg development is slow, lasting 2-3 years before hatching occurs on the sea floor (Packer et al. 2003 a, b, c, d, and e; Stehlik 2007).

Elasmobranchs are omnivorous, feeding on a variety of benthic prey species including crustaceans, amphipods, and a variety of small fishes. The skate species display similar dietary preferences, feeding primarily on polychaetes, decapods, copepods, bivalves, and shrimp but also on a variety of small fishes. Spiny dogfish are more piscivorous, feeding on a variety of fish species including capelin, cod, haddock, herring, mackerel, sand lance, and several species of flatfish. Elasmobranch eggs are preyed on by a variety of fish species, while adults have relatively few predators.

Predators of adults include large gadids, flounders, monkfish, sharks, seals, and dolphins.

Trophic dynamics within the Gulf of Maine/Georges Bank portion of the region have been fundamentally altered, as the depletion of gadids and flounders have coincided with large increases in skate and spiny dogfish populations. Spiny dogfish are now a major predator within this part of the region, accounting for a significant portion of the overall fish biomass in the system. Many have suggested that their recent population increase and associated predation have confounded efforts to rebuild depleted populations of gadids and flounders (FORDM 2009).

Mid-Atlantic Estuarine

The Mid-Atlantic Estuarine species grouping includes three species from the family Scianidae: Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), and weakfish (*Cynoscion regalis*). The family Labridae is represented by tautog (*Tautoga onitis*). The group was selected based upon the species' relative dependence on estuarine habitats to complete various stages of their life history. Specifically, a recent study on relative degree of estuarine dependence concluded that Atlantic croaker, spot, and tautog are obligate users of estuarine habitats while weakfish are facultative users of these areas (Able 2005).

Global distribution of species in the mid-Atlantic estuarine group is limited to the western Atlantic, from Nova Scotia to Florida. Distributions of croaker may extend as far south as Brazil and Argentina. Within the Northwest Atlantic, these species are predominantly found from Long Island Sound to Cape Hatteras, North Carolina, with highest numbers occurring south of Delaware Bay. However, all species do occur in significant numbers along Georges Bank and the Great South Channel. They are occasionally found in the Gulf of Maine in and around Massachusetts Bay and the Jeffreys Ledge and Stellwagen Bank area.

Species within the mid-Atlantic estuarine group are characterized by distinct seasonal migrations, moving inshore and offshore in response to changes in water temperature. Spot enter bays and estuaries in the spring and remain there until late summer or fall when they move offshore to spawn (ASMFC 2009). Adult croaker generally spend the spring and summer in estuaries, moving offshore and south along the Atlantic coast in the fall as nearshore water temperatures decline (ASMFC 2009). When coastal waters warm in the spring, adult weakfish form large aggregations and undertake inshore and northward migrations to bays, estuaries, and sounds from offshore wintering grounds (ASMFC 2009). Adult tautog make shorter seasonal migrations in the fall when water temperatures fall below 10° C, moving from coastal areas to deeper waters (25-45 m) with rugged topography. They move back inshore to coastal and estuarine waters in the spring when water temperatures warm above 11° C (Steimle et al. 1999c).

Species included in this group are characterized by their utilization of coastal bays and estuaries (ASMFC 2009). Spot, croaker, and tautog are recognized as obligate users of these habitats while weakfish are considered facultative users of these areas. Adult spot and weakfish occur across a variety of substrates within nearshore bays and estuaries; habitat selection for these species is influenced by a number of variables including sediment type, summer water temperatures, salinity, and dissolved oxygen levels. Adult croaker prefer muddy and sandy substrates in waters shallow enough to support submerged aquatic plant growth and are also found on oyster, coral, and sponge reefs as well as man-made structures. Temperature and depth are important factors in determining distribution of adults. Distribution and abundance of adult tautog is heavily influenced by the availability of cover for protection during the night when they are not foraging (Steimle et al. 1999c).

Species included in this group reach sexual maturity at relatively young ages (ASMFC 2009). Croaker and weakfish reach sexual maturity between ages 1 and 2, spot mature between ages 2 and 3, and tautog mature between ages 3 and 4. Croaker, tautog, and weakfish all spawn in nearshore habitats in coastal bays and estuaries while spot spawn in offshore waters along the Continental

Shelf. Spawning season for species in this group occurs throughout much of the year. Croaker spawn from July to December, with a peak in late fall and early winter. Spot spawning begins in the fall and continues through the winter into early spring. Tautog spawning primarily occurs near the mouths of estuaries and inshore waters and follows a northward progression through the summer, beginning in April in the southern part of the Mid-Atlantic Bight and extending to the northern area by May. Peak spawning in the central Mid-Atlantic Bight is reported to occur in June and July and declines by August. Weakfish spawning occurs in nearshore coastal waters after the inshore spring migration from March through September, peaking between April and June.

Fertilized eggs of all four species are buoyant and pelagic (ASMFC 2009). Eggs and larvae remain in the water column and are transported to coastal and estuarine waters by tides, currents, and other oceanographic processes. Juveniles utilize a variety of benthic habitats within nearshore nursery areas depending on species before migrating offshore to the open ocean along the Continental Shelf.

These species eat a variety of benthic prey items including polychaetes, mollusks, mussels, shrimp, and fishes. Tautog prey heavily on blue mussels, while weakfish are much more piscivorous than other species in the group, preying on a variety of fishes including menhaden, shad, river herring, sea herring, and sand lance. Weakfish are recognized as an important top predator in Chesapeake Bay, feeding along the edges of eel grass habitats and along channel edges, rock, and oyster reefs (ASMFC 2009). Species within the group are preyed upon by a variety of fishes, spiny dogfish, skates, sharks, and in the case of juvenile tautog, piscivorous seabirds (Steimle et al. 1999c).

Offshore Wintering Guild

The fishes included in the offshore wintering are characterized by similar movements, habitats, and food habits (Musick and Mercer 1977; Colvocoresses and Musick 1984). In particular, these species generally move into shallow coastal waters in the summer months then move offshore to the Continental Shelf during winter months as nearshore water temperatures decrease. The offshore wintering guild group includes black sea bass (*Centropristis striata*), northern sea robin (*Prionotus carolinus*), scup (*Stenotomus chrysops*), and summer flounder (fluke, *Paralichthys dentatus*).

Global distribution of these species is limited to the western Atlantic, from Nova Scotia to Florida. Within the Northwest Atlantic, highest numbers are found from Narragansett Bay in Southern New England to Cape Hatteras, North Carolina. However, all species occur on portions of Georges Bank and the Great South Channel and in the Gulf of Maine, particularly in and around Massachusetts Bay and the Jeffreys Ledge and Stellwagen Bank area.

Species in this guild undertake distinct season migrations, moving inshore and offshore in response to changes in water temperature. Summer flounder, scup, and black seas bass display strong seasonal movements, occupying shallow coastal and estuarine waters in the spring and summer and moving offshore onto the Continental Shelf during the colder winter months. These annual migrations are apparently triggered when bottom water temperatures approach 7° C (Packer et al. 1999f; Steimle et al. 1999d; Drohan et al. 2007). Northern sea robin found north of Cape Hatteras make similar seasonal migrations, seemingly triggered by a broader temperature range of 4.5 to 15.5° C (Collette and MacPhee 2002).

Species in the offshore wintering guild utilize a variety of coastal and shelf habitats depending on season. Adult summer flounder show a strong preference for coarse, sandy substrates in nearshore coastal waters, generally occurring at depths less than 25 m (Packer et al. 1999f). Adult scup are found in a variety of benthic habitats in the warmer months, including soft, sandy bottoms and on or near structures including rocky ledges, wrecks, artificial reefs, and mussel beds, although they appear to demonstrate a strong preference for mixed sand and mud deposits in Long Island Sound. Specific habitats used by adults during the offshore over-wintering period are poorly defined (Steimle et al. 1999d). Adult black sea bass are strongly associated with structurally complex habitats, including eel grass, rocky reefs, cobble, rock fields, wrecks, and shellfish beds. They occupy nearshore coastal waters during spring and summer months and overwinter along the Continental Shelf (Drohan et al. 2007). Specific habitat preferences of adult northern sea robin are not as well defined, though they have been found to be closely associated with deep flats and channel edges in Chesapeake Bay (Collette and MacPhee 2002).

Spawning habitats for species in the offshore wintering guild vary depending on species. Summer flounder spawn in Southern New England and the Mid-Atlantic Bight during two distinct seasons, the strongest occurring in late fall as they move offshore to overwinter and a lesser one occurring in the spring in the southern part of the Mid-Atlantic (Packer et al. 1999f). Scup spawn once per year during their inshore migration from May through August, with a peak in June and July. Most spawning occurs over weedy or sandy areas in Southern New England from Cape Cod, Massachusetts south to the New York Bight (Steimle et al. 1999b). Black sea bass spawn in April-October, peaking in May to July. Spawning generally occurs between Montauk Point, Long Island and Chesapeake Bay and appears to be concentrated on the nearshore Continental Shelf at 20-50 m (Drohan et al. 2007). Less is known about the spawning habitats of northern sea robin, though they are known to spawn in the summer months from June to September, generally from Block Island to Cape Hatteras (Collette and MacPhee 2002).

All species in the guild reach sexual maturity between ages 2 and 4. However, black sea bass are protogynous hermaphrodites, meaning that fish change sex from female to male as they increase in age and size. Females reach sexual maturity at age 2-4 and most fish change sex to male at age 2-5 (Packer et al. 1999f). The fertilized eggs for all four species are buoyant and pelagic and development to the larval phase occurs within a matter of days to weeks. Juveniles migrate to nearshore coastal waters and descend to the seafloor where they begin their demersal life phase. Important juvenile nurseries for these species occur in many of the coastal bays and estuaries of Southern New England and the Mid-Atlantic Bight, including Buzzards Bay, Narragansett Bay, the Hudson-Raritan Estuary, Long Island Sound, Delaware Bay, and Chesapeake Bay. Habitats with structural complexity, including submerged aquatic vegetation, oyster reefs, and man-made structures, appear to be an essential component influencing juvenile survival for scup and black sea bass, while juvenile summer flounder utilize a variety of coastal habitats including marsh creeks, sea grass beds, mud flats, and open bay areas.

Species included in the offshore wintering guild prey on a variety of benthic organisms including polychaetes, amphipods, crustaceans, and fishes. Black sea bass, scup, and northern sea robin feed primarily on polychaetes, amphipods, crustaceans, and bivalves, though fishes are also a part of their diet (Drohan et al. 2007; Steimle et al. 1999d; Collette and MacPhee 2002). Summer flounder are more piscivorous, feeding on hakes, menhaden, and flounders as well as squids, shrimps, and bivalve mollusks (Packer et al. 1999f). These species are primarily preyed upon by other fishes including flounders, hakes, monkfish, skates, and dogfish.

Other Species of Interest

Other species of interest were included in this assessment because of concerns about their conservation status (Atlantic halibut (*Hippoglossus hippoglossus*), Atlantic wolffish (*Anarhichas lupus*)), unique life history characteristics (Acadian redfish (*Sebastes fasciatus*), Atlantic monkfish (*Lophius americanus*), golden tilefish (*Lopholatilus chamaeleonticeps*), and ocean pout (*Zoarces americanus*)), and non-commercial species (longhorn sculpin (*Myoxocephalus octodecimspinosus*)). The team elected to include these species in this assessment, but chose to present findings on a species by species basis rather than within the groupings used for most species.

Acadian Redfish

Acadian redfish occur on both sides of the Atlantic Ocean. In the Northwest Atlantic, they are common from Nova Scotia to New Jersey and have been observed as far south as Virginia. Areas of highest abundance include the Gulf of St. Lawrence, the Continental Shelf northeast of Newfoundland, the southern edge of the Grand Bank, and the Flemish Cap.

Although redfish are not believed to make extensive migrations, Bigelow and Schroeder (in Collette and MacPhee 2002) reported that redfish do make seasonal migrations. They have been observed in deep waters of the Gulf of Maine during summer and early autumn, then migrate south and east where they concentrate during the winter.

Adult redfish are found primarily in deeper waters over substrates of silt, mud, and hard bottom and are rarely observed in sand substrates. There is also evidence that redfish use boulders, corals, anemones, and other structure-forming epifauna for cover. Redfish are also known to make diurnal vertical migrations following movements of euphuasiids, their primary prey species (Pikanowski et al.1999; Stevenson 2008).

Redfish are a slow-growing, long-lived ovoviparous species with very low natural mortality rates. Redfish greater than 22 cm are considered adults and median age for sexual maturity is 5-6 years, ranging from as young as 2 to as old as 10. Very little is known about redfish breeding behavior, but fertilization is internal and fecundity is relatively low. Mating is believed to occur in October-January, but fertilization is delayed until February-April. Redfish eggs are fertilized internally and develop within the oviduct until they are released near the end of the yolk sac phase. The pelagic larval phase generally lasts about 4-5 months, then they descend to the bottom by the fall of their first year. Upon settling to the bottom, juveniles are found on a variety of substrates including silt, mud, and hard bottoms with emergent epifauna. YOY demonstrate strong associations with boulder reefs (Pikanowski et al. 1999; Stevenson 2008).

Redfish feed on a variety of benthic prey items including copepods, euphausiids, amphipods, pandalid and sand shrimp, and fish and invertebrate eggs. Key predators are piscivorous fishes including Atlantic cod, Atlantic halibut, Atlantic wolffish, little skate, monkfish, pollock, larger redfish, silver hake, and white hake. Of these, cod and white hake appear to be most important (Pikanowski et al. 1999; Stevenson 2008).

Atlantic Halibut

Atlantic halibut is found on both sides of the North Atlantic Ocean and in parts of the Arctic Ocean. In the Northwest Atlantic, they are distributed from north of Labrador to south of Long Island. Areas of highest abundance seem to be along the southern edge of the Grand Banks and on the Scotian Shelf from Browns Bank to Banquereau Bank.

Adult Atlantic halibut are found over sand, gravel, and clay substrates along the Continental Shelf and Slope. They are typically found at depths of 40-1000 m, with the NMFS bottom trawl survey capturing most at 25-200 m.

The largest of all the flatfish in the region, Atlantic halibut can reach over 200 cm in length. Late to mature and long-lived, some reach ages of 50 years, achieving sexual maturity between 5 and 15 years. Atlantic halibut spawn between late winter and early spring, peaking between November and December. Spawning grounds are not well known, but generally occur on hard substrates of sand, gravel, and clay on offshore banks and along the Continental Slope (Cargnelli et al 1999(c); Stevenson 2008).

Atlantic halibut eggs are among the largest planktonic fish eggs. Eggs are bathypelagic and float suspended in the water at depths greater than 50 m rather than at the surface. Incubation is strongly temperature-dependent, lasting from 13-20 days at 4-7° C. Larvae have a long developmental period lasting up to 90 days before metamorphosis to the juvenile stage. Settlement to the bottom occurs after metamorphosis is complete. Juveniles are known to inhabit distinct nursery grounds, including Sable Island Gully on the Scotian Shelf, where they remain for 3-4 years before migrating away (Cargnelli et al. 1999(c); Stevenson 2008).

Atlantic halibut feed on a variety of benthic prey items, including crustaceans, mollusks, squid, and fishes such as Atlantic cod, Atlantic herring, alewife, capelin, cusk, flounder, haddock, mackerel, ocean perch, ocean pout, sand lance, sculpin, skates and silver hake. Given their large size they have relatively few predators, primarily monkfish, spiny dogfish, Greenland sharks, and seals (Cargnelli et al. 1999c).

Atlantic Wolffish

The largest of the blenny-like fishes, Atlantic wolffish are distributed on both sides of the Atlantic Ocean. In the Northwest Atlantic, they occur from the Davis Straits in Greenland to Cape Cod. Relatively little is known about the biology, migration, or seasonal movements of the species, though some evidence suggests a migration from deep to shallower waters in the fall and spring. Wolffish are known to prefer complex bottom habitats including rocky outcrops and seaweed beds (Collette and MacPhee 2002; NMFS 2009a).

Atlantic wolffish are a slow-growing, long-lived species that may live more than 20 years. Age at maturity is influenced by temperature, with most reaching sexual maturity by age 6. Males and females form spawning pairs during the spring and summer prior to spawning. Spawning is believed to occur almost year-round, with peak season occurring from September to October. Eggs are believed to be fertilized internally and are laid in large, tight clusters in nests which are guarded by the parental male. Egg incubation is heavily influenced by water temperature, and takes three to nine months. Larval development is pelagic and lasts 20-60 days depending on water temperature. Juveniles are demersal and begin displaying aggressive, territorial behavior at a young age. Growth rates are relatively rapid until age 5-6 when growth begins to slow as sexual maturity is reached (Collette and MacPhee 2002; NMFS 2009a).

Atlantic wolffish feed on a variety of benthic prey items, including bivalves, gastropods, decapods, urchins, and echinoderms. Predators include Atlantic cod, haddock, red hake, sea raven, spiny dogfish, thorny skate, Greenland shark, and gray seal (Collette and MacPhee 2002).

Golden Tilefish

Golden tilefish are distributed in the Northwest Atlantic along the outer Continental Shelf from Nova Scotia to South Florida, and are relatively abundant in the Southern New England to mid-Atlantic region at depths of 80 to 440 m. Tilefish are believed to be relatively sedentary and closely associated with their burrows and are not known for extensive seasonal migrations. Shorter movements may occur when feeding or when seeking to stay within their preferred temperature range (Steimle et al. 1999a).

Distribution of adult tilefish is heavily influenced by substrate, temperature, and depth. They have a narrow temperature preference of 9° to 14° C (known as the "warm belt") and generally occur in and around submarine canyons (including Oceanographer, Hudson, and Norfolk Canyons) where they occupy burrows in sedimentary substrates (Steimle et al. 1999a). As important modifiers and creators of habitat on the outer Continental Shelf and along the slopes and walls of submarine canyons, tilefish create elaborate "pueblo villages" of burrows within clay substrates, presumably to avoid predation (Able et al. 1982; Grimes et al. 1986). Tilefish provide habitat for a variety of other species, including crustaceans, lobster, conger eel, ocean pout, cusk, redfish, and hake.

Tilefish are relatively slow-growing and long-lived. Males and females reach sexual maturity between ages 5 and 7. Little is known about their spawning activity, though they are considered serial or fractional spawners, spawning from March to November with peak spawning activity occurring between May and September. Non-adhesive and buoyant eggs are found in temperatures of 8-19° C (Steimle et al. 1999 a). Larvae occur in the water column from July to September over the outer Continental Shelf in the Mid-Atlantic Bight. Juvenile tilefish occupy similar habitats as adults, creating vertical shaft burrows in clay.

They appear to be more tolerant of low temperatures than adults, which could help recruits survive in marginal habitat conditions.

Tilefish feed on a variety of benthic prey items including bivalve mollusks, polychaetes, sea anemones, echinoderms, and other fishes including conger eel, hagfish, squid, small spiny dogfish, mackerel, herring, squid, and silver hake. Major predators on juvenile tilefish include spiny dogfish, conger eels, and mostly larger adult tilefish, while monkfish are believed to be the primary predator on adults.

The Mid Atlantic Fisheries Management Council has designated a Habitat Area of Particular Concern for juvenile and adult tilefish in the Southern New England/mid-Atlantic region, which encompasses the substrate between the 250 and 1,200 ft isobath line extending from the southern flank of Georges Bank to just north of Delaware Bay.

Longhorn sculpin

Longhorn sculpin are distributed across much of the Northwest Atlantic, occurring from Newfoundland to Virginia. They are common along the Nova Scotia coast and extend as far north as the Gulf of St. Lawrence. In the region, they occur from the Bay of Fundy south to Virginia, with highest numbers found in the western Gulf of Maine, along the flanks of Georges Bank, and south to Long Island Sound. Longhorn sculpin are not known for making extensive migrations, although onshore to offshore movements have been observed as they move from shallower to deeper waters as temperatures approach 20° C (Collette and MacPhee 2000).

Monkfish

The monkfish is a solitary, large, slow-growing, bottom-dwelling anglerfish which occurs in the western Atlantic from the southern and eastern parts of the Grand Banks and the northern side of the Gulf of St. Lawrence to the east coast of Florida, but is common only north of Cape Hatteras. Within the region, they are common in both inshore and offshore areas of the Gulf of Maine and ubiquitous across the Continental Shelf in the Mid-Atlantic Bight. Monkfish make seasonal onshore-offshore migrations in response to temperature changes. In the Gulf of Maine they move and stay offshore to avoid cold coastal conditions in the winter-spring and return inshore as coastal waters warm in the summer and fall. In the Mid-Atlantic, monkfish may avoid overly warm inshore summer conditions and take advantage of a residual cool pool that occurs along the mid- to outer Continental Shelf (Steimle et al. 1999e).

Adult monkfish occur on soft bottom sediments including sand, mud, and shell fragments nearshore and on the Continental Shelf. Juveniles occupy similar substrates but were not captured in the NMFS trawl survey at depths <20 m or temperatures greater than 13° C (Steimle et al. 1999e; Stevenson 2008). Monkfish reach sizes of 140 cm and 22 kg in weight; females reach larger sizes than males and live longer (females reach ages of 11 years, males, 9 years). Males and females reach sexual maturity between 4 and 5 years. Spawning occurs from spring through early fall with a peak in May-June. Monkfish spawn in the early spring off the Carolinas, in May-June in the Gulf of Maine, and into September in Canadian waters. Spawning locations are not well known, but are thought to be on inshore shoals to offshore. Relatively large eggs are shed within buoyant, free-floating ribbon-like mucoid veils or rafts that may be 6-12 m long. This manner of egg production is thought to be unique among fishes. Newly hatched eggs remain protected in the open egg chamber within the mucus veil for two to three days after hatching and are pelagic upon release. Adults spend most of their time on the sandy bottoms where they partially bury their body to support their ambush method of predation (Steimle et al. 1999e).

Monkfish feed on a variety of benthic organisms, primarily fishes including Atlantic cod, Atlantic herring, Atlantic menhaden, black sea bass, butterfish, cunner, eels, flounders, haddock, hake, mackerel, pufferfish, sand lance, sculpins, sea raven, sea robins, skates, silver hake, smelt, spiny dogfish, squid, tautog, tomcod, and weakfish. Major predators include Atlantic cod, monkfish, swordfish, smooth and spiny dogfish, and dusky and sandbar sharks (Steimle et al. 1999e).

Ocean Pout

The ocean pout is a bottom-dwelling, temperate species found on the Atlantic Continental Shelf of North America between Labrador and the southern Grand Banks and Virginia. It can also occur south of Cape Hatteras in deeper, cooler waters. They do not undertake extensive migrations, but do move seasonally to different habitats to remain within their preferred temperature range of 2-10° C (Steimle et al. 1999f).

Adult ocean pout are found over a variety of bottom types including shells, rock, algae, sand, mud, and/or gravel. During winter and spring, they feed over sand or sand and gravel substrates and then move to rocky areas in the fall to spawn (Steimle et al. 1999f; Stevenson 2008).

Ocean pout are relatively long-lived species with males reaching maturity at 2-4 years and females maturing at 5-9 years of age. Spawning occurs in the late summer through winter, peaking between August and October. Spawning occurs on hard bottom, sheltered areas including artificial reefs and shipwrecks at depths <50 m and temperatures <10° C. These spawning and nesting areas include the saline parts of New England estuaries. Fecundity is size-dependent and relatively low, with large females producing more eggs than smaller ones. Ocean pout eggs are fertilized internally. Demersal eggs are laid in gelatinous masses in sheltered places on the bottom including rocky crevices. They are guarded by one or both parents until hatching occurs after two to three months depending on water temperature. Juveniles are found on similar substrates as adults, including shallow coastal waters around rocks, attached algae, and bivalve shells. Juvenile growth rates vary depending on temperature, and they can reach lengths of 10-15 cm after the first year. Adults remain demersal and are not known to form schools or aggregations (Steimle et al. 1999f; Stevenson 2008).

Ocean pout feed on a variety of benthic invertebrates including polychaetes, mollusks, crustaceans, and echinoderms, as well as urchins, scallops, crabs, and lobster. Predators include Atlantic cod, bluefish, hakes, sea raven, skates, spiny dogfish, and harbor seals (Steimle et al. 1999f).

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CHAPTER

8

Small Pelagic Fish

Chris Littlefield

Introduction

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Small pelagic, or forage, fish species comprise a critical component of the incredibly complex and resilient ecosystem of the Northwest Atlantic (Link et al. 2006). Also known as small pelagics, these species, with a few notable exceptions, are abundant. Because they provide crucial ecological links between plankton and higher level predators, small pelagic species bind the entire system together and can help aid the recovery of depressed populations of benthic and pelagic fish, mammals, and birds. There are several species among the small pelagic group currently of concern to conservation, most notably the Atlantic menhaden. Virtually all marine fish and invertebrate species, from egg to adult stages, are forage for other predators at some stage of their lives and most will not be considered here. Zooplankton, worms, crustaceans and other invertebrates, except for two species of squid, also will not be included in this assessment. In addition to their importance to the ecology of the region as a crucial intermediate component of the food web, small pelagic species are subject to varying degrees of fishing effort and exploitation. Until recently, the ecosystem impacts of fisheries conducted on small pelagic species were seldom taken into account.

Technical Team Members

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Selection of Target Species

The team chose eight important species to include in the assessment, six of which are the objects of commercial fisheries, one subject to only a small regional bait fishery. These species were selected after consultation with numerous experts on the basis of their level of importance to the Northwest Atlantic marine ecosystem, especially with regard to their role as prey for a variety of birds, cetaceans, pinnipeds, and many larger coastal and offshore predatory fish species, including large pelagics. We acknowledge the role of the many other small pelagic species in the ecosystem, but felt it was important to limit the analysis to several important ones. Also, as six of eight are the object of significant fisheries and are managed as such, there is abundant information on them which aids in developing conservation strategies.

The species chosen are:

- Atlantic herring *(Clupea harengus)*
- Atlantic mackerel *(Scomber scombrus)*
- Atlantic menhaden *(Brevoortia tyrannus)*
- Northern sand lance *(Ammodytes dubius)*
- American sand lance *(A. americanus)*
- Longfin inshore squid *(Loligo pealeii)*
- Northern shortfin squid *(Illex illecebrosus)*
- Butterfish *(Peprilus triacanthus)*

Population Status and the Importance of Northwest Atlantic Region

Because of widespread overfishing of more desirable groundfish species and large pelagics, small pelagic species comprise a growing global percentage of fish landings, a phenomenon known as "fishing down the food web (Pauly et al. 1998). In some cases, populations of forage species have increased dramatically due to release from "top down" predation pressure as their predators have been removed from the system, or from reduced fishing pressure, or a combination of factors. In the Northwest Atlantic, there are a number of instances of severe declines in small pelagic populations linked to both overfishing and climate change, which have in turn had adverse impacts on predator populations. In the Northwest Atlantic region and elsewhere, the fish community has undergone a shift from demersal to pelagic (including many small pelagic) species (Wood et al. 2008).

This shift has occurred as groundfish populations have decreased and several key species of small pelagics have recovered from previous overfishing, most notably Atlantic herring and Atlantic mackerel. Atlantic herring have been at or near peak levels of abundance in the past several years, relative to previous highs in the 1960s (Overholz 2006a and 2006b). The majority of these eight species have declined since the 1960s when foreign industrial fleets began depleting both groundfish and small pelagic stocks prior to the creation of the Exclusive Economic Zone (EEZ). Domestic exploitation of Atlantic menhaden in State waters surged around the same time. The Northeast Fisheries Science Center initiated its bottom trawl surveys in the 1960s and they remain the only reliable fishery-independent data set for all the species except Atlantic menhaden. Only Atlantic mackerel and Atlantic herring are at or near 1960s levels. Also, it should be noted that the Georges Bank Atlantic herring stock has recovered completely from collapse over the past two decades, a great success story (Overholz and Friedland 2002).

According to the ASMFC (2008), Atlantic menhaden have not been overfished and overfishing is not currently occurring, yet abundance levels are low compared to the 1950s and 1960s. The geographic range of this species has contracted, young-of-the-year indices have been extremely low for the past several years (Maryland Department of Natural Resources 2008), and there are few larger older fish who can migrate into the Gulf of Maine, i.e., through the full migratory range. Although menhaden can live ten years or more, the population is dominated by very young fish. In addition, approximately sixty percent of the fish taken in the reduction fishery (processed for fish meal and oils) in Virginia are subadult (mostly year 2) and are being removed from a very restricted area near the mouth of Chesapeake Bay (Spear 2008).

Loligo squid have demonstrated a relatively stable biomass since the beginning of the National Marine Fisheries Service (NMFS) trawl data series (Hendrickson and

Jacobson 2006). The lack of recovery of the Illex squid population may be due to extreme overfishing in the 1970s, as well as depressed populations of capelin, a key forage species for Illex at the northern limit of their migratory range (i.e. Nova Scotia and Labrador) (Macy 2008). Finally, butterfish reached historic lows around 2000 and the population is still depressed. Though fishing pressure is low, there is significant bycatch in other fisheries (Overholz 2006c).

Sand lance populations exploded during the early 1980s, a response to release from predation pressure due to overfishing of species which prey on them. As some stocks have recovered, most notably herring and mackerel, sand lance numbers have declined. As the only species among the small pelagic group assessed here that are not subject to significant fisheries, sand lance populations are regulated directly by predation which in turn is influenced by fishery impacts (Weinrich et al. 1997).

Ecosystem Interactions and Ecological Dependencies

Small pelagic species are crucial to the health and functioning of marine ecosystems (Read and Brownstein 2003). On a very broad scale, they capture energy from lower trophic levels (phytoplankton, zooplankton, and small planktivorous fish) and transfer it to higher level carnivores including mammals, birds, and numerous species of pelagic and demersal fish and marine invertebrates. Because of their seasonal migrations and other life history traits, they also provide a significant link between coastal and pelagic systems by transporting energy and biomass seasonally from coastal embayments and nearshore waters to offshore waters (Gottleib 1998).

Herbivorous or omnivorous small pelagic species also are capable of removing significant amounts of phytoplankton from the water column. As a result of the often massive numbers and dense schooling behavior of some of these species, they can significantly alter water chemistry on a localized scale by increasing nutrients and depleting oxygen (Oviatt et al. 1972). On a bay- or estuary-wide scale, small pelagic species serve as net exporters of nitrogen from these systems (Gottleib 1998).

Some species in this group compete with one another and with species outside the group, serving as predator or prey depending on life stage. Atlantic herring and Atlantic mackerel consume sand lance. Sand lance competes for *Calanus finmarchicus* (a zooplankton) with endangered northern right whales (Kenney et al. 1986). Both species of squid are piscivorous, and squid are also cannibalistic. Also of note is the importance of small pelagic species to a host of large pelagic fish, as well as cetaceans and birds.

Northwest Atlantic Distribution and Important Areas

Methods

See methods overview in Chapter 5.

Limitations of Data for Small Pelagic Species

Spatial data for determining distribution and important areas was obtained from NMFS bottom trawl surveys. These surveys represent more than four decades of fishery-independent data collection throughout the Northwest Atlantic region, primarily in federal waters but in some state waters as well (inside three miles). When used for sampling small pelagic species, the survey method has some limitations with regard to fish behavior and ecology. These species tend to be found near the surface and/or can outswim the gear, so these species are not sampled as effectively as many demersal species in the trawl surveys. In addition, these fish can make diurnal vertical migrations or exhibit other behaviors that can cause them to be more difficult to catch at certain times of day. A number of experts have cautioned that there are better methods for sampling populations of small pelagic species, such as acoustics, purse seines, or midwater trawls. There is some likelihood that the trawl surveys have missed some important locations where small pelagic fish tend to be close to the surface, and the data may be biased toward areas where these species can be caught in a bottom trawl. It is unclear the extent to which these issues affect the validity of the maps created for this assessment.

Another important limitation of the data is the relatively short time frame (six weeks) in spring and fall within

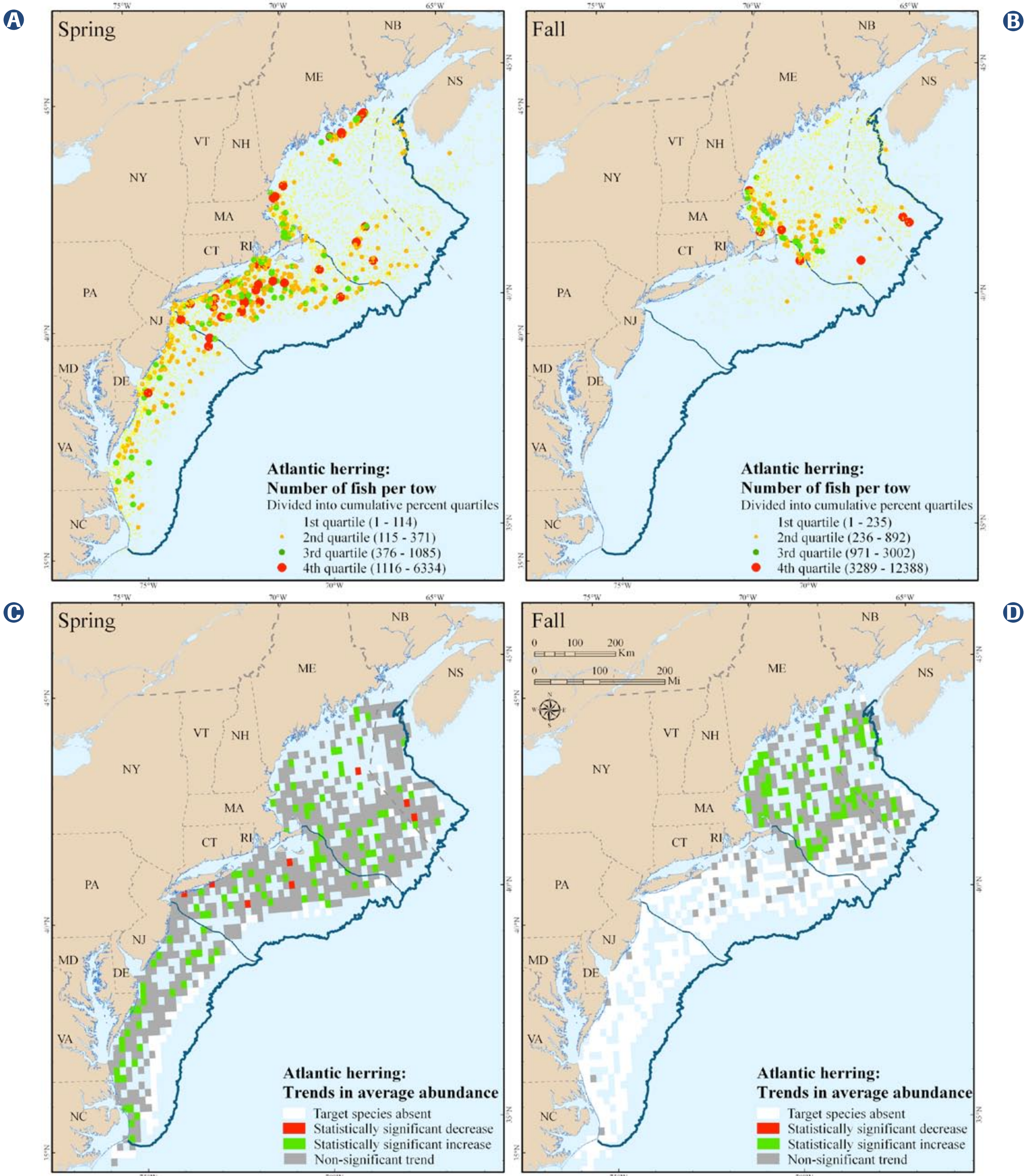

Figure 8-1. Trends in average abundance over 40 years for Atlantic herring during the spring and fall seasons.

which the surveys are conducted. These "snapshots" do not provide information about what is happening the rest of the year. When this aspect of the data is combined with the fact that these species undertake extensive migrations, a question arises as to the overall accuracy of the determination of areas of importance or persistence. As research continues, other sources of data need to be used to corroborate these findings, and would also be useful in verifying observations of spawning aggregations.

Maps, Analysis, and Areas of Importance

American Sand Lance

American sand lance is found mostly inshore of the trawl survey area. As such, American sand lance was not sampled adequately in the NMFS trawl survey.

Important Areas for American Sand Lance:
Not enough data to determine

Atlantic Herring

Distribution maps to correspond to what is known about the species from other studies (Figure 8-1a, b). In the spring, herring are found in high persistence in southern New England waters; other areas of persistence are quite localized, including Georges Bank, the area from Cape Ann to southeast of Nantucket, and very close to shore in Downeast Maine (Figure 8-2a). Less persistent, but significant concentrations are found nearshore from New Jersey to Cape Hatteras. In the fall, the fish appear to congregate in high abundances further north and east, in cooler water of the Gulf of Maine, completely outside of Mid-Atlantic Bight and Southern New England except for the area east of Nantucket near Great South Channel (Figure 8-2b). Significantly increasing trends support other data that demonstrate that this Georges Bank stock has recovered from the collapse of several decades ago (Figure 8-1c, d).

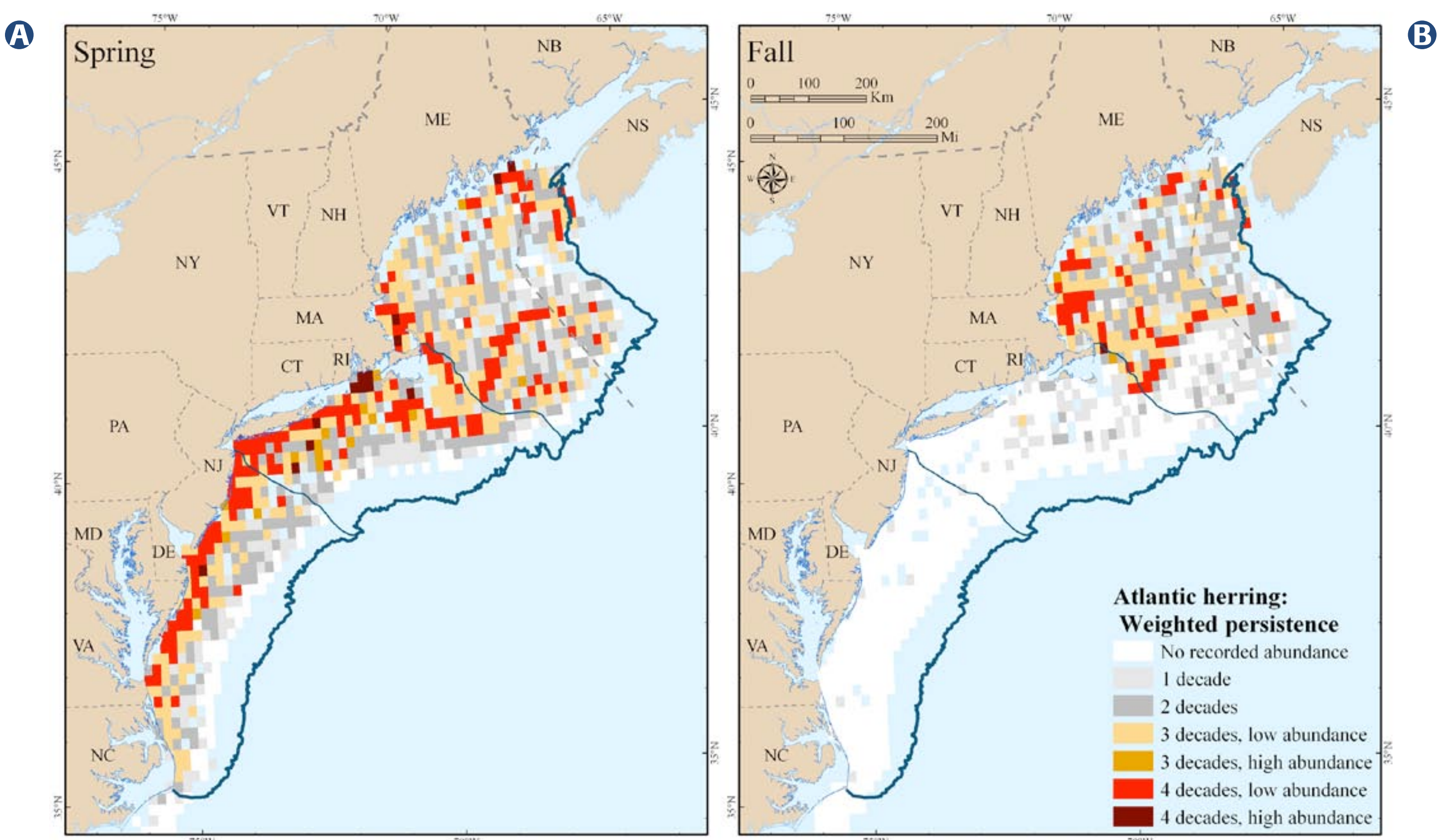

Figure 8-2. Areas with high persistence and abundance over 40 years for Atlantic herring during the spring and fall seasons.

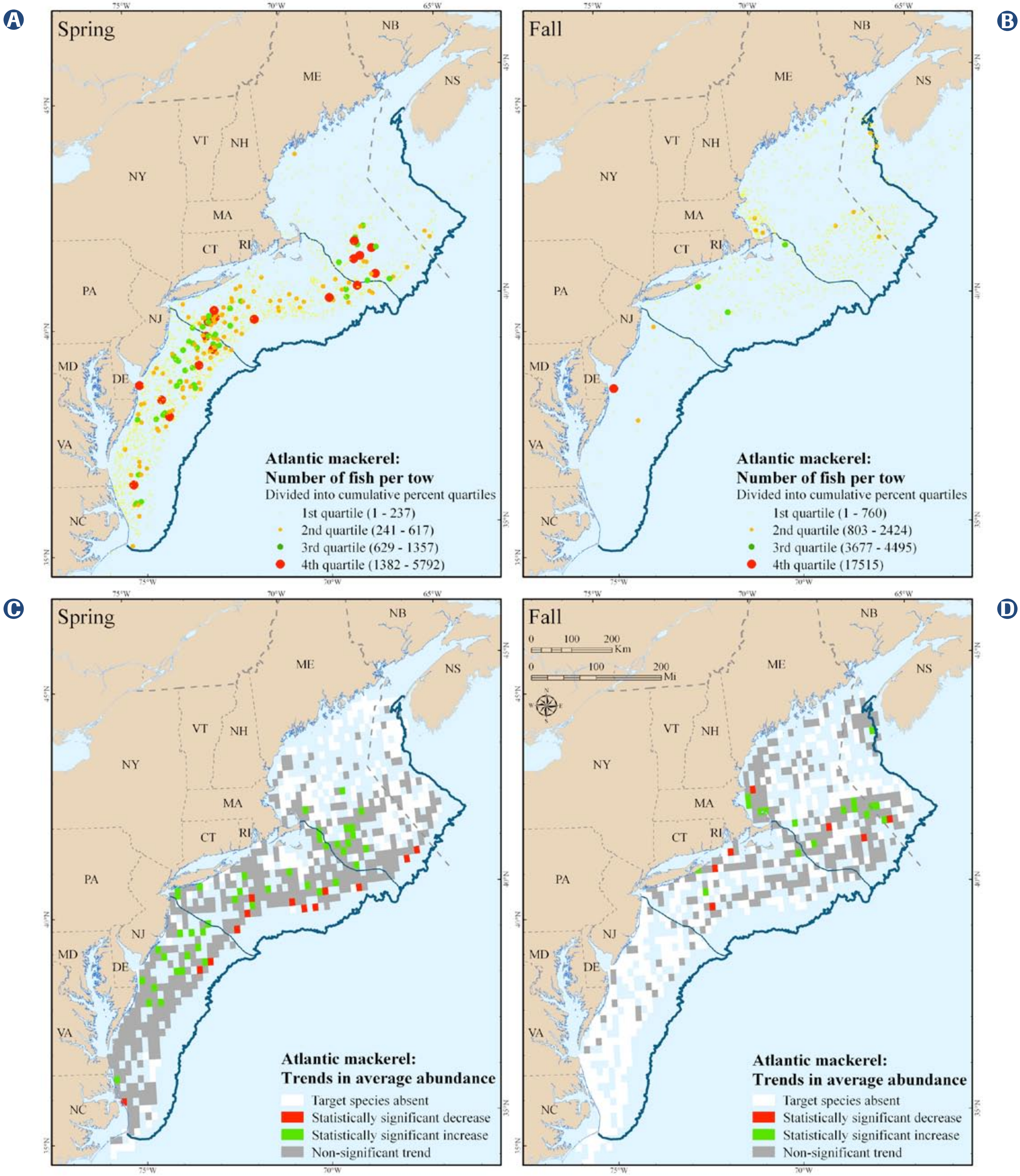

Figure 8-3. Trends in average abundance over 40 years for Atlantic mackerel during the spring and fall seasons.

Important Areas for Atlantic Herring:

Spring: Southern New England shelf waters, Georges Bank, Cape Ann to southeast of Nantucket, inshore eastern Maine

Fall: Gulf of Maine, east of Nantucket

Atlantic Mackerel

Consistent with what is known of this species' life history, in spring (Figure 8-3a), the fish are broadly distributed from Georges Bank to Cape Hatteras along the mid to outer Continental Shelf, as well as closer inshore from Rhode Island to Cape Hatteras. The high persistence/high abundance locations off southern New Jersey are likely associated with a known aggregation/spawning area at around this time of year though the spawn may be later (April/May) than the trawl survey (Figure 8-4a). In the fall, the fish are either scarce in the Northwest Atlantic area, or they are caught in lower numbers because of a change in catchability, or substantial mortality has occurred (Figure 8-4b). The spring and fall trend maps appear to reveal an increase in population size which agrees with the NMFS biomass trend for the species (Figure 8-3c, d). There seems to be a distinct decline in numbers in the spring along the outer shelf off southern New England and the areas immediately adjacent in the Mid-Atlantic Bight and the Gulf of Maine. The fall map shows no distinct pattern in the locations of decrease.

Important Areas for Atlantic Mackerel:

Spring: Shelf waters, mid- to outer Georges Bank to Cape Hatteras, near shore from Rhode Island to Cape Hatteras

Fall: Not enough data to determine

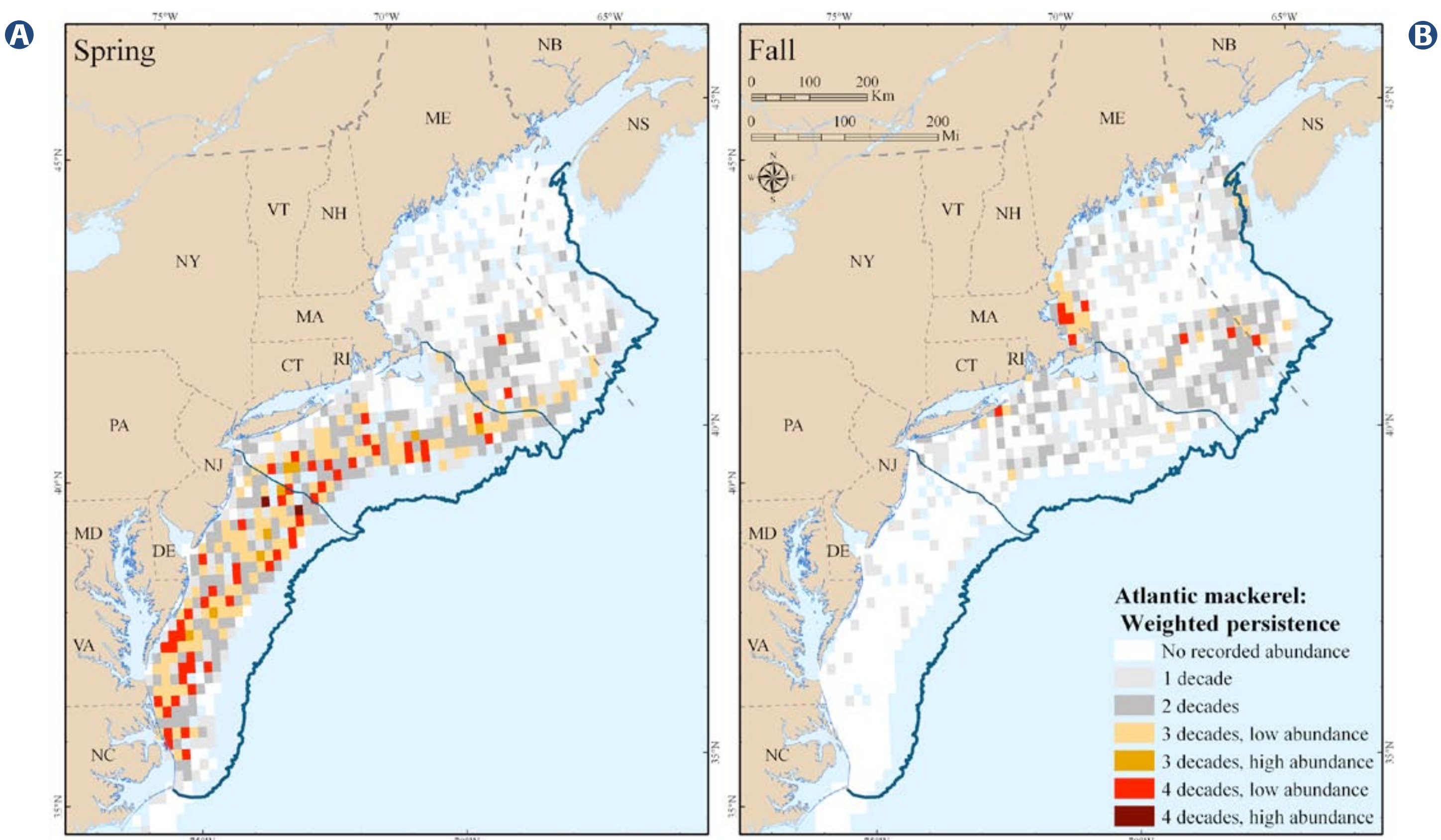

Figure 8-4. Areas with high persistence and abundance over 40 years for Atlantic mackerel during the spring and fall seasons.

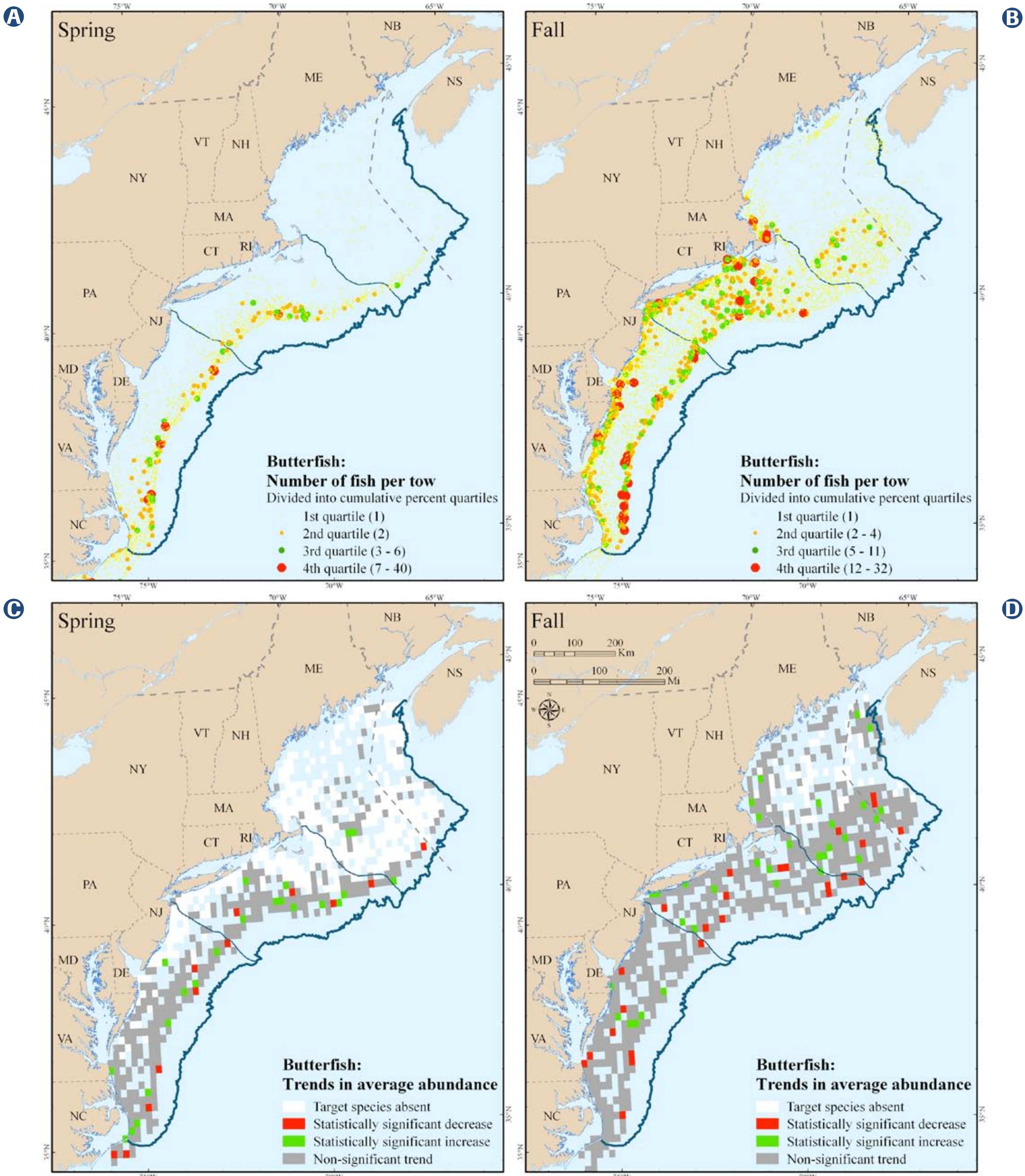

Figure 8-5. Trends in average abundance over 40 years for butterfish during the spring and fall seasons.

Atlantic Menhaden

Because of the small sample size for this species, the maps will not be interpreted. As previously stated, bottom trawls are not the best gear to use for sampling menhaden.

Important Areas for Atlantic Menhaden:

Not enough data to determine

Butterfish

Like several of the other small pelagic species, in spring, butterfish are distributed in a band along the outer Continental Shelf from southern Georges Bank to Cape Hatteras, with a more broadly distributed pattern from inshore to offshore in the fall (Figure 8-5a, b). In the fall, they are very persistent close to shore in the Mid-Atlantic Bight. South of Rhode Island to Georges Bank, they are broadly persistent from inshore to offshore in shelf waters (Figure 8-6b). There seems to be significant, highly localized persistent areas in Cape Cod Bay in the fall. These maps seem to correspond well with what is known about seasonal migration patterns. Southern New England waters seem to be particularly important in both seasons, with the Mid-Atlantic Bight less so except for an area near the northern boundary of the bight (Figure 8-6a). Of particular note is the limited movement of the offshore locations of importance. The large increase in important locations in the fall could be due to catchability or other issues and requires closer investigation. The spring trend map illustrates an immense decline, which is in agreement with NMFS temporal population trends (Figure 8-5c). Curiously, the fall trend analysis does not detect the decline (Figure 8-5d).

Important Areas for Butterfish:

Spring: Outer Continental Shelf from Georges Bank to Cape Hatteras

Fall: Same as spring, plus inshore waters of Mid-Atlantic Bight, all shelf waters from Rhode Island to Georges Bank, Cape Cod Bay

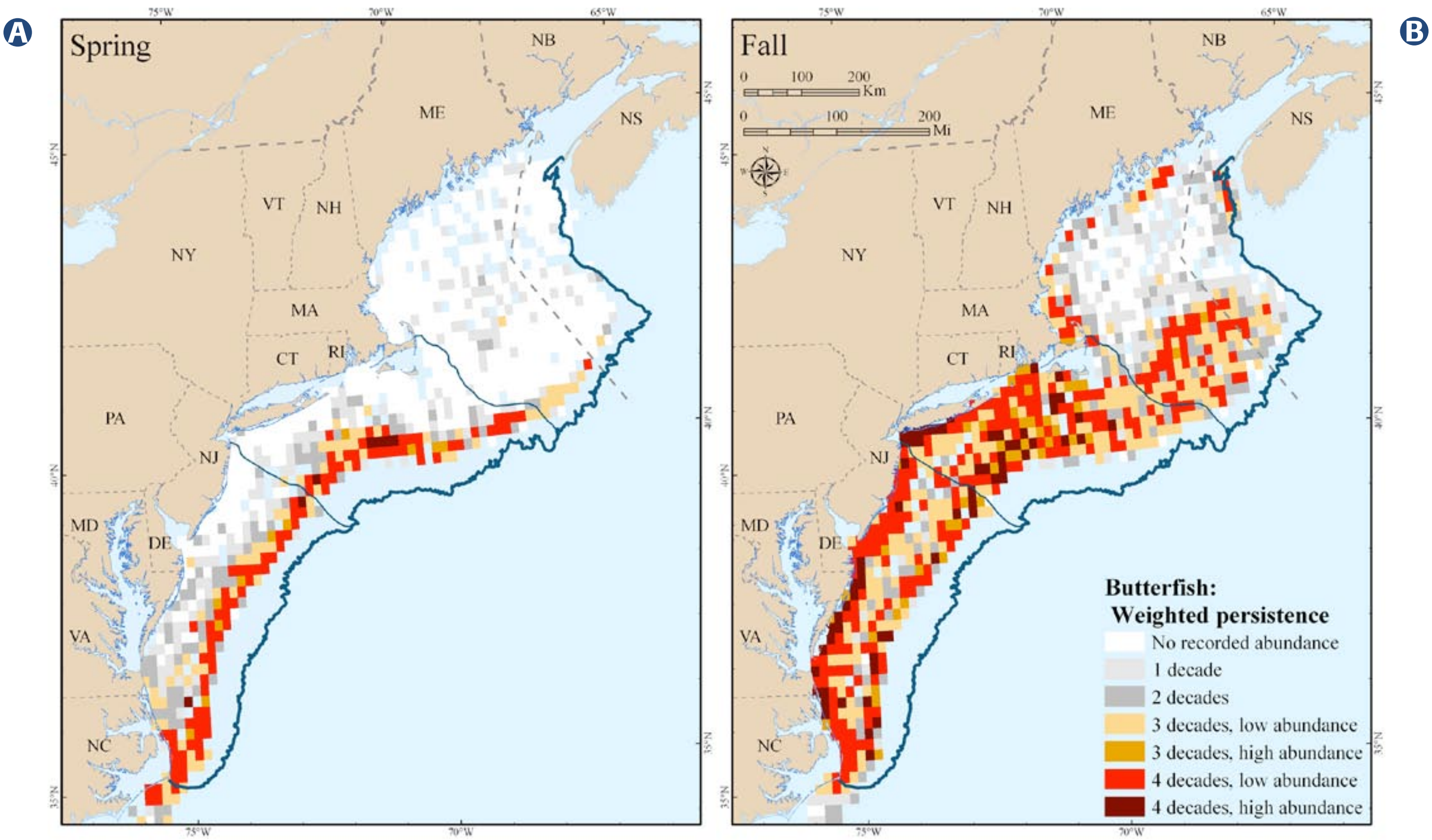

Figure 8-6. Areas with high persistence and abundance over 40 years for butterfish during the spring and fall seasons

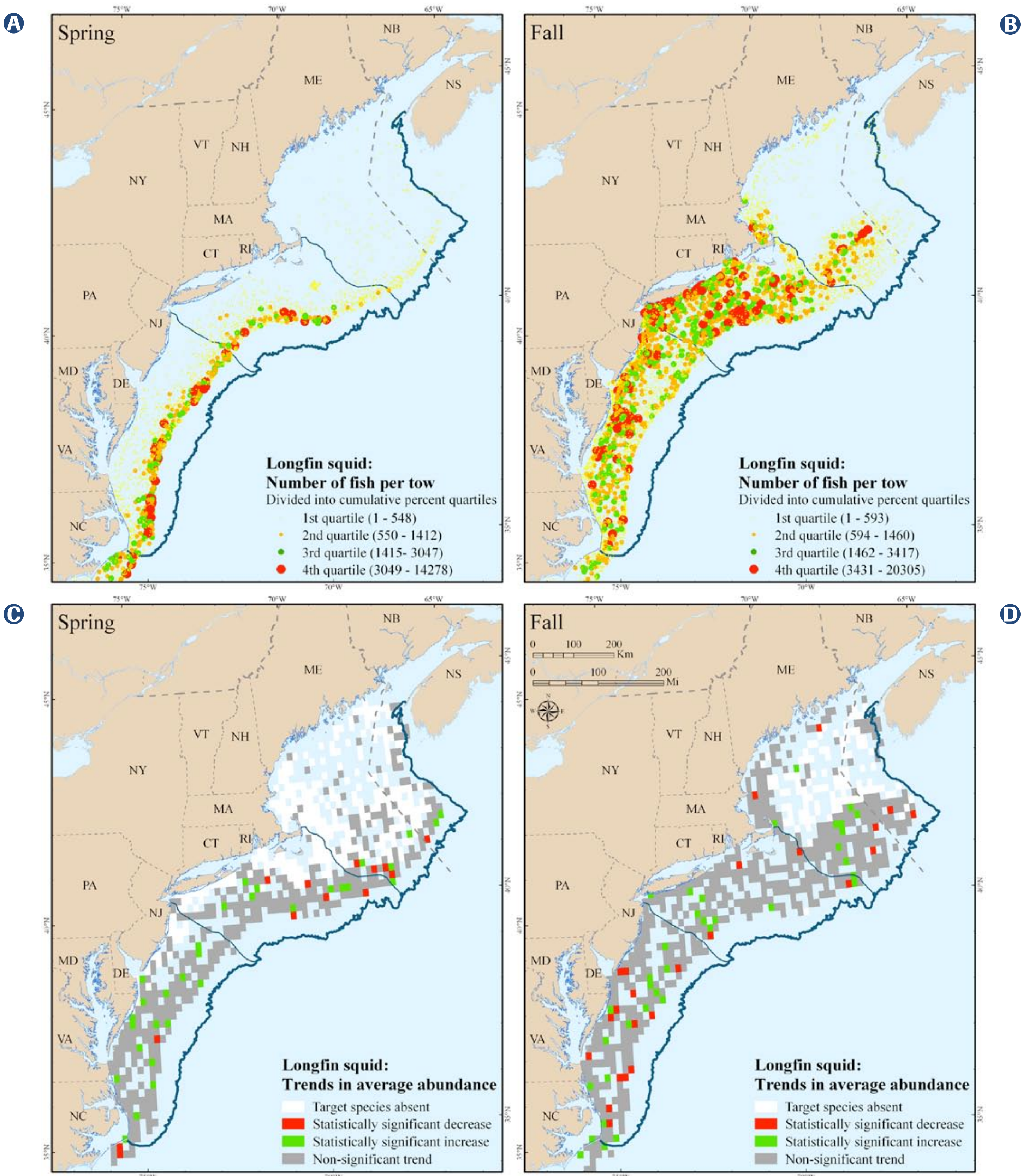

Figure 8-7. Trends in average abundance over 40 years for longfin squid during the spring and fall seasons.

Longfin Inshore Squid

The distribution of this species corresponds well to information on its life history and movements (Figure 8-7a, b). They are persistent near the shelf edge from Cape Hatteras to south of Cape Cod in the spring (Figure 8-8a). In the fall, they are broadly dispersed in shelf waters of southern New England and the Mid-Atlantic Bight, on portions of Georges Bank, Cape Cod Bay, a small area adjacent to the tip of Cape Cod, and inshore (Figure 8-8b). There may be two groups in the fall, possibly representing two main age cohorts, one further inshore than the other. The trend maps seem to indicate a relatively stable population which is in agreement with NMFS biomass trend data (Figures 8-7 c, d).

Important Areas for Longfin Inshore Squid:

Spring: Continental Shelf edge waters, Cape Cod to Cape Hatteras

Fall: Shelf waters, southern New England, Mid-Atlantic Bight, on portions of Georges Bank, Cape Cod Bay, a small area adjacent to the tip of Cape Cod, and inshore

Northern Sand Lance

This species is broadly distributed in the spring from the Chesapeake to Georges Bank, mostly inshore, with a dense concentration in the Cape Ann to Stellwagen Bank area (Figure 8-9a). During the spring, analysis reveals high persistence, but low abundance in an area extend-

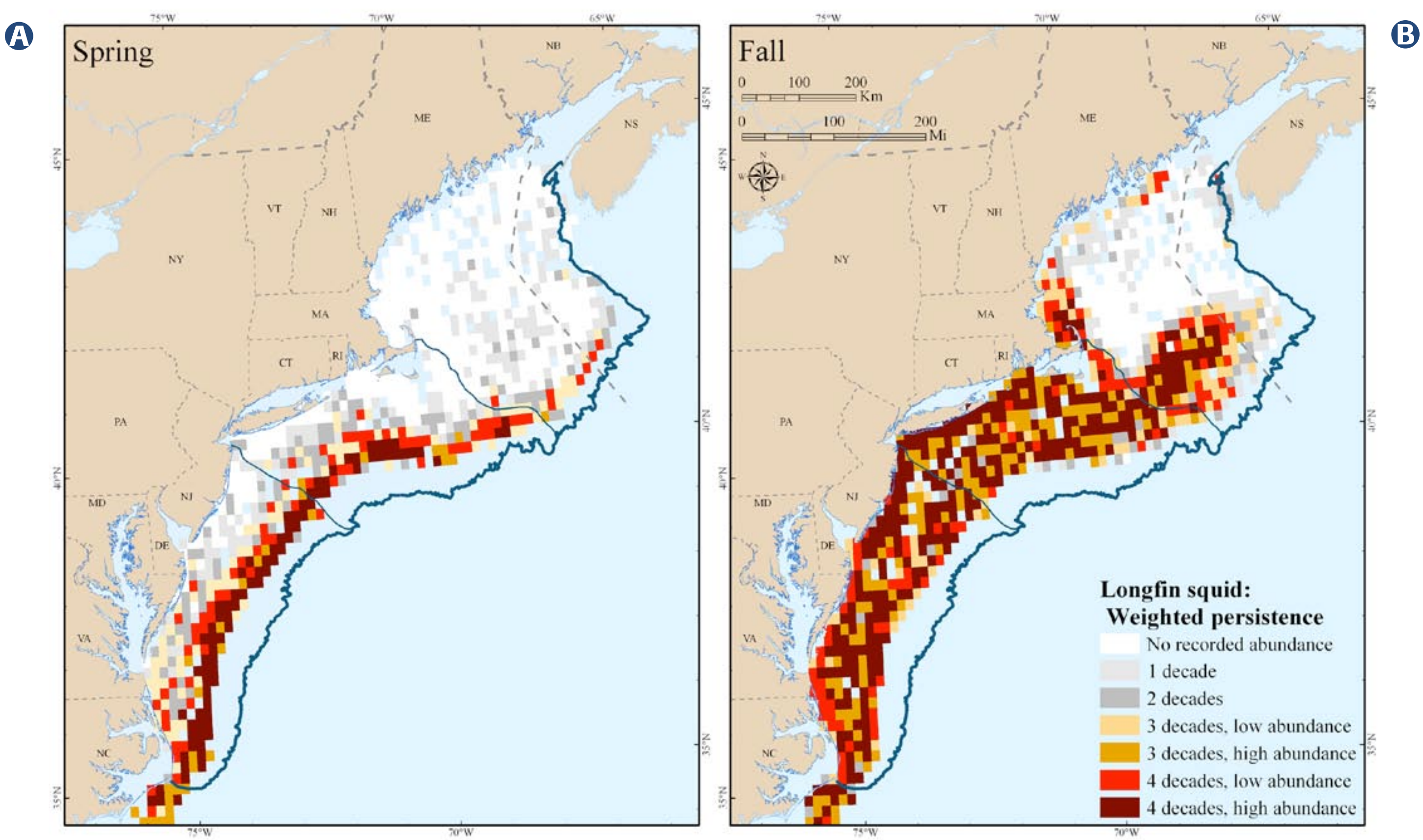

Figure 8-8. Areas with high persistence and abundance over 40 years for longfin squid during the spring and fall seasons.

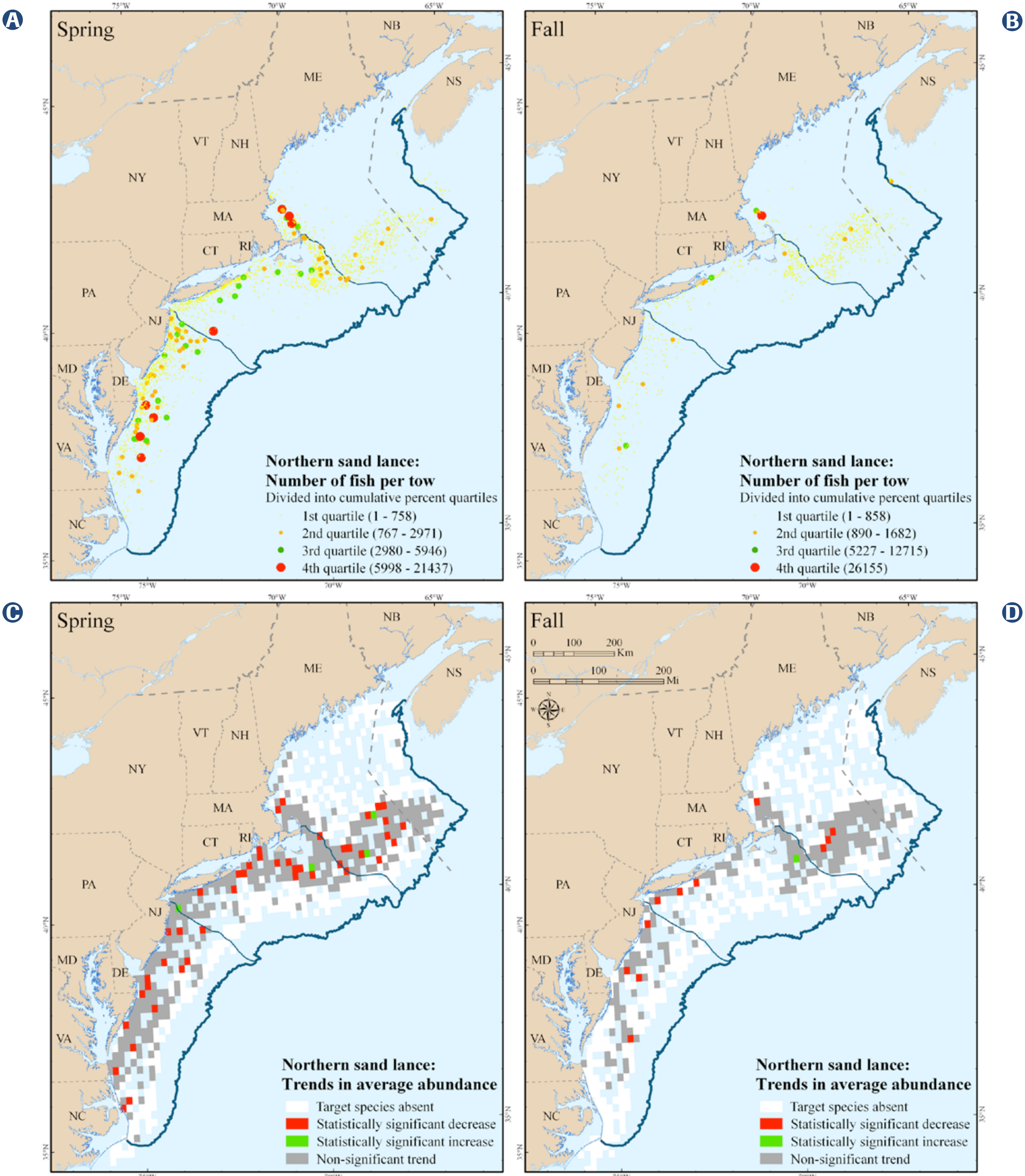

Figure 8-9. Trends in average abundance over 40 years for northern sand lance during the spring and fall seasons.

ing from south of Cape Ann, Massachusetts to southeast of Nantucket, near shore off southern New England and off of Long Island, New Jersey, Delaware, and Virginia, as well as portions of Georges Bank (Figure 8-10a). There are a few scattered high abundance locations that were persistent over three decades, the most noteworthy near Stellwagen Bank. In the fall, areas of high persistence remain in the area from Cape Ann to southeast of Nantucket, and on Georges Bank, as well as a series of isolated sites from Long Island to the shelf off Virginia (Figure 8-10b). The species is much less abundant in the fall, possibly due to predation by fishes, mammals, and birds for the previous half of the year. The spring trend map indicates a broad decline, while the fall map has far fewer points but shows a strong downward trend as well (Figure 8-10a, b). Sand lance populations exploded in the early 1980s when their predator populations were overfished, especially Atlantic mackerel. As predator populations recovered sand lance populations were reduced, the populations have never been as high as in the early 1980s.

Important Areas for Northern Sand Lance:

Spring: Cape Ann, Massachusetts to southeast of Nantucket, Stellwagen Bank

Fall: Cape Ann to Nantucket, Georges Bank, isolated locations from Long Island, New York to Virginia

Northern Shortfin Squid

Distribution maps indicate Illex are fairly persistent and moderately abundant in a narrow band along the edge of the Continental Shelf in the spring from southern Georges Bank to Cape Hatteras, in addition to the recognized spawning area in the Mid-Atlantic Bight (Figures 8-11a, b). They are more persistent in the same area in

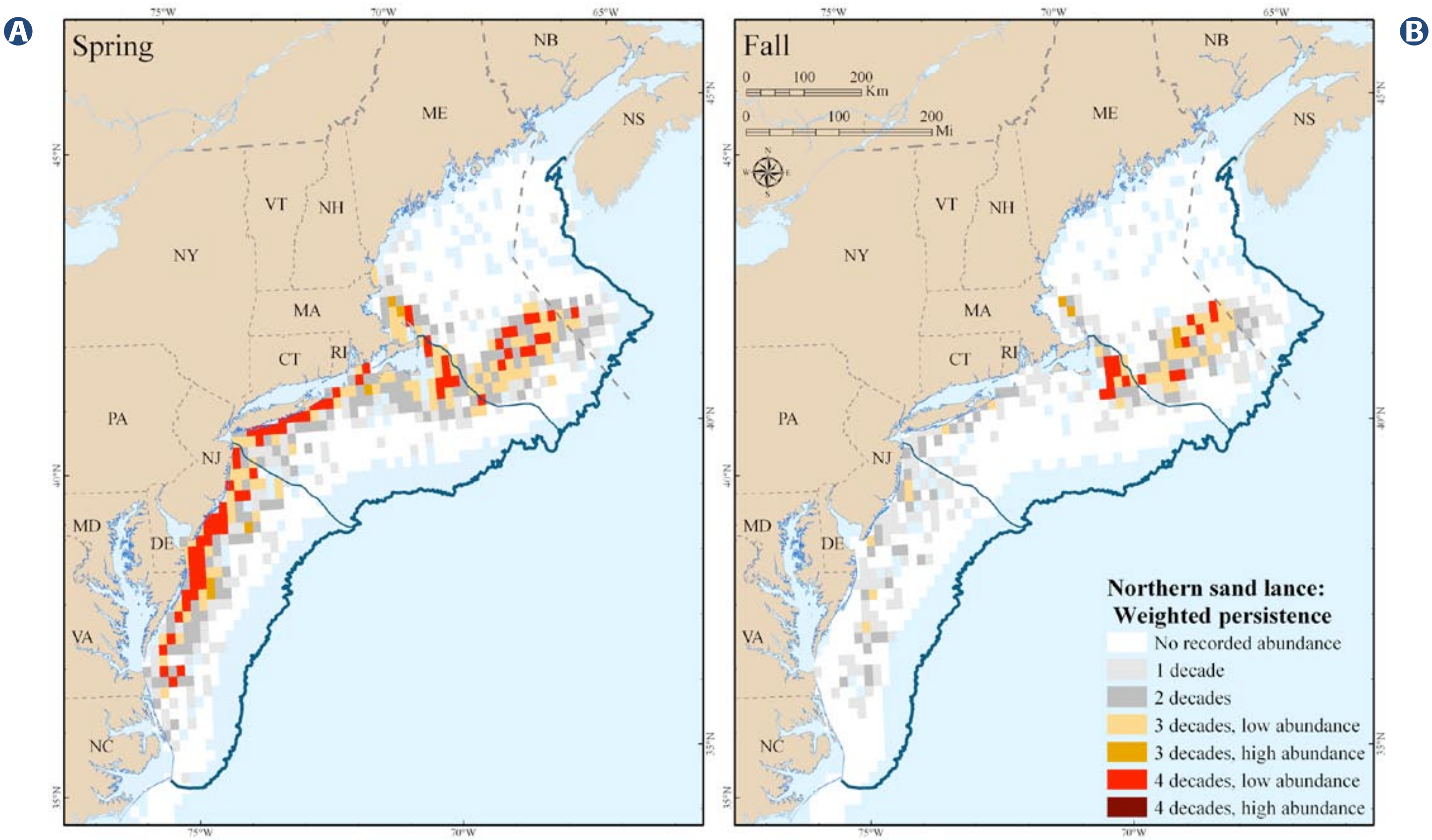

Figure 8-10. Areas with high persistence and abundance over 40 years for northern sand lance during the spring and fall seasons.

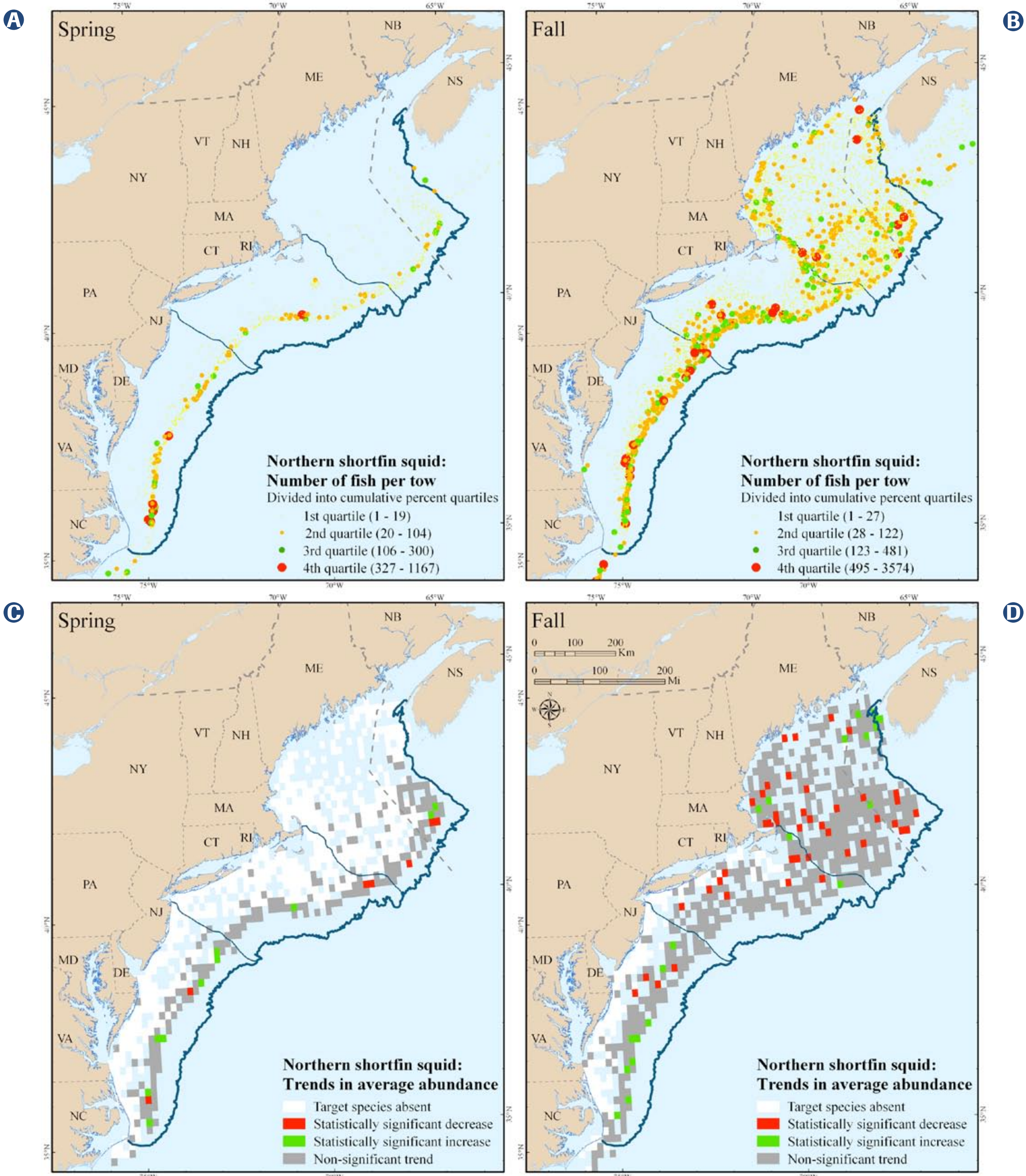

Figure 8-11. Trends in average abundance over 40 years for northern shortfin squid during the spring and fall seasons.

the fall, as well as throughout the Gulf of Maine and on Georges Bank, on the outer portions of the shelf in southern New England and the Mid-Atlantic Bight, and at an isolated spot southeast of Nantucket (Figure 8-12b). Because they are a sub-annual species, it is possible that they are simply more abundant in the fall. There appears to be no strong trend in population size in spring, while the fall map indicates a significant, broad decline mirroring what NMFS has detected in their long-term data set (Figure 8-11c, d).

Important Areas for Northern Shortfin Squid:

Spring: Edge of Continental Shelf, Georges Bank to Cape Hatteras

Fall: Gulf of Maine, outer Continental Shelf waters from Georges Bank to Cape Hatteras

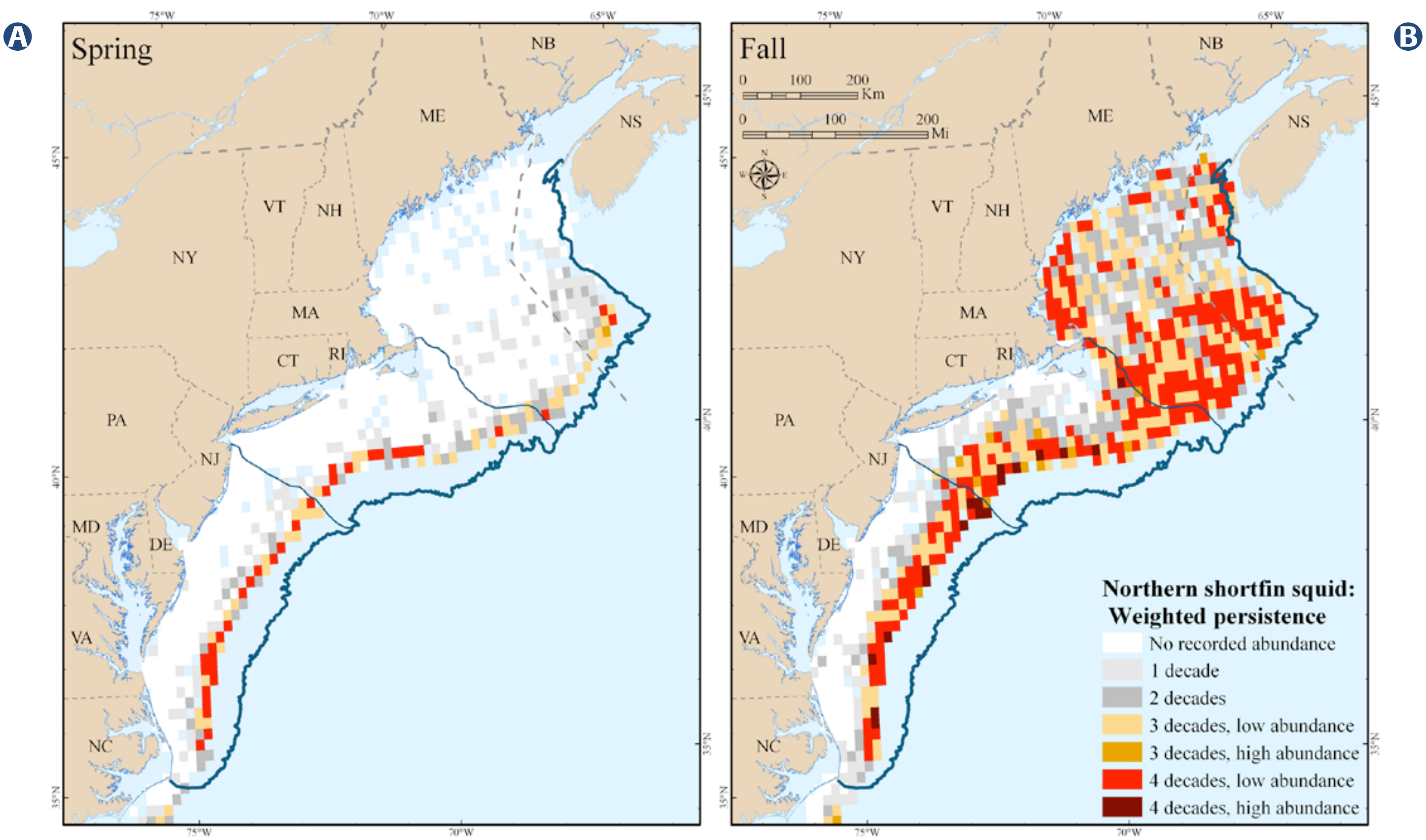

Figure 8-12. Areas with high persistence and abundance over 40 years for northern shortfin squid during the spring and fall seasons.

Human Interactions

Pollution, primarily land-based, is a major threat to these species when they are found in bays and estuaries, especially the estuarine dependent Atlantic menhaden. While some life stages or population segments of some of these species utilize bays and estuaries where they can be impacted by pollution, none are potentially impacted as much as the menhaden. Nitrogen from atmospheric deposition, agriculture, sewage, lawn fertilizers, and from enriched coastal and estuarine sediments, causes excessive plankton and algal growth. As these plankton die, their decomposition can lead to increased frequency of episodes of hypoxia (low oxygen). Such events are widely known to cause episodic mortality and increased disease rates of menhaden. Other pollutants include pesticides and other toxics, estrogen and estrogenic compounds, mutagens, pharmaceuticals, and other substances, many of which can pass through sewage treatment plants unaltered (Kennish 2002).

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Climate change is impacting small pelagic species in a number of ways. As is true on land, the increase in average water temperature is affecting the timing of critical ecological events, such as plankton blooms. Such changes can severely impact the most vulnerable life stages which depend on particular conditions or food items to be present at critical times. This is especially true of larvae which cannot travel to find food if it is not locally available. Climate change can alter the timing and location of fish spawning; for example, it has been suggested that the Atlantic menhaden spawning area may be moving northward which does not allow larvae to be transported as effectively into Chesapeake Bay, their single most important nursery system (Griffin et al. 2007).

Fishing impacts on most small pelagic species are significant. The sizeable catch of Atlantic menhaden, taken near the mouth of Chesapeake Bay, is comprised primarily of subadult fish removed from the population before they have spawned (Spear 2008). While some fishery managers believe the stock is not overfished, others disagree. The bulk of the population is composed primarily of these subadult fish, as opposed to a more optimal broad age/size distribution including significant numbers of older, larger, more fecund fish. Another example of significant fishing impacts is the severe downward trend in the butterfish population over the past several years (Overholz 2006c). Although direct fishing effort on the species has been reduced, bycatch mortality of butterfish in other fisheries has been high. Finally, while there is insufficient information to understand the extent of the damage, bottom trawls and dredges have the potential to damage or destroy the demersal eggs of Atlantic herring, longfin squid, and both species of sand lance.

Another source of mortality is entrainment of eggs, larvae and small fish in power plants; mortality can occur from thermal effluents emitted by power plants as well. As many of these plants are located within large estuaries, it is important to gather high-quality data on the magnitude of this threat in order to determine necessary actions (US EPA 2010). Once again, it is likely that Atlantic menhaden is most impacted. Finally, ocean acidification is a looming threat that has the potential to severely alter marine chemistry, food webs, and a host of other critical processes. The full potential impacts of this threat are unknown.

Management and Conservation

Regulatory Authority

Atlantic herring, Atlantic mackerel, short-finned inshore squid, long-finned squid, and butterfish are managed in federal waters by NMFS under the authority of the Magnuson-Stevens Fishery Conservation and Management Act. Atlantic herring are managed by the New England Fishery Management Council (NEFMC), while the two squid species, butterfish, and mackerel are managed together under the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan by the Mid-Atlantic Fishery Management Council. Atlantic menhaden are managed by the Atlantic States Marine Fisheries Commission (ASMFC), while the two species of sand lance are unmanaged.

Atlantic herring are unique as they are jointly managed by ASMFC and NEFMC because they occur and are fished in both state and federal waters. A variety of tools are used to manage the species, including area management, spawning closures, controls on catch, and a total allowable catch (TAC) for the inshore fishery in the Gulf of Maine. While Atlantic menhaden are managed by ASMFC, they are also under the jurisdiction of the various states throughout their migratory range, each of which has unique rules and regulations regarding harvest.

As all of these species except Atlantic menhaden are transboundary stocks relative to our international maritime border with Canada, they are also subject to the management authority of the Canadian government and the Department of Fisheries and Oceans. Also, several species migrate beyond the limits of the U.S. and Canadian Exclusive Economic Zones.

Current Conservation Efforts

Atlantic herring are being managed by NEFMC in concert with ASMFC. The Georges Bank stock has fully recovered from collapse, biomass is at very high levels, and exploitation rates are moderate (Overholz 2006a). There is a broad age/size distribution and spawning closures in major spawning areas prevent damage to egg beds. A recently enacted NEFMC nearshore Gulf of Maine closure was initiated by the Coalition for the Atlantic Herring Fishery's Orderly, Informed, and Responsible Long-Term Development (CHOIR), a coalition of commercial and recreational fishing interests, whale watch enterprises, and environmentalists, in response to an expansion of the midwater trawl fishery. There was a perception that the large scale capture of Atlantic herring was leading to localized depletion resulting in loss of forage for whales, other wildlife, and species sought by commercial and recreational vessels which prey on herring.

Atlantic mackerel are managed solely by the Mid-Atlantic Fisheries Management Council (MAFMC). Stock levels are high (Overholz 2006b), and there is currently no non-governmental organization (NGO) conservation effort directed toward the species (nor are there such efforts aimed at any of the other federally managed species). Butterfish are at or near historic lows (NEFSC 2008) and NMFS is working on reducing the high bycatch of this species in other fisheries (Overholz 2006c). The Illex squid population, which has not recovered from overfishing that took place in the 1970s, is closely monitored and strict quotas are adhered to in the fishery (W. Macy, Personal communication 2008). There are no conservation efforts directed toward the two unmanaged species of sand lance. In the United States, localized bait fisheries do have the potential to decimate discrete populations of American sand lance as the fish concentrate so heavily in specific locations. In 2008, ASMFC enacted a five year cap on annual harvests of Atlantic menhaden of 109,020 metric tons, in response to pressure from a host of recreational fishing and environmental groups. All states north of Virginia have banned the taking of menhaden for reduction purposes.

Species Accounts

Atlantic Herring *(Clupea harengus)*

Atlantic herring are a common pelagic, planktivorous fish (Bigelow and Schroeder 2002). They are found throughout Northwest Atlantic Continental Shelf waters from Labrador to Cape Hatteras, and in the North and Northeast Atlantic from Greenland to the Straits of Gibraltar, including the North and Baltic Seas. Ranging from shallow inshore waters to offshore, Atlantic herring adults occur predominantly in open water in large schools, while juveniles frequent bays and estuaries from the Chesapeake northward at various times of year, with greater abundance north of Delaware Bay (Bigelow and Schroeder 2002). Atlantic herring spawn in discrete locations from Labrador to Nantucket Shoals, from spring in the more northerly areas to summer and fall in U.S. waters. Juveniles and adults undergo significant migrations during the year in response to temperature, salinity, and food availability. They are relatively long-lived, reaching ages of 15-18 years and lengths of approximately 40 cm.

Atlantic herring deposit adhesive eggs in "beds" on gravel bottom in specific locations both inshore and offshore in the Gulf of Maine, on Georges Bank, and Nantucket shoals (Stevenson and Scott 2005). After hatching, larvae are spread by surface currents, though some larvae are able to remain near their place of hatching for extensive periods. Larvae are found in coastal, estuarine, and offshore waters from the Bay of Fundy to New Jersey. Juveniles are pelagic, found close to shore and in bays and estuaries in their first year of life, and are tolerant of low salinities but avoid estuarine waters south of Long Island Sound during the warmer months. Second-year fish prefer higher salinities when inshore and avoid brackish areas. In the winter, one year olds move to deeper inshore waters while two year old fish can be found offshore from Cape Hatteras to the Bay of Fundy in winter and spring. Food availability, frontal zones and currents can further limit suitable habitat (Bigelow and Schroeder 2002).

During summer and fall, adults are found throughout the Gulf of Maine and in the deeper portions of Georges Bank, with a southerly shift in winter from Cape Hatteras to deeper waters of Georges Bank. During the spring, they are found from the southwest part of the Gulf of Maine to the shelf waters of the mid-Atlantic, again with fish also found in the deeper parts of Georges Bank. They are most abundant where dense plankton concentrations are found, in well-mixed areas and where fronts develop between well-mixed areas and stratified waters (Stevenson and Scott 2005).

Atlantic Mackerel *(Scomber scombrus)*

Atlantic mackerel, a pelagic, fast-swimming species which consumes zooplankton, small fishes and invertebrates, occur on both sides of the North Atlantic as well as in the Baltic, Mediterranean, and Black Seas (Bigelow and Schroeder 2002). In the Northwest Atlantic, they range from Labrador to North Carolina, undergoing extensive seasonal movements. They overwinter along the Continental Shelf edge, and then move inshore then northeast in spring, and in the fall, reverse the movement (Bigelow and Schroeder 2002).

They are sometimes known to enter estuaries and harbors in search of food and to avoid predation, especially when they are young, though occasionally adults can be found in very shallow waters in coastal embayments. Mackerel make significant migrations to and from spawning and wintering areas. During spring they generally are found somewhat closer to shore for spawning off the Mid-Atlantic Bight, and in the southern Gulf of St. Lawrence in midsummer. From spring to fall, they are found in and near surface waters from 46-55 m.

There are two distinct major spawning groups of Atlantic mackerel. The southerly component spawns in spring (April-May) in the Mid-Atlantic Bight, and the northern segment in early summer (June -July) in the southern half of the Gulf of St. Lawrence. Both spawn in waters generally shoreward of the mid-Continental Shelf. Pelagic eggs are found in shelf waters from Cape Hatteras to the Gulf of St. Lawrence, and less than a week transpires before hatching. Larvae are found over the same range, but from May to August, and juveniles begin to appear about two months after hatching. Spawning is also known to occur in Long Island Sound and Cape Cod Bay, as well as near the edge of the Continental Shelf and beyond. Females are serial spawners and lay four to seven batches of eggs (Studholme et al. 1999).

Longfin Inshore Squid *(Loligo pealeii)*

Longfin inshore squid, a pelagic cephalopod mollusk, occur in Continental Shelf and Slope waters from Newfoundland to the Gulf of Venezuela (Bigelow and Schroeder 2002); in the Northwest Atlantic they are most abundant from Georges Bank to Cape Hatteras, moving into the Gulf of Maine in the warmer months. Distribution varies seasonally due to a general inshore migration during the spring and summer. From Cape Hatteras northward, this species migrates offshore during late fall to overwinter along the shelf edge and slope in warmer waters, then returns inshore in the spring, staying until late autumn. Loligo are a subannual species, living less than a year (Jacobson 2005).

During the summer, they are restricted to surface and shallow nearshore waters, but they can be found along the shelf edge and slope in winter. Spawning occurs inshore in areas with rocks and small boulders to which the eggs are attached. Eggs can also be attached to various species of macroalgae and other eggs. Macy (personal communication 2008) has recently discovered that spawning occurs offshore in winter off Chincoteague, Virginia at depths of 50 fathoms (91.4 m), and has also identified the warmer waters near canyon heads as important wintering areas. Spawning occurs throughout the year. Eggs are laid in masses contained within semi-transparent, rubbery capsules. Hatching occurs in days to weeks, incubation time decreasing with increasing water temperature. Distribution of eggs is not well known. After hatching, larvae stay near the surface and move deeper as they grow larger and are broadly distributed.

Northern Shortfin Squid *(Illex illecebrosus)*

The highly migratory northern shortfin squid is found in the Northwest Atlantic from the Florida Straits to Newfoundland (Bigelow and Schroeder 2002). Utilizing both oceanic and shelf habitats, Illex squid undertake long migrations and are short-lived species. It is unclear if the species consists of a single stock or if there are multiple stock components. While spawning is believed to occur throughout the year, and over large areas, the only confirmed spawning location is between Cape Hatteras and southern New Jersey, where spawning occurs during late May. Spawning may also occur south of Cape Hatteras in the Gulf Stream/slope water frontal zone in winter, and near the Blake Plateau off Florida. Females die within days after spawning. It is widely believed the Gulf Stream plays a crucial role in dispersing neutrally-buoyant eggs, paralarvae (a developmental stage unique to cephalopod mollusks), and larvae, transporting them north and east along the shelf/slope waters. Paralarvae are most abundant in the Gulf Stream/slope water convergence zone in February and March, south of Cape Hatteras, though they are found in the same zone all the way to the Grand Banks

later in the year. The high biological productivity of this area is important for larvae and juveniles as well; juveniles begin to migrate onto the shelf in late spring between Cape Hatteras and Nova Scotia. Adults inhabit offshore shelf waters during the summer, except in the Gulf of Maine where they are found quite close to shore. An extensive offshore migration occurs in the fall (Hendrickson and Holmes 2004).

American Sand Lance *(Ammodytes americanus)*

American sand lance are a small, planktivorous, highly abundant fish with both demersal and pelagic traits, having a unique ability (like other species in the genus) to burrow into suitable bottom types (loose sand, sand/shell hash/fine gravel). They are equally noteworthy for aggregating and foraging in dense schools of dozens to thousands of individuals for protection from predators. Closely related to the northern sand lance, the species are often confused. Occurring from Labrador to Cape Hatteras, they are considered by many to be a keystone small pelagic species as they are food for whales, other cetaceans and marine mammals, birds, numerous fish species, squids, and crustaceans (Bigelow and Schroeder 2002).

Generally found in more inshore habitats compared to northern sand lance, they mostly inhabit very shallow coastal waters, inlets, bays, and estuaries, but also occur in shelf waters primarily on offshore banks as well as deeper waters (Auster and Stewart 1986). They are usually found over or near bottoms with substrates which allow them to burrow and seldom occur over rocky bottoms or shores. American sand lance mature in the first or second year of life, and spawn in late fall and early winter. Demersal eggs hatch from sand and fine gravel bottoms as the water temperature cools below 9° C. Exact spawning locations are difficult to determine from the available literature. Widely distributed in shelf waters, larvae consume phytoplankton, fish eggs, and copepod nauplii. Copepods are the primary food for older larvae, juveniles, and adults (Auster and Stewart 1986).

Northern Sand Lance *(Ammodytes dubius)*

Northern sand lance range in Continental Shelf waters from Greenland to North Carolina; in the Northeast Atlantic they are found in the North and Baltic seas (Bigelow and Schroeder 2002). In the Northwest Atlantic, they occur primarily offshore to depths of 108 m, but can be found in very shallow waters on offshore banks and also occur inshore (Winters and Dalley 1988). They require similar, but deeper, habitats as those described above for the American sand lance, with substrate suitable for burrowing. Consequently, they seem to avoid rock and mud bottoms.

They spawn in late fall to winter on sandy bottom habitats, where eggs can adhere to sand grains. Larvae can be extremely long-lived and widely distributed; they are found from February to July in Continental Shelf waters from the Scotian Shelf and Grand Banks to off Chesapeake Bay. Larvae seem to be capable of directed movement offshore, and the transition to juveniles occurs after about three months. Many reach sexual maturity during the first year and most by the second year. Adults have a very broad distribution, and can live as long as 9-10 years, reaching a maximum size of nearly 40 cm, but most are not as large or long-lived (Auster and Stewart 1986). Like American sand lance larvae, *A. dubius* larvae consume phytoplankton, fish eggs, and copepod nauplii. Copepods are the primary food for older larvae, juveniles, and adults. As adults, they tend to forage diurnally, seeking refuge in the bottom during the night (Auster and Stewart 1986).

Butterfish *(Peprilus tricanthus)*

Butterfish are a small, fast growing, short-lived pelagic fish found along the Northwest Atlantic coast and shelf and slope waters from Florida to Nova Scotia. They consume a variety of small invertebrates, and are food for a host of predatory fish (Bigelow and Schroeder 2002). They are most common from Virginia to the Gulf of Maine and occur primarily near the surface but can be found throughout the water column from 0 to nearly 400 m. During summer, the Gulf of Maine, Georges Bank, and Nantucket Shoals are areas of particular abundance (Cross et al. 1999).

Butterfish spawn offshore on shelf waters, and in and around estuaries and bays, between June and August, with the timing of spawning moving northward as the water warms (Overholtz 2006c). In general, they tend to prefer sandy bottoms rather than rocks or mud. Eggs are buoyant and hatch within several days, depending on water temperatures (Bigelow and Schroeder 2002). Larvae inhabit the same waters, and in bays and estuaries are restricted to mixed and saline areas; the same is true for juveniles. Juveniles are often associated with floating seaweed, debris, and jellyfish where they find some protection from predators, but they can survive without such cover. Juveniles and adults move offshore and southward in the fall, wintering along the bottom near the edge of the Continental Shelf off the Mid-Atlantic Bight. During the spring, they begin moving northward and inshore to spawn, and in about a year from hatching at a length of 12 cm, most are sexually mature and begin spawning with the older adults. Most adults live only 2-3 years.

Atlantic Menhaden *(Brevoortia tyrannus)*

Atlantic menhaden are an estuarine-dependent, planktivorous, migratory species, occurring from central Florida to Nova Scotia (Bigelow and Schroeder 2002). They are found from freshwater portions of tidal rivers to the oceanic waters of the Continental Shelf, but are most common in a more restricted range in bays and near-coastal waters from North Carolina to Cape Cod. Feeding habitat is dependent on life stage: larvae feed on the shelf and in bays and estuaries, juveniles (primarily young-of-the-year) in heads of bays and estuaries and into freshwater rivers, and subadults in estuaries and shelf waters primarily from Delaware Bay to Florida. Adults, depending on size, forage in bays, estuaries, and shelf waters from central Florida to Nova Scotia, with the larger, older fish swimming the furthest north (ASMFC 2004). Throughout the post-larval life stages and annual migratory range, feeding areas are generally characterized by high primary productivity, whether in freshwater, bays and estuaries, along shore, or on the shelf.

Spawning occurs on the continental shelf throughout their migratory range in every month of the year (Bigelow and Schroeder 2002). Major spawning habitats are waters off Virginia and North Carolina during September and October and March through May, although spawning does occur in areas north of New Jersey/Long Island (Bigelow and Schroeder 2002). The bulk of recruitment is attributed to the late winter-spring spawn off the Chesapeake and subsequent larval and juvenile development in the bay (ASMFC 2004; Friedland 2007). Eggs hatch in two to three days. Transported by currents on the shelf, most of the larvae move into the Chesapeake, North Carolina coastal waters, and other bays and estuaries along the Northwest Atlantic coast. The transition from the larval to juvenile stage usually occurs in the lower salinity zones of bays and estuaries, and late fall-spawned larvae can overwinter in the estuary. Adults range from the heads of estuaries to well offshore. The fish migrate northward in the spring and summer with the larger fish swimming farther (Griffin et al. 2007). Older, larger menhaden continue to spawn as they move northward along the coast, often outside of large estuaries but also in Long Island Sound, the Peconic Bay system, and Narragansett Bay.

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