4.0 SENSITIVITY INDEX

4.1 OVERVIEW

GMI developed an ESI that synthesizes the physical, biological, and socioeconomic resources data of the Study Area. This ESI was designed to be a planning guide to assist regulatory agencies, developers, and the public with the rapid evaluation of environmental sensitivity and ecological importance of discrete areas within the Study Area (**Figure 4-1**). The collection of additional physical, biological, and socioeconomic data may be required by state and/or federal agencies for offshore development at specific sites for in-depth site-specific assessments.

4.2 INDEX DEVELOPMENT

The environmental sensitivity index was developed using data on physical, biological and socioeconomic resources (features) collected during field studies from January 2008 through December 2009, data published in the literature, and data gathered by governmental agencies such as NJDEP, NOAA, NMFS, and MMS. The resources (features) considered for the index included:

- Artificial reefs
- Marine protected areas (MPAs)
- Shoals
- Habitat areas of particular concern (HAPCs)
- EFH
- Known obstructions
- Known shipwrecks
- Unexploded ordnance (UXO)
- Shipping lanes
- Utility cables
- Modeled avian and marine mammal density data
- Sea turtle sightings per unit effort (SPUE) data
- Commercial fishing grounds
- Recreational fishing grounds

During development of the index, it was determined that shipping lanes, utility cables, obstructions, shipwrecks, and UXO were “prohibited development areas”; therefore, those features were shaded black on the index map (**Figure 4-1**). Two of the above listed resources were not included in the index, HAPCs and UXO. Only one designated HAPC was found within the Study Area. This HAPC is immediately adjacent to the Atlantic City/Brigantine areas (**see Volume IV: Appendix C**, **Figure C-32**). Since the HAPC was for a single, non-listed species, it was not included in the index but but should be noted for potential future development. As for the documented presence of UXO, no data could be obtained that corroborate local knowledge on locations of UXO within the Studty Area.

4.2.1 Spatial Index Creation with Geographic Information Systems

To create the map depicting the spatial relevance of independent physical, biological, and socioeconomic features within the Study Area, selected features were represented as mapping layers which were additively combined and displayed within a continuous surface. The manipulation and conversion of these selected input features allowed for different feature types to be combined for analysis. The majority of the features used to develop the index were in a vector format, either derived from hard copy georeferenced sources or existing databases. The vector data were converted into Boolean grids, a raster format which was classified as having either a presence (1) or absence (0). The production of these raster grids facilitated the use of features created by statistical and geographic analyses. The Inverse Distance Weighted Interpolation (IDWI) technique (GeoStatistical Analyst Tool for ArcGIS 9.3.1) was used to create mapping layers. The IDWI technique is driven by local variation, and the variation of values among the evenly distributed sample points throughout the Study Area. IDWI is an exact deterministic interpolator

and was preferred over other methods such as Kriging. Kriging is most commonly used when a spatially correlated distance or directional bias in the data is known, when data come from a stationary process are normally distributed. For this study, the data were variable and dynamic.

The IDWI technique assumes that features that are closest to each other are more alike than those that are further apart. Values from features closest to the prediction location have a greater influence on the interpolated value for the prediction location than do values from features that are further away. Once the surface interpolation was complete, the features were ranked by classifying the data by the most appropriate means, such as Geometric Interval, Equal Interval, or Natural breaks and converted to raster grids using assigned rank values. The classification method used for the Marine Mammals Density and Sea Turtle SPUE data was Geometric Interval. Geometric intervals work well with data that are not normally distributed and heavily skewed with duplicate values, which was the case with the marine mammal and sea turtle data. The geometric interval classification scheme uses class breaks that are based on class intervals within a geometrical series, ensuring that each class range has approximately the same number of values and a consistent change between intervals. The Avian Density and EFH data were classified using Equal Interval breaks. This method was chosen for the avian data to simplify the interpretation of density contours and to highlight bird concentrations. In doing so, examples were followed of well known seabird density databases (e.g., Certain et al. 2007; McKinnon et al. 2009). Equal Interval for EFH was chosen as a simplistic means of assigning higher ranking to areas with the greatest EFH overlap.

Instead of a multi-classed representation, we used the largest number of classes possible for the ESI while still preserving the spatial distribution of the data. The processed, ranked, and classified data were then incorporated into a Boolean addition overlay. By adding rasters, the physical, biological, and socioeconomic features were synthesized to produce a comprehensive visual output.

The data collected for this study, whether physical or biological, were not combined and holistically modeled to develop the ESI. The differences in data collection techniques, acceptable models for different types of species, and the high variability among the numbers of sightings and individuals, would have generated outputs significantly skewed towards the species and/or groups with the highest number of individuals. Instead, the ESI is a compilation of the data that were modeled for the avian and marine mammal groups, layered with the feature data, and interpolated using IDWI, as described above.

4.2.2 Ranking Data

Physical, biological, and socioeconomic resources data were layered and mapped using the GIS techniques mentioned above to develop and display the ESI; however, each feature had to be assigned a weight or rank to show its environmental or ecological importance. Given the difficulty of ranking one physical resource over another; especially considering that shoals, artificial reefs, and shipwrecks each potentially support high species diversity and abundance, each physical resource was weighted equally with a ranking of 1. Yet, since almost 40 species of fish have designated EFH within the Study Area, all EFH layers were compiled and ranked from 1 to 3. For biological data, the modeled density data were ranked with a minimum value of 1 to a maximum value of 6, with higher densities receiving the highest rankings. By layering all of these features together, the ESI shows an effective index rating (sum of the rankings for all resources within a given location) for the entire Study Area.

4.2.3 Physical Features

The physical features within the Study Area were mapped by gathering available data from the NJDEP, NOAA, NMFS, MMS, U.S. Army Corps of Engineers (USACE), and published literature. The data were mapped in the most precise manner possible to limit distortion or exaggeration of the areal coverage of any given feature. Shipping lanes and utility cables, however, were given a 30.5-m (100-ft) buffer so that these features could be clearly identified on the map. Likewise, shipwrecks and obstructions, which are both point data, were represented by the smallest symbol possible (48-m [150-ft] diameter) that would be visible on a map even though it may not represent an actual size. All other physical resources data were polygons developed from the actual boundaries of each feature (**Figures 4-2** and **4-3**).

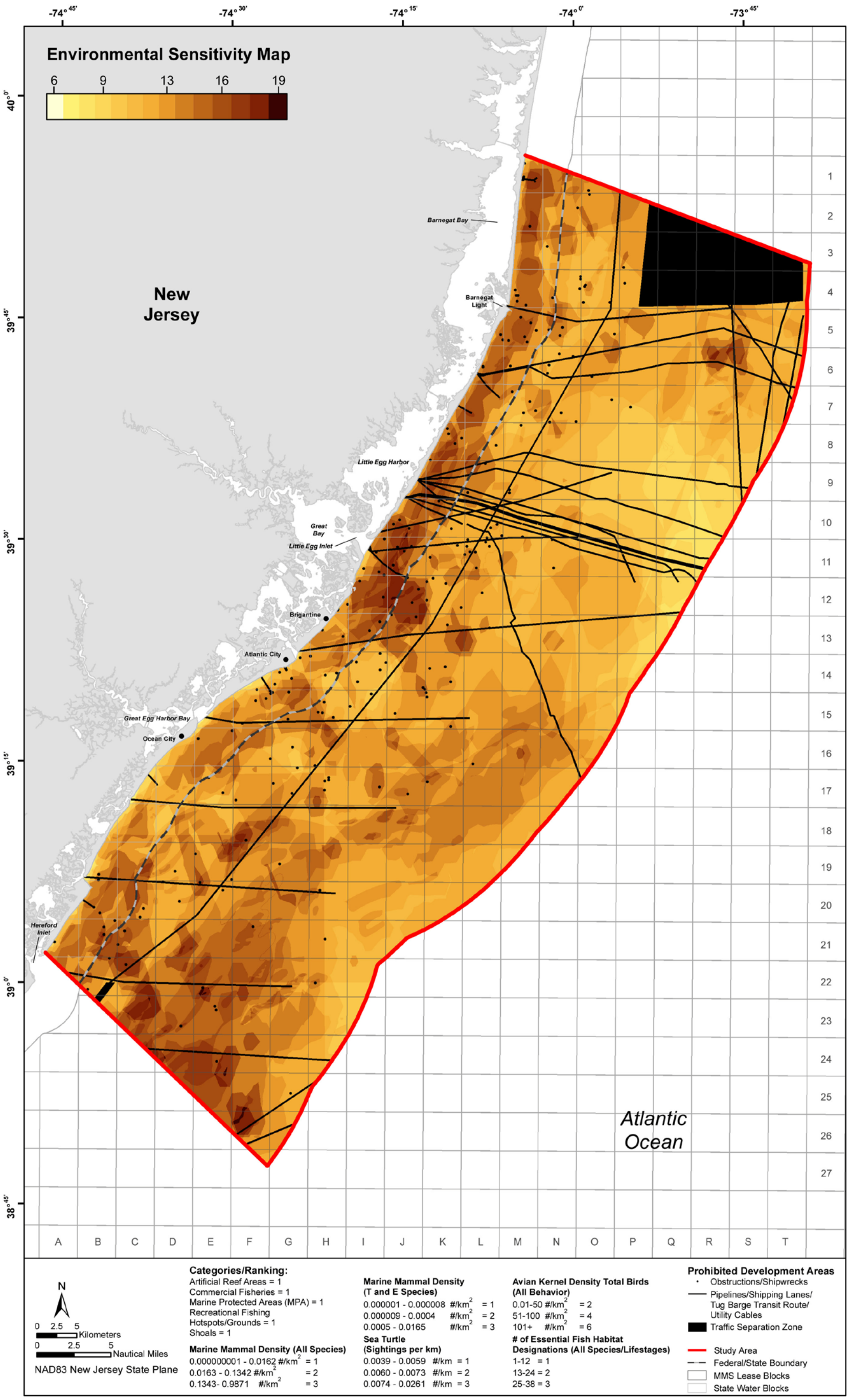

Figure 4-1. Map of the Environmental Sensitivity Index for the New Jersey Study Area.

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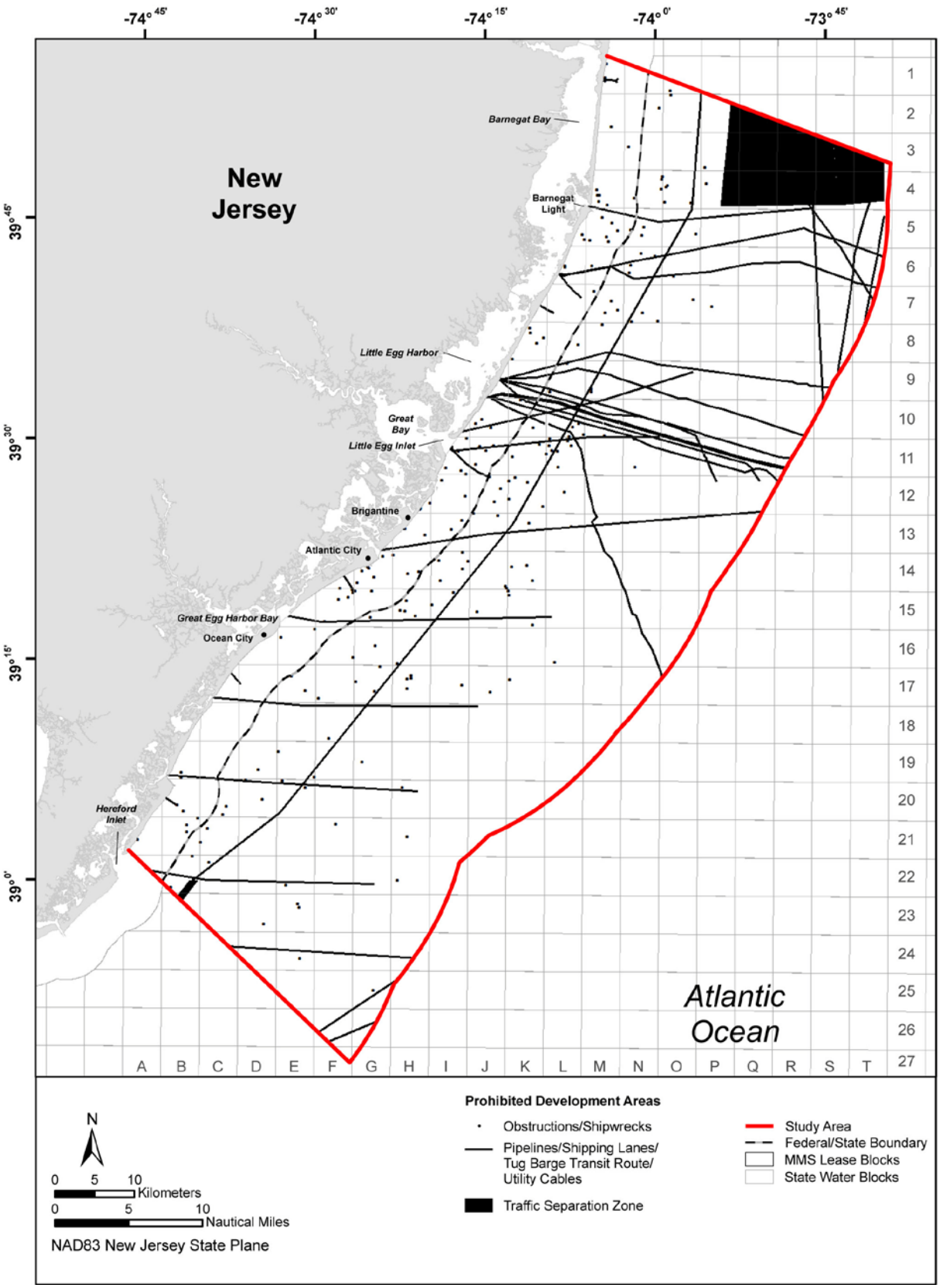

Figure 4-2. Prohibited development areas designated in the Environmental Sensitivity Index.

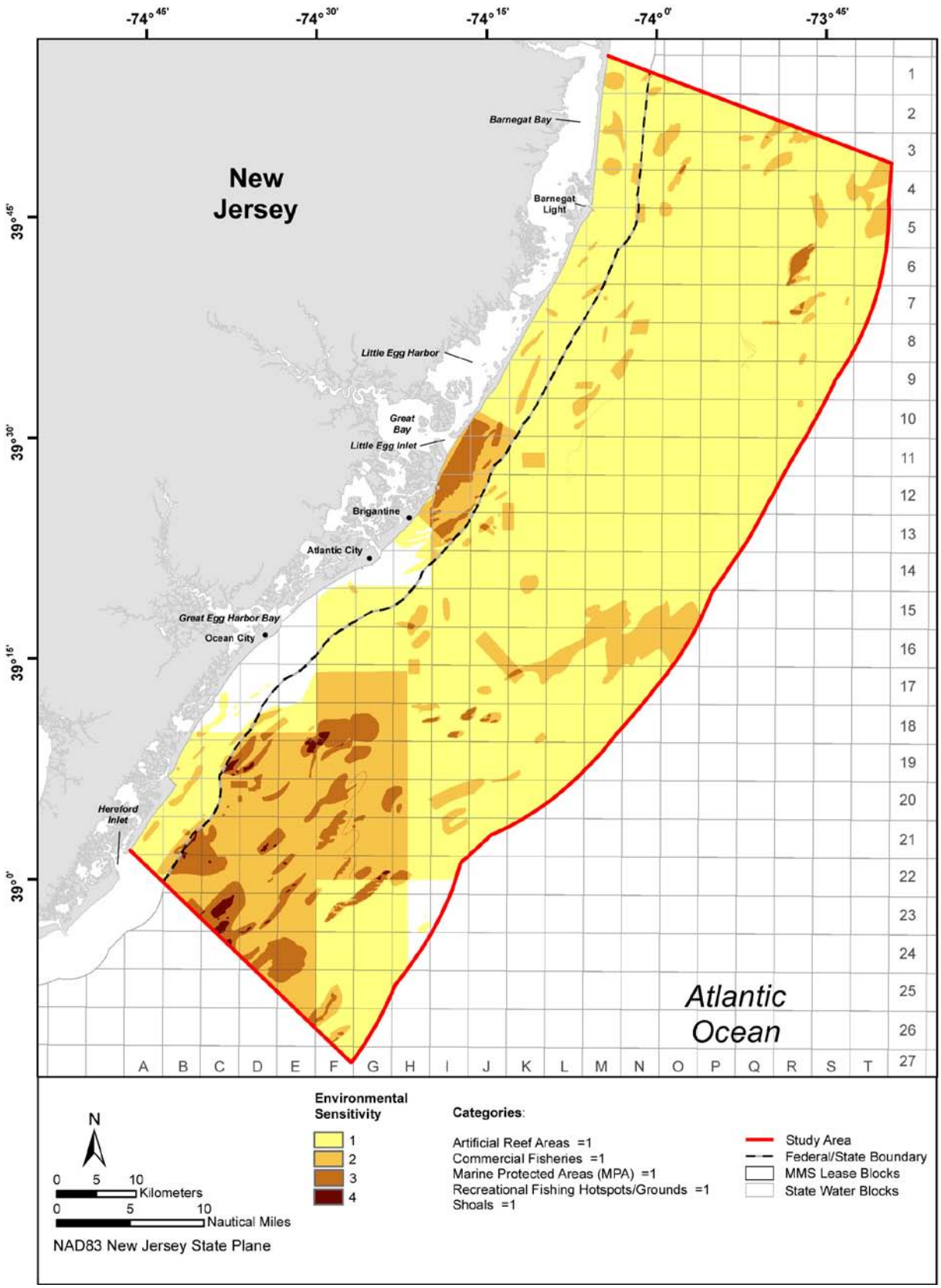

Figure 4-3. Physical features used in the Environmental Sensitivity Index.

4.2.4 Avian Density Data

The avian layer component of the ESI was developed from estimates of total species, all-behavior avian density (number/km^2) calculated through kernel density spatial interpolation (see **Volume II: Chapter 8.0** for more detail). Spatial maps were generated for each time period using the 1-km MMS lease block grid system, with 8,364 total gridpoints (82 longitude values by 102 latitude values). Each gridpoint represented an unsampled site, and avian density was estimated at each gridpoint by calculating a kernel function (modulated by bandwidth h) based on observed counts at neighboring sampled sites (i.e., lon-lat locations along transects passing in proximity to the gridpoint), with the degree of weighting being inversely related to the separation distance between the gridpoint and observation location. The h value governed the degree of dispersion of mass about the central (observed) value, and hence affected the amount of spatial detail in the density estimates. A wide bandwidth (high h value) reflected high dispersion and smoothed out small-scale fluctuations in density, whereas a narrow bandwidth (low h value) captured small-scale variability and structure in the density estimates.

For the sensitivity index, the avian density data were divided into a 3-level ranking system, with the higher the avian density, the higher the index value. The data were divided and ranked as follows:

1. 0.01-50 birds/km^2, which was assigned a weighted or ranking value of 2;
2. 51-100 birds/km^2, which was assigned a ranking value of 4;
3. 101+ birds/km^2, which was assigned a ranking value of 6.

The avian data were ranked higher than other biological data because the probability of impacts from offshore wind energy development over the life of the facility was greater than those expected for other groups. Using this 3-level step function, spatial variations in avian density were reflected in corresponding spatial variations in the ESI, with the strength and degree of correlation depending on the relative influence/contribution of other physical and biological resources affecting the index. **Figure 4-4** shows the avian density layer used in the ESI.

There were insufficient recorded sightings to model the data and calculate densities for threatened and endangered avian species. Because the target species are highly mobile and often use many locations within the Study Area, the index was developed using predicted densities or numbers of biological resources in efforts to minimize skewing data to exact locations where resources were observed. Therefore, raw sighting data were not included in the index. See **Volume I: Section 2.3.3** for details and a map of the listed avian species observed during surveys.

4.2.5 Marine Mammal Density Data

The marine mammal layer incorporated into the ESI was composed of predicted density surfaces estimates generated from habitat modeling. The DSM method was used to generate the surface maps of predicted density in the Study Area at a fine spatial resolution. The data collected from the shipboard and aerial surveys of the baseline study were included in the models (see **Volume III: Chapter 2.0** for more information on survey methodology). Only on-effort sightings and on-effort portions of the tracklines surveyed in a BSS of ≤5 were used in the density surface models for all species/groups except the harbor porpoise. On-effort harbor porpoise sightings used in the model for this particular species were limited to those recorded in a BSS of ≤2 due to the difficulty in detecting this species in a higher BSS. The modeling analyses were limited to species/groups which had 20 or higher on-effort sightings with valid perpendicular sighting distances. There were a sufficient number of sightings to run separate analyses for three species. To account for other species for which there were an insufficient number of sightings, several species were pooled into taxonomic groups, and a pooled density surface was generated. Density surfaces were generated for the following species/groups:

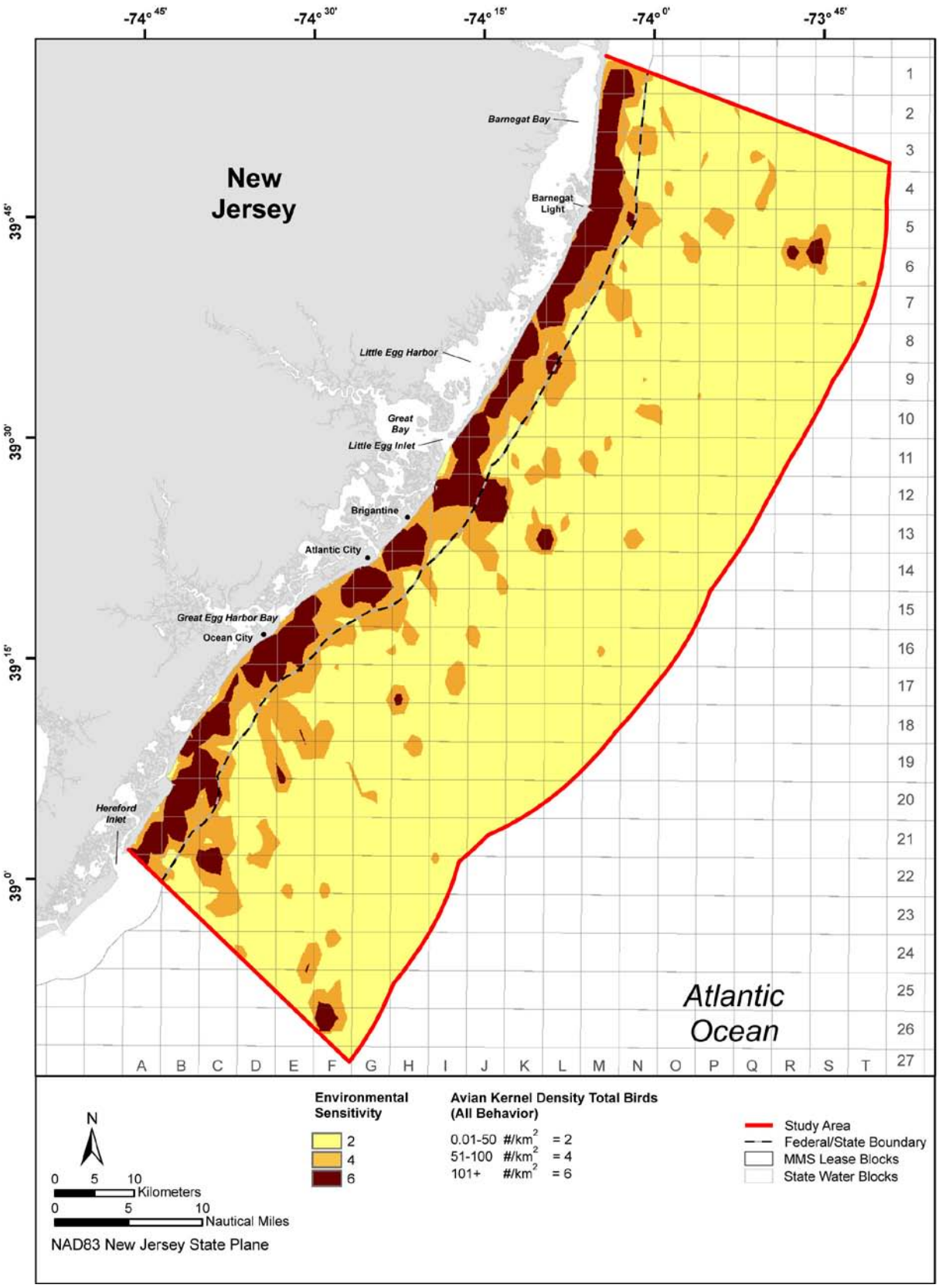

Figure 4-4. Total avian density for all birds/behaviors used in the Environmental Sensitivity Index.

1. Threatened and endangered (T&E) marine mammals year-round: North Atlantic right whale, fin whale, humpback whale
2. Delphinids winter: Short-beaked common dolphin and unidentified dolphin
3. Bottlenose dolphin spring/summer (ship analysis)
4. Harbor porpoise winter

For some species and groups, sufficient sightings data were recorded such that density surfaces could be generated for different seasons. Year-round analyses were limited to those species and groups for which sightings were recorded throughout the year, but not enough sightings were recorded for any particular season. Note that no aerial surveys were conducted in the fall, and the small number of sightings from the shipboard fall surveys prevented the generation of density surfaces for this season.

All analyses were carried out using Distance 6.0 release 2 and the statistical program R (see **Volume III: Chapter 3.0** for more details). The first phase of DSM involved partitioning the survey effort (tracklines) into segments. The DSM analysis engine in Distance utilizes the "count method" in which segment counts (sightings/detections) are modeled as a function of covariates (Hedley and Buckland 2004). The sightings within each segment were converted into an abundance estimate for each segment. The area of the segment (based on chosen segment length and the truncation distance) served as an offset (Thomas et al. 2010). GAMs (Wood 2006) were used to estimate the spatial distribution of abundance/density or counts (the response variable) as a function of numerous geographical, physical, and environmental covariates (explanatory variables), such as longitude, latitude, water depth, distance from shore, bathymetry, SST, and surface chl *a* concentration. After fitting GAMs to the survey data, the resulting DSM (the chosen model) was applied to a prediction grid (composed of 5,000 grid cells) superimposed upon the Study Area so that animal abundance/density could be predicted for any portion of the Study Area and related to specific covariates. The variance of the predicted abundance/density was estimated using the bootstrapping resampling technique (Hedley and Buckland 2004). See **Volume III** for more information on the DSM analyses and the results for each species/group.

The density surfaces generated for each species/group listed above, except the T&E marine mammals, were combined to create a single density surface layer for marine mammals (non-T&E marine mammal layer). Unlike the avian T&E data, enough sightings of T&E marine mammals were obtained during surveys to calculate density estimates. Therefore, a separate layer for T&E marine mammal density was included in the ESI.

The marine mammal density data (non-T&E) were divided into a 3-level ranking system, with the higher the density, the higher the index value. The data were divided and ranked as follows:

1. 0.000000001 – 0.0162 per km^2, which was assigned a weighted or ranking value of 1;
2. 0.0163 – 0.1342 per km^2, which was assigned a ranking value of 2;
3. 0.1343 – 0.9871 per km^2, which was assigned a ranking value of 3.

The T&E marine mammal density data were also divided into the following 3-level ranking system:

1. 0.0000001 – 0.000008 per km^2, which was assigned a weighted or ranking value of 1;
2. 0.000009 – 0.0004 per km^2, which was assigned a ranking value of 2;
3. 0.0005 – 0.0165 per km^2, which was assigned a ranking value of 3.

Figures 4-5 and **4-6** show the two layers for marine mammals included in the ESI.

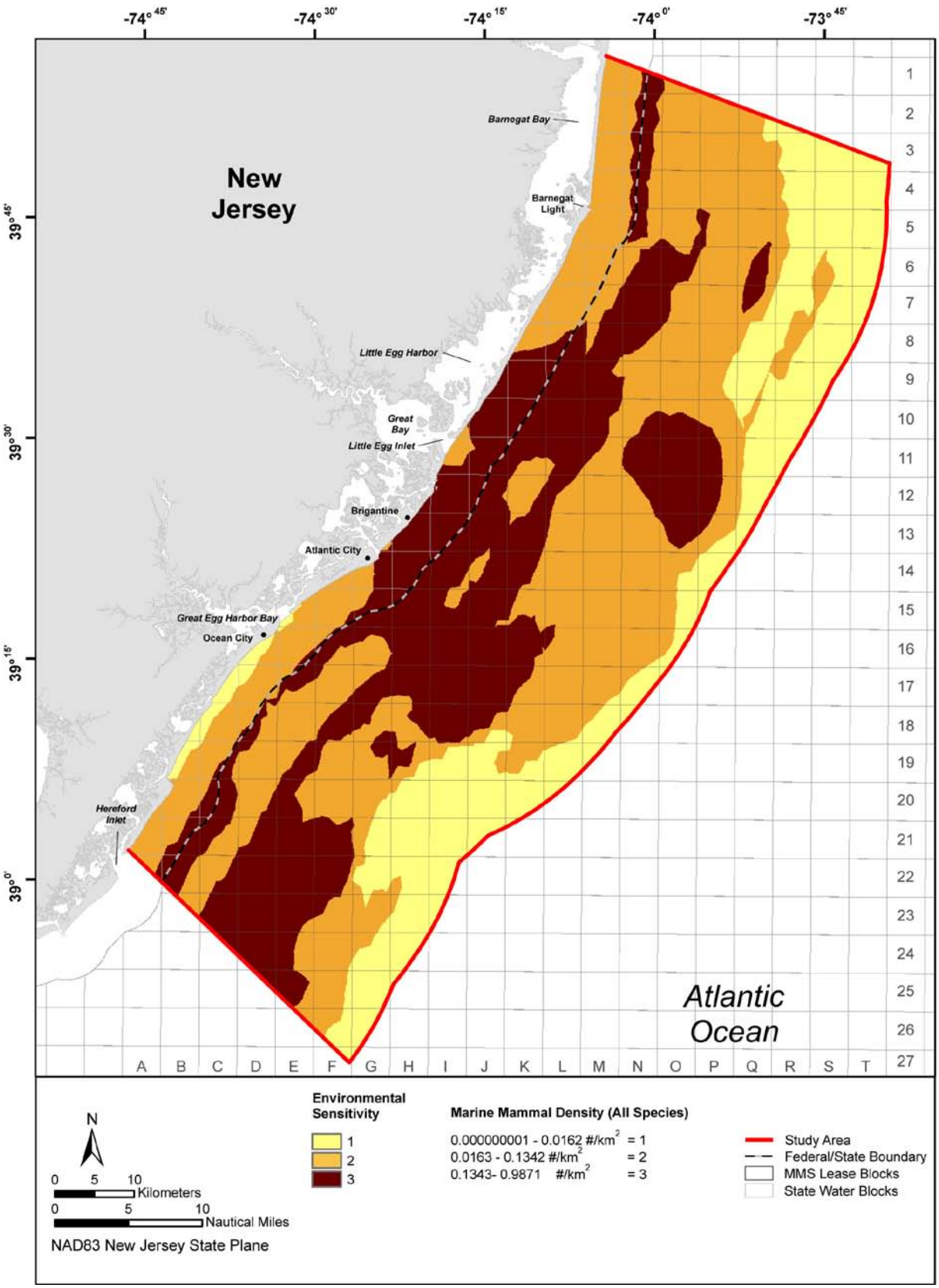

Figure 4-5. Grouped marine mammal density data used in the Environmental Sensitivity Index.

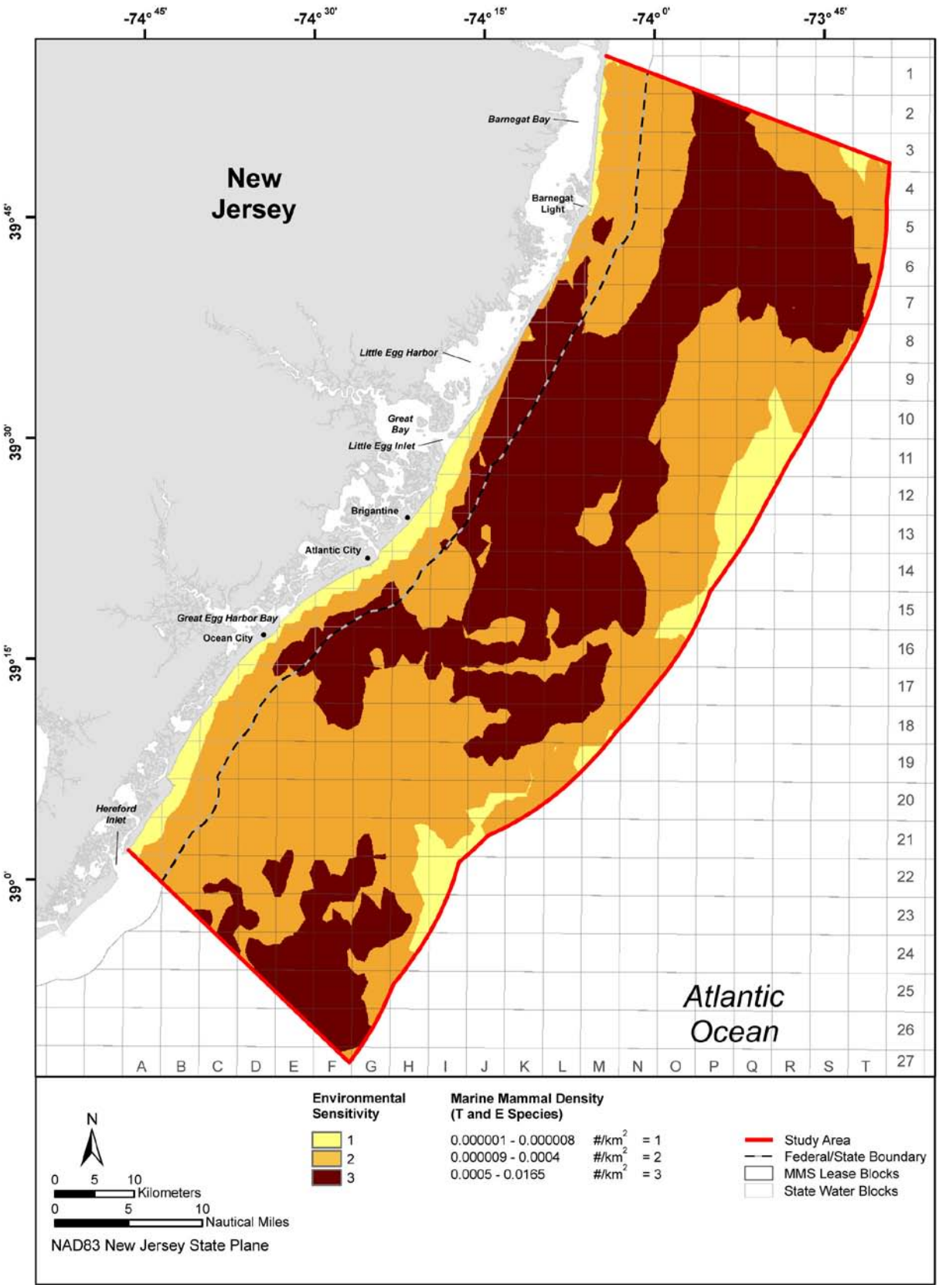

Figure 4-6. Threatened and endangered marine mammal species data used in the Environmental Sensitivity Index.

4.2.6 Sea Turtle Sightings Data

Sea turtle spatial distribution was estimated at each gridpoint using the SPUE method and kriging spatial interpolation. For each observation (sampled site), SPUE (number of sightings/km^2) was calculated by dividing the number of sightings by the effort associated with the given sighting. Knowing the SPUE values at each sampled site, kriging was then applied to estimate SPUE at each gridpoint (unsampled site).

Kriging provides a best linear unbiased estimate (BLUE) of the SPUE value at each gridpoint (unsampled site) based on known SPUE values at neighboring sampled sites, using a set of linear least squares weighted regression estimation algorithms (routines) that minimize estimation variance (error) from a predefined covariance or semivariance model. Unlike trend surface methods, kriging is an exact interpolator, such that the interpolated SPUE value calculated at a sampled site coincides with its known SPUE value (i.e., the kriged surface passes through the data points), provided that the spatially uncorrelated random residual variation ("noise") is zero. Five components of kriging include detrending, semivariogram modeling, neighborhood search, interpolation, and cross-validation.

Kriging is quasi-random in that it contains both deterministic and random components, and only the stationary (random residual) component is kriged. The deterministic (trend) component is subtracted out (separated) from the residual component, the latter of which is kriged, and then the trend component is added back into the kriged residual. A semivariogram model describes the asymptotic relationship between semivariance (or, inversely, covariance) and separation distance between two locations (i.e., an unsampled gridpoint and a sampled site), and a "range" is calculated as the distance beyond which the two points are spatially uncorrelated (independent of each other). For each unsampled gridpoint, a neighborhood search is conducted to identify all sampled sites within the gridpoint's range, and spatial interpolation is then conducted to estimate SPUE at the gridpoint based on the SPUE values at these neighboring sampled sites, using a least squares weighted regression function that minimizes estimation variance. Generally, the relative weight (influence) of a sampled site's SPUE value in affecting the estimated SPUE value at the unsampled site correlates negatively with separation distance.

For the sensitivity index, the sea turtle SPUE data were divided into a 3-level ranking system based on the three quantiles of the SPUE values. The data were divided and ranked as follows:

1. 0.0039 – 0.0059 Sightings per km, which was assigned an index value of 1;
2. 0.0060 – 0.0073 Sightings per km, which was assigned an index value of 2;
3. 0.0074 – 0.0261 Sightings per km, which was assigned an index value of 3.

Using this 3-level step function, spatial variations in sea turtle SPUE were reflected in corresponding spatial variations in the index. **Figure 4-7** shows the sea turtle SPUE layer used in the sensitivity index.

4.2.7 Essential Fish Habitat

Nearly 40 fish and fisheries species of various life stages have EFH designated within the Study Area. It was difficult to rank one species or life stage as more important than the next, so all EFH layers were added to the ESI. To equalize the weighting and ranking of EFH with other resources shown in the index, the data were divided into a three level ranking system, where areas with the most overlap in EFH layers received the highest index ranking. The data were divided and ranked as follows:

1. 1-12 EFH designations, which was assigned an index value of 1;
2. 13-24 EFH designations, which was assigned an index value of 2;
3. 25-38 EFH designations, which was assigned an index value of 3.

Figure 4-8 shows the combined EFH layers used in the ESI. **Volume IV: Appendix A** provides details and maps for each of the EFH species.

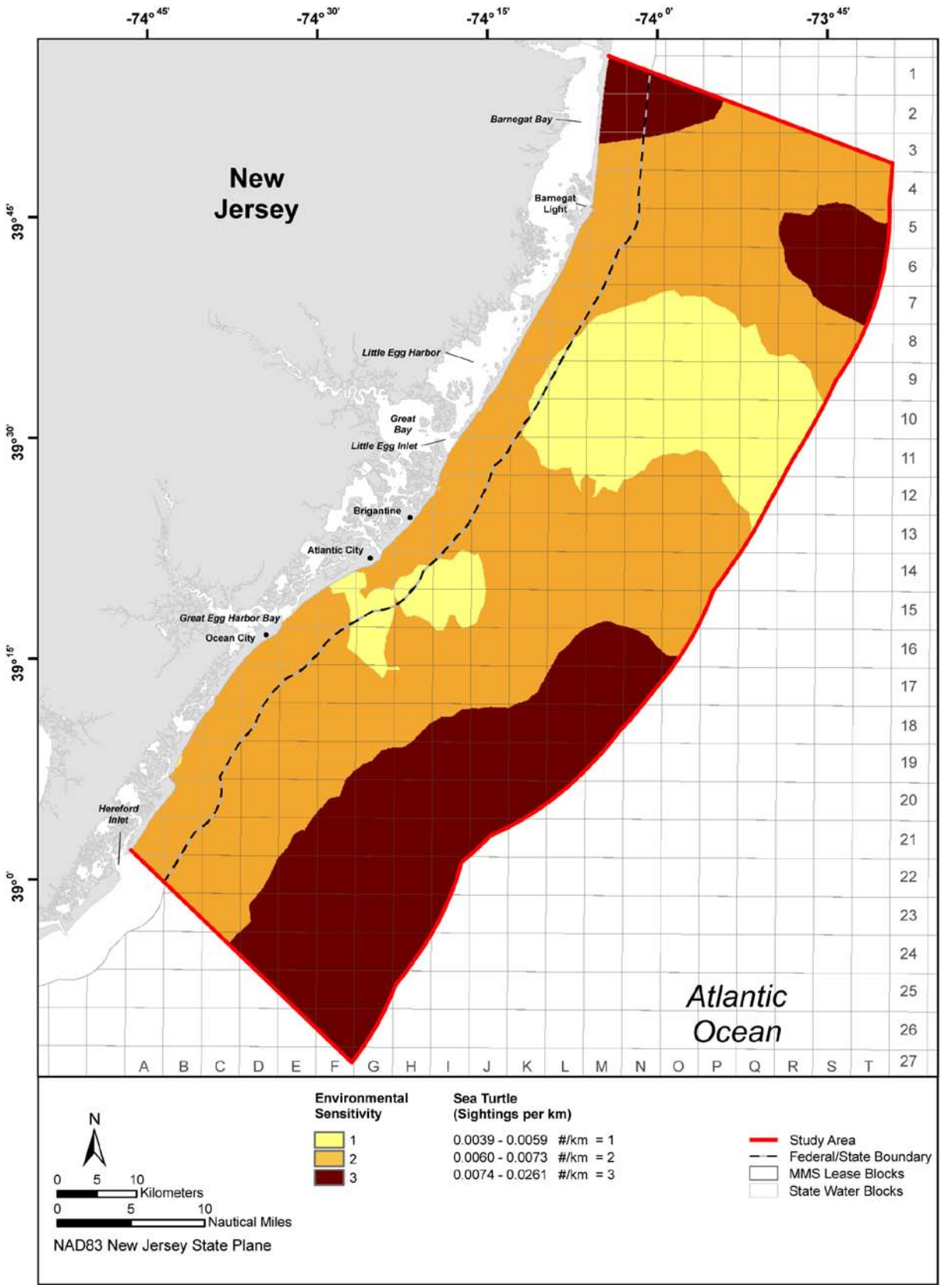

Figure 4-7. Sea turtle data used in the Environmental Sensitivity Index.

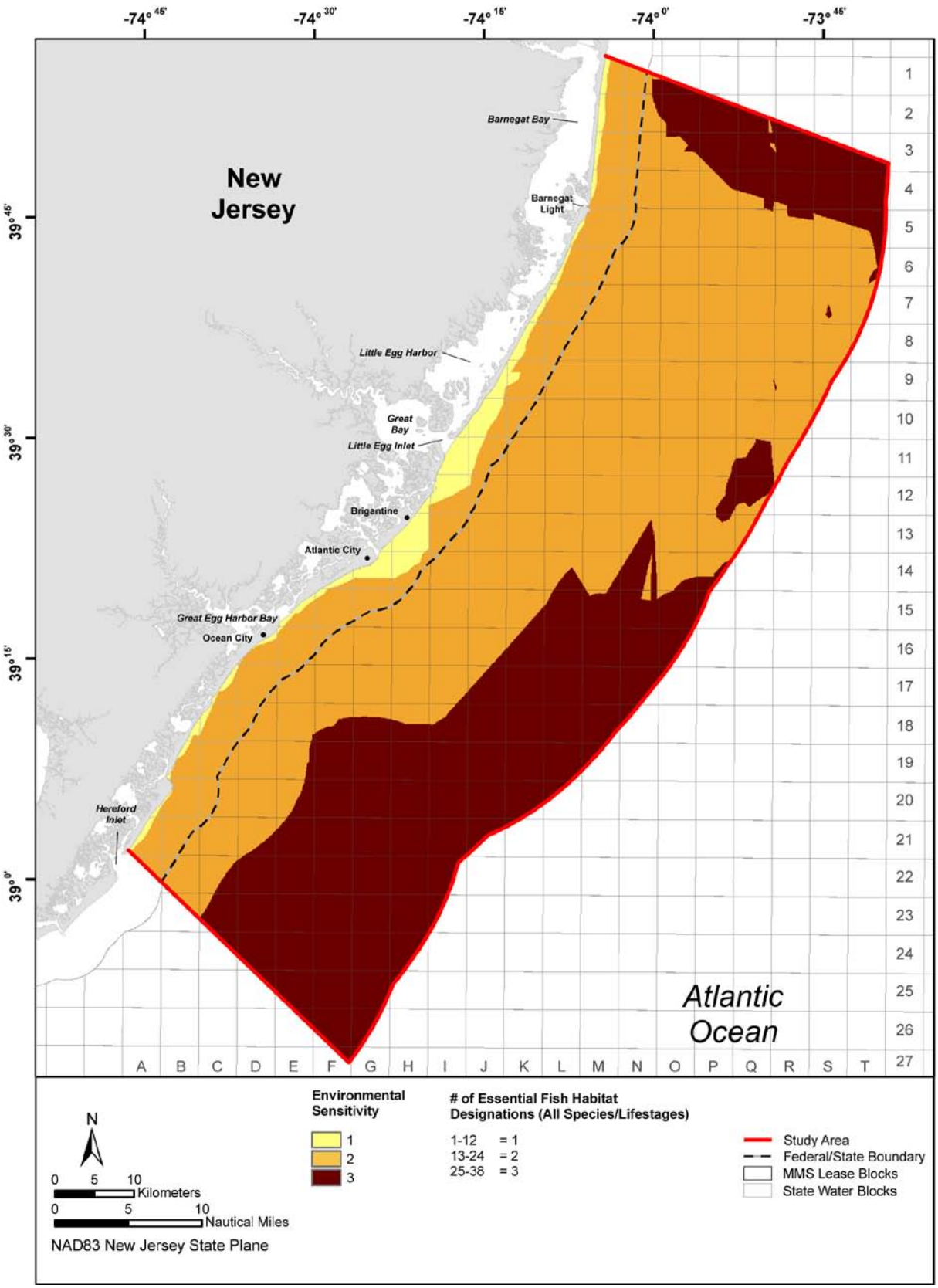

Figure 4-8. Essential Fish Habitat data used in the Environmental Sensitivity Index.

4.3 USING THE ENVIRONMENTAL SENSITIVITY INDEX

The ESI provides a visual representation of the number and distribution of physical, biological, and socioeconomic resources within the Study Area. Although the ESI clearly shows areas with high resource use and overlap, the user cannot discern which resources are found within each of the grid blocks by simply looking at the map (**Figure 4-1**). As such, a table of the resources (features) that make up the contents of each grid block is located in **Table C-1** in **Appendix C**. This table not only details the resources found within a given area, but it also provides the ranking for the biological resources to providce an understanding of the environmental sensitivity for each grid within the Study Area. For example, in block H18 of the ESI (see **Figure 4-1**), portions of the block have rankings of 11, 12, 13, 14, and 15, as well as a prohibited development area. As shown in **Table C-1**, block H18 is comprised of: avian densities with rankings of 2, 4, and 6; marine mammal densities with rankings of 1 and 2; T&E marine mammal density with a ranking of 2; sea turtle densities with rankings of 2 and 3; EFH with rankings of 2 and 3; commercial fishing grounds; a marine protected area; recreational fishing areas; shoals; and shipping lanes.

Using the true boundaries of physical features and the spatial varability of the modeled biological data, it is impossible to assign a single index value to the individual grid blocks. Instead, index values are assigned to the actual area that is overlapped by the data. Therefore, within a single grid block, there may be areas with moderate and low index ratings, such as P12. **Table 4-1** was developed to show index users the breakdown of index values within the Study Area. Index values between 11 and 15 comprised 82.2% of the Study Area. Only 9.3% of the Study Area had an index value of 10 or less, while 8.5% had an index value of 16 or greater. The majority of the areas with highest values were located along the coast, especially near Brigantine and north, as well as the southern extents of the Study Area. Several areas with high values were associated with shoal areas, especially those found in R6, R7, C23, C22, E25, F25, and F26. The lower index values were found primarily in the middle to northern sections of the Study Area that were farthest from shore.

Table 4-1. Percent breakdown for each of the index values with the Study Area. Note these percentages include the environmental resources in the prohibited development areas.

Index value	Area (km^2)	%
6	0.06	0.001
7	1.38	0.029
8	36.31	0.761
9	136.66	2.864
10	267.07	5.596
11	587.23	12.305
12	1211.91	25.395
13	944.66	19.795
14	741.18	15.531
15	439.35	9.206
16	243.50	5.102
17	120.92	2.534
18	39.69	0.832
19	2.27	0.047
Total		100
Prohibited Development Areas	215.44	4.514%

In general, the ESI is a useful tool for preliminary planning for both developers and stakeholders. It provides a quick overview of the potentially sensitive resources off the New Jersey coast, and the areas where these resources are most abundant; however, this index should be used only as a guide to help determine which locations within the Study Area may be suitable for offshore development, as well as those areas that may need to be avoided due to ecological importance. While the ESI should not be used in lieu of site specific resource studies, it provides a good synthesis of baseline data for initial planning purposes and future impact assessments.