



FISH HABITAT CONSERVATION AREA MAPPING AND PRIORITIZATION PROJECT

**A prioritization of Atlantic coastal,
estuarine, and diadromous fish habitats
for conservation**

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1. BACKGROUND

For this project, the Atlantic Coastal Fish Habitat Partnership (ACFHP) worked with the Southeast Aquatic Resources Partnership (SARP) and The Nature Conservancy (TNC) to spatially prioritize fish habitat conservation sites through GIS mapping and analyses for the Atlantic region of the U.S. from Maine to Florida. This effort was split into two separate, sequential projects. The first one covered the geography from North Carolina through the Florida Keys (Southeast Mapping Project), and the second project covered from Maine through Virginia (Northeast Mapping Project).

As part of the National Fish Habitat Partnership (NFHP), ACFHP is expected to prioritize habitats for both protection and restoration. Habitat prioritization is an essential element of ACFHP's [Conservation Strategic Plan](#), which covers the 2017 - 2021 timeframe. Additionally, habitat prioritization is needed for ACFHP to objectively evaluate on-the-ground restoration project proposals. Results will help ACFHP, its partners, and various stakeholders better identify locations in need of habitat restoration – both “Areas of Excellent Fish Habitat” that could benefit from land and watershed protection and expansion by restoring adjacent areas, and “Restoration Opportunity Areas” that would most benefit from restoration (see *Use of the Results* for more details). It is not intended to be used as guidance for regulatory purposes (see *Discussion* for more details). This project focuses on the priority habitats within the ACFHP geography to spatially determine which locations are optimal for diadromous, estuarine, and coastal fish habitat conservation based on the guidance provided by the ACFHP Steering Committee and Science and Data Committee (Tables 1 and 2).

Table 1. Timeline of Science & Data Committee and Steering Committee project engagement for the Southeast Mapping Project.

Committee Engagement	Date	Location
Project introduction to the ACFHP Science & Data Committee	June 12, 2017	webinar
Science and Data Committee meeting to select variables and metrics for analyses	September 27-28, 2017	Arlington, VA
Presentation to the Steering Committee to provide update and solicit feedback	October 16-17, 2017	Norfolk, VA
Presentation to the Steering Committee to provide update and solicit feedback	May 17-18, 2018	Savannah, GA
Science & Data Committee update to solicit feedback	June 15, 2018	webinar
Steering committee meeting to present the final product	November 15-16, 2018	Newburyport, MA

Table 2. Timeline of Science & Data Committee and Steering Committee project engagement for the Northeast Mapping Project.

Committee Engagement	Date	Location
Kickoff meeting with ACFHP Science & Data Committee	May 15-16, 2019	Arlington, VA
Presentation to the Steering Committee to provide update and solicit feedback	October 29, 2019	New Castle, NH
Draft final maps sent to ACFHP Steering and Science & Data Committees	March 9, 2020	email
Final report submitted to ACFHP Coordinator & Atlantic States Marine Fisheries Commission	March 20, 2020	email

2. PROJECT SCOPE

The ACFHP region consists of four separate subregions (Figure 1): North Atlantic (Canada/Maine border to Cape Cod), Mid-Atlantic (Cape Cod to Cape Hatteras), South Atlantic (Cape Hatteras to Cape Canaveral), and South Florida (Cape Canaveral through the Florida Keys). These subregions correspond to the U.S. portions of the Gulf of Maine, Virginian, Carolinian, and Floridian marine ecoregions (Spalding et al. 2007). ACFHP focuses on 3 – 4 priority fish habitats in each subregion (Table 3).

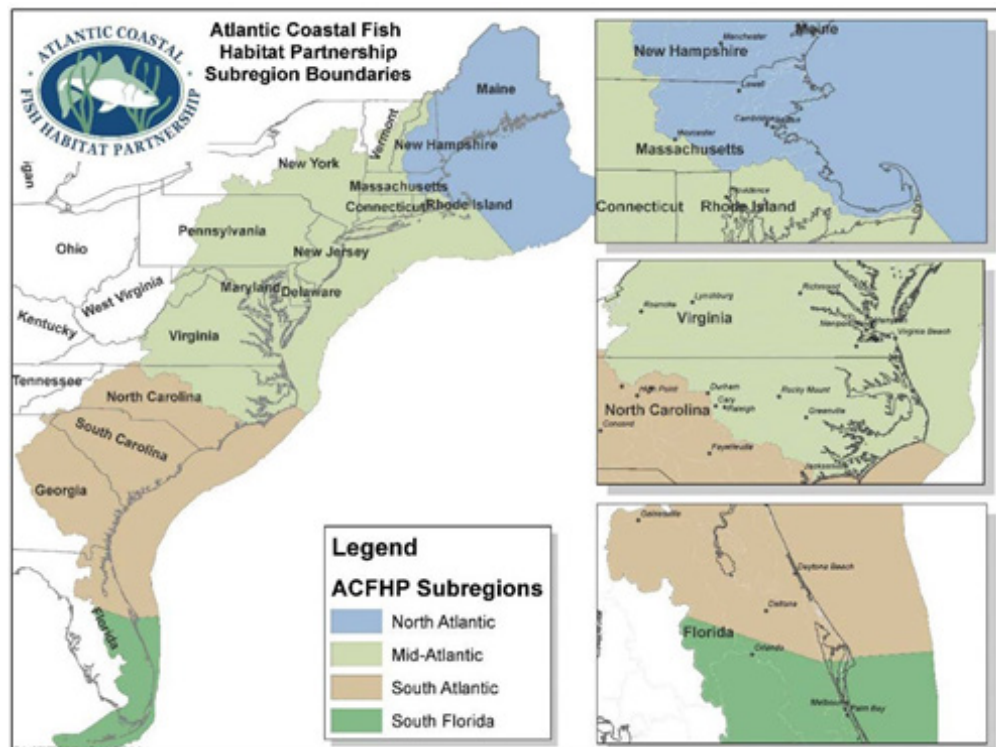


Figure 1. ACFHP subregional boundaries.

The spatial extent of the Northeast Mapping Project covered all of ACFHP's North Atlantic subregion and most of the Mid-Atlantic subregion. The southern boundary of the study was modified to correspond to the Chesapeake Bay watershed in order to minimize overlap with the previous Southeast project which included Virginia waterways that drained into North Carolina. Priority habitats in the North Atlantic include riverine bottom, submerged aquatic vegetation (SAV), and marine and estuarine shellfish beds. Priority habitats in the Mid-Atlantic include riverine bottom, SAV, marine and estuarine shellfish beds, and tidal vegetation.

The Southeast Mapping Project included at least a portion of three of ACFHP's subregions: the Mid-Atlantic (Virginia watersheds that drain into North Carolina waters south to Cape Hatteras), all of the South Atlantic, and all of South Florida. ACFHP's priority habitats in the South Atlantic are the same as in the Mid-Atlantic. SAV, tidal vegetation, and coral and live/hard bottom are ACFHP's priority habitats in South Florida.

Across the ACFHP geography, eight separate but complementary analyses were run to prioritize diadromous, estuarine, and coastal fish habitats as appropriate to correspond with the priority habitats in each subregion (Table 3). In the North Atlantic, the North Atlantic Diadromous Analysis addressed the riverine bottom priority habitat, and the North Atlantic Estuarine Analysis addressed the SAV and marine and estuarine shellfish beds priority habitats. The Mid-Atlantic Diadromous Analysis addressed the riverine bottom priority habitat in the Mid-Atlantic (from Cape Cod through river systems that drain into Virginia waters); the Mid-Atlantic Estuarine

Table 3. Geographic regions and ACFHP priority habits covered by the eight spatial analyses.

Mapping Project	ACFHP subregion	ACFHP Priority Habitat	Analysis
Northeast	North Atlantic	Riverine bottom	North Atlantic Diadromous
		SAV	North Atlantic Estuarine
		Marine and estuarine shellfish beds	
	Mid-Atlantic (Cape Cod to NC drainages)	Riverine bottom	Mid-Atlantic Diadromous
		SAV	Mid-Atlantic Estuarine
		Marine and estuarine shellfish beds	
		Tidal vegetation	
Southeast	Mid-Atlantic (NC-drainages to Cape Hatteras) and South Atlantic	Riverine bottom	South Atlantic Diadromous
		SAV	South Atlantic Estuarine
		Marine and estuarine shellfish beds	
		Tidal vegetation	
	South Florida	SAV	South Florida Estuarine
		Tidal vegetation	
		Coral and live/hard bottom	South Florida Coastal

Analysis addressed the SAV, marine and estuarine shellfish beds, and tidal vegetation priority habitats in the same geography. The South Atlantic Diadromous Analysis addressed the riverine bottom priority habitats for river systems that drained from North Carolina to Cape Canaveral; the South Atlantic Estuarine Analysis addressed the SAV, marine and estuarine shellfish beds, and tidal vegetation priority habitats covering the same geography. The South Florida Estuarine Analysis addressed the SAV and tidal vegetation priority habitats in ACFHP's South Florida subregion, and the South Florida Coastal Analysis covered the coral and live/hard bottom priority habitat in the South Florida subregion.

The following sections outline the eight analyses that were completed through the compilation of existing resources and subsequent calculations and mapping. The specific variables and measurements in each analysis were chosen by regional experts because they covered the entire analysis area and were limited in redundancy (e.g. if impervious surface was included, urban development was not). The Southeast Mapping Project was carried out first, thus the Northeast Mapping Project metrics were largely selected based on the analyses previously done for the Southeast, to mimic as closely as possible the work performed in that geography. Differences in the metrics used will be described in the *Metrics* section of each analysis below. All metrics and final results were reviewed and approved by the Science and Data and Steering Committees. To view the final results online, see Appendix I.

3. DIADROMOUS ANALYSES

The diadromous fish habitat conservation analyses used catchments from the National Hydrography Dataset (NHD) Plus (v2.1) (USGS 2015) as the unit of analysis. Almost 200,000 catchments, averaging 2.3 km², were included in the Northeast project, and approximately 133,000 catchments were analyzed for the Southeast project. The boundaries for the analyses were determined based on the extent of diadromous fish habitat. The North and Mid-Atlantic



Figure 2. Extent of the analysis for Northeast diadromous fish habitats. Purple represents the North Atlantic Diadromous Analysis, and green represents the Mid-Atlantic Diadromous Analysis.

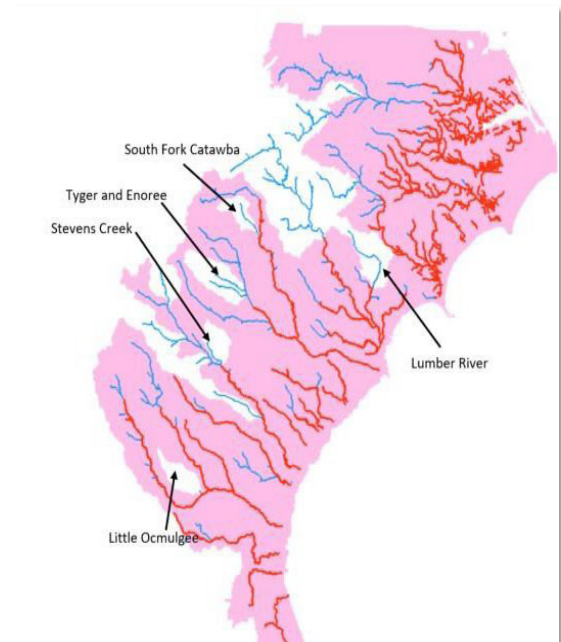


Figure 3. Areas considered for the South Atlantic Diadromous Analysis. Red represents diadromous data from SEACAP, pink represents alosine extent based on TNC's prioritization, and experts were asked about the reaches labeled in black. This analysis ended up using the pink area for its scope.

Diadromous Analyses covered the NHD catchments with current and historical alosine coverage, based on TNC's Fish Habitat Decision Support Tool Alosine Prioritization results and expert opinion (Figure 2) (Martin 2015). The South Atlantic Diadromous Analysis targeted all NHD catchments located within watersheds that harbored diadromous fishes based on TNC's Fish Habitat Decision Support Tool Alosine Prioritization results, the [Southeast Aquatic Connectivity Assessment Project](#) results, as well as expert knowledge from the ACFHP Steering Committee (Figure 3) (Martin 2015). The NHD catchments as well as all variable data were then clipped to the project boundary.

A. METRICS

For all three diadromous analyses (North, Mid-, and South Atlantic), eight metrics which describe some aspect of the suitability or condition of each catchment for diadromous fish habitat were calculated. Because some of these metrics are expressed in relative terms, they were calculated separately for each of the three analyses. Each metric results in an allocation of points to the catchment, up to a possible maximum of 80 points (10 points per metric). See *Discussion* for details about the interpretation of points and their implications for conservation planning.

Table 4. Metrics for the Diadromous Fish Habitat Analyses

Variable	Measurement	Metric
Impervious surface	% impervious surface in upstream drainage area	10 points if \leq (NE) or $<$ (SE) 5% cumulative impervious surface*
Point source pollution	Density of sites in catchment**	10 points if catchment is ranked in the lowest 25% for pollution (least polluted)
Non-point source pollution	% of catchment covered by non-point source pollution**	10 points if the catchment is ranked in the lowest 25% for pollution (least polluted)
Riparian buffers	% of floodplain area with natural land cover	10 points if the catchment is ranked in the top 25% for natural coverage
Potential for species access	Diadromous species presence & ocean access	10 points if catchment had an anadromous species present AND was on a network with zero dams downstream to the ocean
Flow alteration	Volume of all upstream storage	10 points if the catchment is ranked in the lowest 25% for volume
Local fragmentation	Density of road crossings + dams in catchment	10 points if the catchment is ranked in the lowest 25% for fragmentation (lowest number of crossings and dams).
ESA critical habitat	Atlantic salmon and sturgeon critical habitat designation	10 points if the catchment is designated Atlantic sturgeon or Atlantic salmon critical habitat

*Only 3 catchments were equal to 5% in the Southeast Mapping Project.

**The metric for the North and Mid-Atlantic analyses vary from the South Atlantic analysis. Details can be found below.

The eight metrics that were generated for each catchment are summarized in Table 4 and described in more detail in the subsections below. All metrics were generated using custom Python scripts and models primarily using the ArcGIS (version 10.3.1) arcpy package.

i. Impervious surface

The percent impervious surface in the upstream drainage area of each catchment is calculated for each catchment to serve as an indicator for human development. For the South Atlantic analysis, data for percent impervious surface above the catchment were pre-calculated by the Environmental Protection Agency (EPA) within their EPA StreamCat dataset. To calculate this variable, EPA used the National Land Cover Dataset from 2011, and accumulated the amount of impervious surface using each catchment as a pourpoint, resulting in the attributes titled 'PctUrbHi2011Ws,' 'PctUrbMd2011Ws,' 'PctUrbLo2011WS.' These three attributes were added to capture both high, medium, and low densities of urban land use. Therefore, the cumulative percentage of impervious surface above each catchment was calculated. Once these data were obtained, they were joined onto the catchment dataset via the NHD FeatureID. Once joined, a new field was calculated by sequentially ranking the data from 1 to 133,216 (with the highest number being the best value). Then, these ranks were binned into 5% tiers, and those catchments in the top 5% tier were given 10 points, all else were scored zero points (Figure 4).

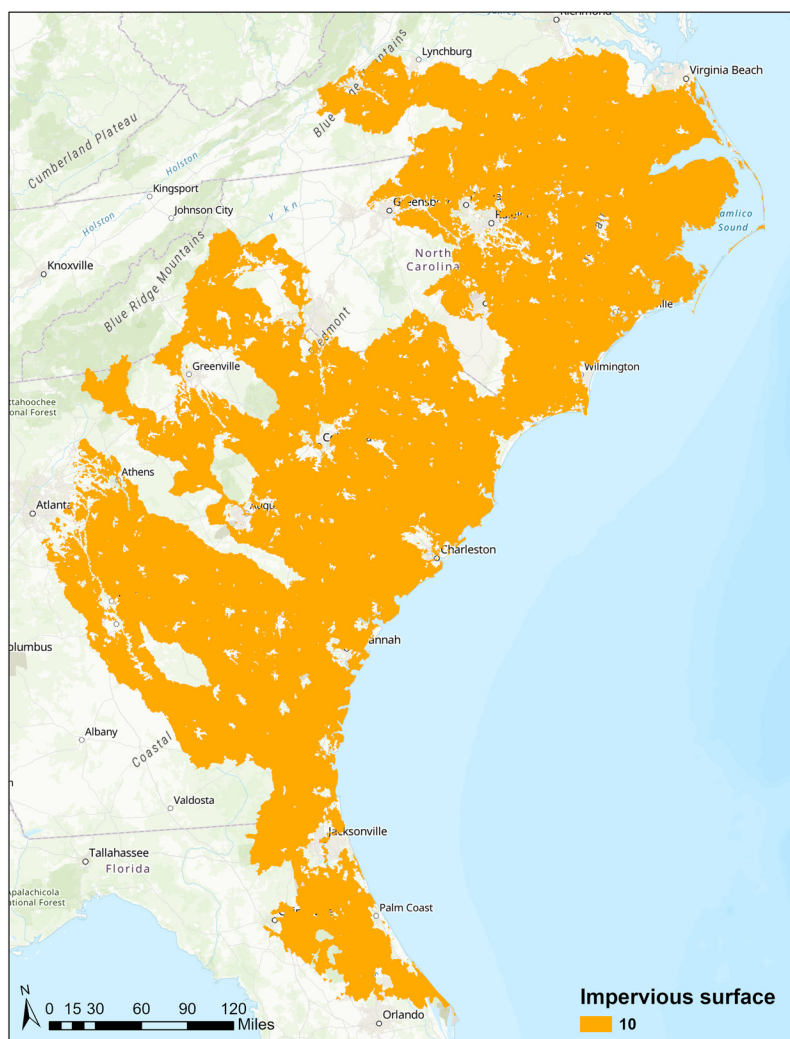


Figure 4. Catchments receiving 10 points for having <5% upstream impervious surface in the South Atlantic.

To generate this metric for the North and Mid-Atlantic analyses, the percent impervious surface was summarized for each individual catchment from the 2016 National Landcover Dataset (USGS 2016). The values for each catchment were obtained using the ArcGIS Zonal Statistics as Table tool, upstream sum and count values were accumulated for all upstream catchments, and percent impervious surface calculated based on the accumulated values. Every catchment with less than 5% total upstream impervious surface was given 10 points (Figure 5).

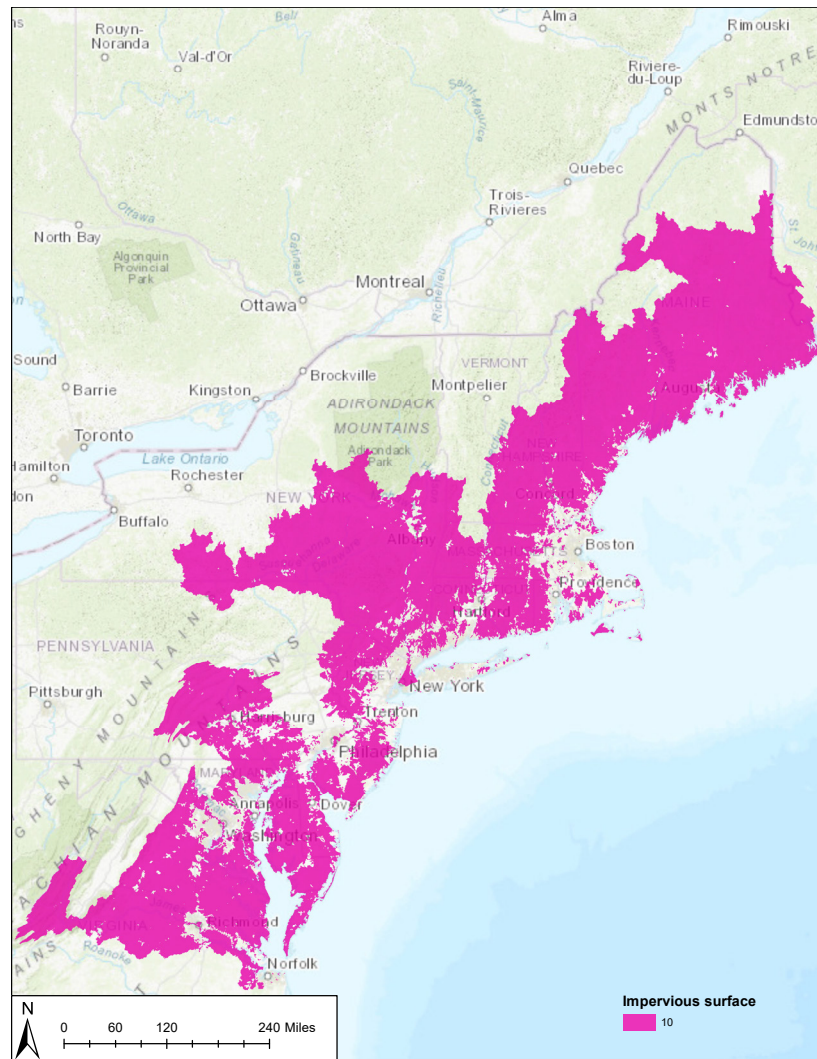


Figure 5. Catchments receiving 10 points for having $\leq 5\%$ upstream impervious surface in the North and Mid-Atlantic.

ii. Point source pollution

Point source pollution was obtained for each catchment from the US EPA's StreamCat database (Hill et al. 2016). For the South Atlantic Diadromous Analysis, toxic release inventory (TRI) site density (attribute titled 'TRIDensCat'); comprehensive environmental response, compensation, and liability information system site density (attribute titled 'NPDESDensCat'); and permit compliance system site density from the year 2014 were combined (units were sites/km²). In the North and Mid-Atlantic, the density of TRI sites within each catchment was joined from the StreamCat 'TRIDensCat' attribute using the catchment's COMID unique identifier. For all analyses, site density was joined to the catchments via 'feature id' and sequentially ranked and binned; those catchments falling in the top 25%, or having the lowest density of sites, were given 10 points and all others were given zero. This metric was calculated separately for the North Atlantic and Mid-Atlantic regions. Note that all catchments with no sites are tied as having the lowest density of sites, therefore the total number of catchments receiving 10 points for this metric exceeds 25% of the total number of catchments.

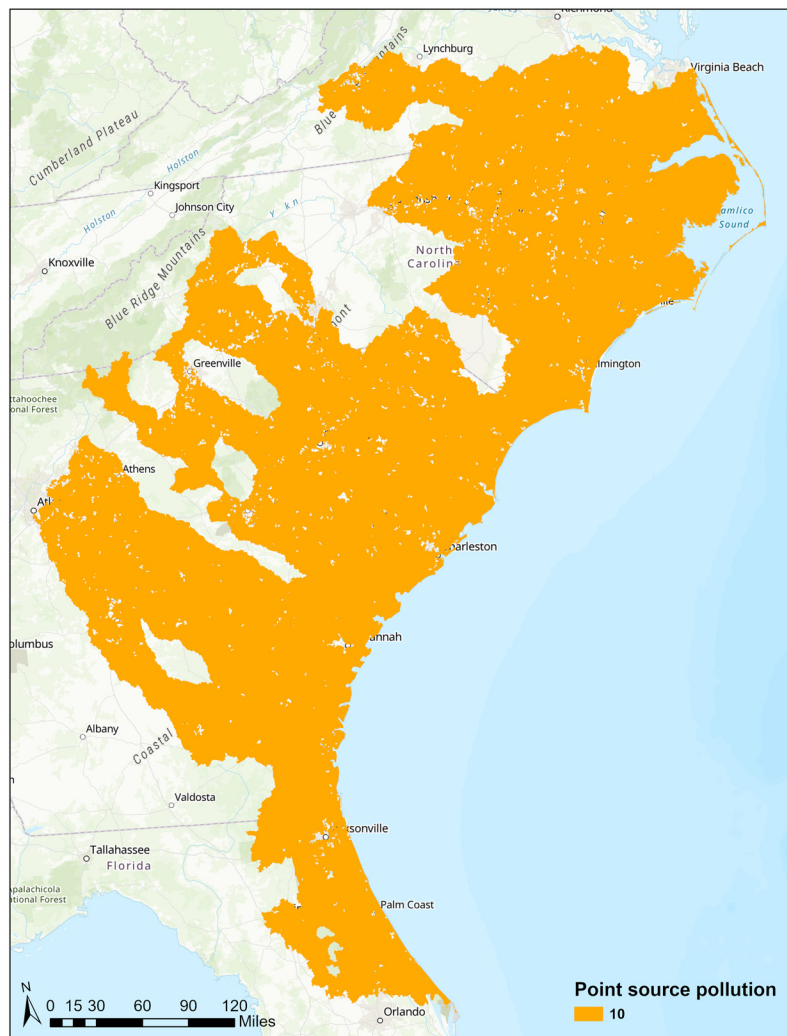


Figure 6. Catchments receiving 10 points for having the least amount of point source pollution in the South Atlantic.

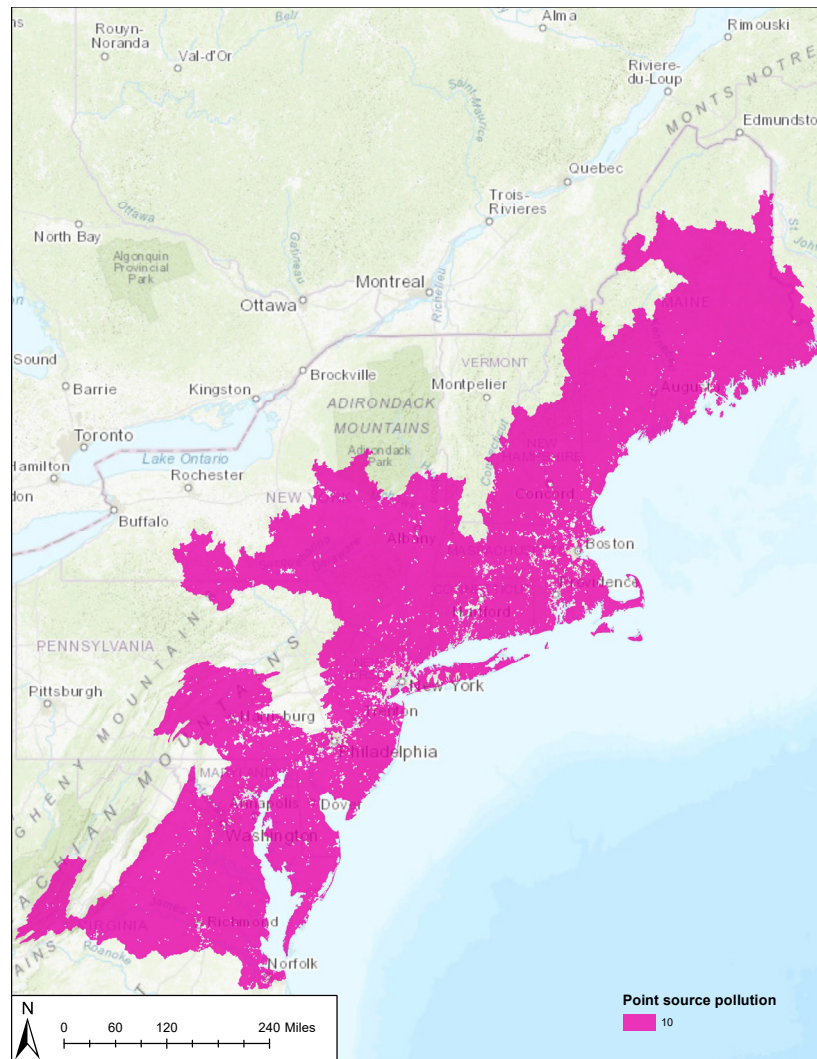


Figure 7. Catchments receiving 10 points for having the least amount of point source pollution in the North and Mid-Atlantic. The North and Mid-Atlantic regions were calculated separately and merged back together to generate this map.

iii. Non-point source pollution

To create a variable for non-point source pollution for the South Atlantic Diadromous Analysis, the USDA Cropscape raster from 2017 (30 x 30 m resolution) was used to determine the percentage of land cover within each catchment that was a type of agriculture (crops, pasture/hay). For this analysis, the ‘tabulate area’ tool was used to identify the area of each land cover type present within each catchment, using the catchments as zones. Then, the areas of these landcover types containing agriculture were summed and divided by the total area to come up with a percentage of agriculture per catchment. Once this metric was calculated, it was sequentially ranked and binned in the same way as the above metrics, and those catchments in the top 25% for the least amount of agriculture were given 10 points.

The non-point source pollution metric for the North and Mid-Atlantic was developed to assess non-point source pollution other than that arising from impervious surfaces (which is assessed directly in another metric). This metric is based on the 2016 NLCD and measures the percent of each catchment covered by developed open space (e.g. golf courses), low intensity developed, pasture/hay, or row crops. It was calculated for each catchment using the ArcGIS ‘tabulate area’ tool. A catchment was assigned 10 points if it was ranked in the lowest 25% of catchments for areal coverage of these classes. This metric was calculated separately for the North Atlantic and Mid-Atlantic regions.

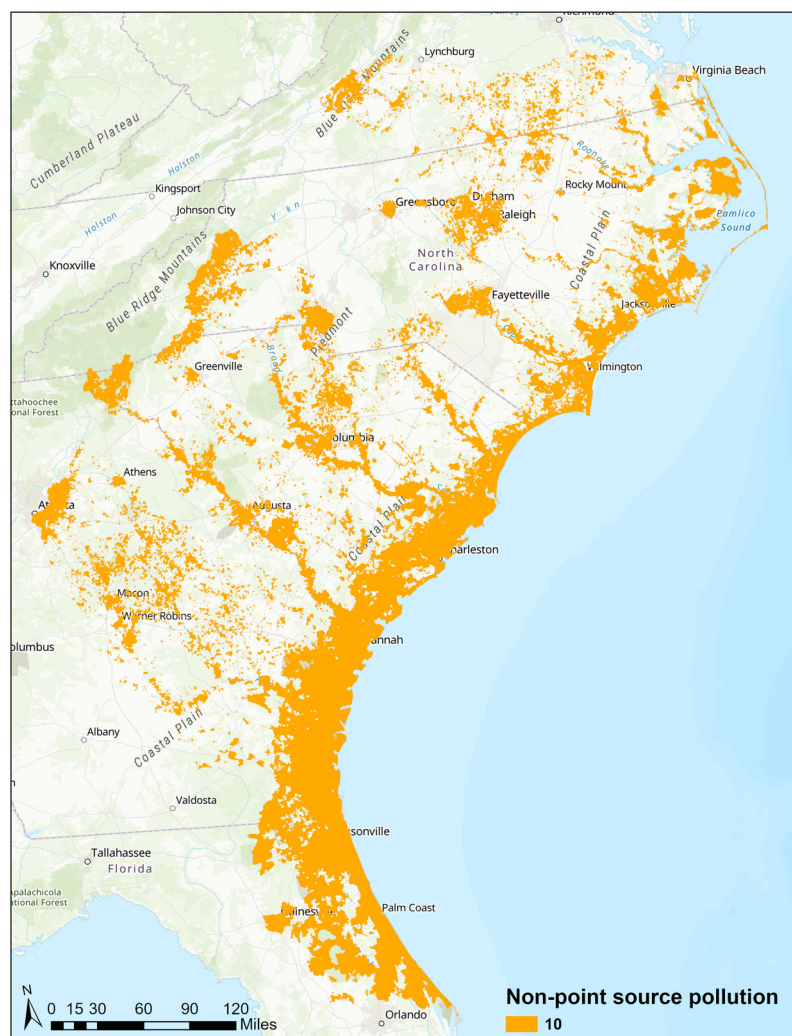


Figure 8. The 25% of catchments receiving 10 points for having the least non-point source pollution in the South Atlantic.

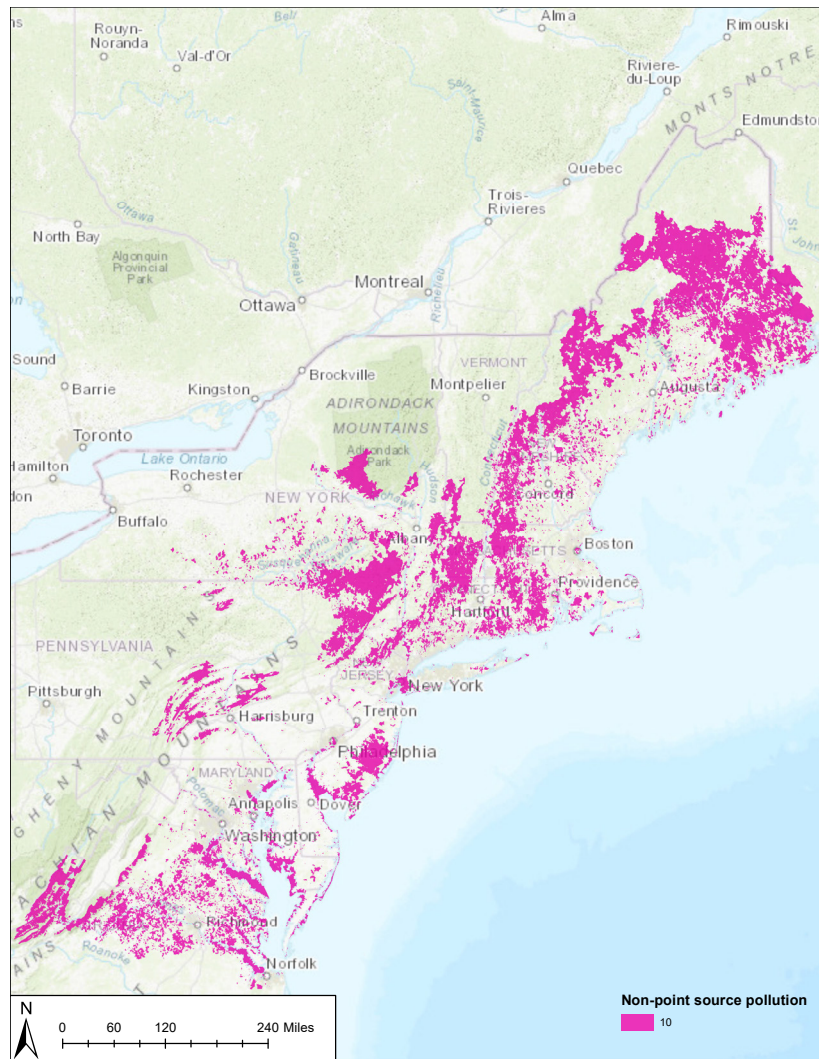


Figure 9. The 25% of catchments receiving 10 points for having the least non-point source pollution in the North and Mid-Atlantic. The North and Mid-Atlantic regions were calculated separately and merged back together to generate this map.

iv. Riparian cover

The riparian cover metric assesses the percent of the riparian zone within each catchment that is under natural land cover. For the South Atlantic, modified floodplain boundaries were used to assess riparian buffer health, rather than applying a uniform buffer width from an NHD line, in order to capture the buffers of large rivers. To calculate this metric, a 100-year floodplain boundary was used to quantify the percentage of natural land cover within each catchment to identify those catchments that had healthy floodplains. A raster dataset delineating each stream's 100-year floodplain boundary was obtained from FATHOM. Because this dataset was of lower resolution than some of the 1:100,000 resolution NHD streams and catchments, a floodplain boundary for these smaller streams needed to be delineated. To delineate this boundary, the NHD streams were converted to a raster and expanded by 90 meters using 'raster calculator,' and then the 'raster to mosaic' tool was used to merge the expanded streams onto the floodplain boundary dataset. This process resulted in a contiguous floodplain boundary dataset that encompassed all catchments in the analysis. This floodplain boundary dataset then

was split at each catchment boundary using the 'Con' tool in GIS, so that each catchment had a floodplain boundary associated with it via the catchment 'FeatureID.' Finally, these floodplain boundaries were used as zones within the 'tabulate area' tool to calculate the percentage of natural land cover (from the National Land Cover Database 2011) within each floodplain boundary. Those catchments falling in the top 25% for highest percent natural land cover within their floodplains were given 10 points and all others were given zero points.

The riparian zone is delineated by the Active River Area (ARA) (Smith et al. 2008) for the North and Mid-Atlantic. Natural land cover was obtained from the 2016 NLCD and defined by the following classes: open water, barren land, deciduous forest, evergreen forest, mixed forest, shrub/scrub, grasslands/herbaceous, woody wetlands, emergent herbaceous wetlands. A catchment was assigned 10 points if it was ranked in the highest 25% of catchments for areal coverage of these classes within its ARA. This metric was calculated separately for the North Atlantic and Mid-Atlantic regions.

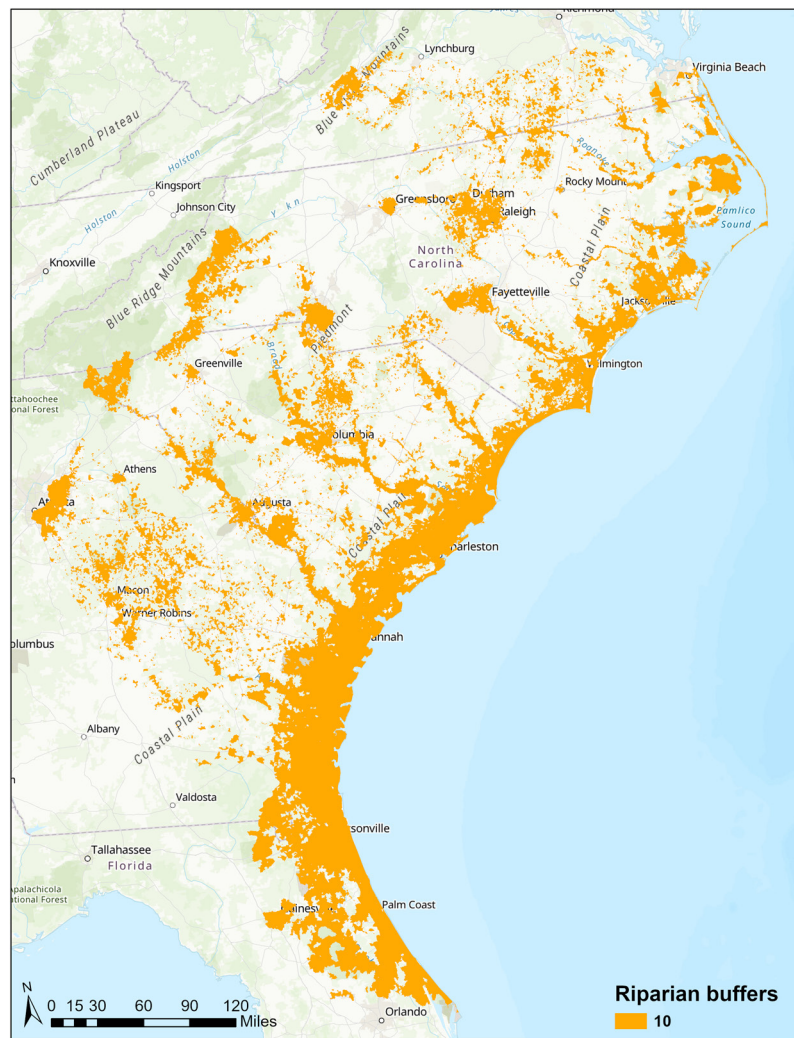


Figure 10. Catchments ranking in the highest 25% for riparian buffers and receiving 10 points in the South Atlantic.

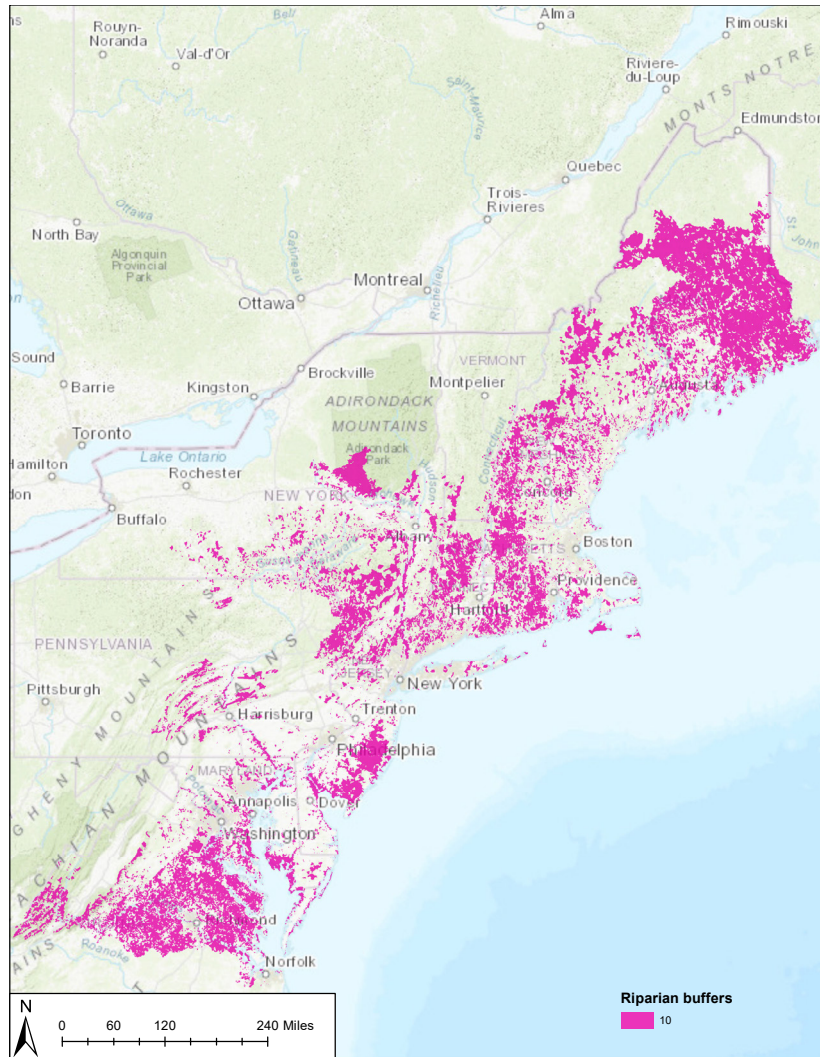


Figure 11. Catchments ranking in the highest 25% for riparian buffers and receiving 10 points in the North and Mid-Atlantic. North Atlantic and Mid-Atlantic regions were calculated separately and merged back together to generate this map.

v. Potential species access

The potential species access metric assesses the presence of anadromous species habitat within a catchment in concert with the number of dams downstream from the catchment. Specifically, a catchment was assigned 10 points if it had anadromous species habitat within it, AND was on a stream network with no downstream dams between it and the ocean. In other words, it highlighted suitable habitats that anadromous species could easily access. The South Atlantic analysis used data from the Southeast Aquatic Connectivity Assessment Project (SEACAP, Martin et al. 2014). The North and Mid-Atlantic analyses were based on data from the Northeast Aquatic Connectivity project (Martin & Levine 2017).

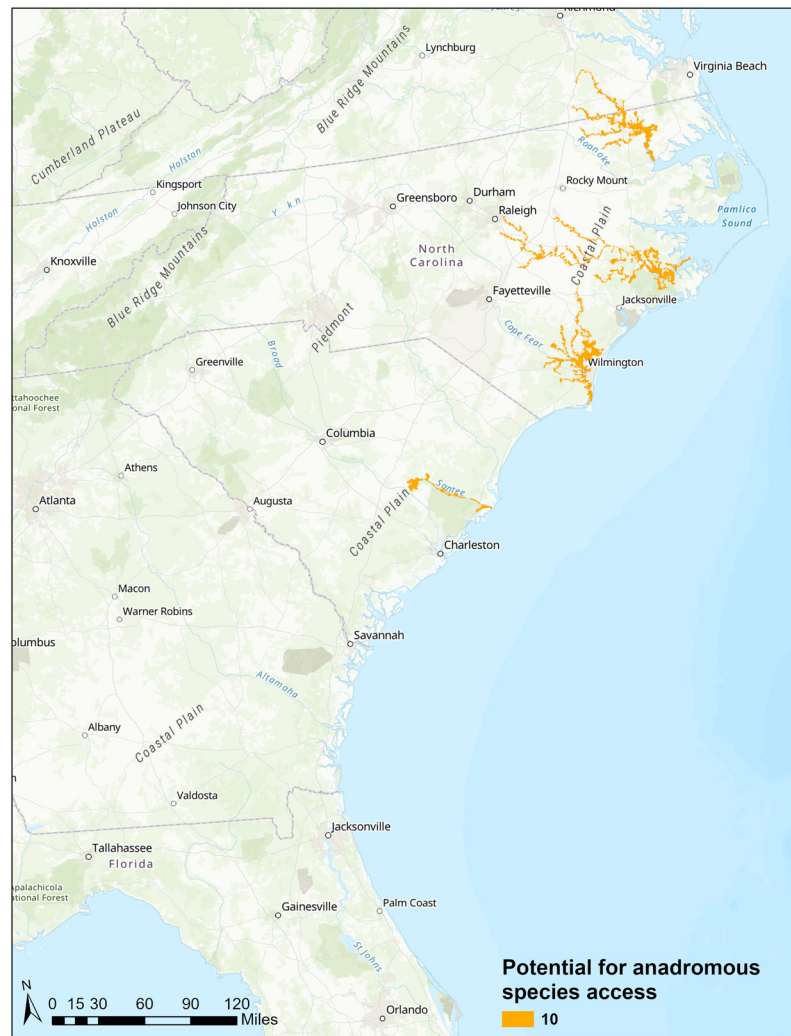


Figure 12. Catchments in the South Atlantic receiving 10 points for potential anadromous species access.

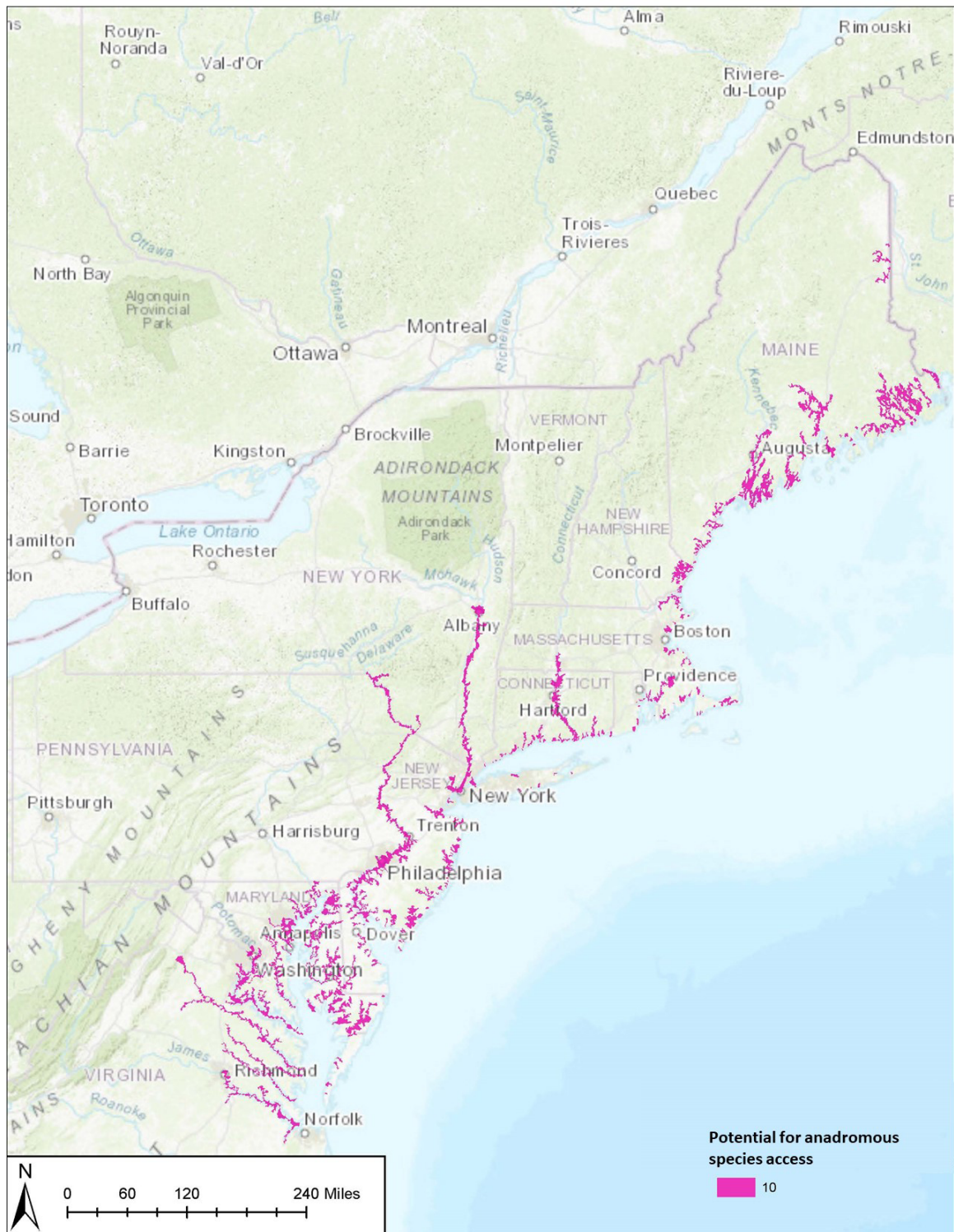


Figure 13. Catchments in the North and Mid-Atlantic receiving 10 points for potential anadromous species access.

vi. Flow alteration

The flow alteration metric assesses the potential for flow alteration upstream of each catchment. This metric was generated by taking the total volume from all reservoirs upstream of each catchment. It represents how much the waterway has been altered, and can serve as an indication of the potential for flooding if barriers were to fail. This metric was obtained directly from the EPA StreamCAT (Hill et al. 2016) data by joining the 'DamNIDStorWS' metric to the catchments using the 'COMID' attribute. A catchment was assigned 10 points if it was ranked in the lowest 25% of catchments for upstream storage volume. Note that all catchments with no upstream storage capacity are tied as having the lowest upstream storage, therefore the total number of catchments receiving 10 points for this metric can exceed 25% of the total number of catchments.

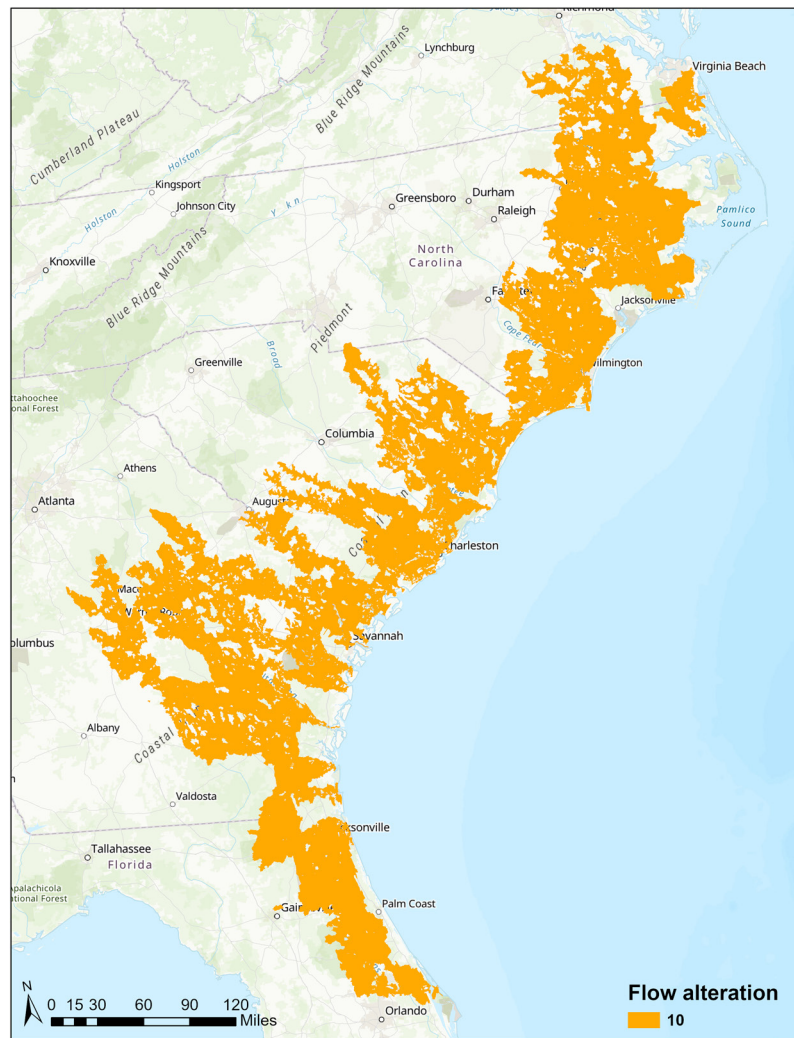


Figure 14. Catchments receiving 10 points for having the least flow alteration in the South Atlantic.

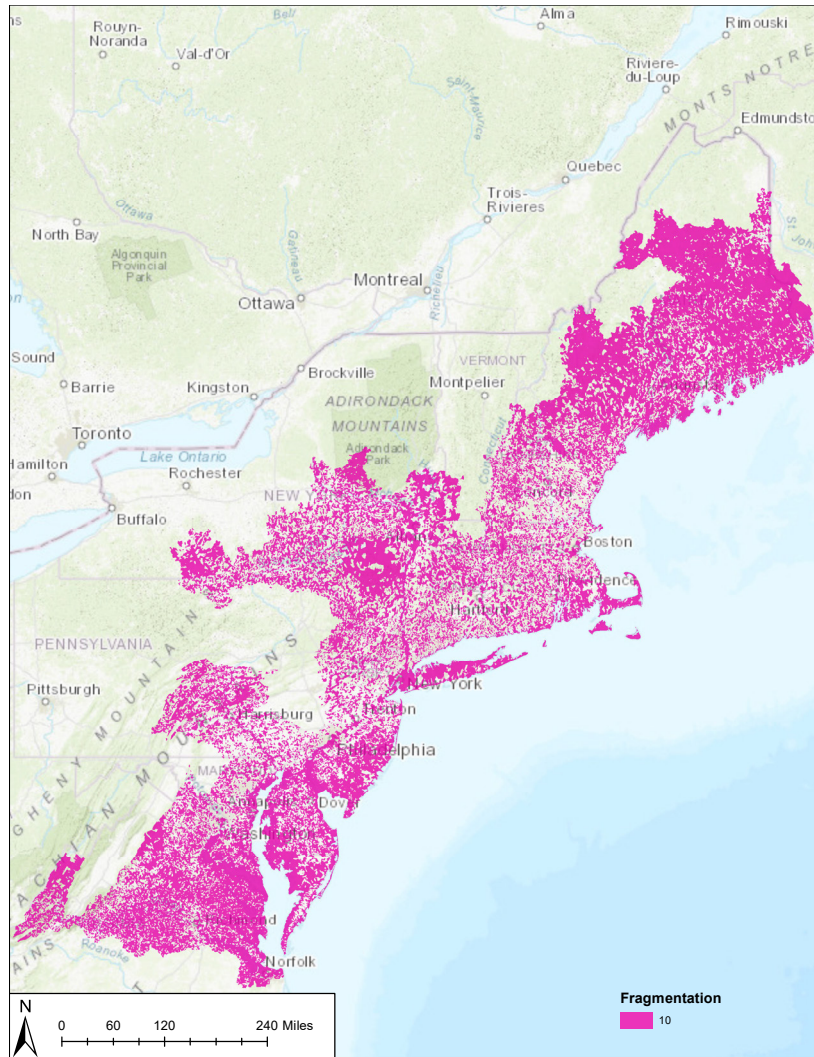


Figure 15. Catchments receiving 10 points for having the least flow alteration in the North and Mid-Atlantic. North Atlantic and Mid-Atlantic regions were calculated separately and merged back together to generate this map.

vii. Local fragmentation

The local fragmentation metric assesses the density of road-stream crossings (e.g. culverts) and dams (collectively “stream barriers”) in each catchment. Highly fragmented areas are much more difficult for fish to access. This metric was calculated as the total number of stream barriers in each catchment, divided by the area of the catchment. A catchment was assigned 10 points if it was ranked in the lowest 25% of catchments for density of these stream barriers. Note that all catchments with no stream barriers are tied as having the lowest density, therefore the total number of catchments receiving 10 points for this metric exceeds 25% of the total number of catchments. The SARP’s Southeast Aquatic Barrier Inventory was used to identify those higher resolution dams and road crossings within each catchment for the South Atlantic Diadromous Analysis. For the North and Mid-Atlantic Diadromous Analyses, data from Martin & Levine 2017 were used.

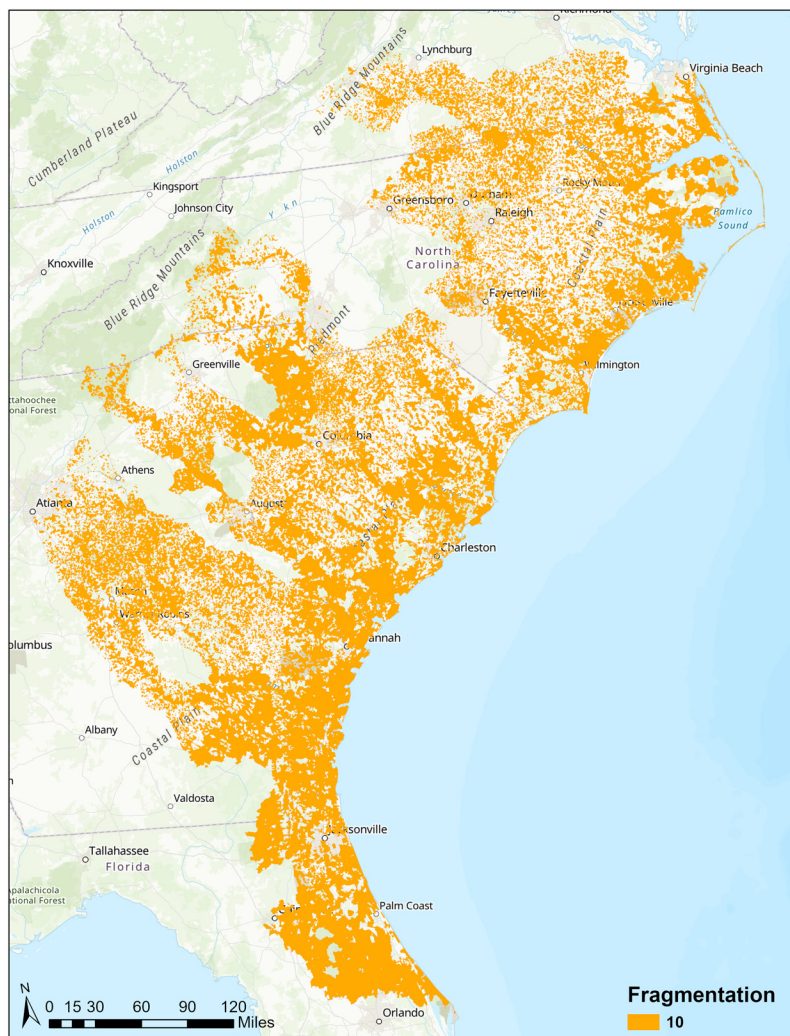


Figure 16. Catchments receiving 10 points for the least amount of fragmentation in the South Atlantic.

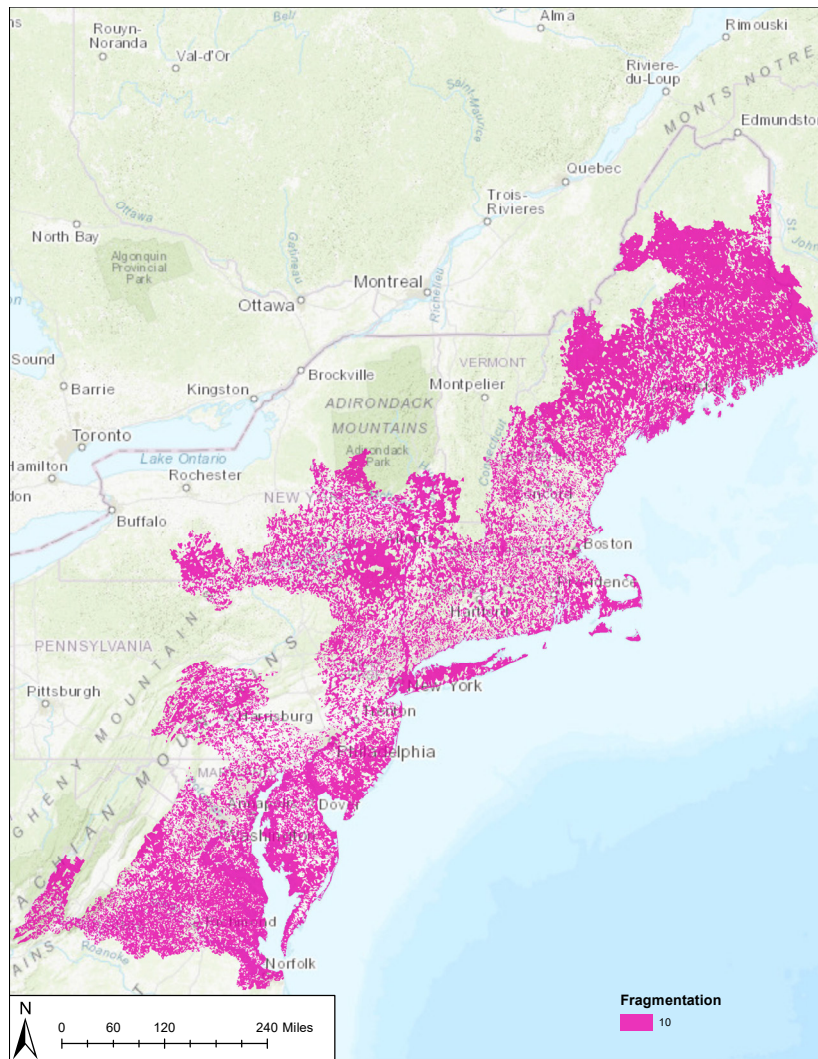


Figure 17. Catchments receiving 10 points for the least amount of fragmentation in the North and Mid-Atlantic. North Atlantic and Mid-Atlantic regions were calculated separately and merged back together to generate this map.

viii. ESA critical habitat

Catchments were evaluated for Endangered Species Act critical habitat since these areas are under Federal protection and are less likely to experience negative habitat impacts than comparable areas that aren't designated as critical habitats. Catchments that were located in areas designated as critical habitat for Atlantic salmon (by HUC10 watershed) or Atlantic sturgeon (by river reach) were assigned 10 points. Spatial data on critical habitats was obtained from the NOAA National Marine Fisheries Service (NOAA 2014 and 2017a).

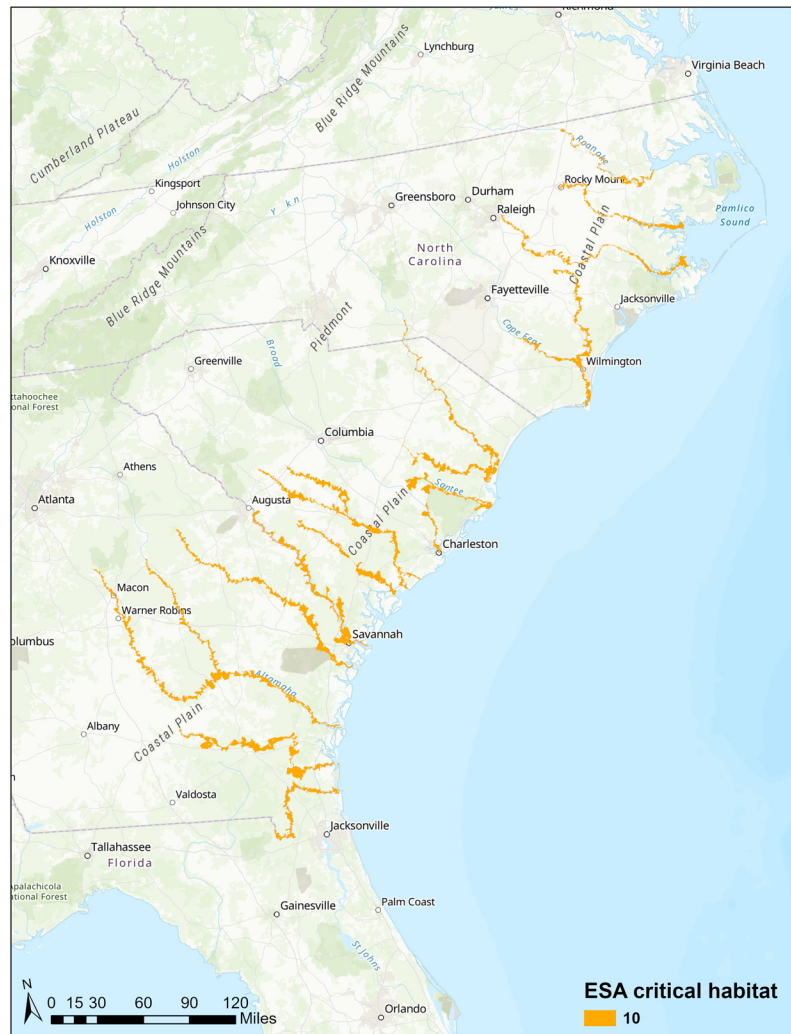


Figure 18. Catchments that have been designated as critical habitat for Atlantic sturgeon in the South Atlantic.

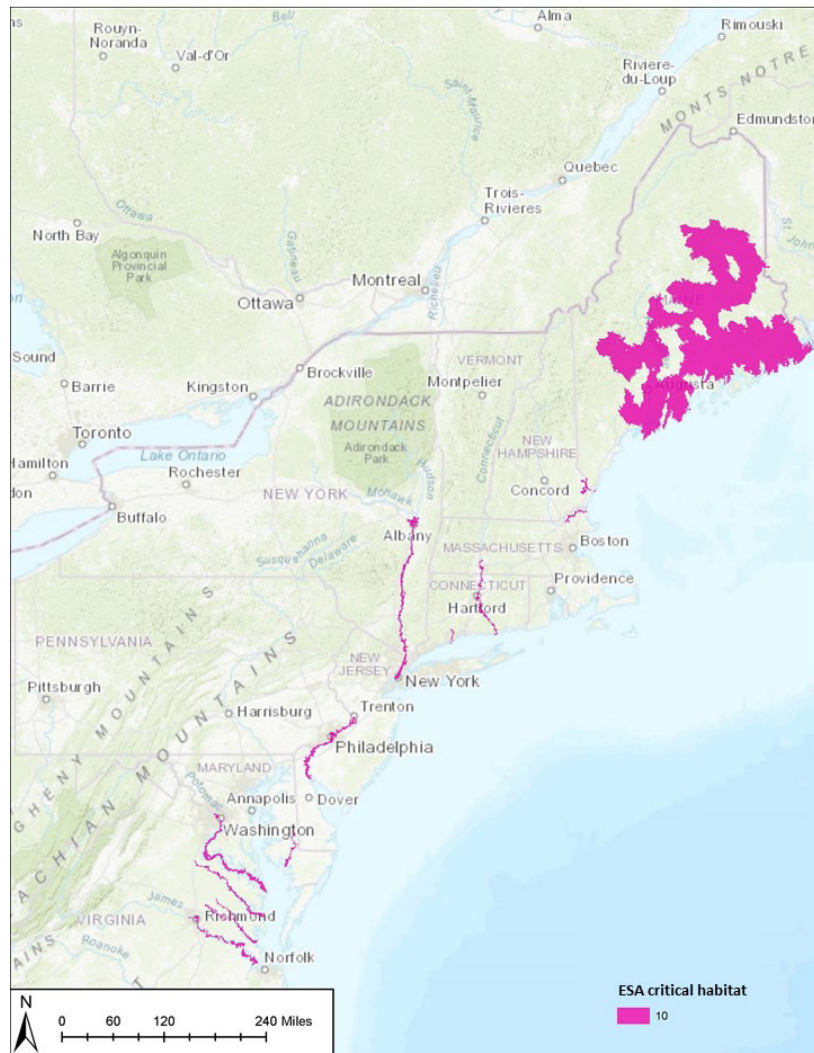


Figure 19. Catchments that have been designated as critical habitat for Atlantic salmon or Atlantic sturgeon in the North and Mid-Atlantic.

B. RESULTS

The eight component metrics were then summed for each catchment, producing a composite score with a maximum value of 80 (10 points for each of eight metrics), as depicted in Figures 20 and 21. See *Discussion* for advice on how to interpret and use the results of these analyses.

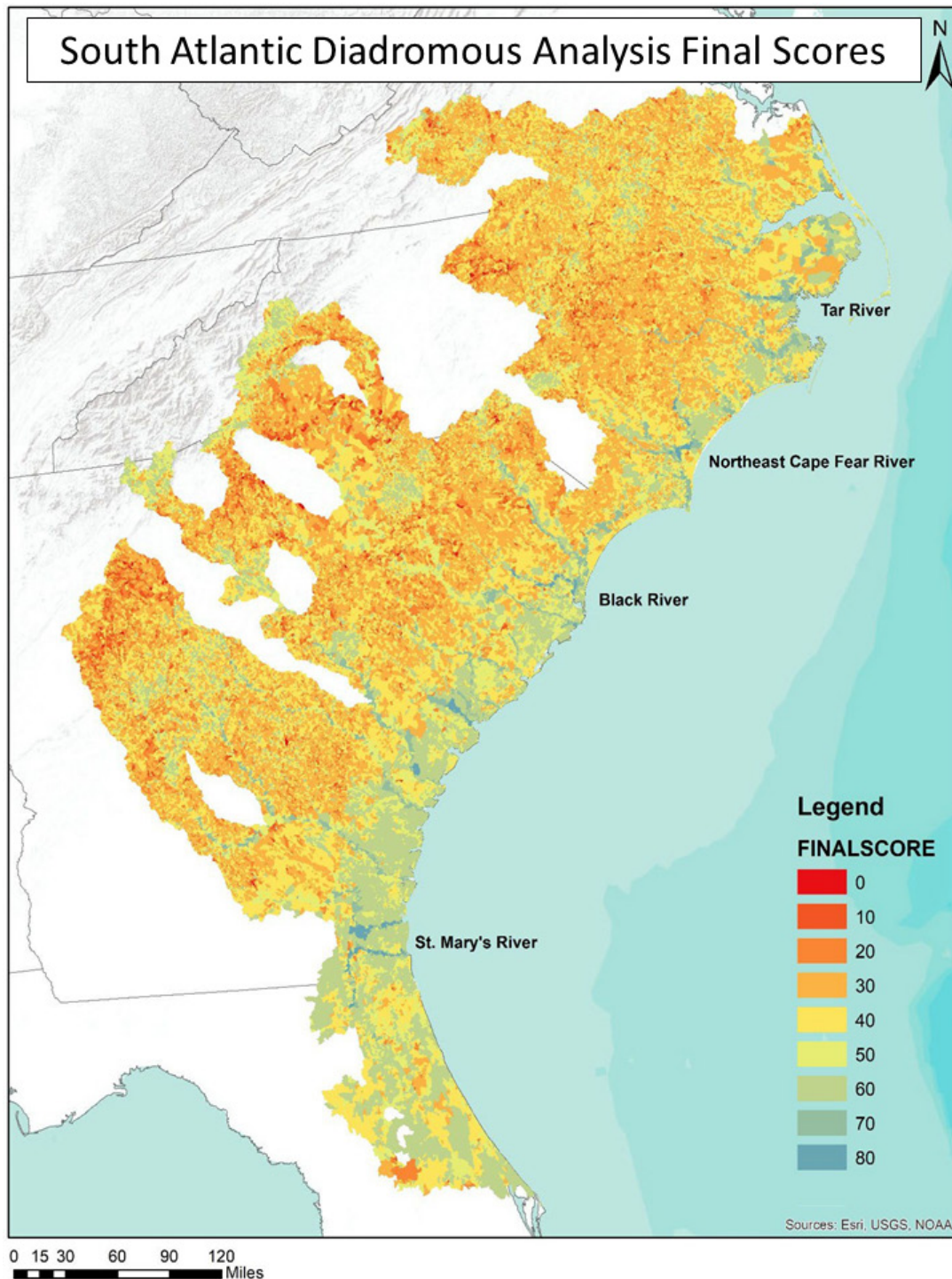


Figure 20. Results of the South Atlantic Diadromous Analysis. Higher scores (blue) are likely areas better suited for protection (Areas of Excellent Fish Habitat), whereas medium scores – those yellow or green, are likely better suited for restoration (Restoration Opportunity Areas). Locations with the highest scores are labelled.

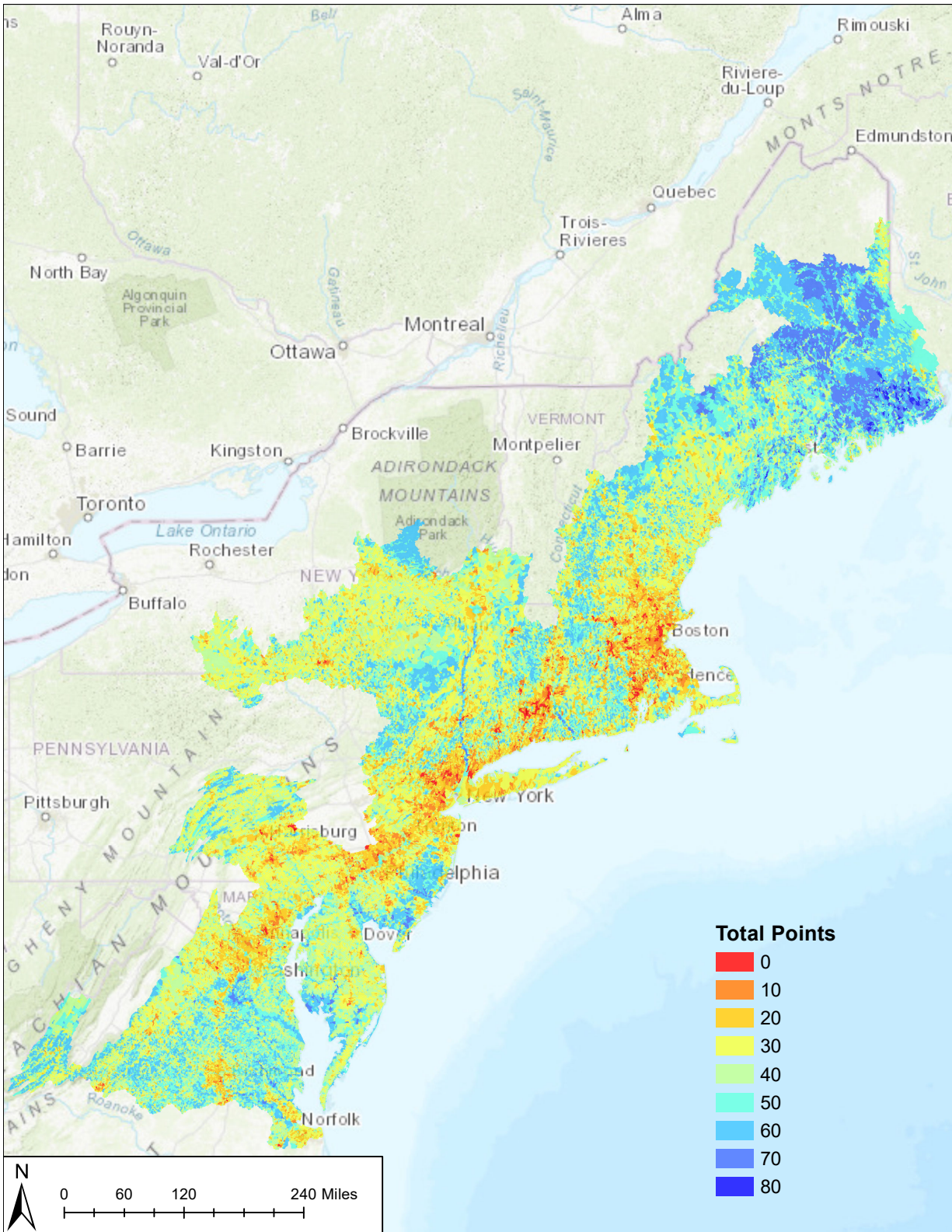


Figure 21. Results of the North and Mid-Atlantic Diadromous Analyses. Higher scores (blue) are likely areas better suited for protection (Areas of Excellent Fish Habitat), whereas medium scores – those yellow or green, are likely better suited for restoration (Restoration Opportunity Areas).

Results of the North and Mid-Atlantic Diadromous Analyses show that highly urbanized areas – especially the ‘Bo-Wash Corridor’ from Boston to Washington, DC – have some of the lowest scores, while undeveloped Northeastern Maine has some of the highest scores.

The results of the South Atlantic Diadromous Analysis show that larger mainstem rivers having little development, and often times protected lands, are best suited for conservation. One example of this is in the catchment titled ‘Northeast Cape Fear River’ (Figure 22). This stretch of river was listed as having five species downstream, and the top score for the South Atlantic Diadromous Analysis. The Angola Bay Game Land is also present within the catchment. However, not all of the catchment is protected, providing that restoration and protection opportunities are still possible in the area.

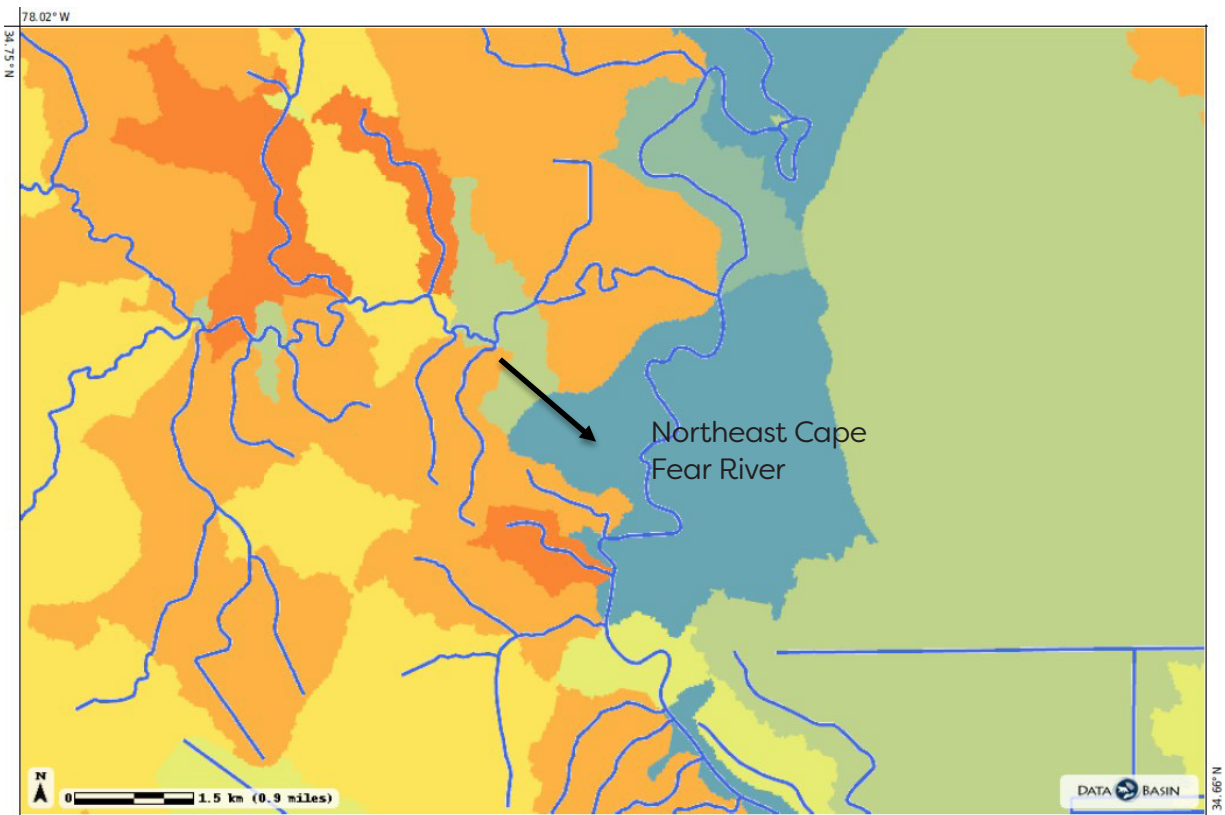


Figure 22. The Northeast Cape Fear River Catchment (black arrow in this figure and labeled in Figure 20) in North Carolina, scored as one of the highest priorities in the South Atlantic Diadromous Analysis. Part of the catchment is secured lands (Angola Bay Game Land), but not all.

4. ESTUARINE ANALYSES

The four estuarine analyses (North Atlantic, Mid-Atlantic, South Atlantic, and South Florida) used a grid of 1-km² hexagons as the unit of analysis. These were created using the 'create hexagon tessellation' tool within ArcGIS. The extent of the hexagons within the ACFHP study area was defined on the landward side by the NOAA Environmental Sensitivity Index (ESI) (NOAA 2017b) shoreline. On the seaward side in the South Atlantic and South Florida analyses, the extent of the hexagons is defined by the open water between shorelines (Figure 23). Most South Atlantic and South Florida waters have barrier island that serve as natural boundaries for the analysis. For Florida Bay, Biscayne Bay, and the Gulf of Mexico, hexagons that intersected polygons with these names within the North American Water Dataset (Esri) were selected. In the North and Mid-Atlantic, there are less natural boundaries in the form of barrier islands, so depth contours were selected as cutoffs for the seaward extent of the analyses. The 60' depth contour (Figure 24 left) was used for the North Atlantic, and the 35' depth contour (Figure 24 right) was used for the Mid-Atlantic. The depths were selected based on the deepest extent of habitat-building shellfish in those subregions: blue mussel in the North Atlantic and Eastern oyster in the Mid-Atlantic. Depth contours were obtained from NOAA's National Centers for Environmental Information (NCEI) (NOAA 2015). Hexagons falling between the NOAA ESI shoreline and the relevant depth contour were selected for inclusion in the analyses. A hexagon was selected for inclusion even if only a portion of it falls within the relevant depth range. The full extent of the hexagons used in the North and Mid-Atlantic Estuarine Analyses is depicted in Figure 25. Similar to the diadromous analyses, a series of metrics were generated for each of the hexagons in the analysis.

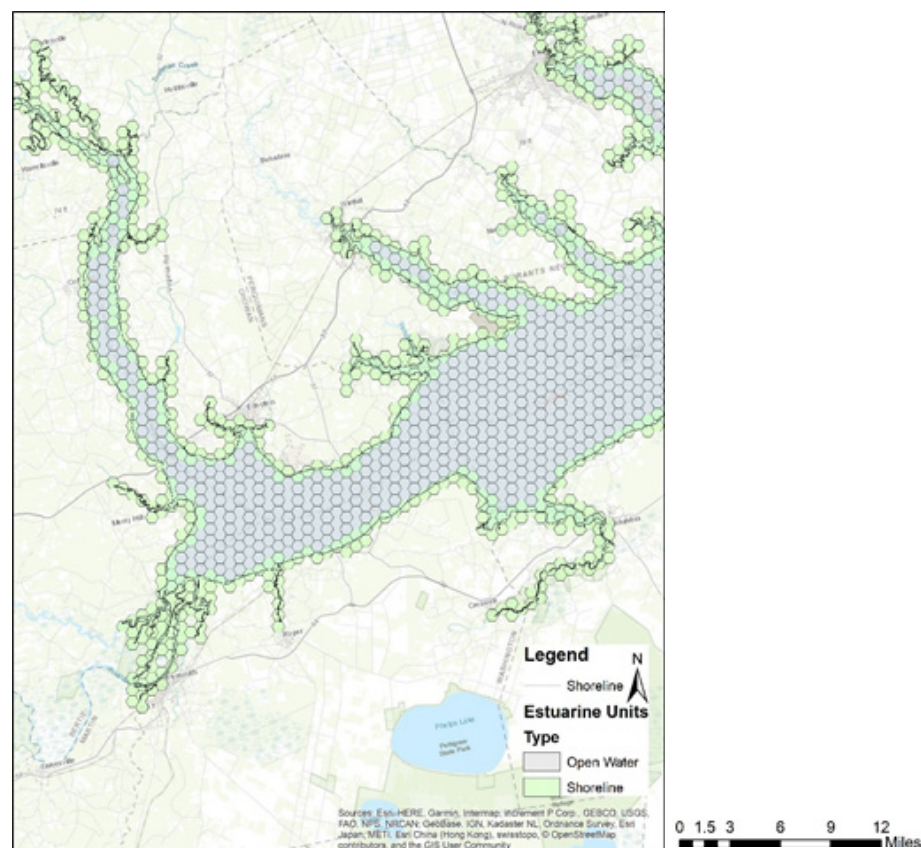


Figure 23. Hexagons generated for the estuarine analysis. Green represents those that intersect the NOAA ESI, and gray is open water. Both were included in the South Atlantic and South Florida Estuarine Analyses.

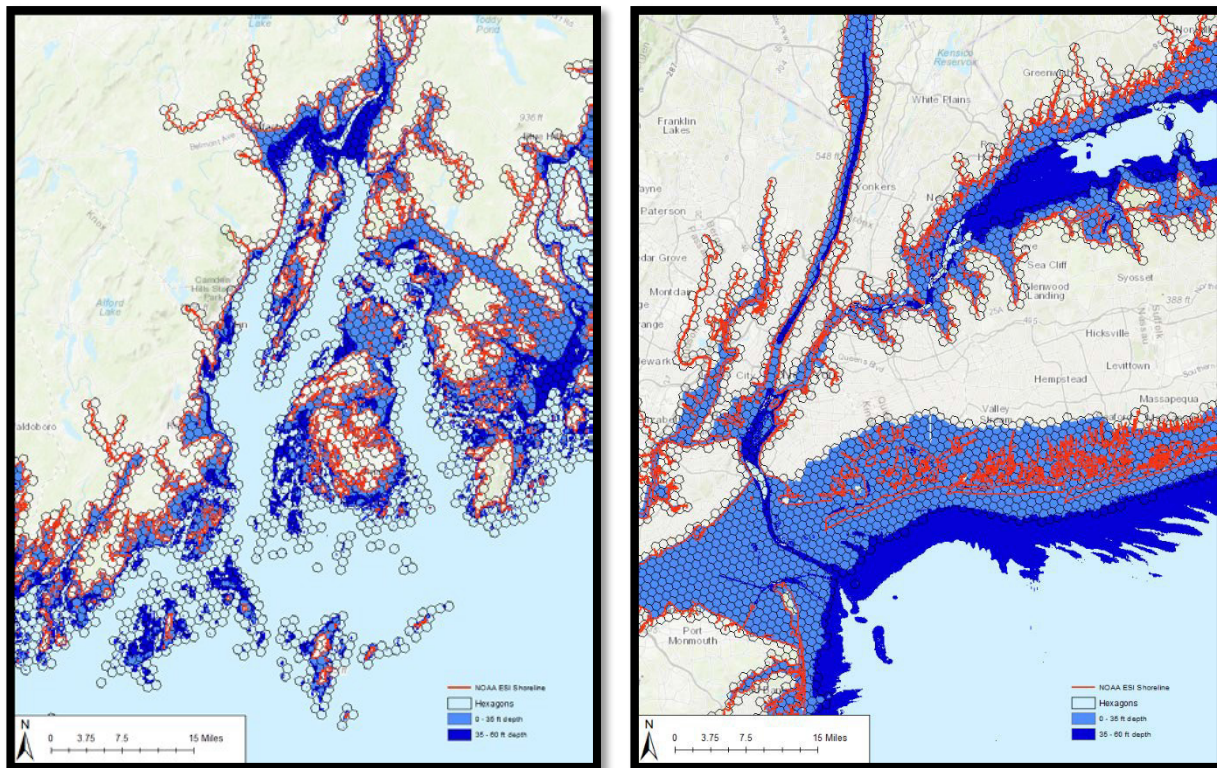


Figure 24. Examples of landward and seaward extent of the estuarine analysis hexagons in the North Atlantic (left) and Mid-Atlantic (right).

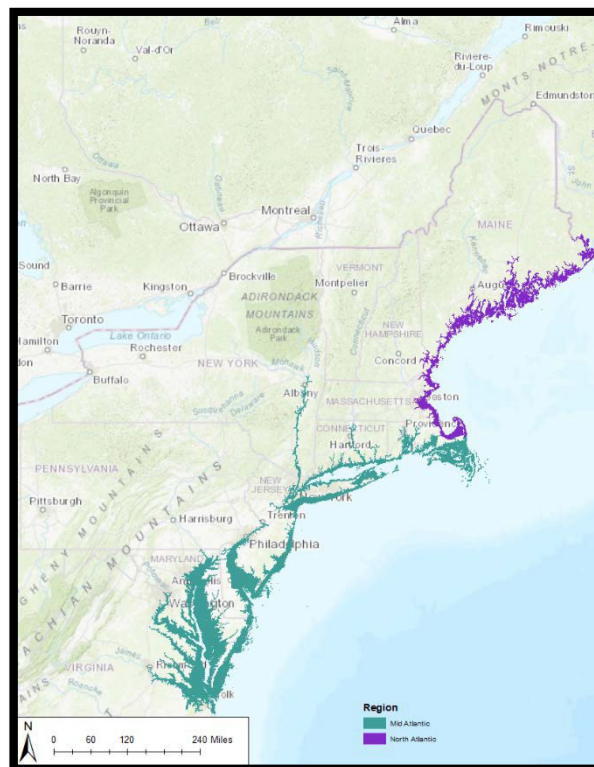


Figure 25. The full extent of the North and Mid-Atlantic Estuarine Analyses.

A. METRICS

The eight metrics that were generated for each hexagon are summarized in Table 5 and described in more detail in the subsections below. As with the diadromous analyses, all metrics were generated using custom Python scripts primarily using the ArcGIS (version 10.3.1) arcpy package for the Northeast, and model builder for the Southeast. The metrics for the South Atlantic and South Florida were selected to describe a wide range of indicators without being redundant. In order for a metric to be included in the analysis, it had to cover the entire geographic range of the analysis. For the North and Mid-Atlantic analyses, metrics were largely selected based on the work previously done in the Southeast project, to mimic as closely as possible the work that had previously performed in that geography. All metrics and final results were reviewed and approved by the Science and Data and Steering Committees.

Table 5. Variables, measurements, and metrics for the Estuarine Analyses.

Variable	Measurement	Metric
Seagrass and oyster reef habitat	% of polygon covered by w or oyster reef	10 points if the polygon ranks in the top 25% for coverage
Wetland habitat	% of polygon covered by wetlands	10 points if the polygon ranks in the top 25% for coverage
Water-vegetation edge ⁺	Length of estuarine-marsh-water edge in the polygon	10 points if the polygon ranks in the top 25% for length
Proximity to protected habitat*	Distance to a protected area	10 points if the polygon is within 1/2 km of a protected area
Proximity to development	Distance from marinas and ports	10 points for the 25% of polygons farthest from marinas and ports
Water quality*	303(d) sites	10 points for the 25% of polygons least associated with 303(d) sites
Hardened shoreline	Length of hardened shoreline within the polygon	10 points for the 25% of polygons with the least amount of hardened shoreline
Habitat fragmentation	Linear ft. of causeway within a polygon	10 points if the polygon has 0 ft. of causeways

⁺This metric was not included in the South Florida Estuarine Analysis

^{*}The metric for the Northeast Project (North and Mid-Atlantic analyses) is different than the Southeast Project (South Atlantic and South Florida analyses). Details can be found below.

i. Seagrass and oyster reef habitat

The percent of each hexagon that is covered by submerged aquatic vegetation (SAV) or oyster beds was calculated. Both SAV and oyster reefs are priority habitats in all (SAV) or most (oyster reefs in the North, Mid-, and South Atlantic) ACFHP subregions, and are used by fish as habitat along the entire coast. Data pertaining to the locations of seagrass and oyster reef habitat in the South Atlantic and South Florida were obtained from TNC's South Atlantic Bight Marine Assessment (SABMA). SAV data for the North and Mid-Atlantic analyses were obtained from The Nature Conservancy's Eastern Conservation Science team (Ribera 2019) and represent a compilation of state-level data. Oyster data for the North and Mid-Atlantic were compiled from multiple sources including the Chesapeake Bay Coastal and Marine Ecological Classification Standard (CMECS) (NOAA 2013), Delaware Bay Benthic Mapping Project (DNREC et al. 2010), Connecticut Departments of Agriculture and Energy and Environmental Protection (2019), Northeast Regional Ocean Council (NROC 2019) including both oysters and blue mussels, Rutgers (2019) and VOSARA (2019). For the North and Mid-Atlantic, the oyster data were merged into a single layer. For all analyses, the oyster data were then merged with the SAV data and the resulting data layer "flattened" to eliminate double counting of overlapping datasets. Next the

percent of each hexagon that intersected the merged layer was calculated for each hexagon. Ten points were assigned to the hexagon if it ranked in the top 25% for SAV/oyster coverage; all other hexagons received zero points.

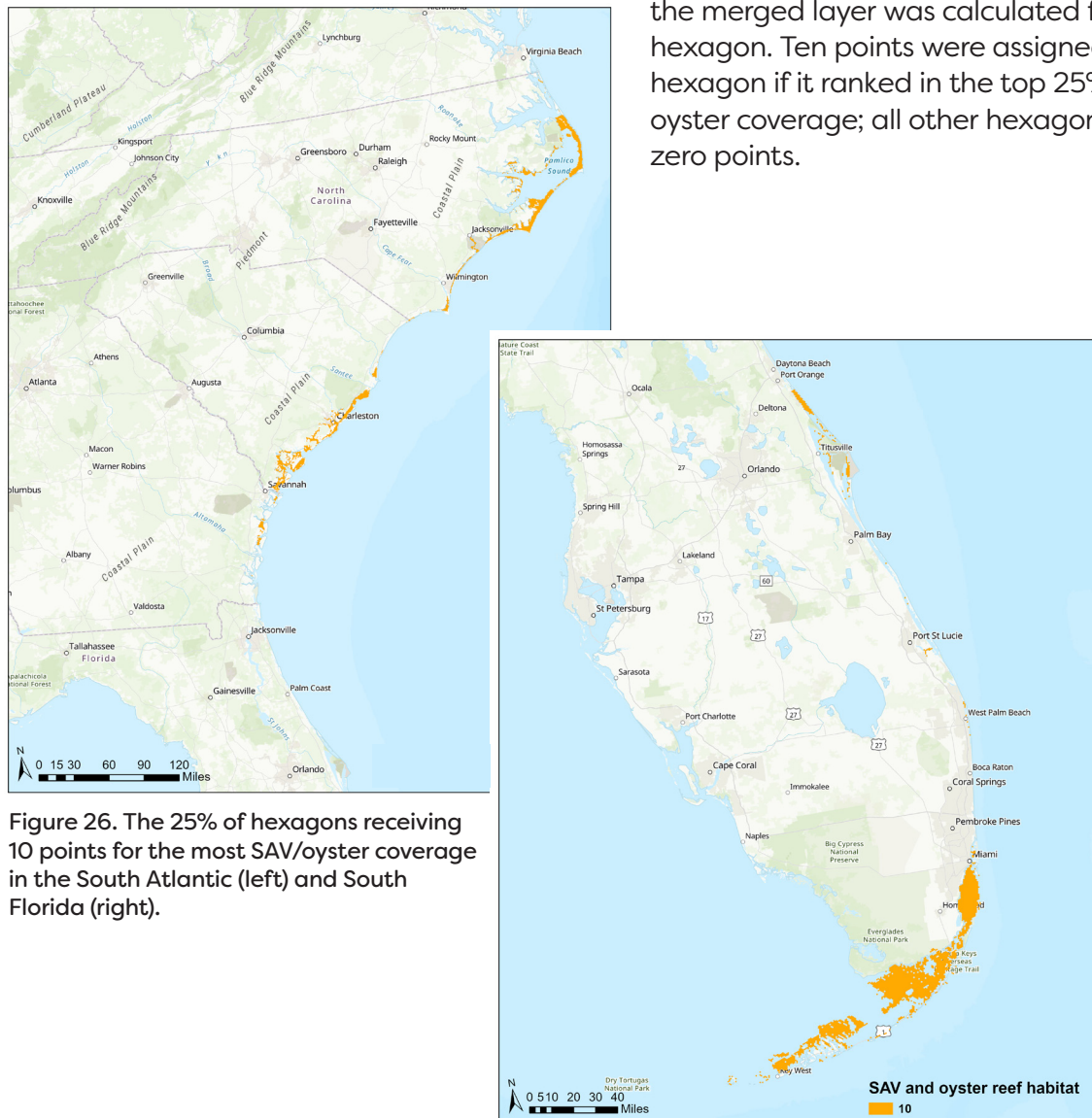


Figure 26. The 25% of hexagons receiving 10 points for the most SAV/oyster coverage in the South Atlantic (left) and South Florida (right).

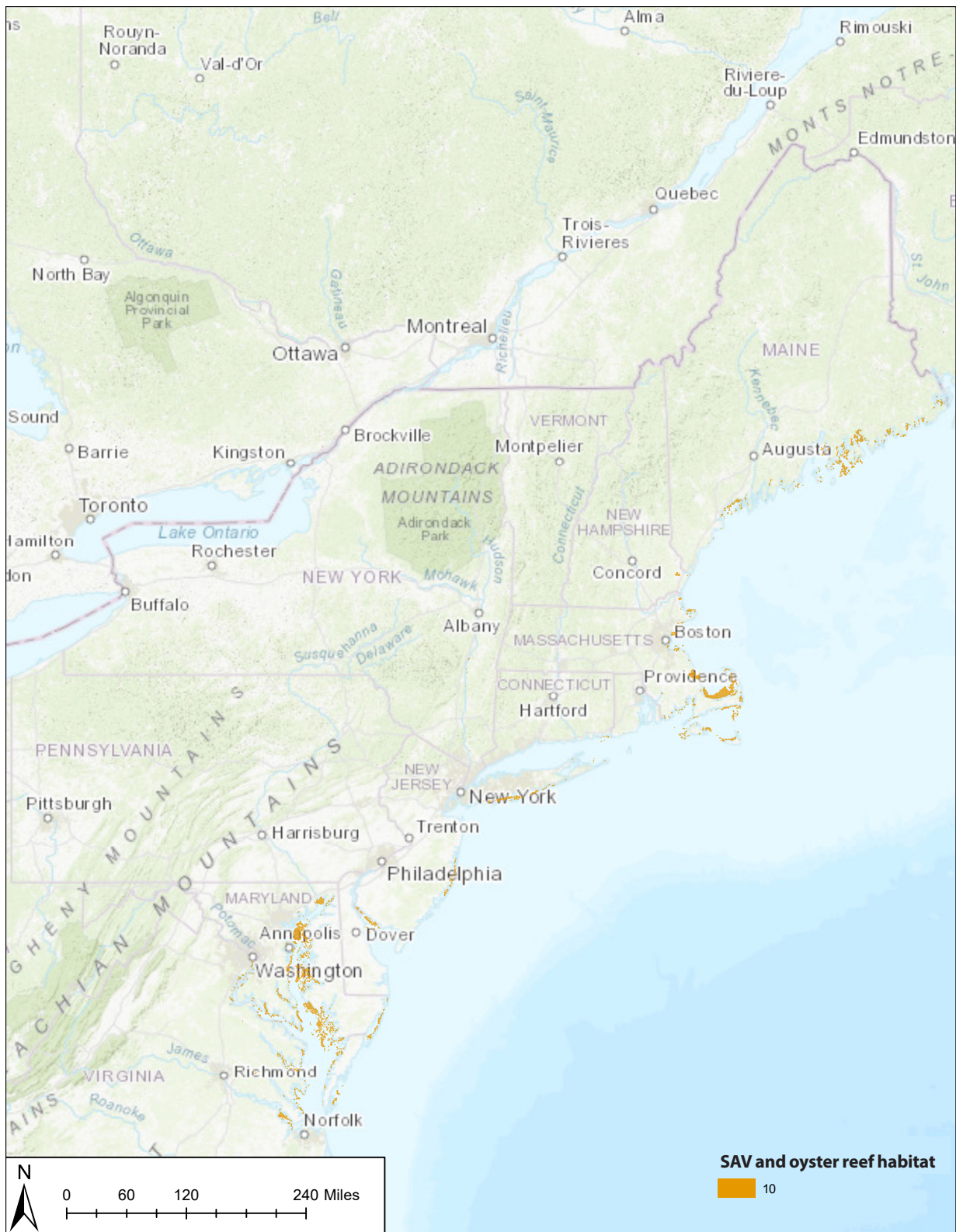


Figure 27. The 25% of hexagons receiving 10 points for the most SAV/oyster coverage in the North and Mid-Atlantic. This metric was calculated separately for the Mid-Atlantic and North Atlantic subregions, and merged together to create this map.

ii. Wetland habitat

Wetland habitat (tidal vegetation) is a priority habitat in ACFHP's Mid- and South Atlantic and South Florida subregions, and serves as fish habitat along the entire coast. The percent of each hexagon covered by estuarine wetlands was calculated using the National Wetlands Inventory (NWI) (USFWS 2018). Estuarine intertidal wetlands were identified using the 'NWI ATTRIBUTE' field, where 'ATTRIBUTE' Like 'E2%.' Ten points were assigned to the hexagon if it ranked in the top 25% for estuarine wetlands.



Figure 28. The 25% of hexagons receiving 10 points for the most wetland coverage in the South Atlantic (left) and South Florida (right).

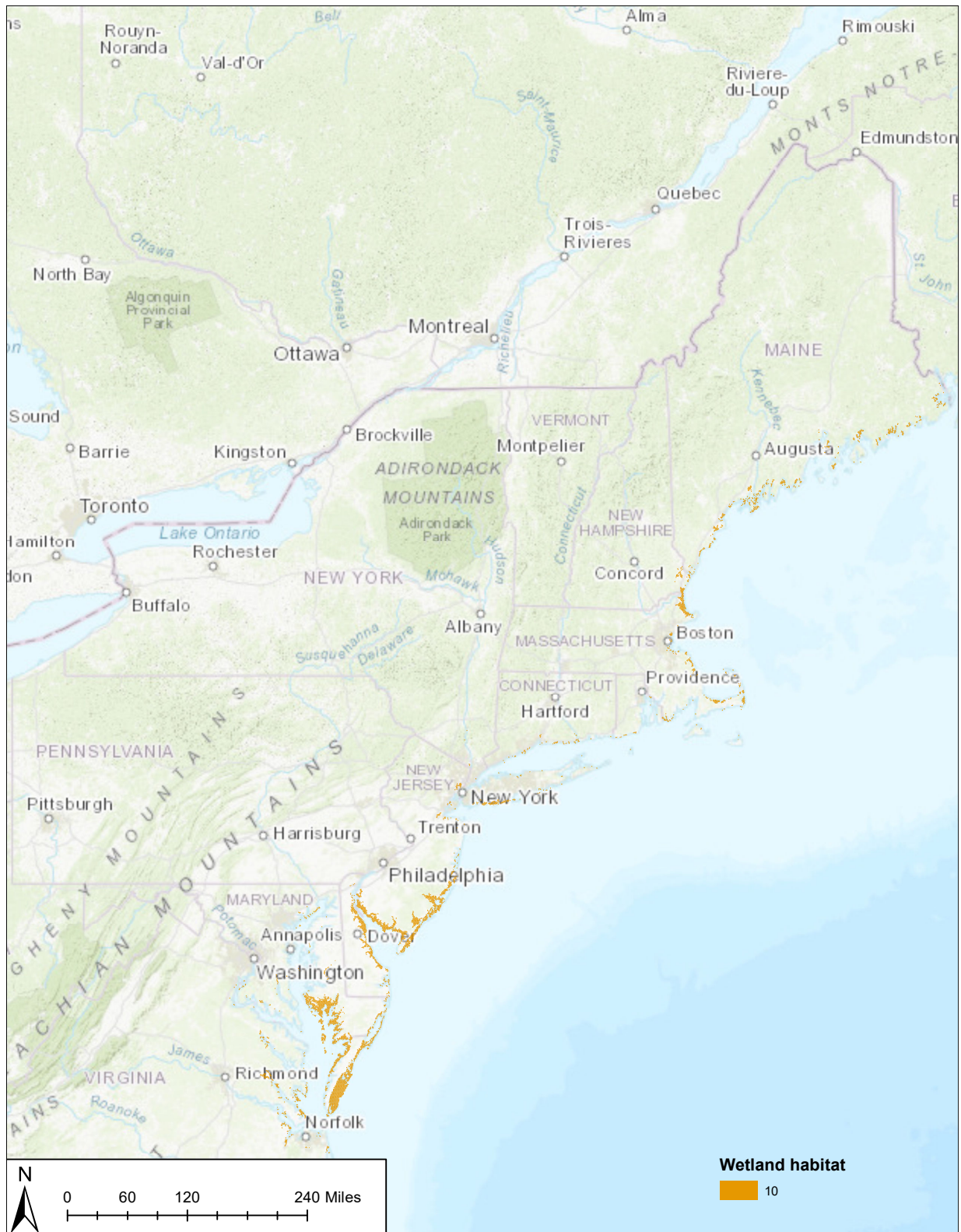


Figure 29. The 25% of hexagons receiving 10 points for the most wetland coverage in the North and Mid-Atlantic. This metric was calculated separately for the Mid-Atlantic and North Atlantic subregions, and merged together to create this map.

iii. Water-vegetation edge

Wetland edges are excellent sources of habitat for fishes, so this metric was included in the analysis as another way of quantifying habitat availability. For the South Atlantic analysis, data were obtained from the South Atlantic Landscape Conservation Cooperative (SALCC). This analysis was performed by the SALCC to identify the length of the water's edge that intersects wetlands. The data were in raster format, with a rating of 1:4 for each 30 x 30 m² cell representing the length of marsh. To use these data in the analysis, the average score for each hexagon was calculated using the 'zonal statistics as table' tool and the hexagons as zones. For the North and Mid-Atlantic analyses, the estuarine wetlands identified for the wetland habitat metric were also used to develop a metric which assessed the amount of wetland edge habitat which provides shelter and nursery habitat for juvenile fish and other biota. The estuarine wetland polygons were dissolved to remove internal boundaries then the perimeter of the dissolved wetland polygons was assessed for each hexagon. For all three analyses, 10 points were assigned to the hexagon if it ranked in the top 25% for estuarine wetland edge length. This metric was not included in the South Florida analysis because the SALCC does not extend into peninsular Florida, and the alternative way of calculating the metric was developed when carrying out the Northeast Mapping Project.

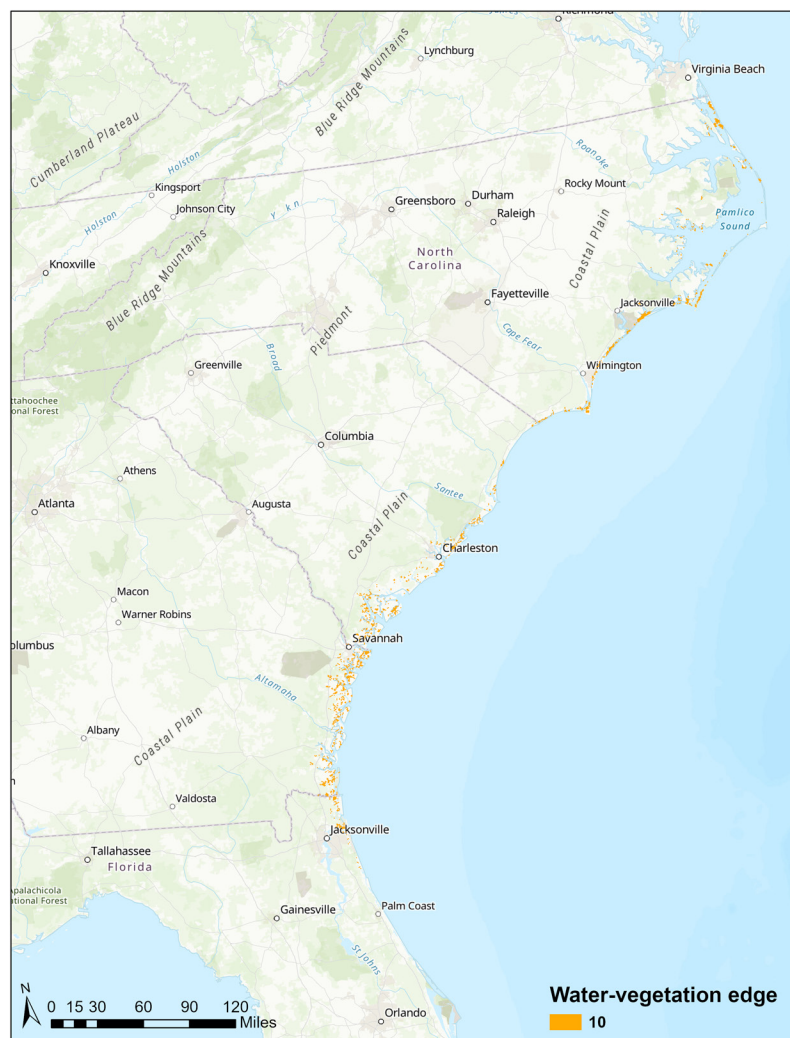


Figure 30. The 25% of hexagons receiving 10 points for the most water-vegetation edge in the South Atlantic.

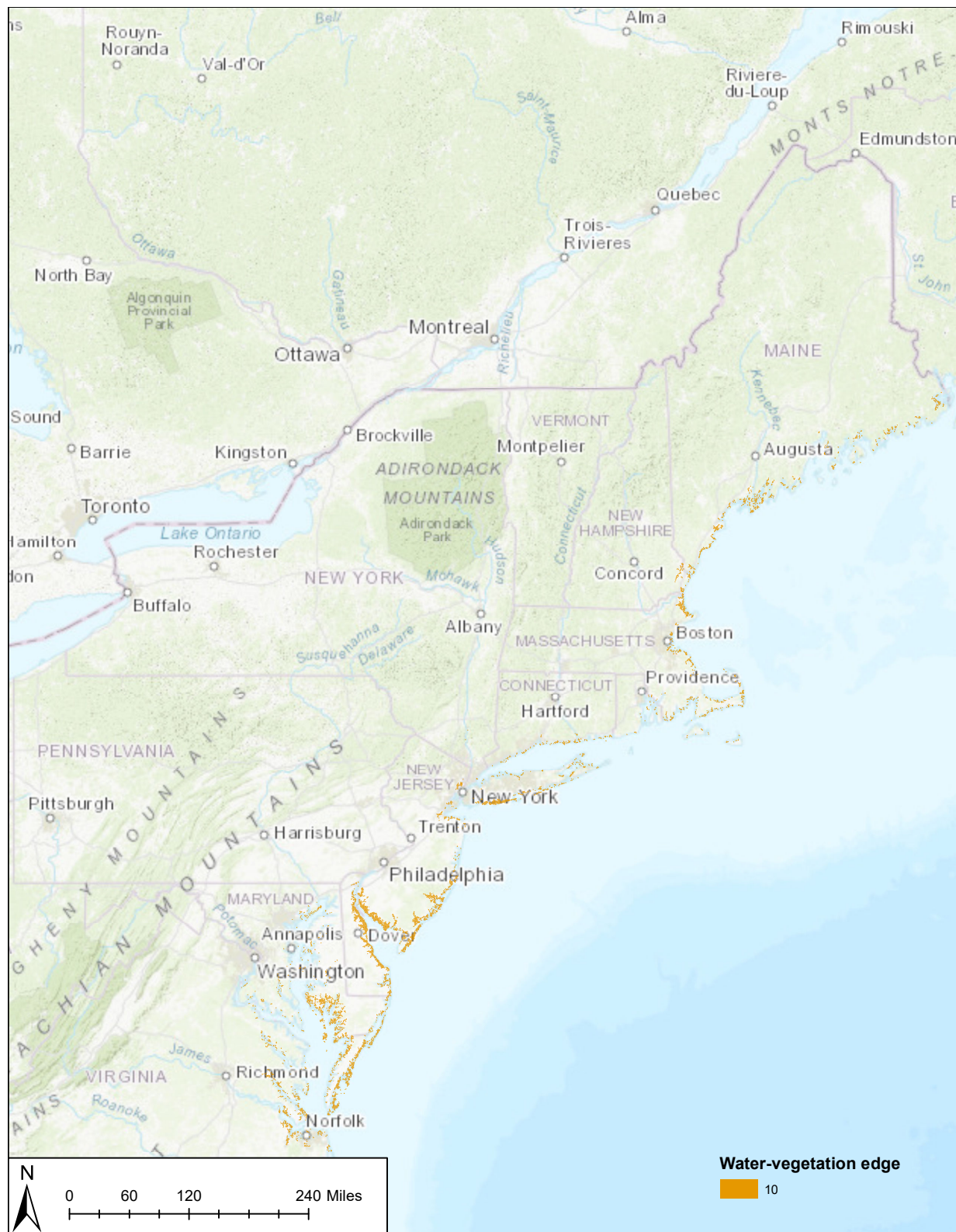
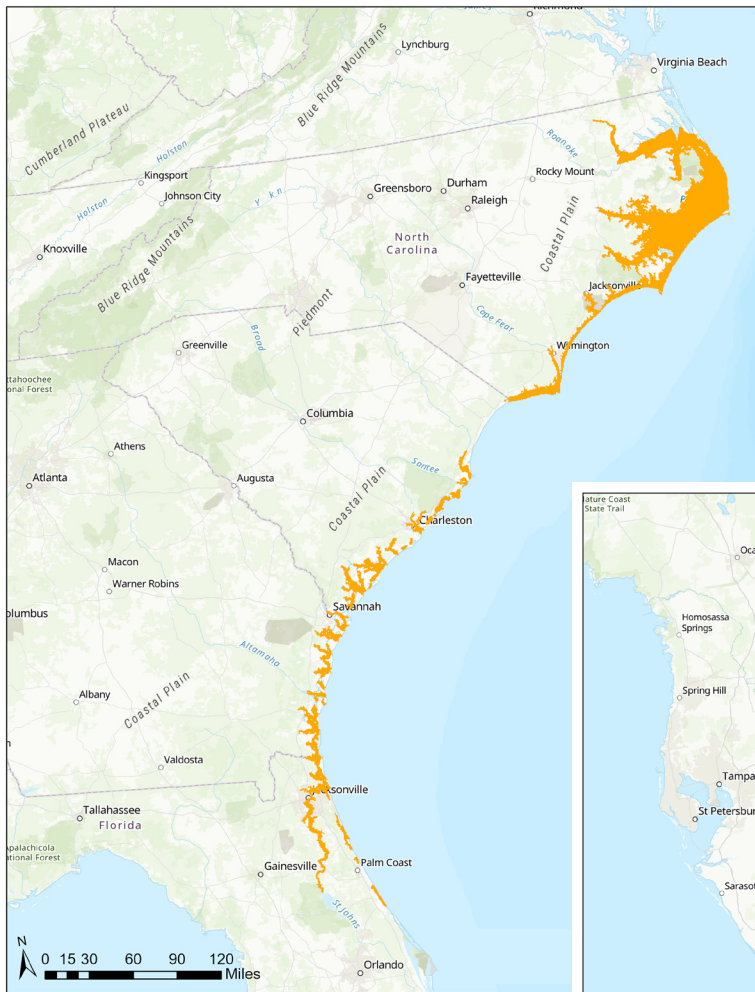


Figure 31. The 25% of hexagons receiving 10 points for the most water-vegetation edge in the North and Mid-Atlantic. This metric was calculated separately for the Mid-Atlantic and North Atlantic subregions, and merged together to create this map.

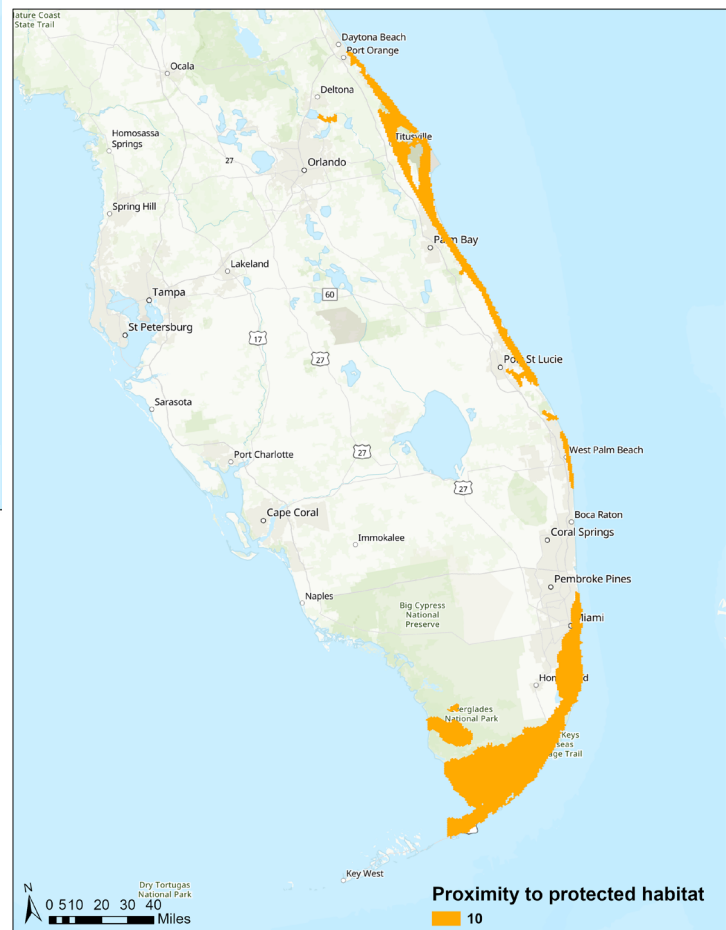
iv. Proximity to protected habitat

Each hexagon was assessed for its distance from the nearest protected area to serve as an indication of how likely a location would be developed or altered in the future. Protected habitat for the South Atlantic and South Florida analyses were designated by using the Habitat Areas of Particular Concern (HAPC) dataset obtained from the NOAA Marine Cadastre. A planar distance from each hexagon to an HAPC was calculated using the 'near' tool in ArcGIS. It is important to note that for this variable, the majority of estuaries are considered to be inlet HAPCs in the Southeast, so very few hexagons were outside of these boundaries. All hexagons within ½ km of an HAPC were given 10 points, and all others were given zero points.



For the North and Mid-Atlantic analyses, this metric was based on secured lands data from the Protected Areas Database (PAD-US) (USGS 2018). The PAD-US data was filtered so that only protected areas with a GAP status of 1, 2, or 3 were included. Ten points were then assigned to a hexagon if it was within ½ km of these protected areas, and all other hexagons received zero points.

Figure 32. Hexagons receiving 10 points for being located within 1/2 km of a protected area in the South Atlantic (left) and South Florida (right).



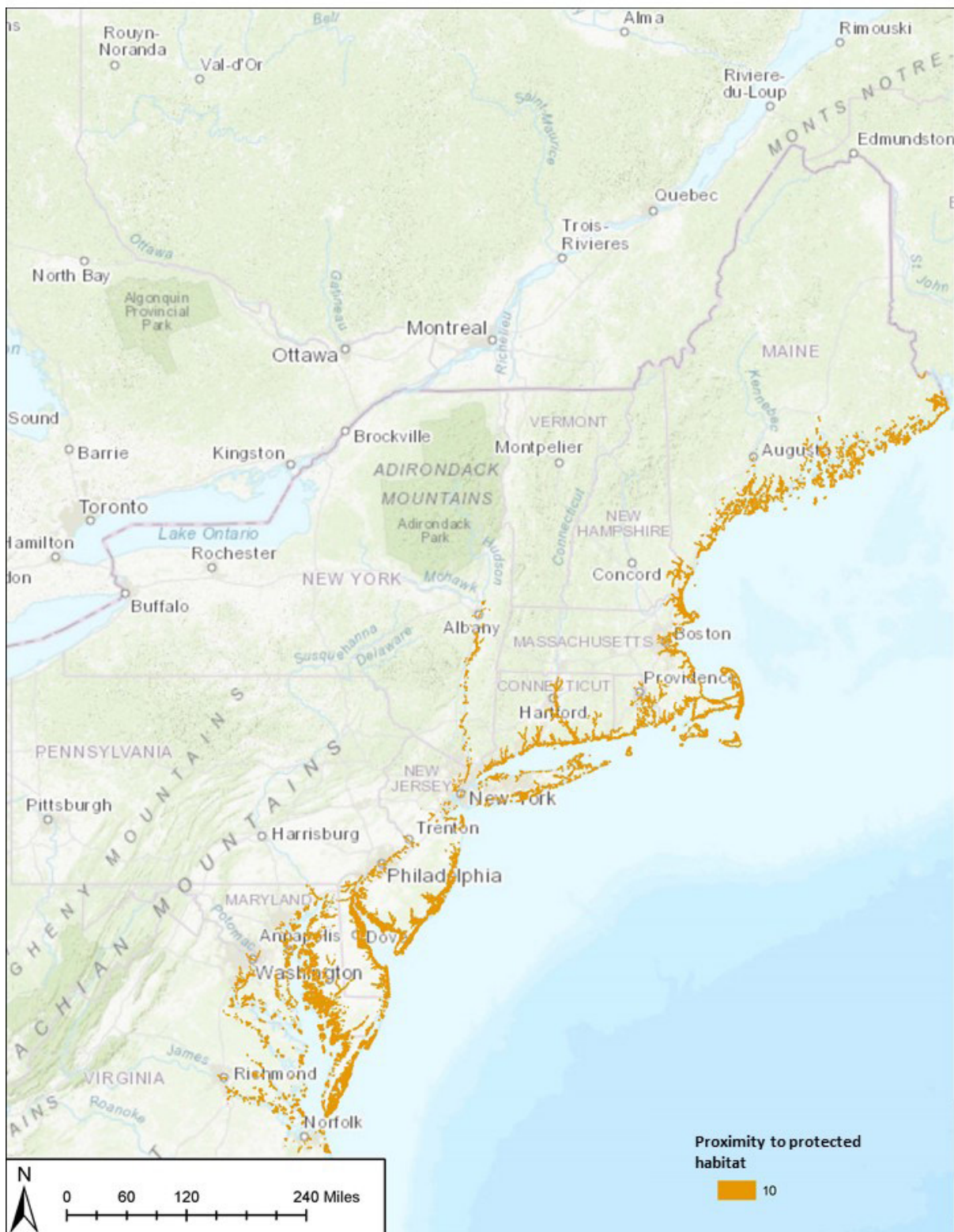
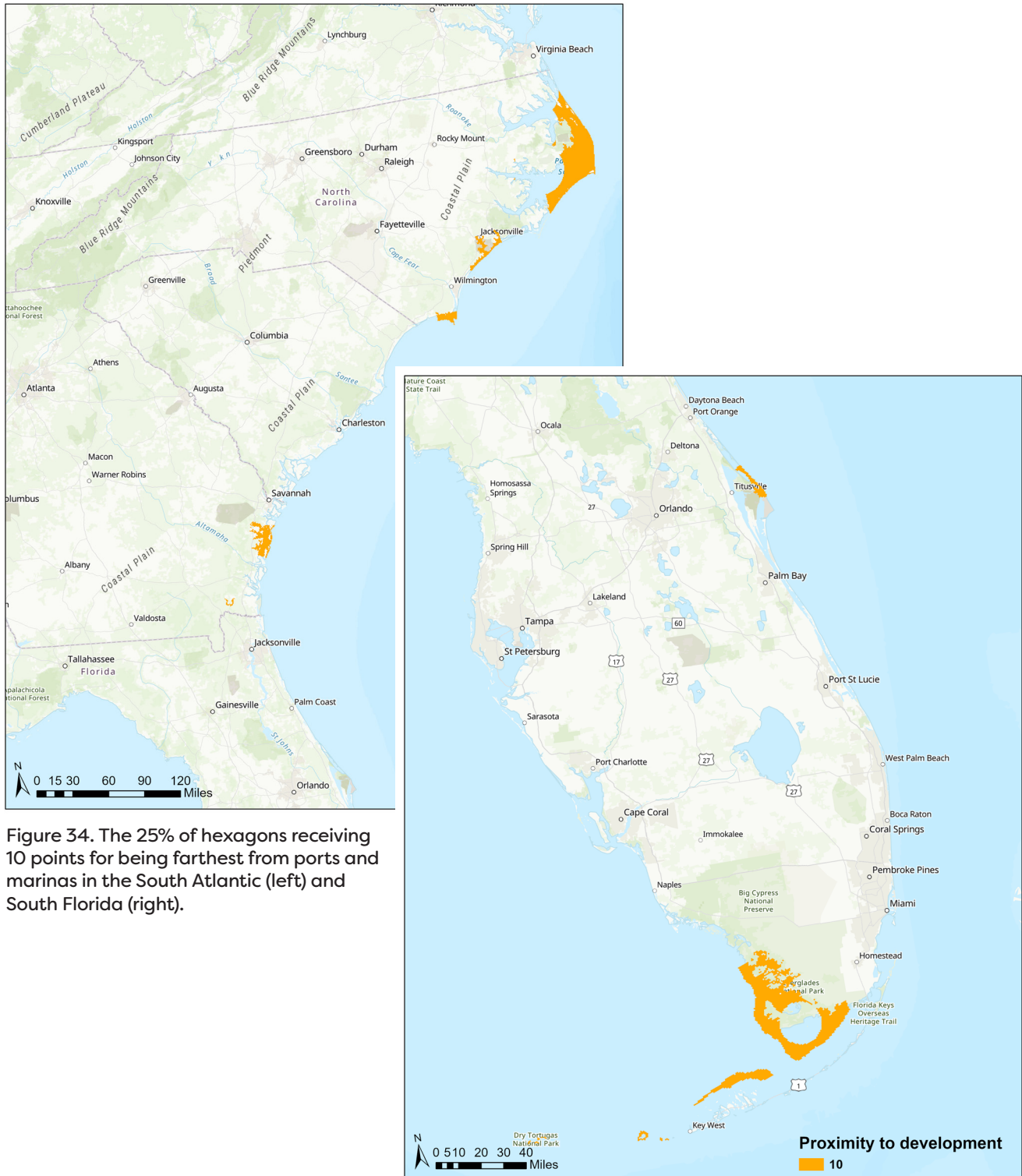


Figure 33. Hexagons receiving 10 points for being located within 1/2 km of a protected area in the North and Mid-Atlantic. This metric was calculated separately for the Mid-Atlantic and North Atlantic subregions, and merged together to create this map.

v. Proximity to development

Hexagons were assessed for their proximity to development, as measured by distance to the nearest ports/marinas. Ports/marinas were obtained from the TNC SABMA and supplemented with state data where available for the South Atlantic and South Florida. For the North and Mid-Atlantic analyses, DOT (2019) ports data were used. Ten points were assigned to the hexagons that were among the 25% of hexagons farthest from marinas and ports, all other hexagons received zero points.



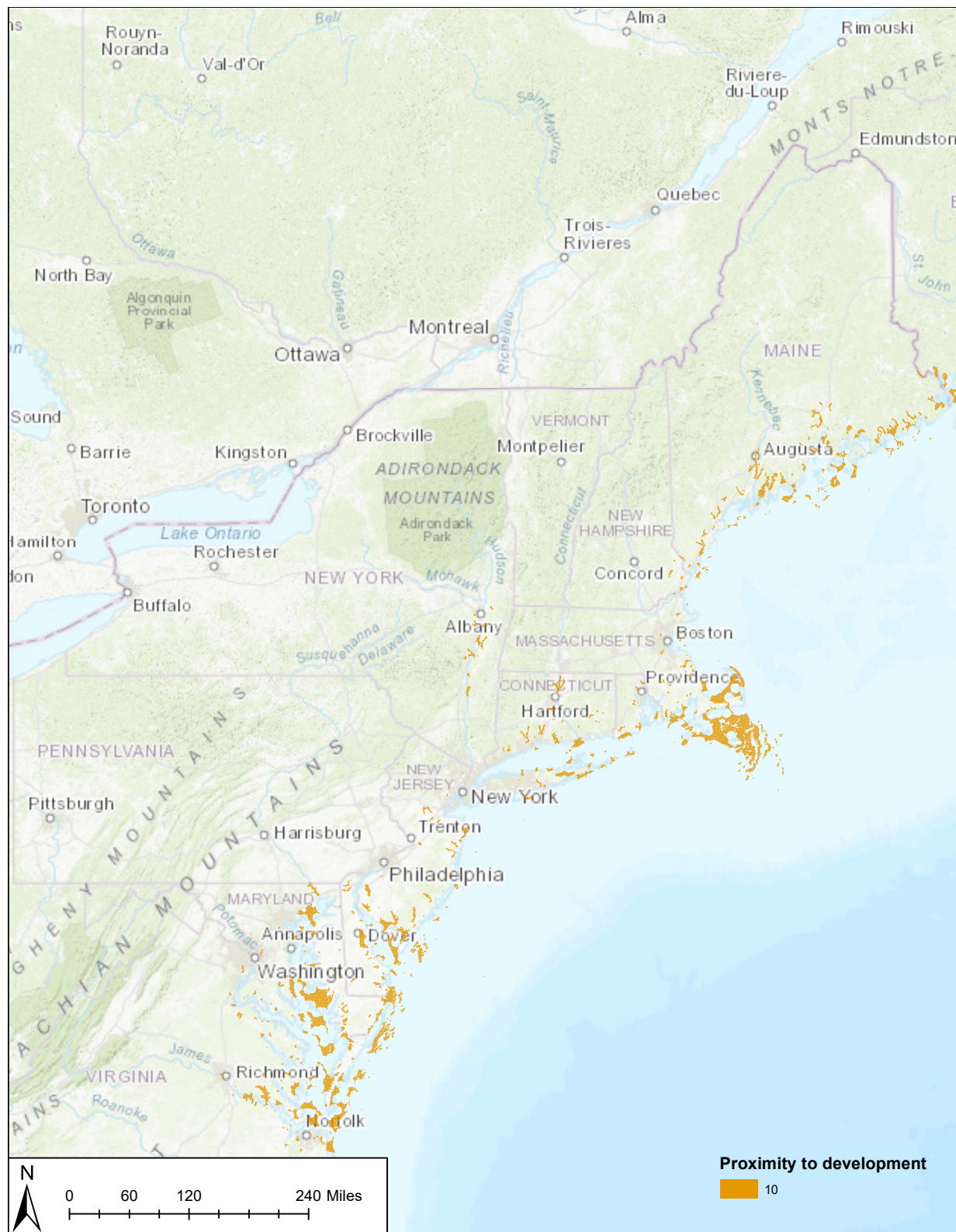


Figure 35. The 25% of hexagons receiving 10 points for being farthest from ports and marinas in the North and Mid-Atlantic. This metric was calculated separately for the Mid-Atlantic and North Atlantic subregions, and merged together to create this map.

vi. Water quality

Identifying a suitable measurement to assess water quality within estuaries was particularly challenging, given multiple sources of non-point source pollution, complex mixing patterns, and the large area covered by estuaries. To create a metric for this variable, 303(d) listed waters were used. Hexagons were assessed for water quality based on whether or not they fall within 303(d) listed waters (EPA 2015 for the Southeast Mapping Project and 2019 for the Northeast Mapping Project). For the North and Mid-Atlantic analyses, waters that were 303(d) listed due to fecal coliform pollution were not considered for this metric due to inconsistent reporting between states (e.g. the entire Connecticut coastline is 303(d) listed for fecal coliform, while neighboring Long Island does not list their Long Island Sound waters as 303(d) waters). Ten points were assigned to a hexagon if it does not overlap with these 303(d) listed waters, all other hexagons received zero points.

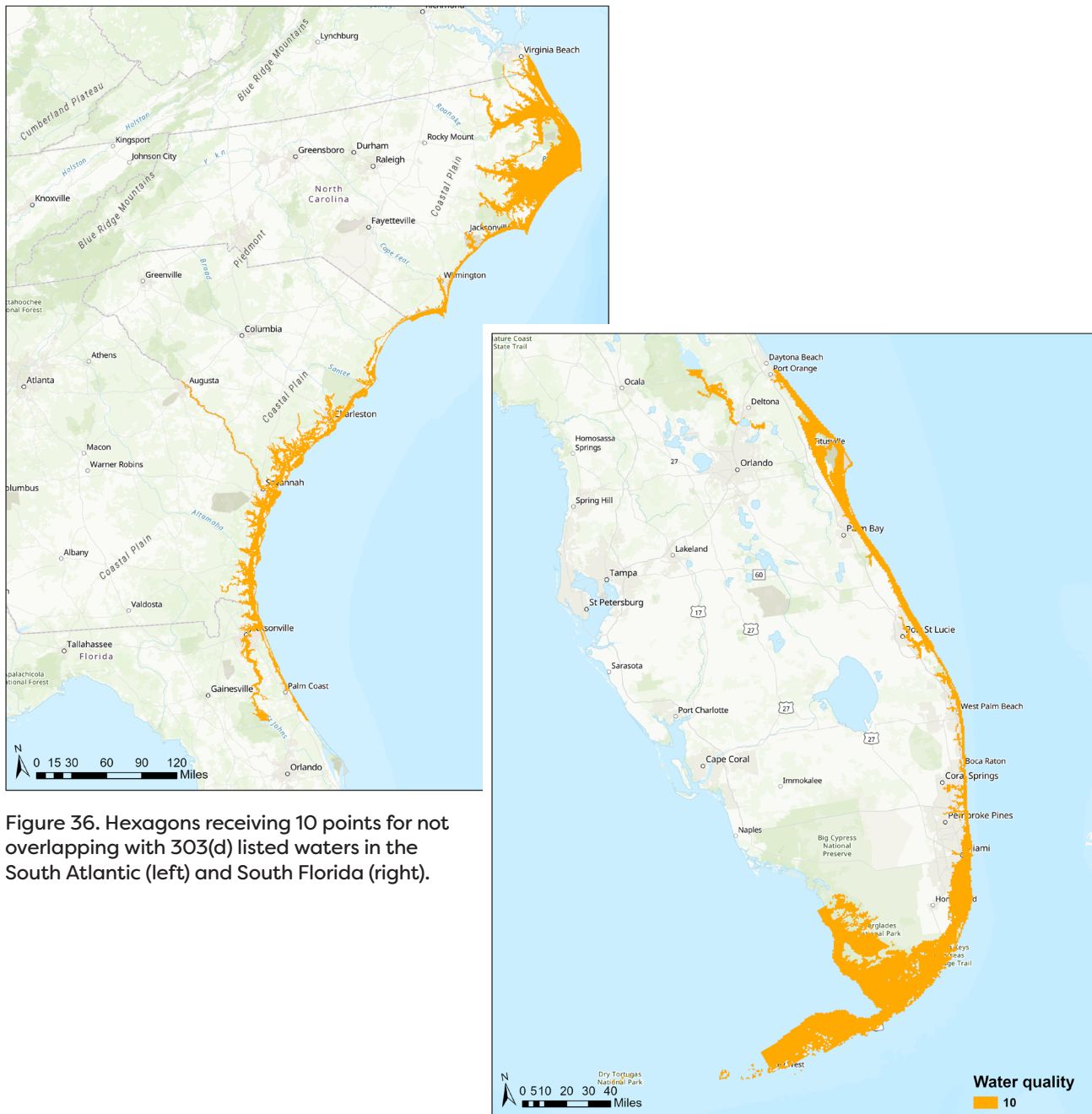


Figure 36. Hexagons receiving 10 points for not overlapping with 303(d) listed waters in the South Atlantic (left) and South Florida (right).

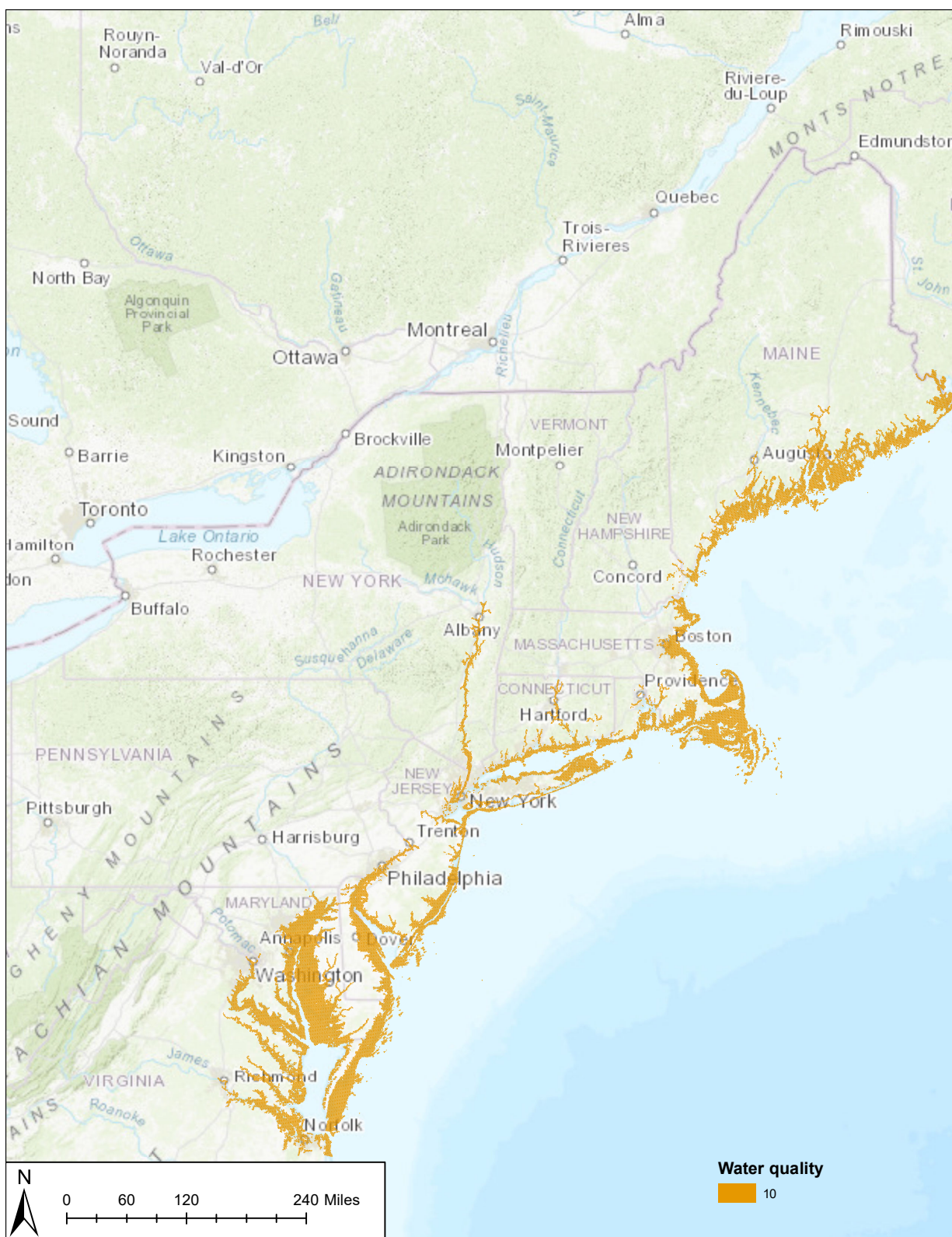


Figure 37. Hexagons receiving 10 points for not overlapping with 303(d) listed waters (excluding those listed for fecal coliform) in the North and Mid-Atlantic.

vii. Hardened shoreline

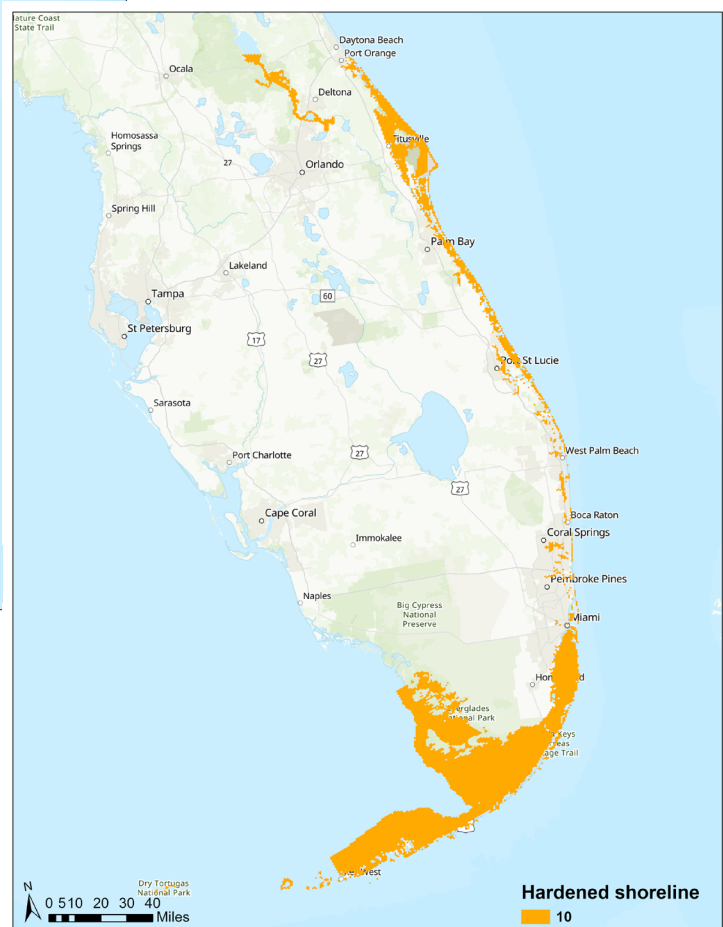
The length of hardened shoreline served as both a proxy for development and areas that cannot be easily restored to natural fish habitat. Hardened shoreline data for the South Atlantic and South Florida analyses were obtained from the TNC SABMA. To quantify the length of the hardened shoreline (in km) within each hexagon, the 'intersect' tool was used to split the hardened shoreline polylines at the hexagon boundaries. The resultant split polylines were dissolved by 'Hexagon GridID' to quantify the number of km of hardened shoreline within each hexagon.

Length of hardened shoreline was calculated for each hexagon in the North and Mid-Atlantic using data from NOAA's (2017b) ESI. Hardened shoreline was pulled out of this dataset using the query 'GENERALIZED_ESI_TYPE LIKE "%1%," which includes armored shoreline as well as sections of shoreline which are combinations of armored and another class (e.g. vegetated/armored). For

all four analyses, 10 points were assigned to the 25% of hexagons with the least amount of hardened shoreline. Note that all hexagons with no hardened shoreline are tied at zero, therefore the total number of hexagons receiving 10 points for this metric exceeds 25% of the total number of hexagons.



Figure 38. Hexagons receiving 10 points for having the least amount of hardened shoreline in the South Atlantic (left) and South Florida (right).



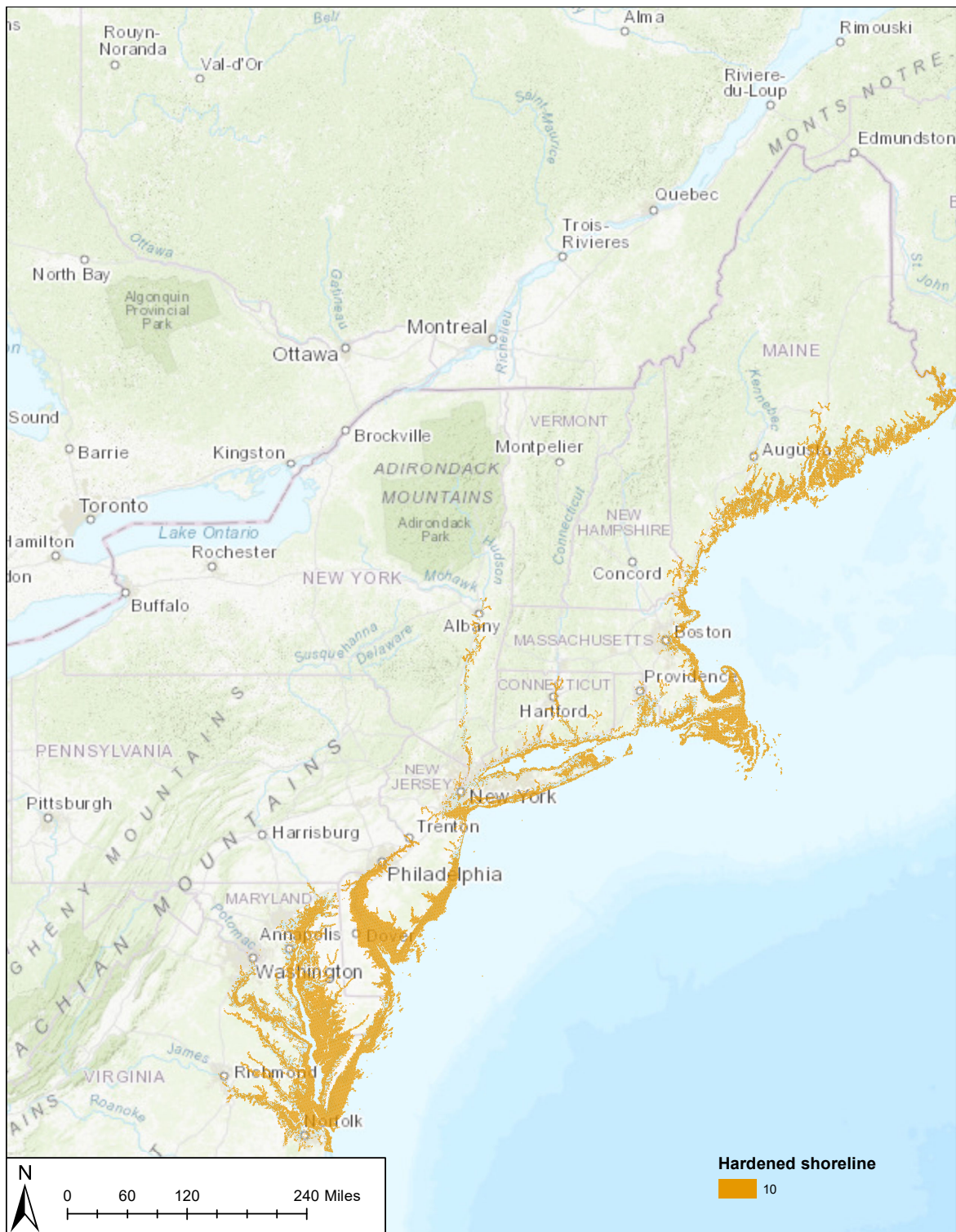


Figure 39. Hexagons receiving 10 points for having the least amount of hardened shoreline in the North and Mid-Atlantic. This metric was calculated separately for the North Atlantic and Mid-Atlantic subregions, and merged together to create this map.

viii. Habitat fragmentation

Habitat fragmentation was used as an indicator of development and habitat degradation. Hexagons with the least amount of habitat fragmented by causeways were identified for this variable. Causeways were defined as a road having marsh on at least one side (Figure 40). To create these causeways, TIGER Roads data (US Census Bureau 2018) were used to first identify all roads within estuarine areas. These roads were then clipped by the hexagon boundaries using the 'clip' tool. Tidal wetlands previously generated from NWI data (USFWS 2018) were then aggregated using the 'aggregate polygons' tool with a distance of 300 m to remove any small gaps from within them that would erroneously identify an area of road as being devoid of wetlands all together. The orange arrow in Figure 40 depicts this error, when road fill on either side of the wetland creates a gap between the road line and the wetlands data. Despite the road fill, this is still considered a causeway. By aggregating the wetland polygons, this road fill gap was filled in. Once the wetlands were aggregated, the clipped roads were split by the wetlands boundaries using the 'intersect' tool, resulting in those roads that crossed wetlands, or causeways. The 'dissolve' tool was then used to dissolve the causeways by 'hexagon GridID,' specifying 'shape length' and 'SUM' in the statistics field in order to quantify the length of causeway within each hexagon. Lengths were converted to linear feet, and those hexagons with zero linear feet of causeway were given 10 points, all others were given zero points.

Note that all hexagons with no causeways are tied at zero, therefore the total number of hexagons receiving 10 points for this metric exceeds 25% of the total number of hexagons.

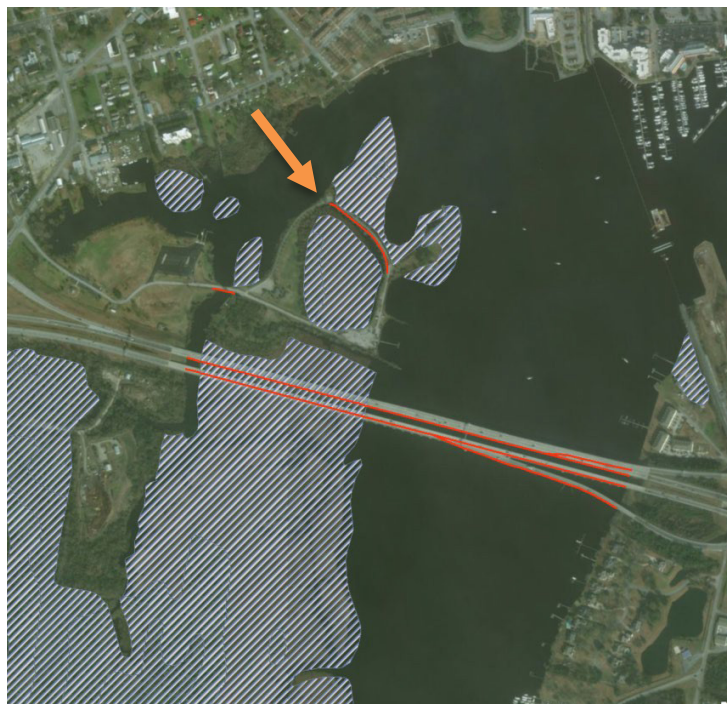


Figure 40. Causeways (red) generated for the habitat fragmentation variable. The orange arrow depicts an error that was corrected by aggregating wetland polygons.

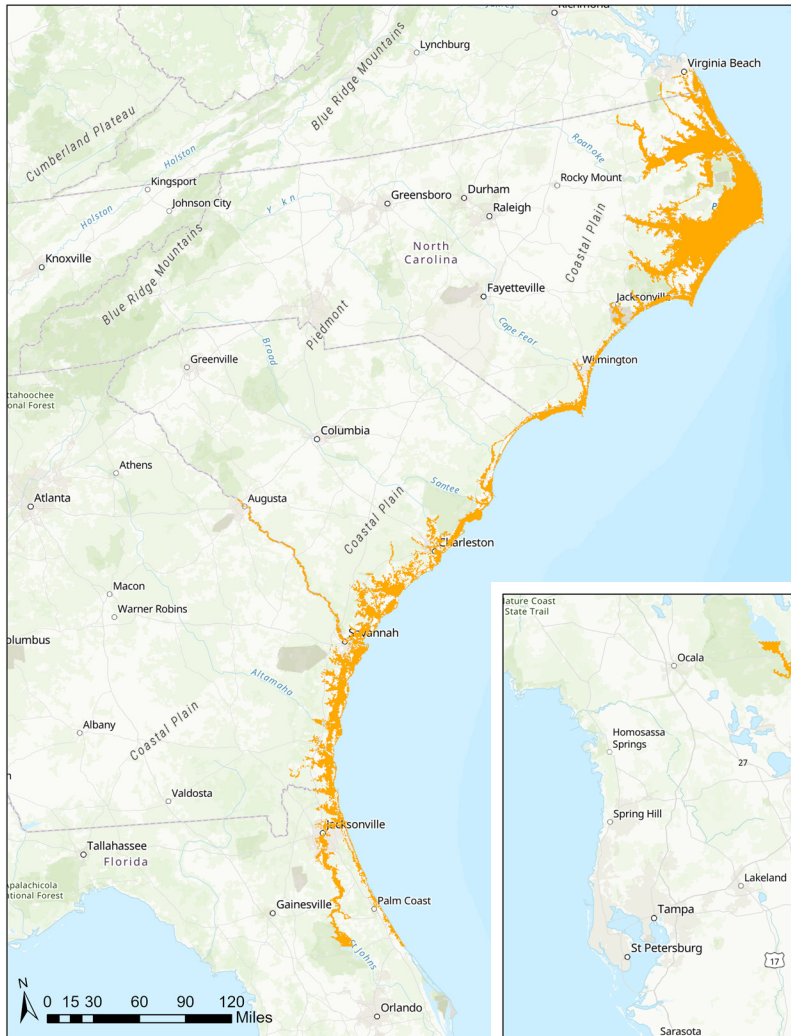
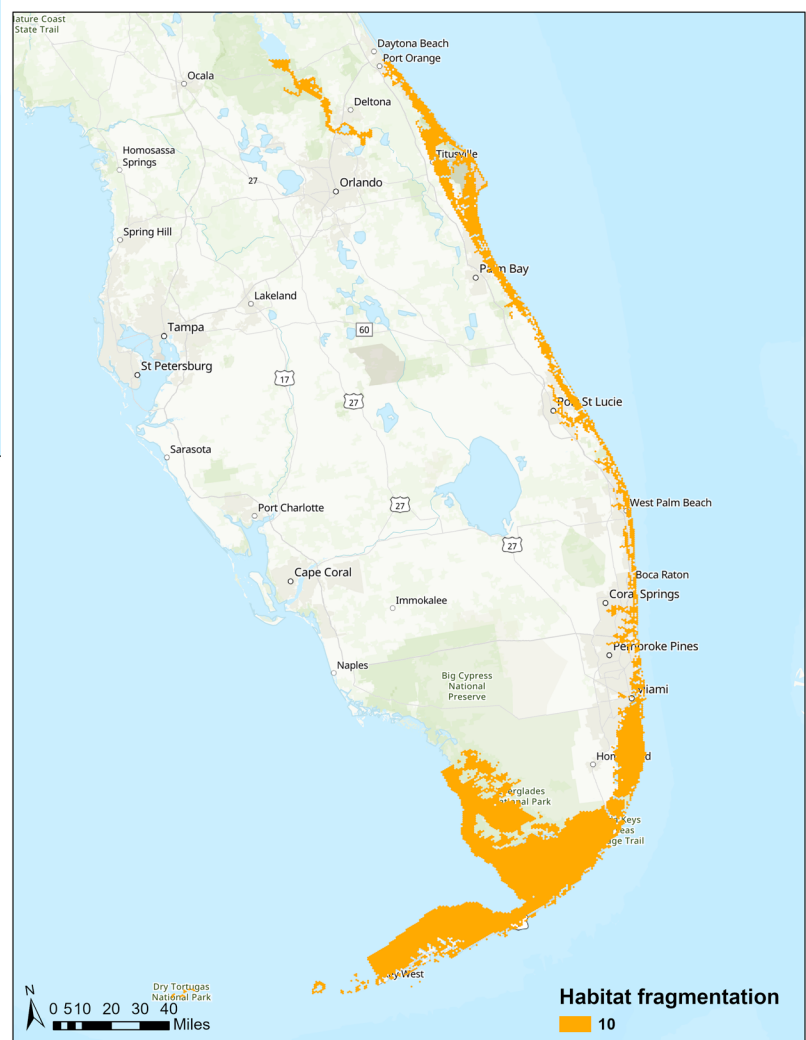


Figure 41. Hexagons receiving 10 points for having zero feet of fragmentation (causeways) in the South Atlantic (left) and South Florida (right).



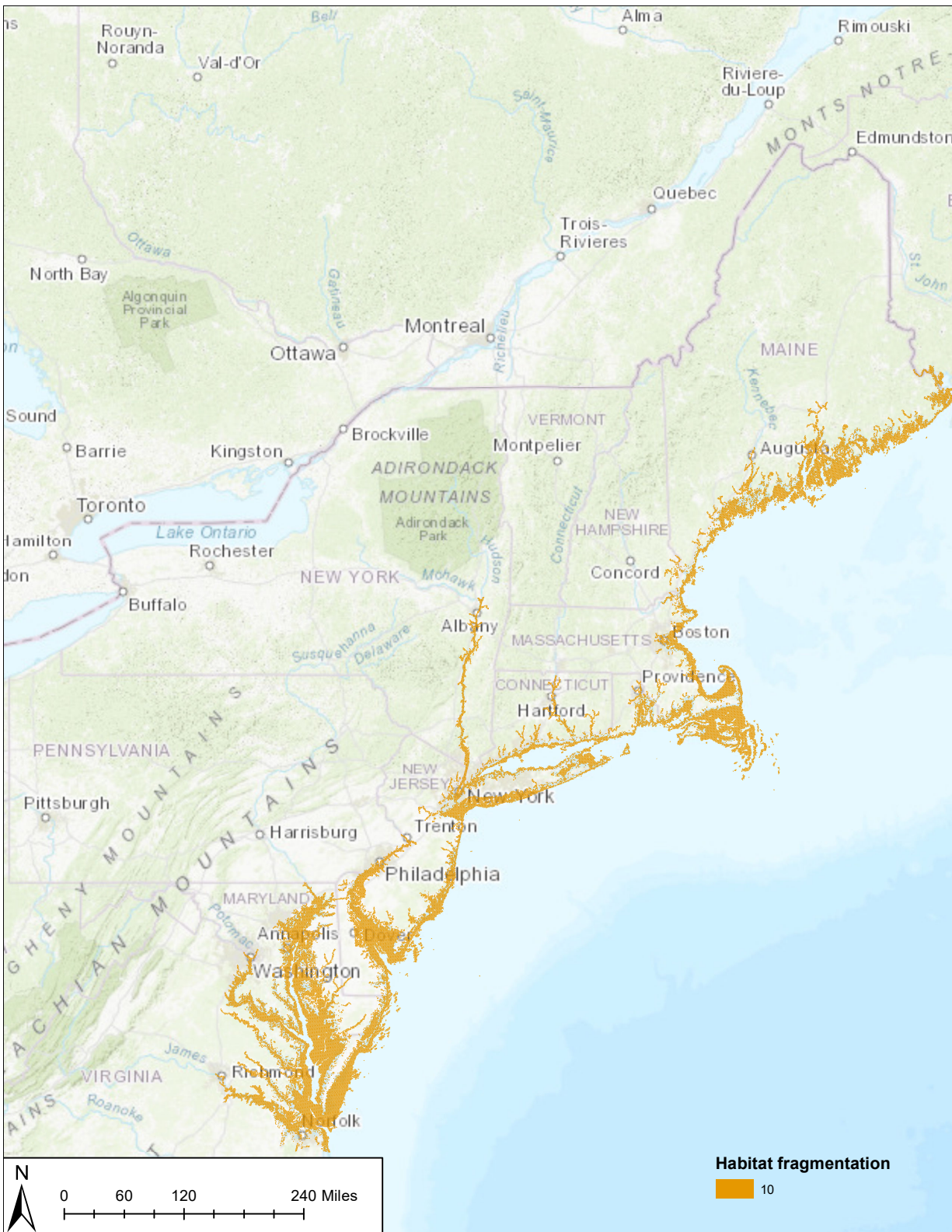


Figure 42. Hexagons receiving 10 points for having zero feet of fragmentation (causeways) in the North and Mid-Atlantic.

B. RESULTS

The eight component metrics (seven in South Florida) described above were added together for each hexagon, producing a composite score with a maximum value of 80 (North, Mid-, and South Atlantic) or 70 (South Florida) (10 points for each of eight metrics), as depicted in Figures 43 and 44. See *Discussion* for advice on how to interpret and use the results of these analyses.

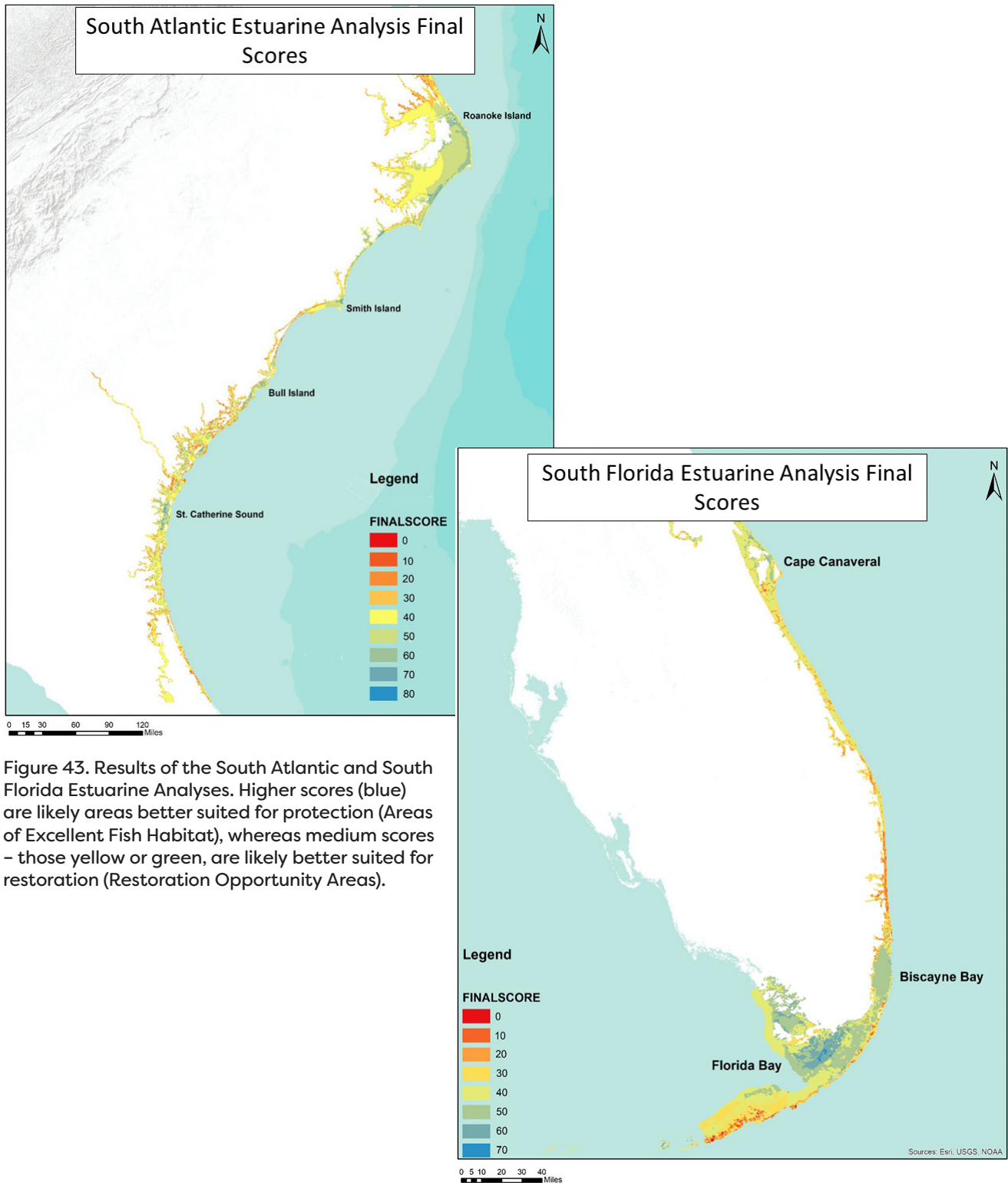


Figure 43. Results of the South Atlantic and South Florida Estuarine Analyses. Higher scores (blue) are likely areas better suited for protection (Areas of Excellent Fish Habitat), whereas medium scores – those yellow or green, are likely better suited for restoration (Restoration Opportunity Areas).

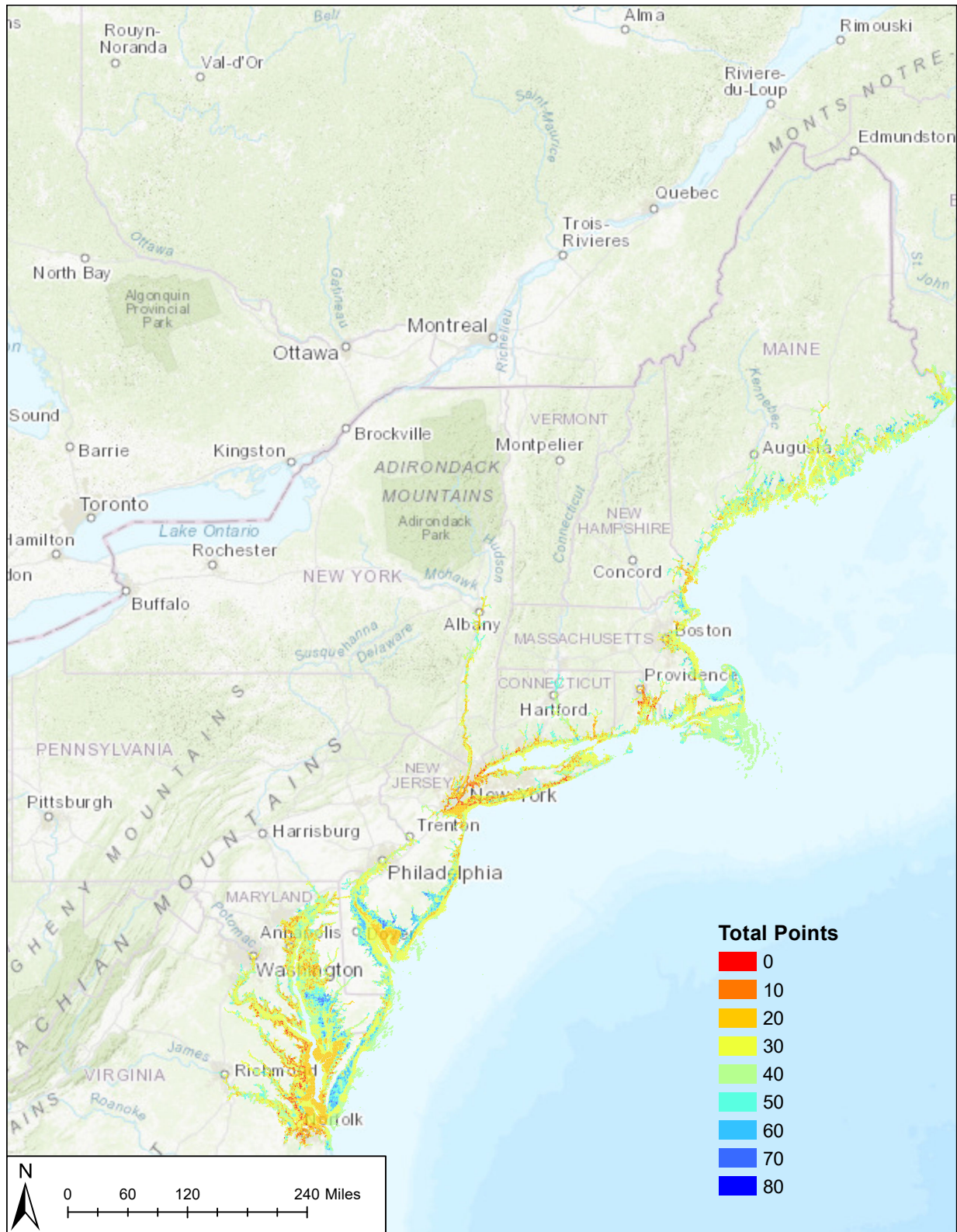


Figure 44. Results of the North and Mid-Atlantic Estuarine Analyses. Higher scores (blue) are likely areas better suited for protection (Areas of Excellent Fish Habitat), whereas medium scores – those yellow or green, are likely better suited for restoration (Restoration Opportunity Areas).

Results of the estuarine analyses highlighted many high scoring areas that were already protected, such as Roanoke Island and the Elizabeth River, both in North Carolina (Figure 45). However, other clusters of hexagons that are not protected also fell into the top tier of scores (arguably more ‘pristine’ areas based on our metrics), highlighting the need to further protect “Areas of Excellent Fish Habitat” along the coast.

It is important to note that these analyses often assigned high scores to open water, especially in the South Atlantic and South Florida. Open water hexagons ranked higher than shoreline hexagons in many cases because they tended to be furthest from development, but might not be well suited for conservation due to the multiple uses for these spaces. In the future, including information on open water impacts such as trawling, as well as species presence and diversity, should be included when updating this analysis. In addition, sub-setting the analysis to include only those hexagons marked as ‘shoreline’ and re-ranking and scoring the hexagons could be completed if a shoreline-only scenario is desired.

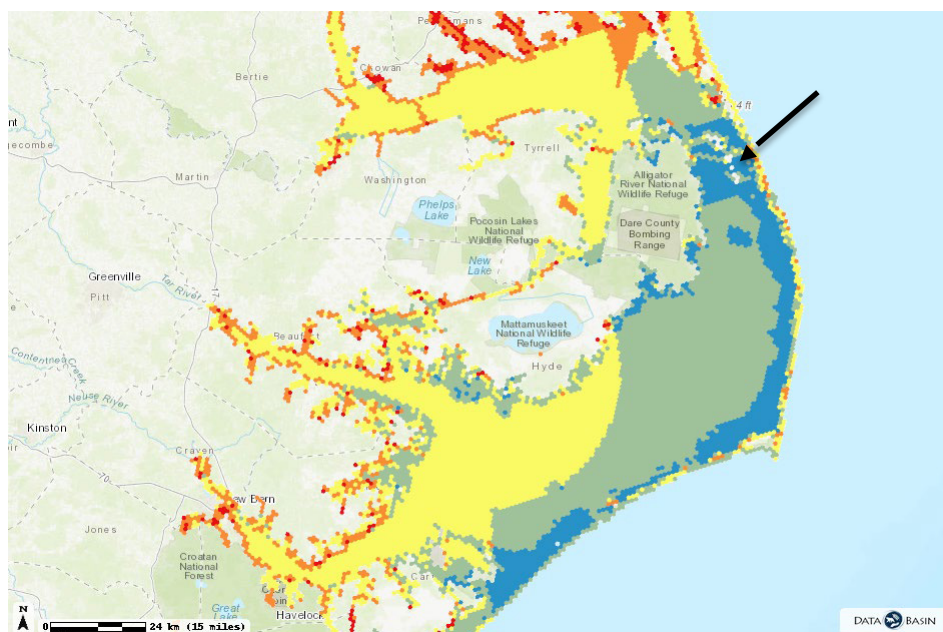


Figure 45. Roanoke Island (black arrow) in North Carolina, had a high score in the South Atlantic Estuarine Analysis. Part of the island is secured lands, but not all.

5. SOUTH FLORIDA COASTAL ANALYSIS

The goal of the South Florida Coastal Analysis was to identify coastal areas south of Cape Canaveral that contained coral habitat, a priority habitat for ACFHP's South Florida subregion. The ACFHP Science and Data Committee decided that all coral habitat was in need of conservation, regardless of quality, due to the slow growth and immediate threats to South Florida reefs (including bleaching, pollution, and disease). Because coral reef restoration is expensive, incapable of replicating the diversity of natural reefs, and already has a multitude of organizations focused solely on these efforts, ACFHP thought it was best to communicate that these reefs are in trouble, and use the map produced in the South Florida Coastal Analysis for outreach purposed to try and minimize threats moving forward.

A. METHODS

To identify priority coral habitat, we combined the Unified Reef Map from the Florida Fish and Wildlife Conservation Commission (FL FWC) with coral reef and hard bottom HAPC designations. The latter were selected using 'select by attribute' on the Marine Cadastre's HAPC data. These two datasets were then merged together using the 'merge' tool in GIS, to show all of those areas considered to be important for corals.

B. RESULTS

The South Florida Coastal Analysis highlights both HAPCs and known coral and hard bottom habitat. Originally for this scenario, 10' squares were the target unit of analysis. However, after identifying all of the area that coral habitat is located, the squares were too large and resulted in a swath of priority area that covered the entire South Florida coast. As a result, the combined dataset of the Unified Reef Map and coral HAPCs were used as the final areas for protection (Figure 46). If more data becomes available in the future, another unit of analysis may be more appropriate.

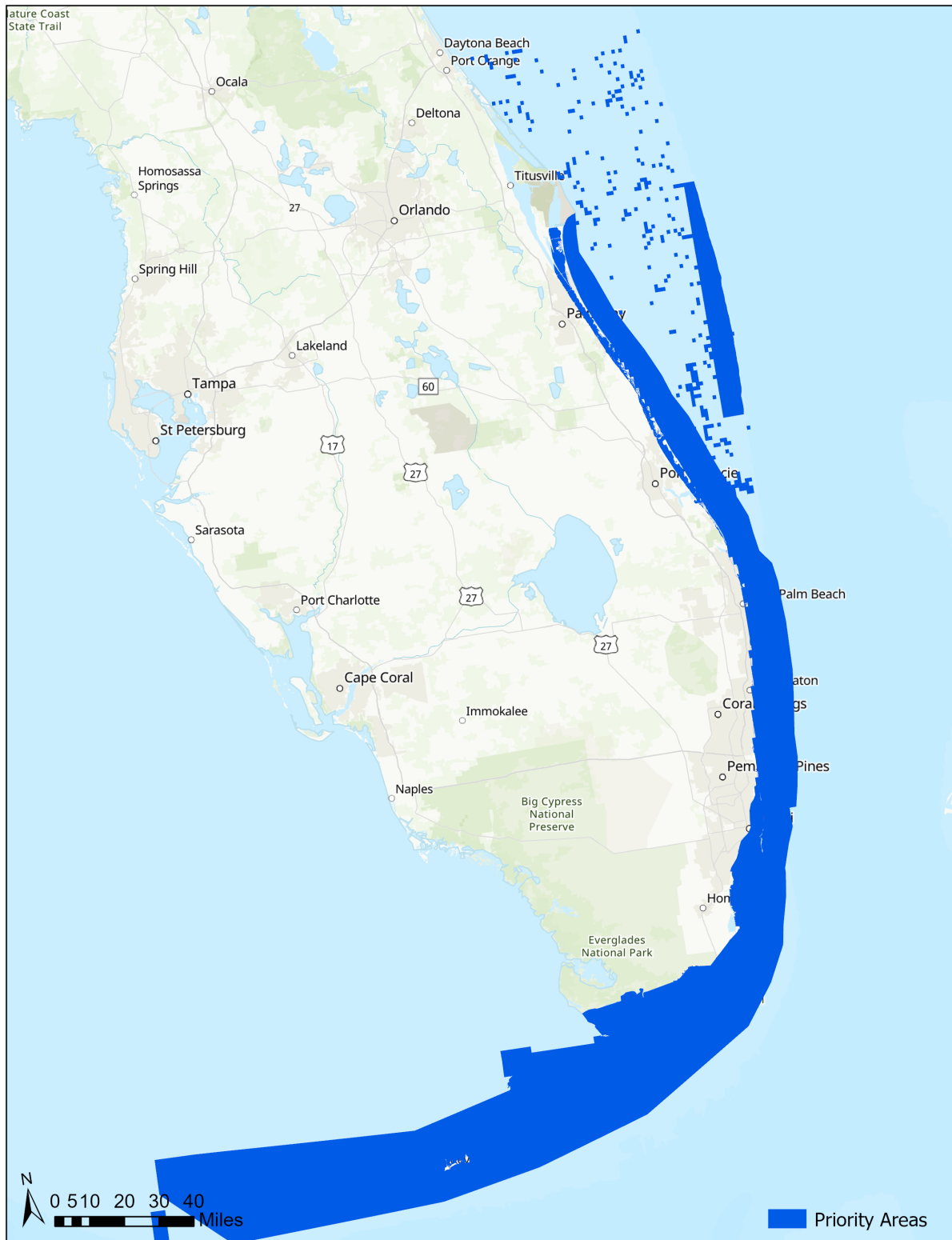


Figure 46. Results of the South Florida Coastal Analysis. Blue areas indicate coral and hard bottom, based on the FL FWC Unified Reef Map and 'coral reef and hard bottom' HAPC designations.

6. DISCUSSION

A. CAVEATS

This project was ACFHP's first attempt at spatially prioritizing areas for diadromous, estuarine, and coastal fish habitat conservation. It is meant to provide a high-level understanding of conservation opportunities for resource managers, ACFHP, and other stakeholders to identify areas that are best suited for fish habitat conservation. While it incorporates best available regional datasets, it is important to recognize that it does not incorporate local-scale information or context that is critical to understand before taking any conservation actions. Also, some datasets are updated in sections as new data become available, and thus might not all be collected at the same time (e.g. the wetlands data is updated on a rolling basis). Therefore, these results should be used as a starting point to help inform and guide fish habitat conservation planning. It is not intended to provide a definitive "answer" and should not be used as the sole factor in any decision-making process. We encourage users to explore more current or refined datasets, or more localized assessments (e.g. work is underway for a Chesapeake Bay Assessment, as well as a Northeast Regional Habitat Assessment) for their specific area if it is available. Further, these analyses focus on the conservation of ACFHP priority habitats, and do not necessarily reflect the need for conservation of other fish habitats, the overall ecosystem, or other entities.

Though a variety of variables were included in these analyses, not all variables that affect fish habitat were considered. Some variables were not included in the analysis due to mixed effects or lack of spatial coverage. For example, sea level rise and sea surface temperature projections were left out, because these changes would affect our priority habitats differently. Sea level rise might create an opportunity for SAV expansion, but drown tidal vegetation. Fish presence and fishing data were not included, because sampling methods were inconsistent across our study area, and were unavailable in many of the shallow water habitats. Additionally, due to lack of quantitative information, all metrics were weighted equally in the analyses, and the 25% cutoff scores were chosen for consistency, not based on data. For these reasons, we do not recommend selecting areas for protection (e.g. Special Management Zones, Marine Protected Areas, Wildlife Management Areas, etc.) based solely on these results. Finally, spatial comparisons should only be made within each of the eight analyses, and not across them, because of the different variables and metrics used.

B. USE OF THE RESULTS

The final results for the analyses are expressed in terms of total points from 0 – 80 (except for South Florida Estuarine Analysis which has a total possible score of 70), which are the summed result of each of the component metrics. A catchment (diadromous scenario) or hexagon (estuarine scenario) with 80 points performs well across all metrics, while one with 0 points performs well across no metrics.

We designated catchments or hexagons with higher scores (>60) as "Areas of Excellent Fish Habitat." It is unlikely that much improvement is needed to ensure availability of fish habitat at these sites because they are in good condition and face few threats. Therefore maintaining the current condition is the primary conservation action. These areas might be a good candidate for protection. "Restoration Opportunity Areas" fall in the middle of the score range (20 - 60) – these are areas that are doing well in some respects, but the sites can be improved upon. It is likely that a restoration project, especially one that targets the variables that did not contribute

points towards the final score, would have a big impact here. If, for example, an estuarine marsh hexagon scores fairly well, but doesn't receive points for wetland habitats, then wetland restoration activities could be undertaken to improve its overall score and, by extension, increase available fish habitat. "Degraded Areas of Opportunity" received few points (<20), and face many challenges based on the variables included in the analysis. A restoration project, unless it is large in scale or targets many of the variables in the analysis (ex. reduction of impervious surface or sewage system infrastructure), will not likely increase availability of fish habitat as much as one in a restoration opportunity area. ACFHP does not, however, intend for readers to interpret a grade <20 as an ACFHP recommendation that no action(s) should ever be taken in these areas.

C. RESEARCH NEEDS

- A better understanding of the relationship between fish presence and habitat presence and health is needed.
- To better inform the effects of point and non-point source pollution, estuarine mixing and hydrodynamics models for all estuaries would be helpful.
- More quantitative data to support cutoffs for the various metrics would be helpful in the assessment. Aside from a few metrics (e.g. impervious surface, Atlantic sturgeon Critical Habitat), the 25% cutoff for receiving points for a particular variable was chosen for consistency, but not based on scientific findings.
- More information to guide a weighted analysis for each variable would be helpful. Currently, each variable is treated equally in the analysis, but it's very likely that they do not impact fish habitat equally.
- Consistent oyster reef and SAV coverage across the region would be helpful to ensure accurate representation across states.

7. CITATIONS AND DATA

Note all data were accessed between July 2017 and April 2018 for the Southeast Mapping Project and between May and November 2019 for the Northeast Mapping Project.

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MAPS

All datasets are hosted online in the Databasin Map:

<https://databasin.org/maps/e8327d587c1a4eb583cf9a007361dc8c/active>

To toggle the different Habitat Analyses on and off, click the 'Layers' tab on the box in the upper left corner of the map. Check the boxes located to the left of each analysis of interest under 'Datasets.'

For a quick User Guides, visit:
hyperlink

For Databasin video tutorials, FAQs, and support staff, visit:
<https://databasin.org/help>.

DATA

To download the GIS data for each map, go to the 'Layers' tab on the left and click on the 'play' button to the right of the Habitat Analysis you're interested in, then click 'details.' Click on the title of the Analysis that pops up under the header 'Dataset Details.' This will take you to a new page, with all of the Habitat Analysis' details. Click on the 'Data Layers' tab under the map, and scroll to the bottom. The 'Metadata Files' are located there, available for download.

Alternatively, you can access the page directly via the following links:

North Atlantic Diadromous Analysis

<https://databasin.org/datasets/879f2d0a20ec4e1d8c75ca44ed22dad1>

North Atlantic Estuarine Analysis

<https://databasin.org/datasets/f1e511c9a12642c1a0b03c48ac7fcdbc>

Mid-Atlantic Diadromous Analysis

<https://databasin.org/datasets/2ca34f1c75af4ed6bd13cbc482037774>

Mid-Atlantic Estuarine Analysis

<https://databasin.org/datasets/964cff03b10846e583eb732e91fb24e0>

South Atlantic Diadromous Analysis

<https://databasin.org/datasets/1319cc9dec6c4bb188cbc3e9e5e719b0>

South Atlantic Estuarine Analysis

<https://databasin.org/datasets/0d21c83295984c3c89d7edf60d046ec8>

South Florida Estuarine Analysis

<https://databasin.org/datasets/89314044554344bd98b1e099d52cc74d>

South Florida Coastal Analysis

<https://databasin.org/datasets/80119a55b4c34aec95604c3e06ddddd5a>