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Distribution of scientifically collected blueline tilefish *(Caulolatilus microps)* in the Atlantic, and associated habitat. SEDAR50-DW04

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Introduction

Blueline tilefish, *Caulolatilus microps* (a.k.a. gray tilefish; hereafter blueline) is a deep water species found in the Gulf of Mexico and Northwest Atlantic. In an extensive report on biology of tilefishes, Dooley (1978) reported it's distribution as follows "*Distribution.*—(?) Cape Henry, Va.; Cape Lookout, N.C. to Florida; Florida-Gulf of Pensacola, Fla. (probably throughout Gulf)." Later authors report it's distribution as "Cape Lookout, North Carolina, to Campeche Bank, Mexico" (Harris et al. 2004). Similar distributions have been repeated by many later authors (Ross and Huntsman 1982; Ross and Merriner 1983; Robins et al. 1986; Harris et al. 2004, ; also see http://www.fishbase.org/summary/Caulolatilus-microps.html). However, the Northeast Fisheries Science Center Bottom Trawl Survey, which operates primarily north of Cape Hatteras is known to catch blueline, and commercial landings of blueline of one metric ton have been reported as far north at New Jersey and Rhode Island, in 2000 and 2004, respectively (https://www.st.nmfs.noaa.gov/commercial-fisheries/). Thus it appears that the northern extent of the blueline tilefish distribution is being underestimated in the literature.

Several environmental variables have been implicated as important descriptors of blueline habitat. The most notable variables are depth (e.g. Dooley 1978; Sedberry et al. 2006) and bottom temperature (e.g. Sedberry et al. 2006). But this species is known to construct and take shelter in burrows, thus associated substrates have also been noted. Dooley (1978) notes the abundance of blueline off of North Carolina over rubble bottom, though does not provide a reference, while Able et al. (1987) report in detail on the sediment composition of blueline burrows, finding them to be primarily comprised of sand and silt.

Blueline is a federally managed species and was recently assessed as a single stock in the Atlantic (SEDAR 2013). Because its distribution crosses management boundaries, it has become important to the Mid-Atlantic and South Atlantic Fishery Management Councils (MAFMC and SAFMC, respectively) to evaluate the biological stock structure of the species. Here I provide a synthesis synthesis of most of the available data for blueline tilefish collected by scientific studies where specific latitude and longitude (lat-lon) data were collected, to investigate distribution of blueline and habitat variables associated with site they are known to occupy in the Northwest Atlantic.

Materials and Methods

Spatial distribution of scientific collections

Spatially precise records of blueline tilefish, with latitude, longitude, and date information, have been obtained from four sources: Northeast Fisheries Science Center Bottom Trawl Survey (NEFSC BTS; Nitschke and Miller 2016*b*), the Northeast Fisheries Observed Program (NEFOP; Nitschke and Miller 2016*a*), the Southeast Reef Fish Survey (SERFS; Kolmos et al. 2016), and the Cooperative-With-Industry Data Collection Project (CDCP; Kellison 2016). Together, these observations represent the most complete set of scientifically collected records for this species with precise latitude and longitude data. Aggregating and mapping these data also allowed us to evaluate the continuity of the distribution of blueline, and identify possible gaps in their distribution that might suggest stock sub-structure.

Habitat and environmental data

In order to characterize the habitat of blueline tilefish, I analyzed the environmental variables associated with precise records. These variables included depth, bottom temperature, salinity, and sediment composition (i.e. percent clay, silt, sand, and gravel). Sediment data was not directly available from fish collections and was obtained from the USGS East-Coast Sediment Texture Database (http://woodshole.er.usgs.gov/project-pages/sediment/). Sediment raster layers were interpolated from point estimates were spatially joined to each fish sampling coordinates, to obtain an estimate for that record.

Results and interpretation

Summary of scientific collections

Tows conducted on the NEFSC BTS employed similar trawl gear, but some gear differences exist in the historical time series (Azarovitz 1981), and a much larger net has been used in recent years (Politis et al. 2014). Out of 39962 tows conducted from 1963 to 2015, from 28.8°N to 44.9°N latitude, the NEFSC winter, spring, and fall bottom trawl surveys have caught 49 blueline tilefish on 42 separate tows (Fig. 1). Blueline were caught from 1982 to 2015, and from 32.8°N to 40.4°N latitude. It is important to note that the southern limit of the NEFSC bottom trawl survey has changed over time and has only extended to 34.5°N, since 1986 (Azarovitz 1981; Despres-Patanjo et al. 1988).

The SERFS uses various types of fishing gear, but here I consider only data from gear types known to catch blueline. Out of 23044 fishing events conducted from 1977 to 2015, from 27.2°N to 35°N latitude, the SERFS has caught 844 blueline tilefish in 366 separate fishing events (Fig. 2). Blueline tilefish were caught by eight different gear types, with three gear types responsible for 0.75% of fishing events that caught blueline: short-bottom longline (n=103), Kali pole (n=97), and Chevron trap (n=74; Table 1). The temporal and spatial range of blueline catches was from 1979 to 2015, and from 29.7°N to 34.5°N latitude.

The NEFOP observed a total of 19983 pounds of blueline tilefish catches from four gear types: trawl (13653 lbs), gill net (248 lbs), longline (6012 lbs), and lobster traps (70 lbs). The temporal and spatial range of blueline catch data was from 1997 to 2016, and from 35.6°N to 41.3°N latitude (Fig. 3).

The CDCP collected a total of 1025 blueline tilefish with two main year types: manual or automated hook and line (n = 167) and longline (n = 736). The temporal and spatial range of blueline caught by the CDCP was from 2015-09-17 to 2015-11-30, and from 24.3°N to 38.9°N latitude (Fig. 4).

Sampling efforts at ODU collected a large number of blueline tilefish (n = 982) from which biological samples were obtained, representing a large proportion of the biological samples collected north of Cape Hatteras. The spatial resolution of the capture locations was limited to 1.0° × 1.0° lat-lon bins representing NOAA statistical areas, with most (0.92%) of the samples collected in statistical area 626, with the remaining samples from areas 625, 631, and 632. All samples were collected between 2009-05-26 and 2011-12-28.

Distribution of scientific collections

Though all of the collections employed different sampling methods and invested different amounts of effort, plotting the locations of all blueline tilefish specimens together should be helpful for investigating general patterns in blueline tilefish distribution (Fig. 6). Overall, the plot supports previous reports of a limited depth range of blueline tilefish at deeper depths, but does not appear to match previous descriptions of blueline distribution in the Atlantic. The southernmost specimen in the Atlantic were collected by the SERFS in northern Florida, and the northernmost specimen was collected by the NEFSC BTS on Georges Bank, and both of these sampling locations are at least 100 km away from the nearest neighboring specimen, despite substantial sampling between specimens. The distribution of blueline appears relatively continuous between southern South Carolina and northern New Jersey along the 100-200 m depth countours. Density of blueline was relatively high off of northern South Carolina, low in southern North Carolina, and relatively high again between Cape Lookout and northern coastal Virginia. Viewing latitude data in density plots of NEFSC and SERFS sites where blueline were present also suggests lower densities of blueline between ≈ 33 and 35°N latitude, however corresponding density plots of all survey locations also show somewhat lower effort in that range. Though not intended to be a survey of abundance, the CDCP data shows a more continuous distribution over that range, but does show a slight valley there, between two modes (Fig. 7).

Habitat associated with scientific collections

Density plots of sites occupied by blueline versus depth all suggest two depth modes with peaks around 100 m and 180 m. The NEFSC data shows blueline to be much more common in the shallower mode, with 50% of occupied sites between 86 and 117 m; it also shows that a lot of NEFSC BTS sampling has occurred in that depth range. The SERFS data shows that blueline are much more common in the deeper mode, with 50% of occupied sites between 102 and 198 m; it also shows that relatively limited sampling occurs over the entire depth range occupied by blueline. The CDCP data shows nearly equal modes at deeper and shallower depths (Fig. 8).

Bottom water temperature of sites occupied by blueline were similar between NEFSC (mean = 12.4° C; range = 8-18° C) and SERFS collections (mean = 15.5° C; range = 7.9-22.7° C), with nearly identical minima. The NEFSC BTS typically samples colder waters, and the SERFS tends to sample more warmer water sites, but both surveys appear to survey many sites within the range of temperatures that blueline occupy (Fig. 9).

Observations from the SERFS survey provide some tendency for blueline to occupy sites with somewhat lower salinity than the modal value for the survey, though blueline occupy much of the range of salinity values observed by the survey (Fig. 10).

Benthic sediment data was reported as percent composition of clay, silt, sand, and gravel at 18810 specific lat-lon locations. To generate full spatial coverage of NEFSC and SERFS sampling locations, these values were interpolated by simply averaging values within $0.25° \times 0.25°$ lat-lon bins. These interpolated values are plotted separately for each sediment type (Figs. 11, 12, 13, and 14). Interpolated raster values were joined to NEFSC and SERFS point data to estimate the sediment composition of all sampling sites and those occupied by blueline. Density plots of sites by percentage of each sediment type were generated to characterize the sediment composition of blueline tilefish (Figs. 15, 16, 17, and 18). Considering these sediment maps and the distribution map of all blueline tilefish samples (Fig. 6), it is seems apparent that north of Cape Hatteras, the depth contours occupied by blueline roughly trace the intersection of inshore sediments dominated by sand and offshore sediments dominated by clay and silt. This does not appear to be the case south of Cape Hatteras, however it appears that sediments approximately 100 km southeast of the area of high blueline density off of northern South Carolina are uniquely high in clay and silt, perhaps indicating something unique about the benthos that blueline prefer. Density plots show that sediments at sites occupied by blueline from both surveys are dominated by sand (NEFSC median = 91; SERFS median = 98), but NEFSC sediments contain somewhat more silt (NEFSC median = 6.8; SERFS median = 2), and clay (NEFSC median = 1.9; SERFS median = 0). Gravel was a minimal component of sediments at most sites. Despite apparent differences in sediment composition at sites occupied by blueline between the surveys, density plots of all sites are similar to plots for blueline-occupied sites. This seems to suggest that blueline presence is relatively independent of sediment composition and may largely be due to other factors such as depth and temperature. These observations of sediment composition are consistent with Able et al. (1987) in that they show blueline occupying predominantly sandy sites, but appear to be much sandier than what those authors found in blueline burrows. A simple comparison of the geographic location of Able et al.'s (1987) study area (centered at 28.73°N, 80.00°W; indicated by an × in Figs. 11, 12, 13, and 14)) against the coarse resolution sediment maps provided here suggest that the burrows that they studied were in an area that was higher in silt and clay and lower in sand than most of the sites that blueline occupy in the Southeast. So perhaps the spatial resolution of sediment data obtained in the present analysis is too coarse to accurately characterize the sediments used by blueline to construct their burrows. But it also seems that at a coarser scale, the sediment composition of Able et al.'s (1987) study area was less sandy than most of the region, and may not be representative of the sediment characteristics of blueline habitat in other locations.

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Table 1 Summary of fishing events for SERFS gear types known to catch blueline tilefish catches. n trial = number of fishing events, n success = number of fishing events that caught blueline tilefish, P success = proportion of fishing events that caught blueline tilefish

Gear description	n trial	n success	P success
Chevron trap (marmap)	16375	74	0.0045
Experimental trap	224	26	0.1161
Florida ”antillean” trap	1710	7	0.0041
Hook and line	1223	5	0.0041
Kali pole standard (marmap)	199	97	0.4874
Long-bottom longline, 1 mile, 100 hooks (bottom longline)	536	41	0.0765
Short-bottom longline - 20 hook, 25.6 m (vertical longline)	1208	103	0.0853
Snapper reel, electric or manual, 2 hooks; bandit reel	1627	13	0.0080

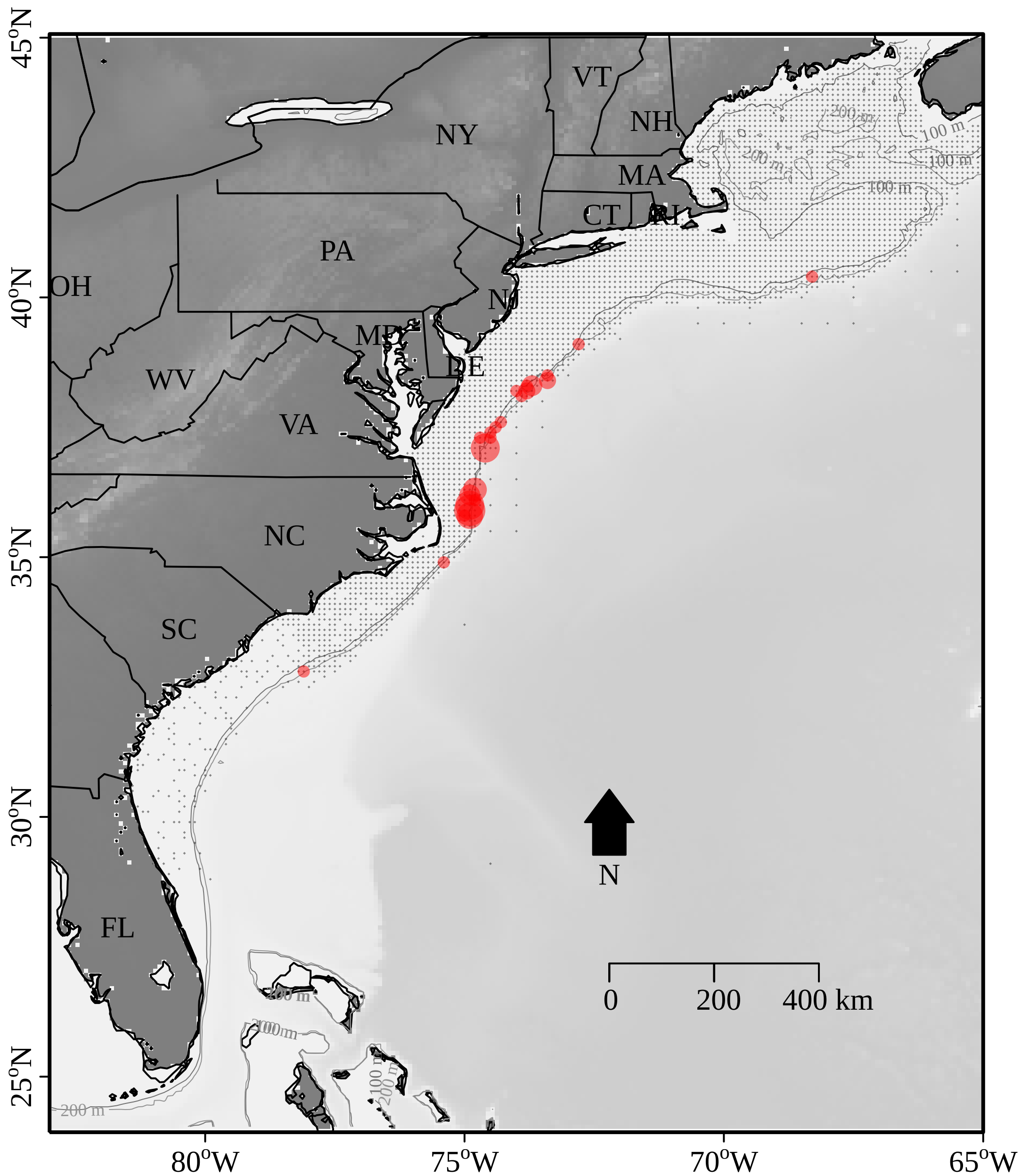

FIG. 1 Map of all sampling locations for Northeast Fisheries Science Center Winter, Spring, and Fall Bottom Trawl Surveys from 1963-2015, aggregated by $0.1^\circ \times 0.1^\circ$ lat-lon bins. Colored points represent positive blueline tilefish collections. For positive collections, point size (area) is scaled to the maximum number of fish caught in any lat-lon bin.

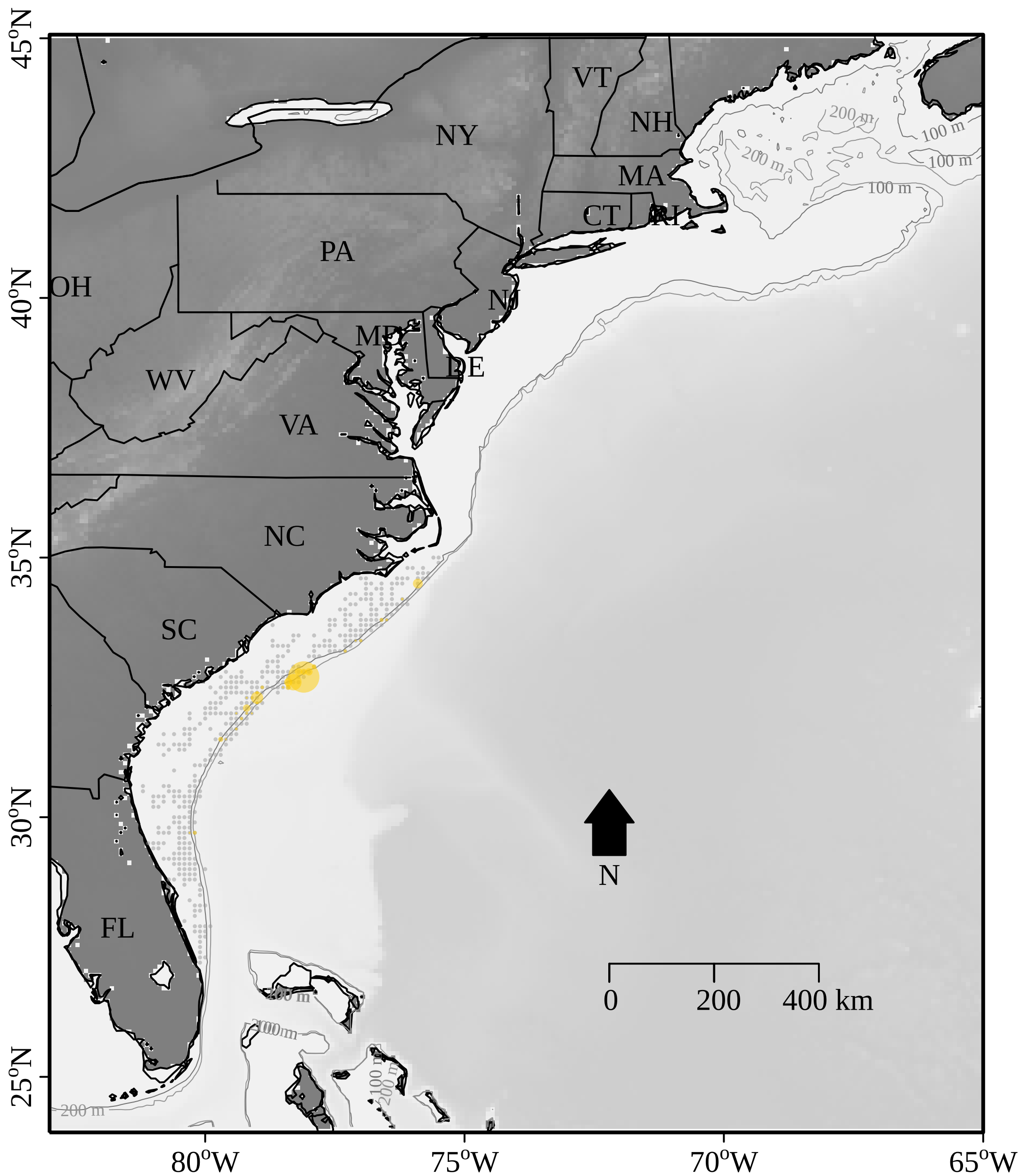

Fig. 2 Map of all sampling locations for Southeast Reef Fish Survey (SERFS) from 1977-2015, aggregated by $0.1° \times 0.1°$ lat-lon bins. Colored points represent positive blueline tilefish collections. For positive collections, point size (area) is scaled to the maximum number of fish caught in any lat-lon bin.

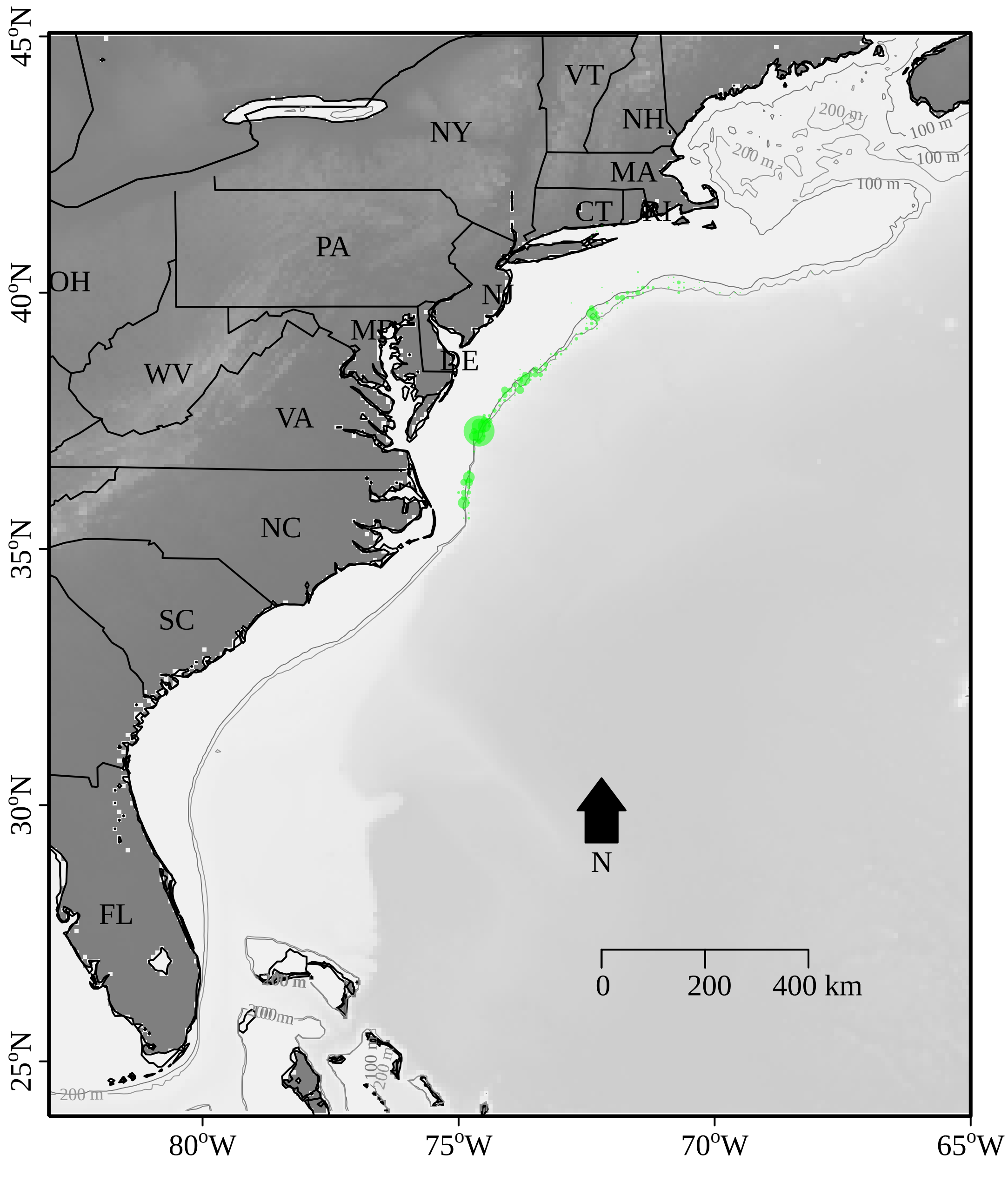

Fig. 3 Map of all positive blueline tilefish collections for the Northeast Fisheries Observer Program from 1997-2016, aggregated by $0.1° \times 0.1°$ lat-lon bins. Point size (area) is scaled to the maximum number of pounds of fish caught in any lat-lon bin.

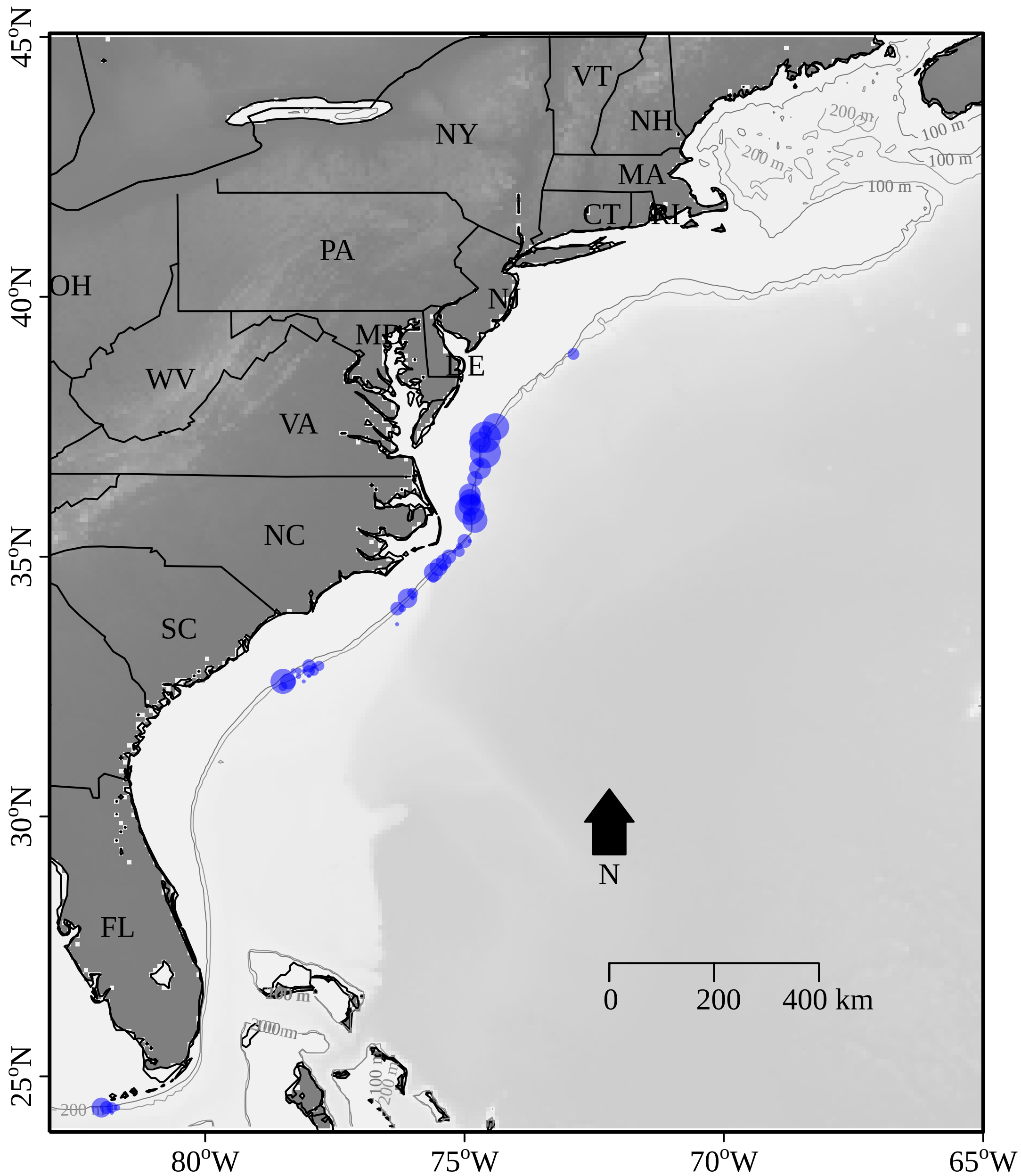

FIG. 4 Map of all positive blueline tilefish collections for the Cooperative-With-Industry Data Collection Project, aggregated by $0.1^\circ \times 0.1^\circ$ lat-lon bins. Point size (area) is scaled to the maximum number of fish caught in any lat-lon bin.

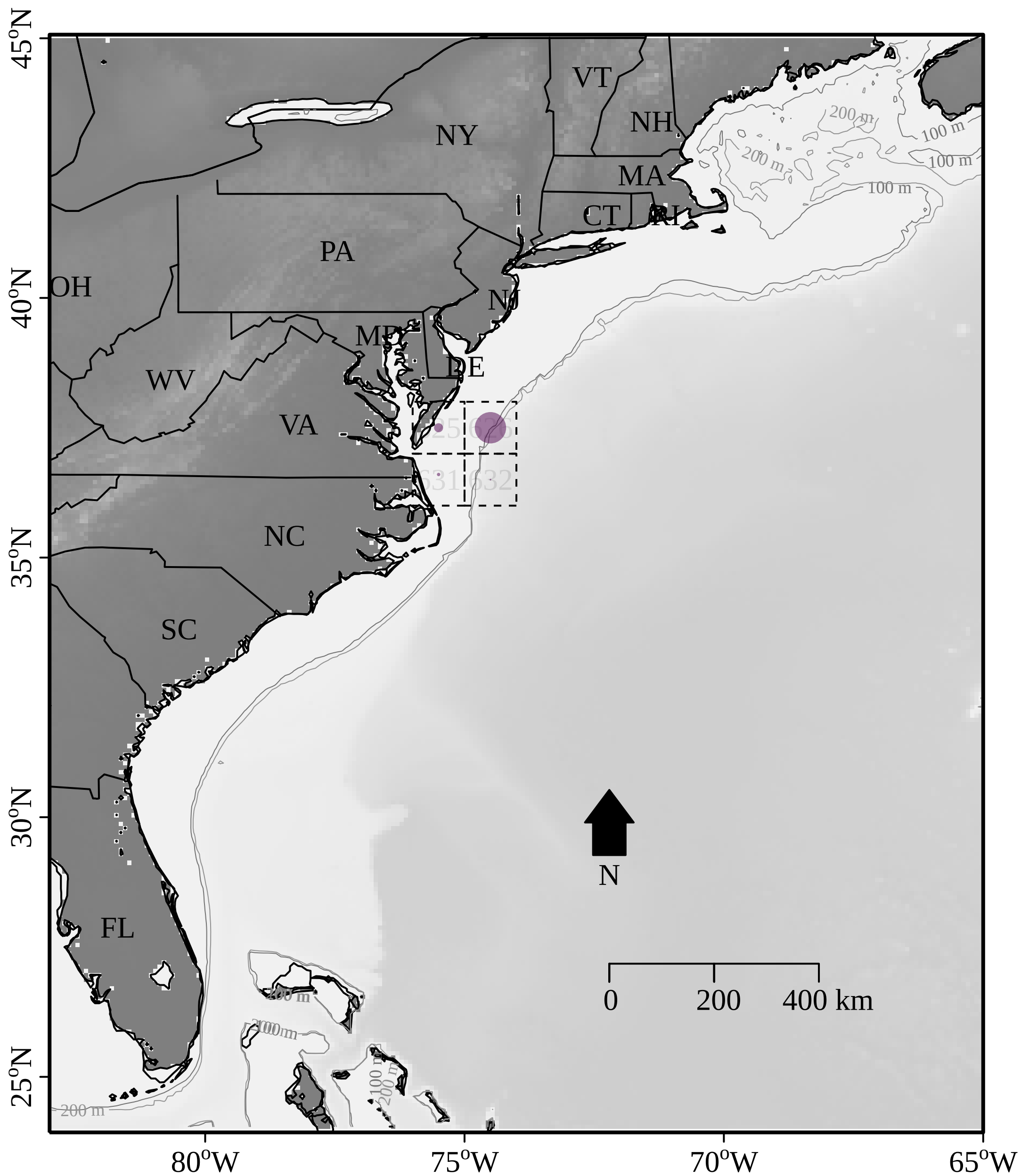

Fig. 5 Map of all positive blueline tilefish collections for the ODU sampling from 2009-2011, aggregated by 1.0° × 1.0° lat-lon bins representing NOAA statistical areas. Point size (area) is scaled to the maximum number of fish caught in any bin. Light grey text centered on each bin displays the statistical bin number

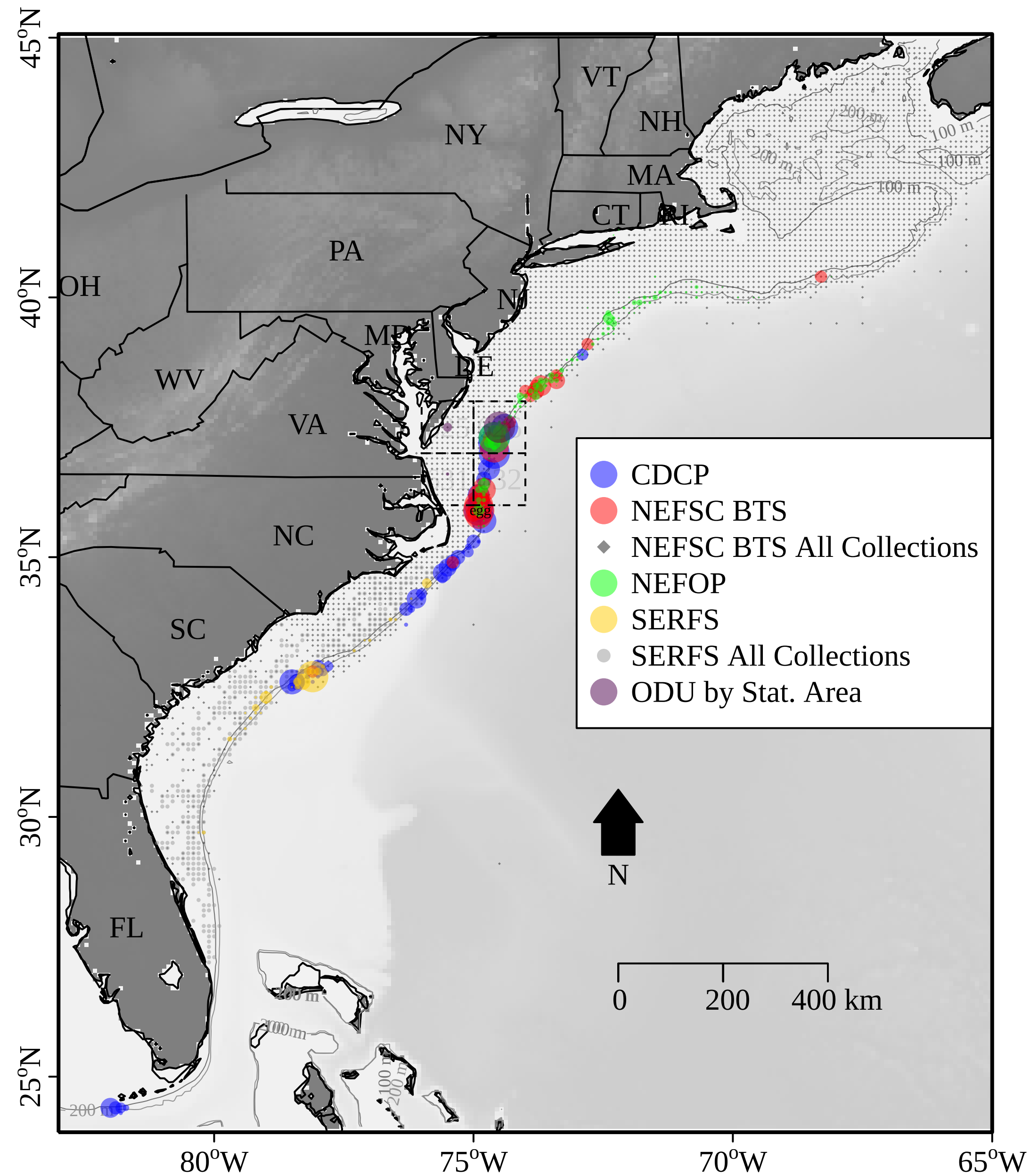

Fig. 6 Map of all positive blueline tilefish collection locations and all sampling locations for NEFSC Winter, Spring, and Fall bottom trawl surveys from 1963-2015, and all SERFS sampling locations for gear types known to catch blueline tilefish, from 1977-2015. For NEFSC, SERFS, NEFOP, and CDCP samples, observations were aggregated by $0.1° \times 0.1°$ lat-lon bins. Samples from the ODU study were presented at the highest spatial resolution available, $1.0° \times 1.0°$ lat-lon statistical grid cells. Point colors and shapes are presented in the legend. For points representing positive blueline tilefish collections, point size (area) is scaled to the maximum number of fish caught (or pounds caught for NEFOP data) in any lat-lon bin for each data set (i.e. points are scaled separately for each data set). The word "egg" is also plotted at the location of the single blueline tilefish egg collected by Lewis et al. (2016).

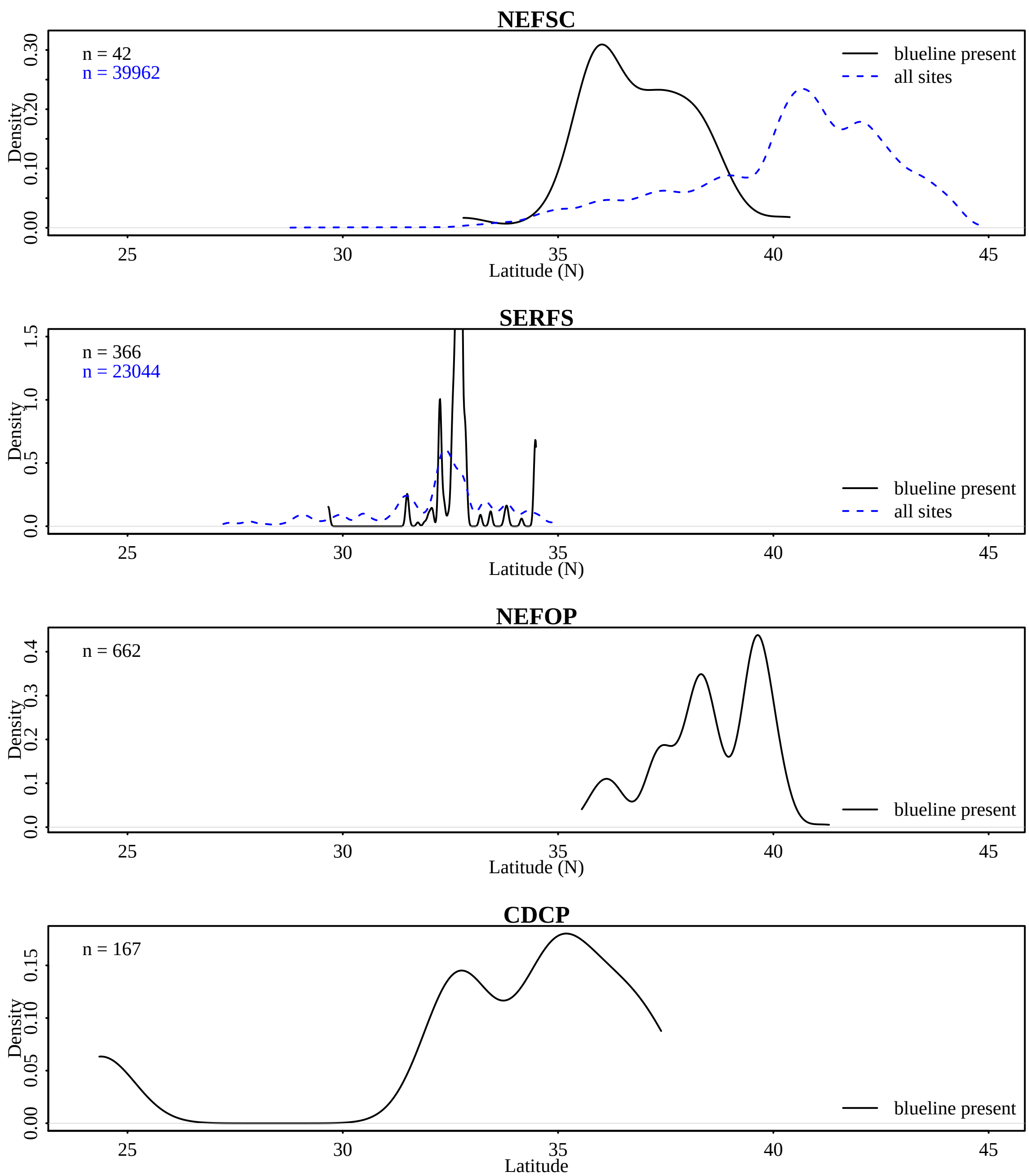

Fig. 7 Density plots of blueline tilefish presence at a sampling site, by latitude (degrees north), plotted separately for each collection that recorded latitude. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites.

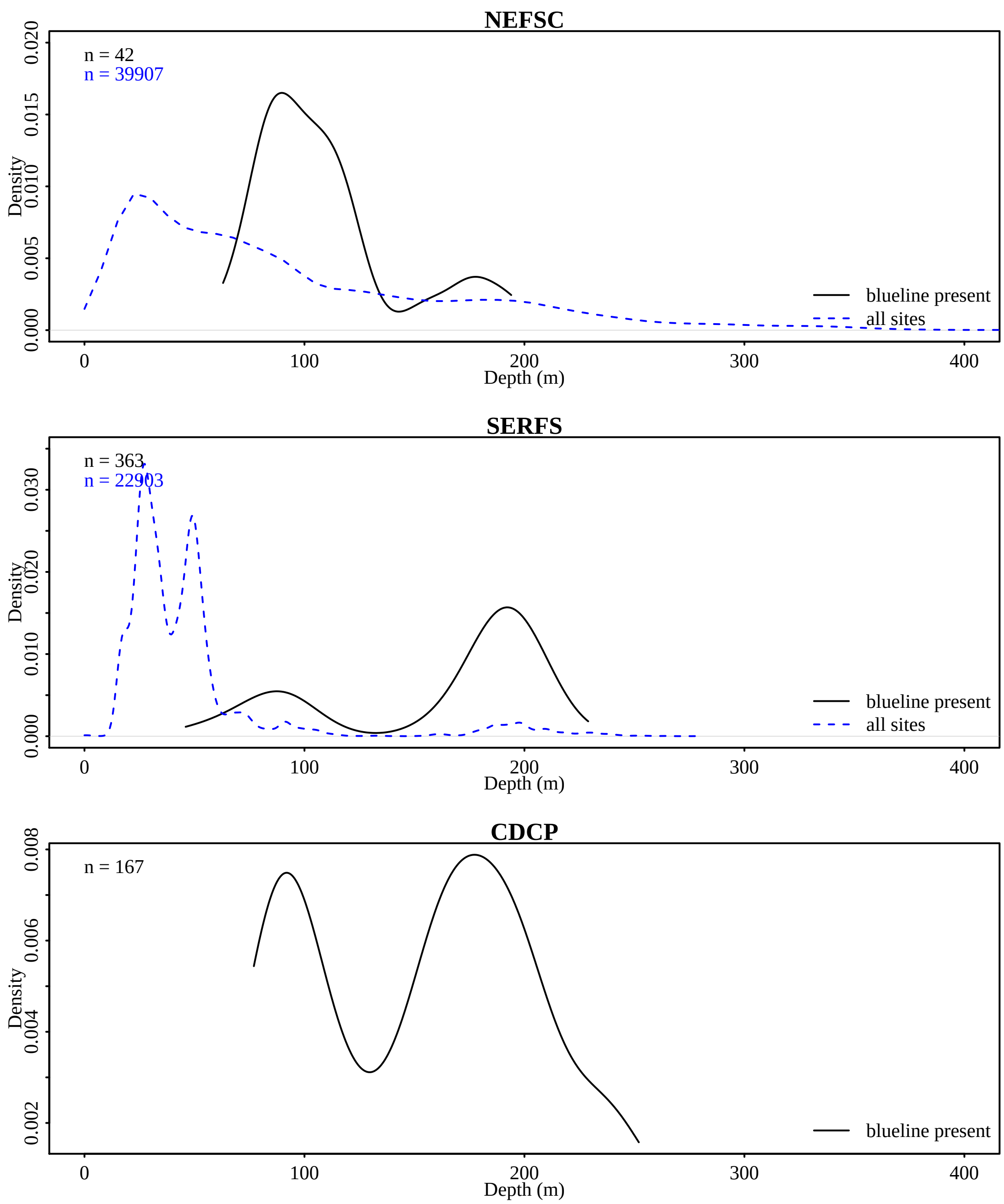

Fig. 8 Density plots of blueline tilefish presence at a sampling site, by depth in meters, plotted separately for each collection that recorded depth. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites.

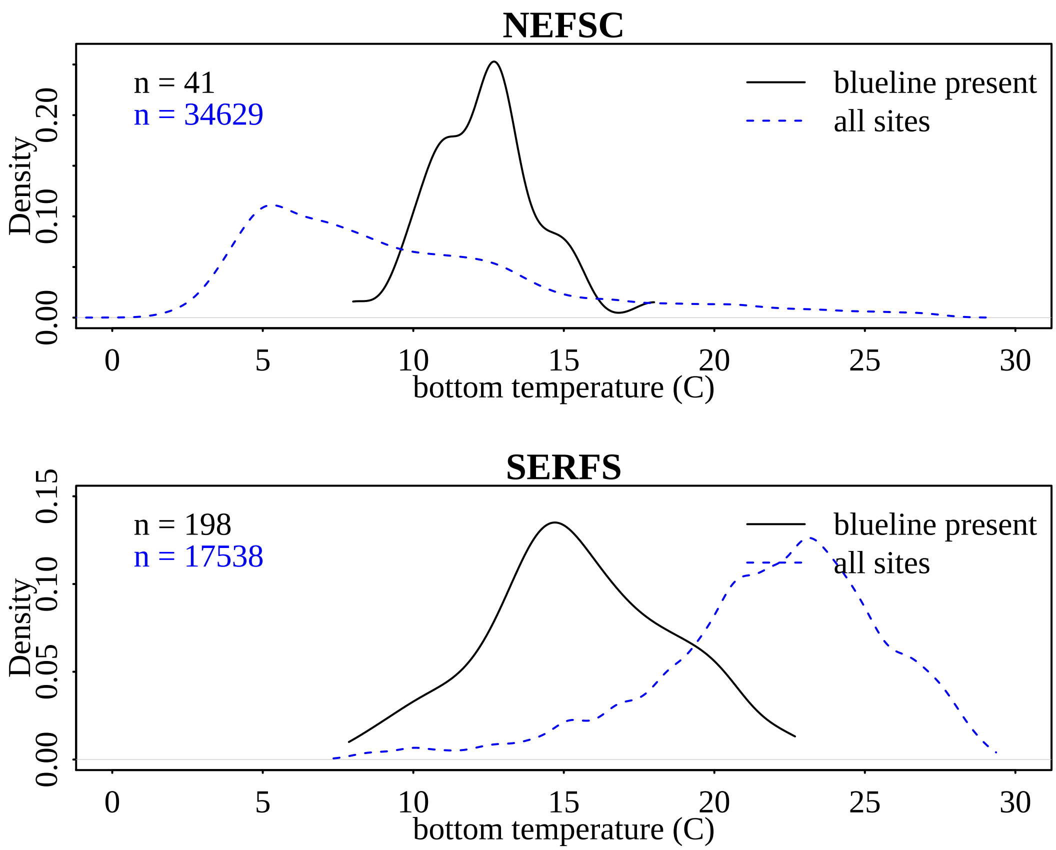

FIG. 9 Density plots of blueline tilefish presence at a sampling site, by bottom temperature in degrees Celcius, plotted separately for each collection that recorded bottom temperature. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites.

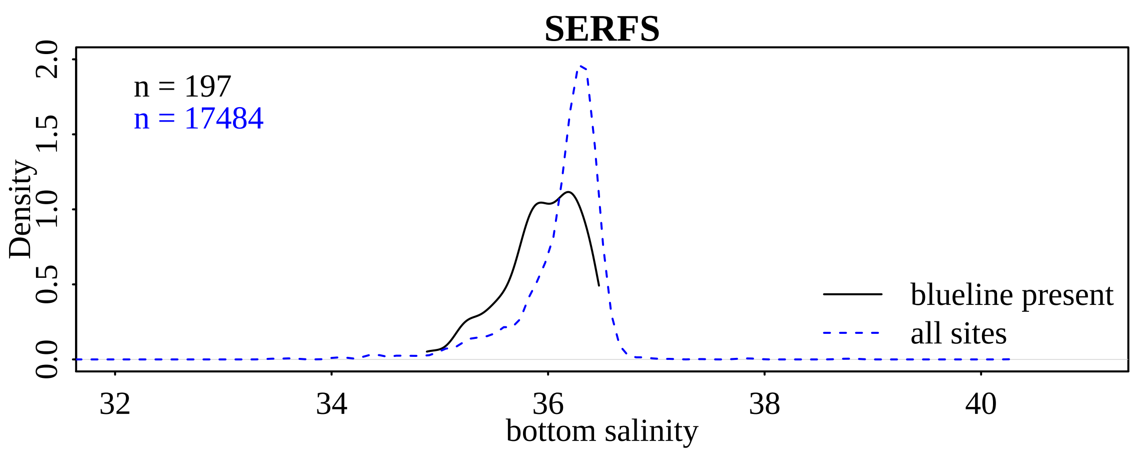

Fig. 10 Density plots of blueline tilefish presence at a sampling site, by bottom salinity for SERFS. A density plot of all sampling sites was also drawn. Sample sizes (n) indicate number of sampling sites.

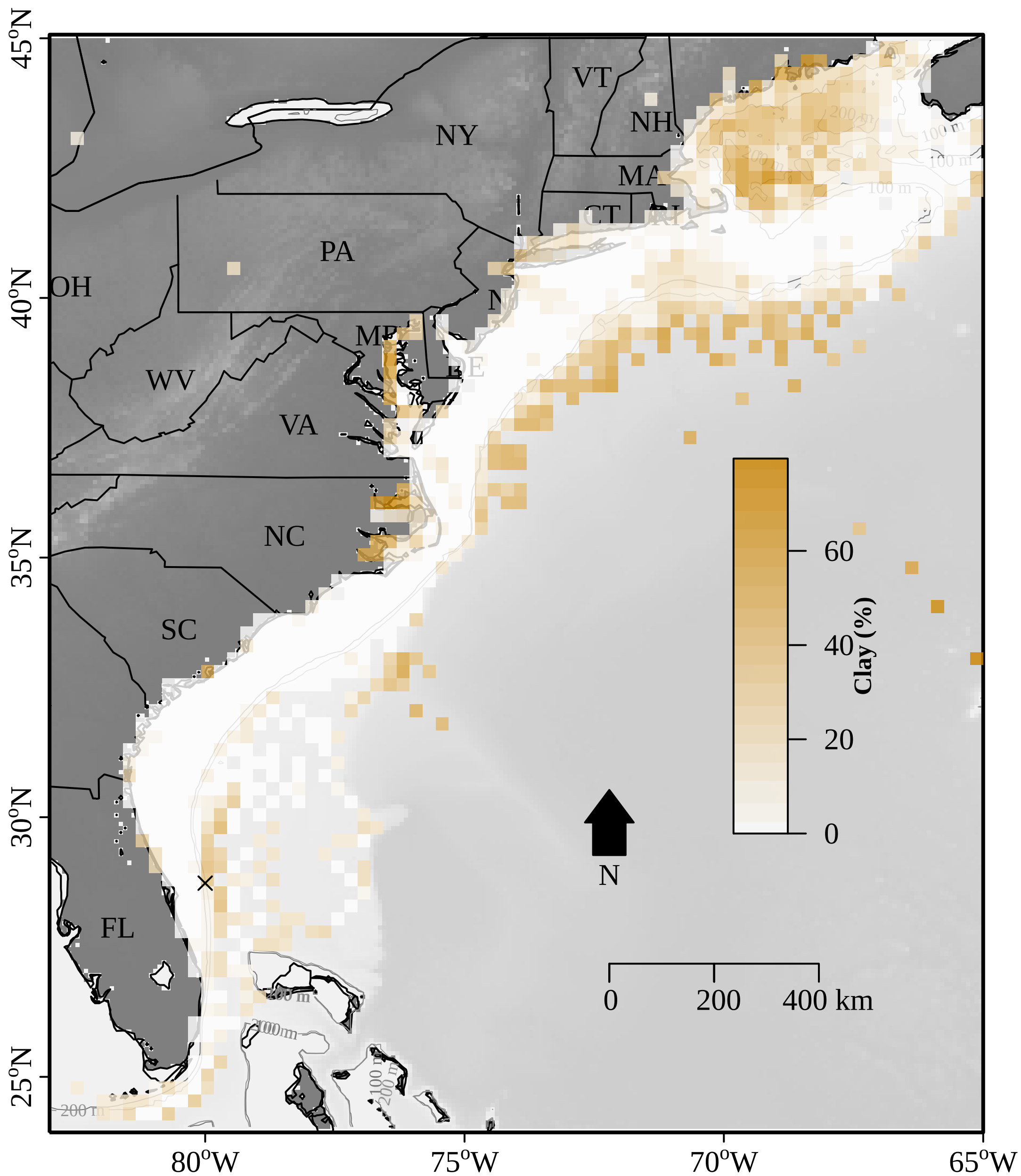

Fig. 11 Map of percent clay in benthic sediments based on values obtained from the USGS East Coast Sediment Texture Database, averaged within each grid cell. A black × centered at 28.73°N, 80.00°W indicates the center of Able et al.'s (1987) study area where sediment composition of blueline tilefish burrows was measured.

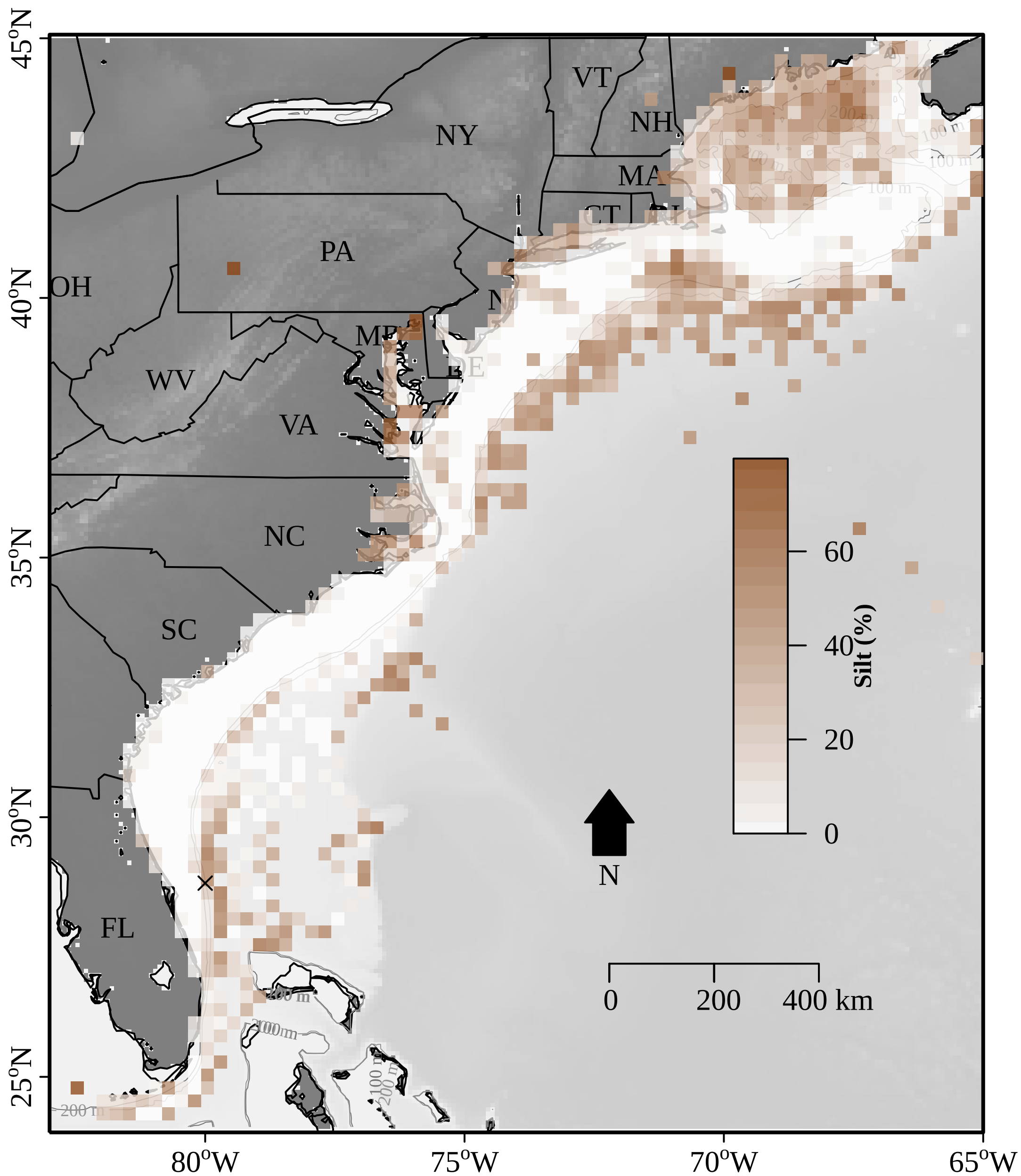

FIG. 12 Map of percent silt in benthic sediments based on values obtained from the USGS East Coast Sediment Texture Database, averaged within each grid cell. A black × centered at 28.73°N, 80.00°W indicates the center of Able et al.'s (1987) study area where sediment composition of blueline tilefish burrows was measured.

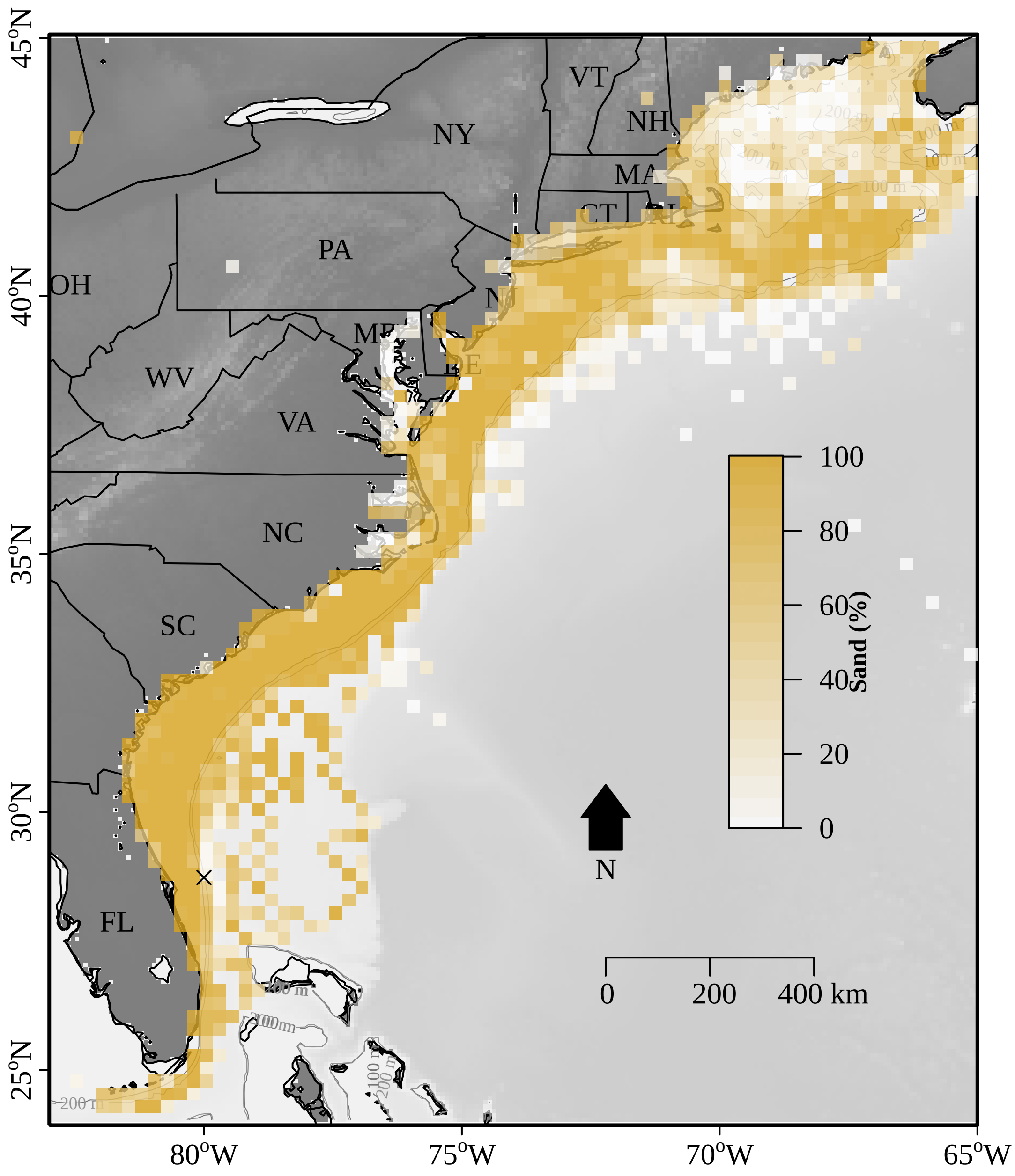

FIG. 13 Map of percent sand in benthic sediments based on values obtained from the USGS East Coast Sediment Texture Database, averaged within each grid cell. A black × centered at 28.73°N, 80.00°W indicates the center of Able et al.'s (1987) study area where sediment composition of blueline tilefish burrows was measured.

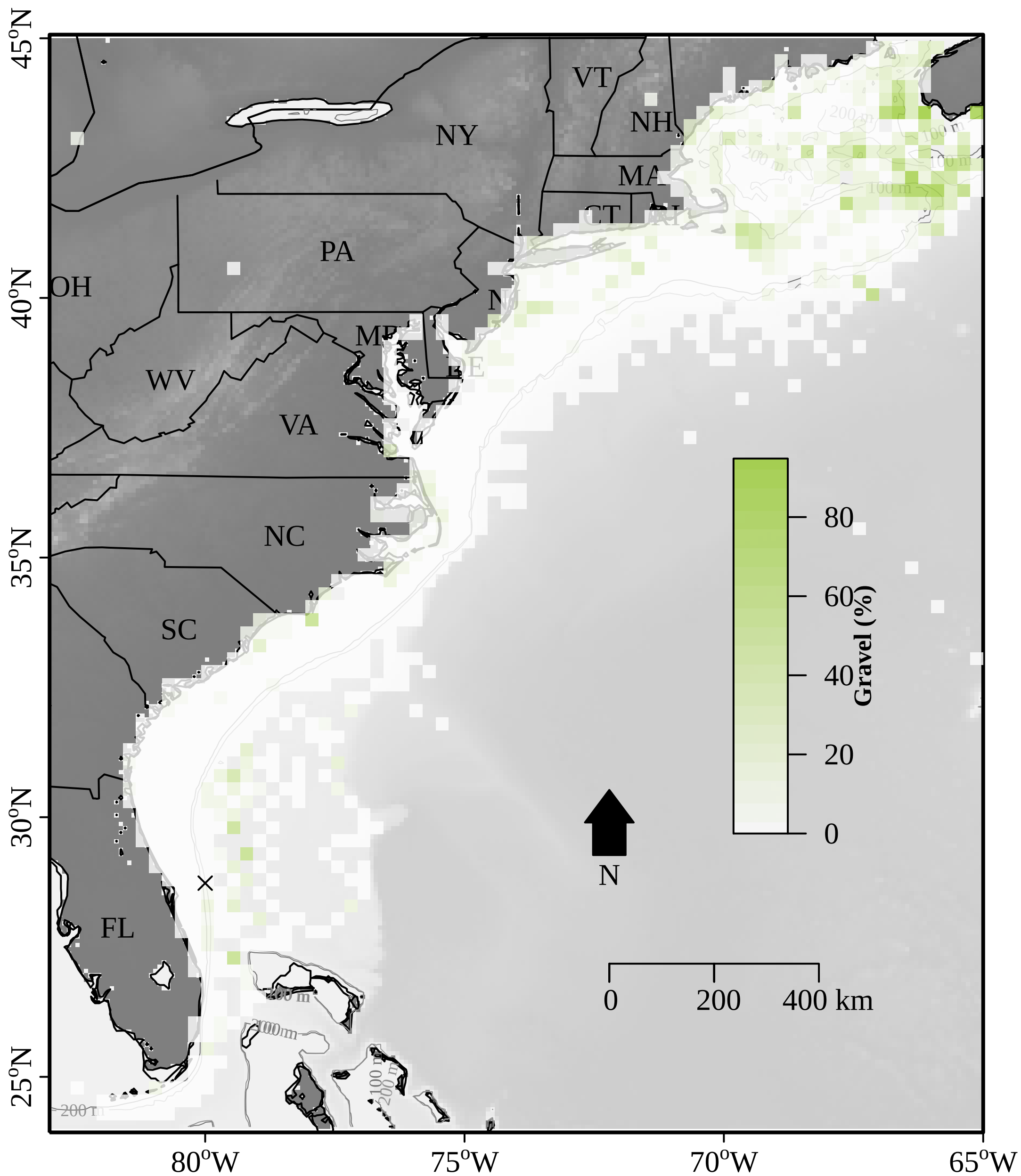

Fig. 14 Map of percent gravel in benthic sediments based on values obtained from the USGS East Coast Sediment Texture Database, averaged within each grid cell. A black × centered at 28.73°N, 80.00°W indicates the center of Able et al.'s (1987) study area where sediment composition of blueline tilefish burrows was measured.

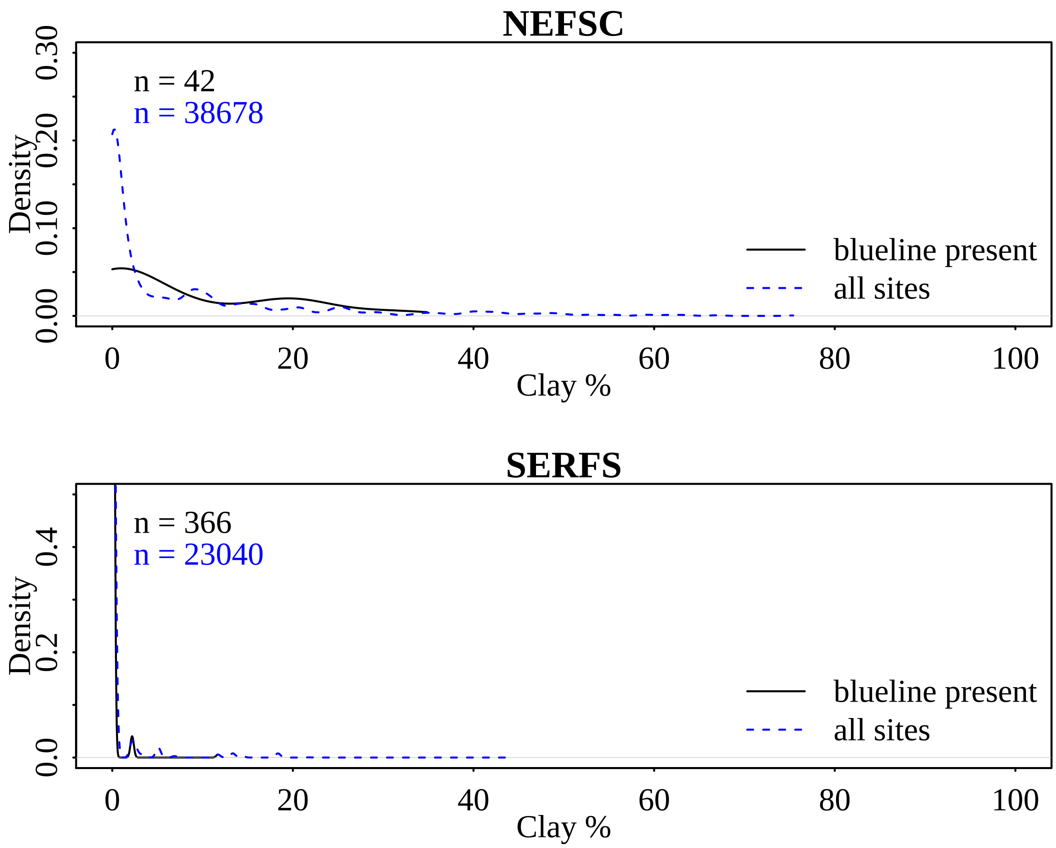

Fig. 15 Density plots of blueline tilefish presence at a sampling site, by percent of sediment comprised of clay. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites. Sediment data was obtained from the USGS East Coast Sediment Texture Database and spatially, converted to a raster layer, and spatially joined to lat-lon positions.

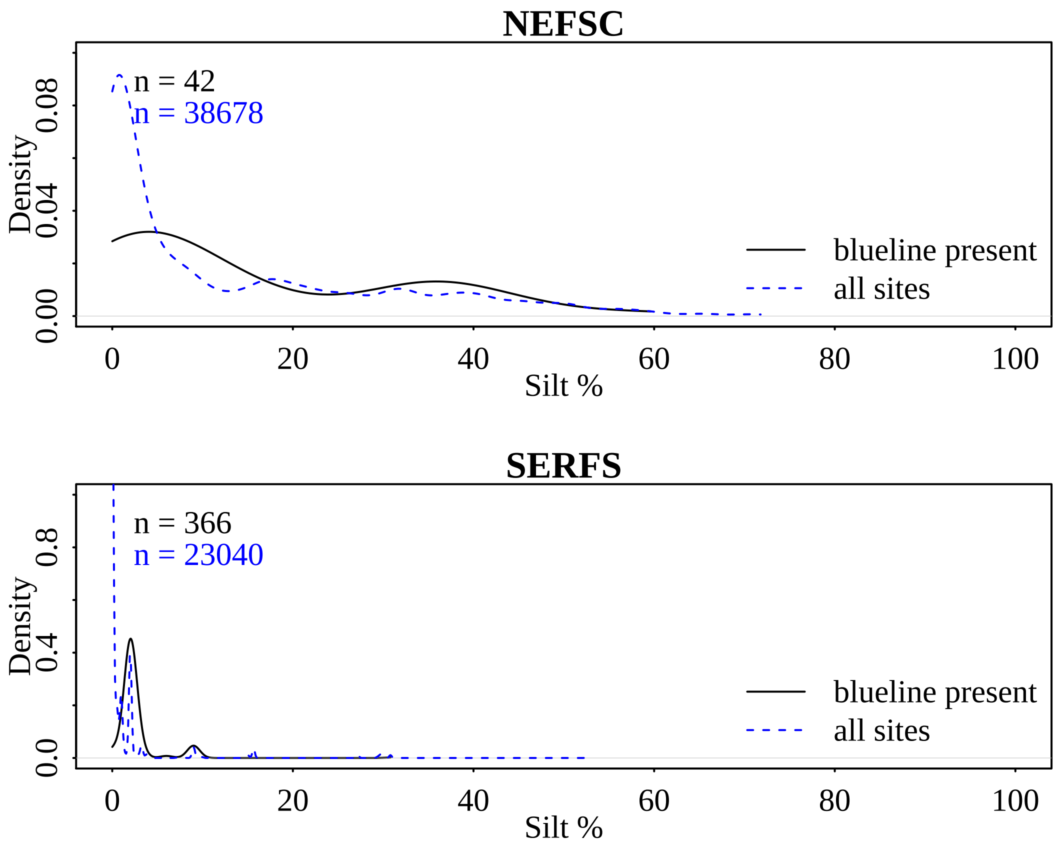

Fig. 16 Density plots of blueline tilefish presence at a sampling site, by percent of sediment comprised of silt. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites. Sediment data was obtained from the USGS East Coast Sediment Texture Database and spatially, converted to a raster layer, and spatially joined to lat-lon positions.

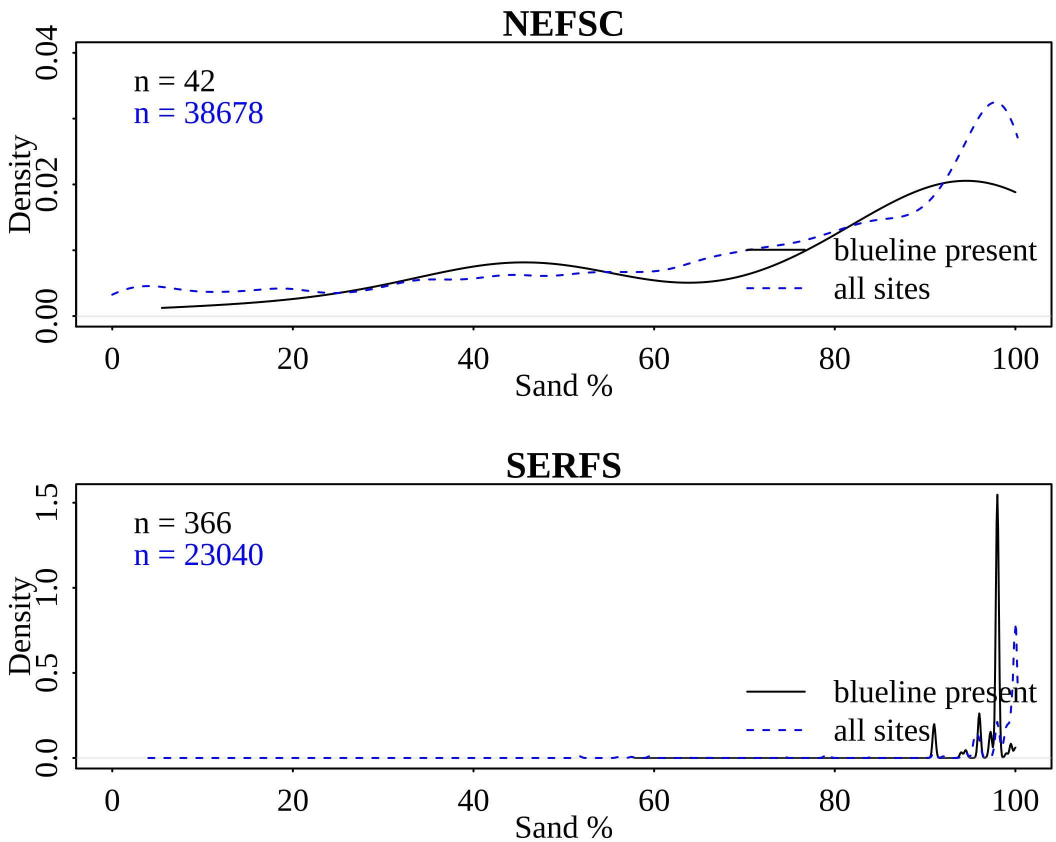

Fig. 17 Density plots of blueline tilefish presence at a sampling site, by percent of sediment comprised of sand. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites. Sediment data was obtained from the USGS East Coast Sediment Texture Database and spatially, converted to a raster layer, and spatially joined to lat-lon positions.

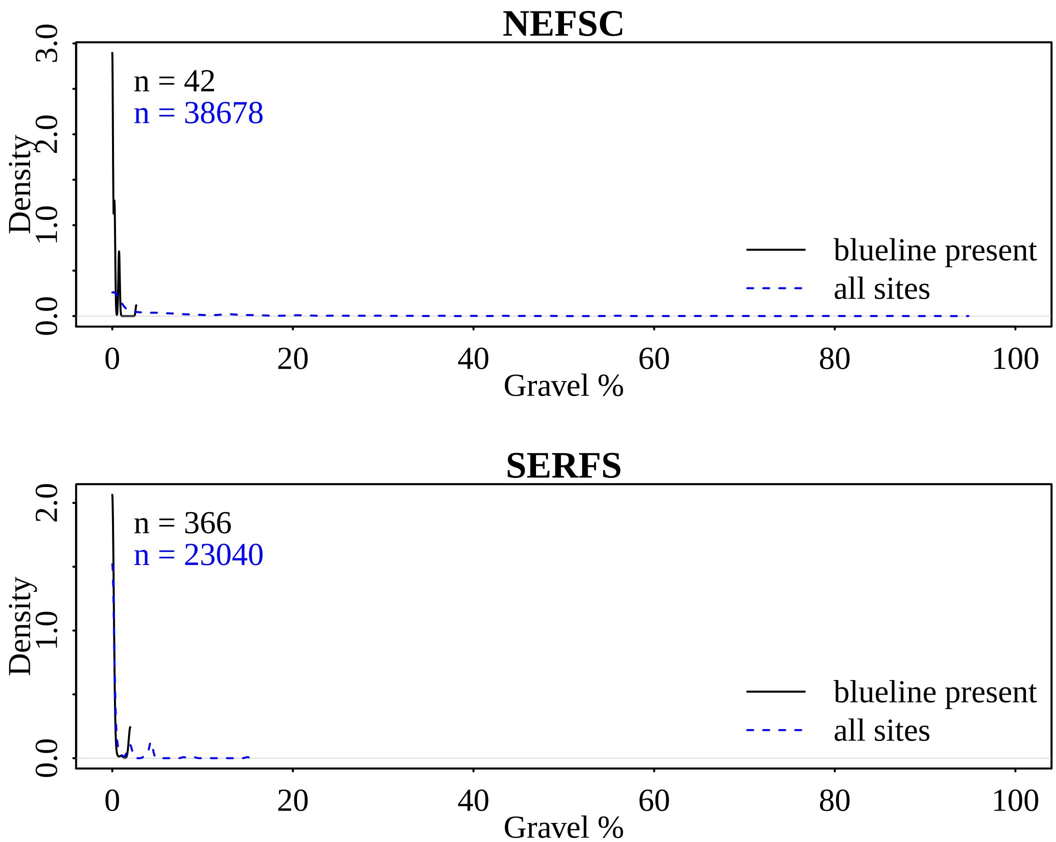

Fig. 18 Density plots of blueline tilefish presence at a sampling site, by percent of sediment comprised of gravel. For NEFSC BTS and SERFS, density plots of all sampling sites were also drawn. Sample sizes (n) indicate number of sampling sites. Sediment data was obtained from the USGS East Coast Sediment Texture Database and spatially, converted to a raster layer, and spatially joined to lat-lon positions.