Southeast Blueprint 2023 Development Process

Released October 13, 2023

Last updated February 2, 2024

Preferred citation for this document: Southeast Conservation Adaptation Strategy (SECAS). 2023. Southeast Blueprint 2023 Development Process. Available online: https://www.sciencebase.gov/catalog/file/get/64f8da38d34ed30c20546a6a?name=Southeast_Blueprint_2023_Development_Process.pdf

Contents

Background

Introduction to the Southeast Conservation Blueprint

The Southeast Conservation Blueprint is the primary product of the Southeast Conservation Adaptation Strategy (SECAS). It is a living, spatial plan to achieve the SECAS vision of a connected network of lands and waters across the Southeast and Caribbean. The Blueprint is regularly updated to incorporate new data, partner input, and information about on-the-ground conditions.

The Need for a Blueprint

The lands and waters of the Southeast United States and Caribbean are changing rapidly, reshaped by climate change, urban growth, and increasing human demands on resources. While these forces span the boundaries of political jurisdictions, the conservation community does not have a comprehensive, cross-boundary, and inter-organizational strategy for how to sustain shared resources in the face of future change.

The History of the Blueprint

The Southeast Conservation Blueprint is the primary product of the Southeast Conservation Adaptation Strategy, a regional conservation partnership spanning the Southeast United States and Caribbean. It identifies the most important places for collective action by the conservation community to achieve the SECAS vision of a connected network of lands and waters. The Blueprint has evolved over time through an iterative revision process, improving its accuracy, spatial resolution, regionwide consistency, and utility to conservation professionals.

In the fall of 2013, SECAS leadership set a goal of developing a first-generation Southeast Blueprint for landscape-scale conservation by the fall of 2016. Many different conservation planning efforts were already underway, but most eco-regional plans only covered parts of states, while state-specific plans stopped at the state line. The results of all this parallel planning did not yet add up to an integrated regional strategy.

Three years later, Version 1.0 of the Southeast Blueprint was released in December 2016. Development of this first Blueprint relied heavily on Landscape Conservation Cooperative (LCC) partnerships across the Southeast and Caribbean. This plan provided the first ever integration of spatial plans developed through the South Atlantic, Appalachian, Gulf Coastal Plains and Ozarks, Gulf Coast Prairie, North Atlantic, and Caribbean LCCs.

Version 2.0 of the Southeast Blueprint was released in November 2017. This plan incorporated the improved subregional Blueprints from several LCCs and established priority connections with western states through the Crucial Habitat Assessment Tool. Significant improvements over Version 1.0

included improved consistency across LCC boundaries, improved consistency in climate change response, and improved integration beyond the Southeast.

Version 3.0 of the Southeast Blueprint was first introduced at the October 2018 Southeastern Association of Fish and Wildlife Agencies (SEAFWA) annual conference, and officially released in February 2019. Its development occurred during a time of transition for the LCC Network where the structure and function of some LCCs was changing. Despite these changes, the capacity and commitment to continue to support Blueprint users and improve the Southeast Blueprint remained strong, evidenced by the many examples of Blueprint implementation, as well as progress on Blueprint improvements. Blueprint 3.0 added full coverage of Texas, integrated threat layers covering the full Southeast, and a hubs and corridors layer covering part of the region.

Version 4.0 of the Southeast Blueprint was released in October 2019 at the SEAFWA annual conference. Improvements over the previous version include: corrected overprioritization in Texas, Oklahoma, and the mountains of West Virginia and Virginia; improved priorities in the Lower Mississippi Valley, Louisiana marshes, and the Southern Appalachians; updated inputs from Florida and the Middle Southeast subregion; expanded marine coverage to include state and federal waters around Florida; and expanded hubs and corridors that covered all of Florida.

Southeast Blueprint 2020 was released in October 2020 at the virtual SEAFWA annual conference. Significant improvements over the previous versions include: finer resolution and a more connected network of priorities in the inland South Atlantic subregion; updated data and a more consistent approach to cross-state prioritization in the Middle Southeast subregion; and better integration in areas of overlap between the South Atlantic Blueprint, Florida Blueprint, and Nature’s Network design.

Southeast Blueprint 2021 was released in November 2021 following the virtual SEAFWA annual conference. Significant improvements over the previous versions include: updated and improved indicators, better incorporation of equity, deep-sea coral, fire, and important grasslands, and multiple connectivity improvements in the South Atlantic subregion, as well as correcting a scoring issue in the Middle Southeast subregion.

Southeast Blueprint 2022 was released in October 2022 at the SEAFWA annual conference. Rather than continuing to stitch together so many different subregional plans, the 2022 Blueprint took massive strides toward regional consistency by using the same methods and indicators across 15 states of the Southeast. To provide more complete coverage of the SECAS geography, Blueprint 2022 also incorporated two additional input plans: the latest update to the Florida Marine Blueprint for marine areas in Florida and the Caribbean Landscape Conservation Design for inland areas in Puerto Rico.

Southeast Blueprint 2023 was released in October 2023 at the SEAFWA annual conference. For the first time, this Blueprint used a consistent approach across the entire geography and did not have to stitch together any subregional inputs. The 2023 Blueprint expanded consistent methods and indicators to Puerto Rico, the U.S. Virgin Islands, and nearshore U.S. Caribbean waters, as well as to the full extent of U.S. waters in the Atlantic Ocean and Gulf of Mexico. It also included minor refinements to the inland continental Southeast priorities and updated hubs and corridors for the full Blueprint area.

Southeast Blueprint 2023 Overview

The 2023 version of the Blueprint identifies priority areas based on a suite of natural and cultural resource indicators representing terrestrial, freshwater, and marine ecosystems. A connectivity analysis identifies corridors that link coastal and inland areas and span climate gradients. Figure 1 on the next page provides an overview of the Southeast Blueprint 2023 development process.

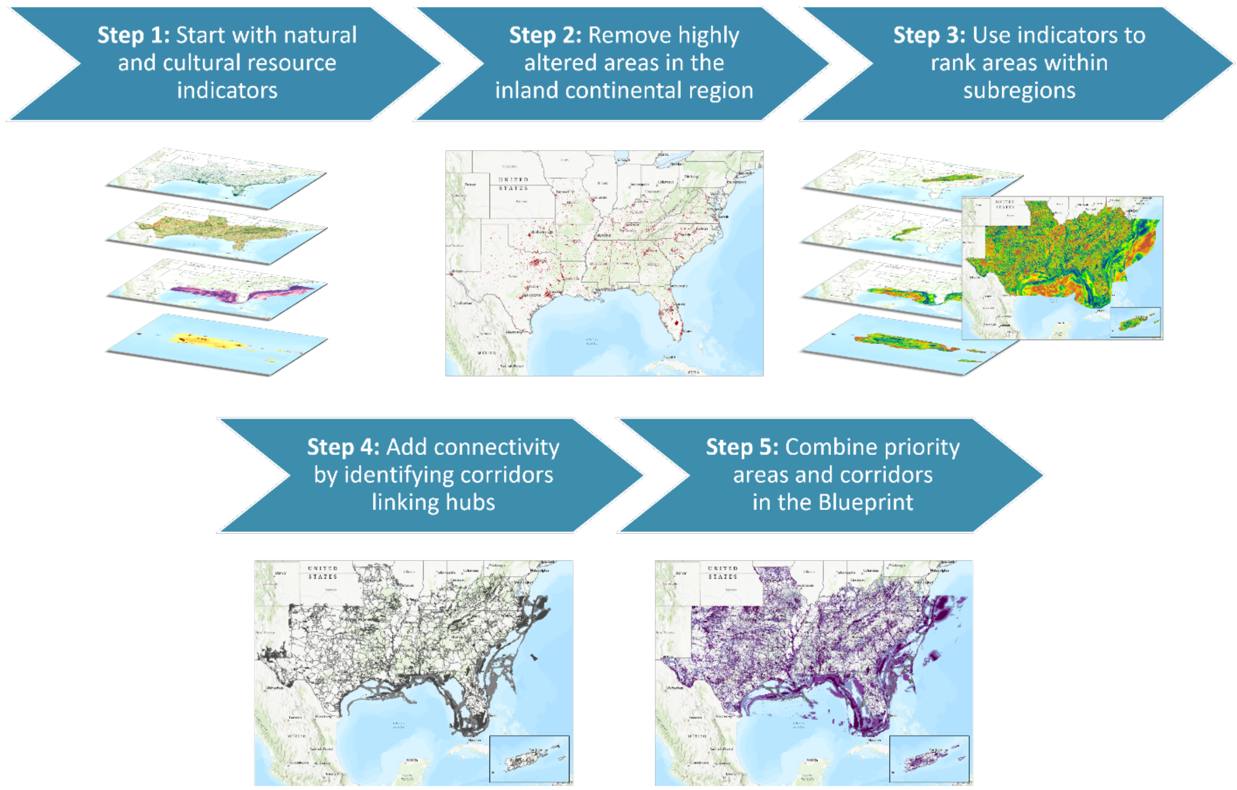

Figure 1. The overall process of developing Southeast Conservation Blueprint 2023.

Step 1: The terrestrial, freshwater, and coastal/marine ecosystems of the Southeast and U.S. Caribbean are represented by 61 natural and cultural resource indicators.

Step 2: To aid in the modeling process, we remove highly altered areas in the continental Southeast (i.e., urban areas and reservoirs) that generally would not be prioritized in the Blueprint anyway.

Step 3: The SECAS geography is divided into 23 subregions. A program called Zonation ranks the pixels in each subregion according to their indicator scores, using a modeling approach that conserves high-value representations of all indicators collectively. Pixels that rank higher in Zonation become higher priority in the Blueprint.

Step 4: We use a least-cost path connectivity analysis to identify corridors that link hubs across the shortest distance possible, while also routing through as much Blueprint priority as possible. In the continental geography, inland corridors connect large patches of highest priority Blueprint areas and/or protected lands. Marine/estuarine corridors connect large estuaries and/or large patches of highest priority Blueprint areas within broad marine mammal and turtle movement areas. In the Caribbean geography, corridors connect large patches of highest priority Blueprint areas and/or protected lands.

Step 5: Combining the areas of highest Zonation ranking with the corridors produces Southeast Blueprint 2023.

Accessing Blueprint Data

- Start simple in the Blueprint Explorer, an easy-to-use online viewer that allows you to create custom reports and discover what's driving the Blueprint priorities
- Visit the Blueprint page of the SECAS Atlas to dig deeper into the Blueprint and underlying data layers, and make your own maps
- Download the Blueprint data for direct use in your desktop GIS

Intended Uses

More than 350 people from over 140 organizations are already using the Blueprint to guide conservation action and investment across the SECAS geography. So far, it has helped bring in more than $100 million in conservation funding to protect and restore over 200,000 acres. A few things to keep in mind when using the Blueprint:

- The Blueprint identifies areas where conservation action would have the biggest impact for a connected network of lands and waters. A range of conservation activities could benefit those priority areas, including management, economic incentives, and protection. The Blueprint should not be interpreted as a plan for land acquisition.
- The Blueprint is not intended to be used in isolation of other datasets. Instead, it provides a regional perspective that, in combination with local data and knowledge, can help inform decisions about where to focus conservation action in the face of future change.
- If you want to find your piece of the Blueprint, you can explore the underlying indicator and connectivity data. These underlying layers can help identify important areas for corridors, birds, water quality, climate resilience, prescribed burning, reforestation, and much more. They can help you tell the unique story of what makes your area of interest special. Contact a member of Blueprint user support staff if you'd like some help.
- As a living spatial plan, the Blueprint is always a work in progress. We maintain a list of the problems with the Blueprint that have been identified in the review process so far. Those "known issues" are captured in this report and on the SECAS website. The Blueprint will continue to be refined to incorporate improvements to the input data and methods, as well as feedback from Blueprint users and other partners.

Contact Blueprint Staff

Do you have a question about the Blueprint? Would you like help using the Blueprint to support a proposal or inform a decision? Staff across the Southeast are here to support you! The Blueprint is also revised based on input from people like you. So, if you have a suggestion on how to improve the priorities, let us know!

To get help or provide feedback, reach out to a member of SECAS user support staff: http://secassoutheast.org/staff.

Indicators

The indicators drive the identification of priority areas for a connected network of lands and waters within the Southeast Conservation Blueprint. One suite of indicators applies to the continental Southeast portion of the Blueprint, which spans the 15 contiguous Southeast states and surrounding marine environment out to the end of U.S. waters. Another suite of indicators applies to the U.S. Caribbean and surrounding nearshore marine environment. A brief summary of each indicator is available on the SECAS website. Spatial data for each indicator is available on the Blueprint page of the SECAS Atlas.

Continental

Terrestrial

East Coastal Plain Open Pine Birds

This indicator identifies areas within the historic longleaf pine range east of the Mississippi River where creating or maintaining open pine habitat would most benefit six focal species of birds (Bachman's sparrow, red-cockaded woodpecker, Henslow's sparrow, red-headed woodpecker, Northern bobwhite, brown-headed nuthatch). It prioritizes areas for open pine conservation based on suitability for longleaf pine, feasibility of prescribed burning, proximity to protected lands, habitat suitability for focal bird species, and proximity to bird source populations. It originates from the East Gulf Coastal Plain Joint Venture's prioritization of areas for open pine ecosystem restoration.

Reason for Selection

Open longleaf pine forests once spanned nearly 90 million acres across the Southeast, supporting a rich community of wildlife and plants. Fire suppression, deforestation, and conversion to ecosystems dominated by loblolly and slash pine have dramatically reduced the extent of longleaf and caused the decline of many associated species. In addition, pine and prairie birds are experiencing significant declines and are currently off-track for meeting the SECAS 10% goal, so it is important that the Blueprint capture opportunities to conserve, restore, and manage open pine habitat. This indicator also promotes consistency with the longleaf and open pine ecosystem priorities of the East Gulf Coastal Plain Joint Venture (EGCPJV).

Input Data

- Bird priorities from Prioritization of areas for open pine ecosystem restoration in the Southeastern United States (bird_priority.tif); read the project final report; read a news article about the project; explore the data in the EGCPJV Open Pine Decision Support Tool
- Estimated Floodplain Map of the Conterminous U.S. from the Environmental Protection Agency's (EPA) EnviroAtlas; see this factsheet for more information; download the data

The EPA Estimated Floodplain Map of the Conterminous U.S. displays "...areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood). These data are based on the Federal Emergency Management Agency (FEMA) 100-year flood inundation maps with the goal of creating a seamless floodplain map at 30-m resolution for the conterminous United States. This map identifies a given pixel's membership in the 100-year floodplain and completes areas that FEMA has not yet mapped" (EPA 2018).

- 2019 National Land Cover Database (NLCD)
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Reproject the EGCPJV bird priority data to NAD 1983 Contiguous USA Albers (EPSG 5070).
- If an area intersects an EPA Estimated Floodplain, change the value to NoData.
- If an area is something besides Evergreen Forest or Mixed Forest in the 2019 NLCD, change the value to NoData. Because the bird priority layer was made with older landcover data, this step helps remove areas that do not currently have pine trees.
- The EGCPJV bird data provides a raster with scores of 0-100 representing the relative potential for open pine bird response to conservation action. Reclassify this raster as shown in in the legend below.
- Add zero values to represent the extent of the source data and to make it perform better in online tools. Assign a value of 0 to any pixel that had a value ≥ 0 in the original bird priorities layer but was converted to NoData above.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = High priority for open pine conservation for focal bird species (Bachman's sparrow, red-cockaded woodpecker, Henslow's sparrow, red-headed woodpecker, Northern bobwhite, and brown-headed nuthatch) (score >80-100)
4 = Medium-high priority (score >60-80)
3 = Medium priority (score >40-60)
2 = Medium-low priority (score >20-40)
1 = Low priority (score 0-20)
0 = Not a priority (not identified as upland pine)

Known Issues

- The EGCPJV's open pine bird model includes frequently inundated floodplain areas. These areas are unlikely to be potential open pine habitat. To address this in the indicator, we removed areas within the EPA estimated floodplain.
- This indicator prioritizes some areas outside of the floodplain that were not historically open pine habitat.
- The 2019 NLCD classes used to exclude non-pine areas of the open pine bird model (evergreen forest and mixed forests) do not exclusively target pine trees. For example, the evergreen class can include other evergreen tree species like Eastern red cedar or southern magnolia. In addition, the NLCD likely misclassifies other types of land cover as evergreen or mixed forests. As a result, this indicator may leave in some areas prioritized in the bird model that are not actually pine. Conversely, the NLCD also likely misclassifies some areas of pine as other land cover classes, which could cause pine areas prioritized in the model to be inadvertently excluded from the indicator.
- This indicator does not capture areas where planting new pine stands in existing agricultural areas would benefit open pine birds.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Equitable Access to Potential Parks

This cultural resource indicator prioritizes places to create new parks that would fill gaps in equitable access to open space within socially vulnerable communities in urban areas. It identifies areas where residents currently lack access to parks within a 10-minute walk (accounting for walkable road networks and access barriers like highways and fences), then prioritizes based on park need using demographic and environmental metrics. This indicator originates from the Trust for Public Land's ParkServe park priority areas and the Center for Disease Control's Social Vulnerability Index.

Reason for Selection

Protected natural areas help foster a conservation ethic by providing opportunities for people to connect with nature, and also support ecosystem services like offsetting heat island effects (Greene and Millward 2017, Simpson 1998), water filtration, stormwater retention, and more (Hoover and Hopton 2019). In addition, parks, greenspace, and greenways can help improve physical and psychological health in communities (Gies 2006). However, parks are not equitably distributed within easy walking distance for everyone. This indicator aligns with Executive Order 14008, which calls for a greater focus on environmental justice and equity, as well as public health, land and water conservation, and climate change resilience. It also complements the urban park size indicator by capturing the value of potential new parks.

Input Data

- The Trust for Public Land (TPL) ParkServe database, accessed 8-8-2021: Park priority areas (ParkServe_ParkPriorityAreas_08062021)

  From the TPL ParkServe documentation:

  The ParkServe database maintains an inventory of parks for every urban area in the U.S., including Puerto Rico. This includes all incorporated and Census-designated places that lie within any of the country's 3,000+ census-designated urban areas. All populated areas in a city that fall outside of a 10-minute walk service area are assigned a level of park priority, based on a comprehensive index of six equally weighted demographic and environmental metrics:

  - Population density
  - Density of low-income households – which are defined as households with income less than 75 percent of the urban area median household income
  - Density of people of color
  - Community health – a combined index based on the rate of poor mental health and low physical activity from the 2020 CDC PLACES census tract dataset
  - Urban heat islands – surface temperature at least 1.25o greater than city mean surface temperature from The Trust for Public Land, based on Landsat 8 satellite imagery
  - Pollution burden - Air toxics respiratory hazard index from 2020 EPA EJScreen

The 10-minute walk

For each park, we create a 10-minute walkable service area using a nationwide walkable road network dataset provided by Esri. The analysis identifies physical barriers such as highways, train tracks, and rivers without bridges and chooses routes without barriers.

- CDC Social Vulnerability Index 2018: RPL_Themes

  Social vulnerability refers to the capacity for a person or group to "anticipate, cope with, resist and recover from the impact" of a natural or anthropogenic disaster such as extreme weather events, oil spills, earthquakes, and fires. Socially vulnerable populations are more likely to be disproportionately affected by emergencies (Wolkin et al. 2018).

  In this indicator, we use the "RPL_THEMES" attribute from the Social Vulnerability Index, described here. "The Geospatial Research, Analysis, and Services Program (GRASP) at Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry developed the Social Vulnerability Index (SVI). The SVI is a dataset intended to help state, local, and tribal disaster management officials identify where the most socially vulnerable populations occur (Agency for Toxic Substances and Disease Registry [ATSDR] 2018)" (Flanagan et al. 2018).

  "The SVI database is regularly updated and includes 15 census variables (ATSDR 2018). Each census variable was ranked from highest to lowest vulnerability across all census tracts in the nation with a nonzero population. A percentile rank was calculated for each census tract for each variable. The variables were then grouped among four themes.... A tract-level percentile rank was also calculated for each of the four themes. Finally, an overall percentile rank for each tract as the sum of all variable rankings was calculated. This process of percentile ranking was then repeated for the individual states" (Flanagan et al. 2018).

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Convert the ParkServe park priority areas layer to a raster using the ParkRank field. Note: The ParkRank scores are calculated using metrics classified relative to each city. Each city contains park rank values that range from 1-3. For the purposes of this indicator, we chose to target potential park areas to improve equity. Because the ParkRank scores are relative for each city, a high score in one city is not necessarily comparable to a high score from another city. In an effort to try to bring more equity into this indicator, we also use the CDC Social Vulnerability Index to narrow down the results.
- Reclassify the ParkServe raster to make NoData values 0.
- Convert the SVI layer from vector to raster based on the "RPL_Themes" field.

- To limit the ParkRank layer to areas with high SVI scores, first identify census tracts with an "RPL_Themes" field value >0.65. Make a new raster that assigns a value of 1 to census tracts that score >0.65, and a value of 0 to everything else. Take the resulting raster times the ParkRank layer.
- Reclassify this raster into the 4 classes seen in the final indicator below.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

3 = Very high priority for a new park that would create nearby equitable access
2 = High priority for a new park that would create nearby equitable access
1 = Moderate priority for a new park that would create nearby equitable access
0 = Not identified as a priority for a new park that would create nearby equitable access (within urban areas)

Known Issues

- This indicator could overestimate park need in areas where existing parks are missing from the ParkServe database. TPL regularly updates ParkServe to incorporate the best available park data. If you notice missing parks or errors in the park boundaries or attributes, you can submit corrections through the ParkReviewer tool or by contacting TPL staff.
- Within a given area of high park need, the number of people served by the creation of a new park depends on its size and how centrally located it is. This indicator does not account for this variability. Similarly, while creating a new park just outside an area of high park need would create access for some people on the edge, the indicator does not capture the benefits of new parks immediately adjacent to high-need areas. For a more granular analysis of new park benefits, ParkServe's ParkEvaluator tool allows you to draw a new park, view its resulting 10-minute walk service area, and calculate who would benefit.
- Beyond considering distance to a park and whether it is open to the public, this indicator does not account for other factors that might limit park access, such as park amenities or public safety. The TPL analysis excludes private or exclusive parks that restrict access to only certain individuals (e.g., parks in gated communities, fee-based sites). The TPL data includes a wide variety of parks, trails, and open space as long as there is no barrier to entry for any portion of the population.
- The indicator does not incorporate inequities in access to larger versus smaller parks. In predicting where new parks would benefit nearby people who currently lack access, this indicator treats all existing parks equally.

- This indicator identifies areas where parks are needed but does not consider whether a site is available to become a park. We included areas of low intensity development in order to capture vacant lots, which can serve as new park opportunities. However, as a result, this indicator also captures some areas that are already used for another purpose (e.g., houses, cemeteries, and businesses) and are unlikely to become parks. In future updates, we would like to use spatial data depicting vacant lots to identify more feasible park opportunities.
- This indicator underestimates places in rural areas where many people within a socially vulnerable census tract would benefit from a new park. ParkServe covers incorporated and Census-designated places within census-designated urban areas, which leaves out many rural areas. We acknowledge that there are still highly socially vulnerable communities in rural areas that would benefit from the development of new parks. However, based on the source data, we were not able to capture those places in this version of the indicator.

Other Things to Keep in Mind

- The zero values in this indicator contain three distinct types of areas that we were unable to distinguish between in the legend: 1) Areas that are not in a community analyzed by ParkServe (ParkServe covers incorporated and Census-designated places within census-designated urban areas); 2) Areas in a community analyzed by ParkServe that were not identified as a priority; 3) Areas that ParkServe identifies as a priority but do not meet the SVI threshold used to represent areas in most need of improved equitable access.
- This indicator only includes park priority areas that fall within the 65th percentile or above from the Social Vulnerability Index. We did not perform outreach to community leaders or community-led organizations for feedback on this threshold.
- This indicator is intended to generally help identify potential parks that can increase equitable access but should not be solely used to inform the creation of new parks. As the social equity component relies on information summarized by census tract, it should only be used in conjunction with local knowledge and in discussion with local communities (NRPA 2021, Manuel-Navarete et al. 2004).
- Some areas identified in this indicator are not eligible to be prioritized in the final Blueprint. When we perform the optimization process in Zonation, we remove areas in the NLCD high and medium intensity development classes (see the Running Zonation section). Ideally, we would leave in the medium density development class, as it includes more vacant areas that could serve as potential parks. The NLCD medium intensity development class is defined as areas with a mixture of constructed materials and vegetation, where impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units. We are working on new methods that will allow us to include these areas in future Blueprint updates.

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There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Fire Frequency

This indicator uses remote sensing to estimate the number of times an area has been burned from 2013 to 2021. It combines burned area layers from U.S. Geological Survey Landsat data and the inter-agency Monitoring Trends in Burn Severity program. Landsat-based fire predictions within the range of longleaf pine are also available through Southeast FireMap.

Reason for Selection

Many Southeastern ecosystems rely on regular, low-intensity fires to maintain habitat, encourage native plant growth, and reduce wildfire risk. Historically in the South, "fires burned as often as once a year or more in Coastal Plain pine systems or as infrequently as every 50 years or more on north-facing or cove sites in the mountains", typically started by lightning or by Indigenous Americans using fire to manage open savannas. As a result, the forests and grasslands of the South contain many species that not only tolerate fire but require it. Fire suppression during the 20th century led to the loss and deterioration of many fire-adapted ecosystems and their associated wildlife and plant species. Today, "prescribed burning is an important tool throughout Southern forests, grasslands, and croplands" (Waldrop and Goodrick 2012).

Input Data

- Base Blueprint 2022 extent
- 2019 National Land Cover Database (NLCD)
- Floodplain Inundation Frequency Southeast version, available on request (email yvonne_allen@fws.gov)
- Landsat 8 Burned Area Products (ver. 2.0, Oct 2021)
- Monitoring Trends in Burn Severity (2020 data release, released 4-22-2022): National Burned Areas Boundaries Dataset
- Base Blueprint 2022 subregions
- Southeast Blueprint 2023 extent

Mapping Steps

- Identify burns using the annual burn frequency rasters in the Landsat 8 Burned Area (LBA) Products. Note: This LBA data source differs from the burned area probability raster used by Southeast FireMap 1.0 (Beta). The burn probability data was found to greatly overestimate the extent of burned area across the full region of the Southeast. Currently Southeast FireMap is limited to the historic range of longleaf pine.
- Sum the annual LBA rasters to calculate the number of times a pixel has been burned from 2013-2021 using the ArcPy Spatial Analyst Cell Statistics "SUM" function.
- Reclassify to a value of 0 the burned areas that are most likely to be false positives.
    - Assign a value of 0 to pixels classified in the 2019 NLCD as one of the following land cover types: Cultivated crops, barren (31), all urban (21, 22, 23, 24), woody wetlands (90) and open water (11). Fire in these pixels was often either not natural or likely misclassified. Clusters of pixels in barren landcover were often industrial sites and quarries.

    - Assign a value of 0 to areas with inundation frequency values from 5 to 100. Inundated vegetation is often misclassified as burned area since they have similar spectral signatures in remote sensing.
- Identify burns using the annual Monitoring Trends in Burn Severity (MTBS) data. These data are very robust, but only capture large fires on a subset of public lands. Therefore, we use them in conjunction with the LBA data.
- Sum the annual MTBS rasters to calculate the number of times a pixel has been burned from 2013-2021 using the ArcPy Spatial Analyst Cell Statistics "SUM" function.
- Combine LBA and MTBS results using ArcPy Spatial Analyst Cell Statistics to calculate the maximum number of times a pixel was classified as burned using the LBA and MTBS datasets.
- Reclassify the resulting raster so that all values of 3+ receive the maximum value of 3 in the final indicator, as shown below.
- Clip to the spatial extent of Base Blueprint 2022.
- Use the Base Blueprint 2022 subregions to mask out the "Marine Shelf and Extension" and "Marine Gulf Stream" subregions from the indicator. These two subregions were not evaluated for fire frequency because they are outside the scope of this terrestrial indicator.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

3 = Burned 3+ times from 2013-2021
2 = Burned 2 times from 2013-2021
1 = Burned 1 time from 2013-2021
0 = Not burned from 2013-2021 or row crop

Known Issues

- The LBA data layers overestimate fire frequency in open areas with wet soils. Wet soils can be much darker than dry soils and may be misclassified as burned areas. This misclassification was improved by removing areas classified as cultivated crops. A mask built upon the combination of Floodplain Inundation Frequency and NLCD woody wetlands was also used to reduce misclassifications.
- This indicator overestimates fire frequency in places with major impediments to burned area detection/mapping. Impediments include rapid green-up following a burn, cloud cover and shadows obscuring burn signatures, difficulty detecting or differentiating a low intensity burn signature beneath tree canopies, and the satellite product resolution often being too coarse to capture fine-scale differences or small burns.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Great Plains Perennial Grasslands

This indicator measures the percent of perennial forbs and perennial grass to evaluate grassland condition across the Great Plains. Grasslands in this area with a high percentage of perennials are less likely to be impacted by woody encroachment, less susceptible to non-native annual grasses, and more likely to support important plants, birds, and pollinators. This indicator originates from Rangeland Analysis Platform vegetation cover data.

Reason for Selection

The extensive grasslands of the Great Plains once stretched from Canada to Mexico, with a plant community dominated by native perennials and forbs. However, conversion to agriculture and other land uses have significantly reduced their extent, while overgrazing and fire suppression have also increased the amount of invasive and non-native plants. Great Plains grasslands support many rare and unique plant species, pollinators (e.g., the Monarch butterfly), birds, and other grassland-adapted animals (e.g., the prairie chicken). Since grassland birds are experiencing significant declines and are currently off-track for meeting the SECAS 10% goal, it is particularly important that the Blueprint capture known and potential grasslands.

Input Data

- Rangeland Analysis Platform (RAP) vegetation cover v3; download the data (vegetation-cover-v3-2021.tif, last updated 8-1-2022)
- 2019 National Land Cover Database (NLCD)
- Base Blueprint 2022 subregions
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Make a raster using only band 4 (perennial forbs and grass) from the RAP vegetation cover data.
- Remove from the resulting raster areas identified in the 2019 NLCD as water (11), urban (21-24), and crop (82). This removes fewer natural areas and is consistent with how the data are displayed in the RAP viewer.
- Combine the following subregions from the Base Blueprint 2022 subregions to create a Great Plains extent: Edwards Plateau, High Plains and Tablelands, Plains and Timbers, Southern Texas Plains, and Texas Blackland Prairies & Plains. While the data extended farther east and into southwest Texas, the indicator performed poorly in those places, so we excluded them from the indicator.
- Clip the previous raster to the created Great Plains extent.
- Bin the values of the resulting layer into five equal bins of 20% each, seen in the final indicator values below. 20% was chosen as the bin size because, based on comparisons to existing conserved areas and satellite imagery, more detailed classes appeared to correlate less with overall grassland condition, while less detailed classes appeared to miss impacts from woody encroachment.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = 81-100% perennial forbs and perennial grass
4 = 61-80% perennial forbs and perennial grass
3 = 41-60% perennial forbs and perennial grass
2 = 21-40% perennial forbs and perennial grass
1 = 0-20% perennial forbs and perennial grass

Known Issues

- This indicator likely underestimates grassland condition in areas where the natural reference conditions include a high percentage of annual forbs and grasses.
- This indicator overestimates condition in some urban areas. While there are grasslands in good condition in and around cities, the vegetation model was trained on points that were primarily outside of cities and doesn't perform as well on some grassland features in cities like large, regularly mowed fields.
- This indicator overprioritizes wetlands, which can appear to be high-scoring perennial grasslands.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Greenways & Trails

This cultural resource indicator measures both the natural condition and connected length of greenways and trails to characterize the quality of the recreational experience. Natural condition is based on the amount of impervious surface surrounding the path. Connected length captures how far a person can go without leaving a dedicated path, based on common distances for walking, running, and biking. This indicator originates from OpenStreetMap data and the National Land Cover Database.

Reason for Selection

This indicator captures the recreational value and opportunities to connect with nature provided by greenways and trails. Greenways and trails provide many well-established social and economic benefits ranging from improving human health, reducing traffic congestion and air and noise pollution, increasing property values, and generating new jobs and business revenue (ITRE 2018). The locations of greenways and trails are regularly updated through the open-source database OpenStreetMap, while data on condition are regularly updated through the National Land Cover Database (NLCD).

Input Data

- Base Blueprint 2022 extent
- OpenStreetMap data “roads” layer, accessed 2-27-2023

  A line from this dataset is considered a potential greenway/trail if the value in the “fclass” attribute is either bridleway, cycleway, footway, or path. OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

- 2019 National Land Cover Database (NLCD): Percent developed imperviousness
- Southeast Blueprint 2023 extent

Mapping Steps

The greenways and trails indicator score reflects both the natural condition and connected length of the greenway/trail.

Natural condition

Natural condition is based on the amount of impervious surface surrounding the greenway/trail. Since perceptions of a greenway's "naturalness" are influenced both by the immediate surroundings adjacent to the path, and the greater viewshed, natural condition is calculated by averaging two measurements: local impervious and nearby impervious.

Local impervious is defined as the percent impervious surface of the 30 m pixel that intersects the trail. Nearby impervious is defined as the average impervious surface within a 300 m radius circle surrounding the path (note: along a 300 m stretch of trail, we only count the impervious surface within a 45 m buffer on either side of the trail, since pixels nearer the trail have a bigger impact on the greenway/trail experience). The natural classes are defined as follows:

3 = Mostly natural: average of local and nearby impervious is ≤1%
2 = Partly natural: average of local and nearby impervious is >1 and <10%
1 = Developed: average of local and nearby impervious is ≥10%

Connected length

The connected length of the path is calculated using the entire extent of the potential greenways/trails dataset. A trail is considered connected to another trail if it is within 2 m of the other trail. Length thresholds are defined by typical lengths of three common recreational greenway activities: walking, running, and biking. The 40 km threshold for biking is based on the standard triathlon biking segment of 40 km (~25 mi). Because a 5K is the most common road race distance, the running threshold is set at 5 km (~3.1 mi) (Running USA 2017). The 1.9 km (1.2 mi) walking threshold is based on the average walking trip on a summer day (U.S. DOT 2002).

- Using the statistics software R, download the OpenStreetMap data for the continental Southeast area.
- Select all lines from the OpenStreetMap data that have a highway tag of either footway, cycleway, bridleway, or path. These are all considered potential trails.
- Removed all lines marked as private.
- Identify lines from the potential trails that are tagged as sidewalks. Assign them a value of 1 in the indicator.

Final scores

If the potential greenway/trail was tagged as a sidewalk in the "other tags" field, it is given a value of 1 to separate sidewalks from what most people think of as a trail or greenway. If a pixel does not intersect a potential greenway/trail but overlaps with a value that is not NoData in the 2019 NLCD impervious surface layer, it is coded with a value of 0. Then clip to the spatial extent of Base Blueprint 2022. As a final step, clip to the spatial extent of Southeast Blueprint 2023.

		Trail length				Sidewalk
		L ≥ 40 km	40 km > L ≥ 5 km	5 km > L ≥ 1.9 km	L < 1.9 km	
Average of local and nearby impervious	Imp ≤ 1%	7	6	5	4	
	1% < Imp < 10%	6	5	4	3	1
	Imp ≥ 10%	5	4	3	2	
Sidewalk		1				

Final indicator values

Indicator values are assigned as follows:

7 = Mostly natural and connected for ≥40 km

6 = Mostly natural and connected for 5 to <40 km or partly natural and connected for ≥40 km

5 = Mostly natural and connected for 1.9 to <5 km, partly natural and connected for 5 to <40 km, or developed and connected for ≥40 km

4 = Mostly natural and connected for <1.9 km, partly natural and connected for 1.9 to <5km, or developed and connected for 5 to <40 km

3 = Partly natural and connected for <1.9 km or developed and connected for 1.9 to <5km

2 = Developed and connected for <1.9 km

1 = Sidewalk

0 = Not identified as trail, sidewalk, or other path

Known Issues

- This indicator sometimes misclassifies sidewalks as greenways and trails because they are not tagged as a sidewalk in the OpenStreetMap data.
- This indicator occasionally misclassifies driveways as sidewalks in places where they are not correctly tagged as private in OpenStreetMap. These typically appear as isolated pixels receiving a score of 1 on the indicator.
- OpenStreetMap does not provide a complete inventory of greenways and trails in the Southeast. Paths that are missing from the source data will be underprioritized in this indicator. For example, some trails are missing within National Wildlife Refuges.
- When calculating nearby impervious for one greenway, if there's another greenway within 300 m, impervious surface from the different but overlapping greenway buffer area is also used to compute natural condition. This is an unintended issue with the analysis methods. Investigation into potential fixes is ongoing.

- This indicator includes trails and sidewalks from OpenStreetMap, which is a crowdsourced dataset. While members of the OpenStreetMap community often verify map features to check for accuracy and completeness, there is the potential for spatial errors (e.g., misrepresenting the path of a greenway) or incorrect tags (e.g., mislabeling a path as a footway that is actually a road for vehicles). However, using a crowdsourced dataset gives on-the-ground experts, Blueprint users, and community members the power to fix errors and add new greenways and trails to improve the accuracy and coverage of this indicator in the future.
- This indicator sometimes underestimates greenway length when connections route under bridges or along abandoned dirt roads. Some of these issues have been fixed through active testing and improvement, but some likely remain.
- The indicator doesn't currently include areas where future greenways are planned.

Disclaimer: Comparing with Older Indicator Versions

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Intact Habitat Cores

This indicator represents the size of large, unfragmented patches of natural habitat. It identifies minimally disturbed natural areas at least 100 acres in size and greater than 200 meters wide. This indicator originates from Esri's green infrastructure data.

Reason for Selection

Large areas of intact natural habitat are favorable for conservation of numerous species, including reptiles and amphibians, birds, and large mammals. The Esri Green Infrastructure data covers the entire United States and has been used in other broad-scale conservation planning efforts, so using this existing data helps align the Blueprint with other conservation efforts and reduce duplication of effort. We chose to use "Core Size (acres)" as the metric for this indicator. Other evaluation attributes included in this index, such as the default "Core Score", were less suitable because they were calculated using inputs that are duplicative of other indicators.

Input Data

- Esri Green Infrastructure Data: Intact habitat cores by state, core size (acres)

  We downloaded this dataset by state from arcgis.com. The Esri Green Infrastructure website provides more information about these data, access to the models utilized to generate them, and additional online applications for green infrastructure planning. More information about the intact habitat cores is available here and in this FAQs document.

  Esri's description of the core size metric states: "Cores were derived from the 2011 National Land Cover dataset. The 'natural' land cover classes were included, and all 'developed' and 'agricultural' classes, including crop, hay and pasture lands, were excluded. The resulting cores were tested for size and width requirements (at least 100 acres in size and greater than 200 m) and then converted into unique polygons."

- 2019 National Land Cover Database (NLCD)
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Create a new feature class by merging all the state-level "Intact Habitat Cores (March 2017)" polygon feature classes that cover the Southeast region using the ArcPy Merge function.

- Delete identical polygons from the merged feature class using the ArcPy Delete Identical function. This removes duplicate polygons that span state boundaries and are included in multiple state layers.
- Convert the polygon to a raster using the ArcPy Polygon to Raster function using the value field of "Acres". This results in a raster dataset with 30 m cell size with values based on the "Core Size (acres)" field calculated by the Esri Green Infrastructure Data group.
- Change NoData values (pixels not covered by an intact habitat core) to 0. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Use NLCD to remove zero values in deep marine areas, which are outside the scope of this terrestrial indicator. Reclassify to NoData any area with a pixel value >0 in the NLCD.
- Reclassify the above raster into 4 classes, seen in the final indicator values below.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

> 3 = Large core (>10,000 acres)
> 2 = Medium core (>1,000-10,000 acres)
> 1 = Small core (>100–1,000 acres)
> 0 = Not a core

Known Issues

- The core analysis for this indicator is based on the 2011 NLCD, not the more recent 2019 NLCD. The data creator (Esri) plans to update the source data to more recent landcover next year. Esri has also shared the scripts and input data used to create this layer, which may also help update this indicator in the future.
- Even small dirt roads serve as hard boundaries for habitat cores. While this makes sense for some species, the effective size of the patch for some more mobile animals is likely underestimated.
- Waterbodies like reservoirs are also considered part of habitat cores, so this layer likely overestimates the effective size of the habitat core for most species.

Disclaimer: Comparing with Older Indicator Versions

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Literature Cited

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Interior Southeast Grasslands

This indicator represents grasslands in the interior southeastern United States, which support important plants, birds, and pollinators. It includes grasslands with and without trees that are historically maintained by geology (e.g., outcrops, glades, and barrens), fire (e.g., Piedmont prairies), and/or the regular violent flooding on the banks of high-energy rivers known as "riverscour" (e.g, riverscour prairies). Known grasslands receive the highest scores, followed by bumble bee habitat buffers around known sites, areas in potentially compatible management, and restoration opportunities within grassland geology. This indicator combines data from multiple sources, including the Southeastern Grasslands Institute, the Central Hardwoods Joint Venture, the Rangeland Analysis Platform, and more.

Reason for Selection

Native grasslands are important for many endemic species, provide critical habitat and food for pollinators, and are often hotspots for biodiversity. Once a predominant ecosystem type, grasslands have significantly declined from their historical extent and often occur in fragmented patches like fencerows, powerline corridors, roadsides, corners of old fields, and small clearings among forests. In part because of the regular disturbance (e.g., mowing, fire) typically required to maintain high-quality grasslands, they are difficult to detect through remote sensing and are not well-captured by other indicators. In addition, grassland birds are experiencing significant declines and are currently off-track for meeting the SECAS 10% goal, so it is important that the Blueprint capture known and potential grassland habitat.

Input Data

- Base Blueprint 2022 subregions
- Central Hardwoods Ecological Potential Vegetation
- The Nature Conservancy's Resilient and Connected Network project: Geophysical settings
- Known grassland prairies dataset for the Middle Southeast subregion, provided by Toby Gray with Mississippi State University (available on request by emailing toby@gri.msstate.edu); this is an improved version of the Known Prairie Patches in the Gulf Coastal Plains and Ozarks (GCPO) layer
- Known Piedmont prairie locations in the South Atlantic subregion: We identified known prairie locations by requesting spatial data on known prairies from the 74 members of the Piedmont Prairie Partnership mailing list and other prairie managers (Wake County Open Space program and Prairie Ridge Ecostation in NC). We combined that information with known locations in Virginia aggregated by the Virginia Natural Heritage Program (available on request by emailing rua_mordecai@fws.gov).

- Southeastern Grasslands Institute polygons from selected iNaturalist projects. We used only projects with polygons digitized at a fine resolution and did not include projects with more coarse polygons covering a large area. Specific projects used were: allegheny-mountains-riverscour-barrens, big-south-fork-riverscour-barrens-1, big-south-fork-riverscour-barrens-2, big-south-fork-riverscour-barrens-4-us, big-south-fork-riverscour-barrens-6, biodiversity-of-piedmont-granite-glades-outcrops, bluff-mountain-fen, caney-fork-sandstone-riverscour-barrens-and-glades, clear-creek-sandstone-riverscour-barrens, clear-fork-river-riverscour-barrens, craggy-mountains-mafic-outcrops-and-barrens, cumberland-plateau-escarpment-limestone-barrens, cumberland-river-limestone-riverscour-glades, daddy-s-creek-riverscour-barrens, dunbar-cave-prairie-restoration, eastern-highland-rim-limestone-riverscour-glade, emory-river-sandstone-riverscour-barrens, falls-of-the-ohio-river-limestone-riverscour-glade, flat-rock-cedar-glades-and-barrens-state-natural-area, grasshopper-hollow-fen, gunstocker-glade, hiwassee-river-phyllite-riverscour-glade, ketona-dolomite-barrens, laurel-river-riverscour-barrens-and-glades, lime-hills-limestone-barrens, limestone-barrens-of-the-western-valley-of-the-tennessee-river, little-mountains-limestone-barrens, little-river-canyon-riverscour-barrens-and-glades, moulton-valley-limestone-glades, mulberry-fork-of-black-warrior-river-riverscour-barrens-and-glades, muldraugh-s-hill-limestone-barrens, nashville-basin-limestone-glades, new-river-riverscour-barrens, obed-river-sandstone-riverscour-barrens, outer-bluegrass-dolomite-barrens, ridge-and-valley-sandstone-outcrops, rock-creek-sandstone-riverscour-barrens, rockcastle-river-sandstone-riverscour-barrens, shawnee-hills-sandstone-glades-and-outcrops, southern-blue-ridge-mountains-grass-balds, southern-blue-ridge-mountains-serpentine-barrens, southern-blue-ridge-phyllite-outcrops, southern-ridge-and-valley-limestone-glades, southern-ridge-and-valley-shale-barrens, southern-ridge-and-valley-siltstone-barrens, tennessee-ridge-and-valley-dolomite-barrens-and-woodlands-tn-us, the-farm-prairie-and-oak-savanna, tin-top-road-savanna, western-allegheny-escarpment-limestone-barrens, western-highland-rim-limestone-glade-and-barrens, western-valley-limestone-barrens-decatur-co-north-us, western-valley-limestone-barrens-hardin-wayne-cos, western-valley-limestone-barrens-perry-co, western-valley-silurian-limestone-barrens, white-s-creek-sandstone-riverscour-barrens-and-glades
- Esri U.S. Electric Transmission Line dataset (last updated 4-3-2022)
- Rangeland Analysis Platform (RAP) vegetation cover v3; download the data (vegetation-cover-v3-2021.tif, last updated 8-1-2022)
- Protected Areas Database of the United States (PAD-US) 2.1 Combined Fee Easement
- 2019 National Land Cover Database (NLCD)
- Southeast Blueprint 2023 extent

Mapping Steps

- Define the extent of this indicator using the Base Blueprint 2022 subregions layer. Include as part of the extent of this indicator polygons with the following values in the SubRgn_II field: ‘Central Gulf Coastal Plain’, ‘Interior Plateau’, ‘Mid East Gulf Coastal Plain’, ‘North Appalachians’, ‘North Piedmont’, ‘Ozarks and Plains’, ‘South Appalachians’, ‘South Piedmont’.

- Merge into a single feature class the individual known grassland polygons from the Piedmont Prairie Partnership, Middle Southeast subregion, and Southeastern Grasslands Institute. For the known grassland polygons that were originally .kml files, convert to feature class using the Batch Import Data function. Use a Repair Geometry function to clean up the converted .kml files. Then, combine all feature classes using the Union function.
- From the PAD-US 2.1 Combined Fee Easement layer, select the polygons that are part of the Grassland Reserve Program using the following selection: Loc_Ds = 'GRP' Or Unit_Nm LIKE '%Grasslands Reserve Program%' Or Unit_Nm LIKE '%Grassland Reserve Program%'.
- Combine the known grassland and Grassland Reserve Program polygons using a Union function. Convert to a raster and assign known grasslands a value of 5.
- Buffer the full known grassland layer by 800 m to capture the habitat needs of bumble bees for foraging, nesting, and overwintering (Schweitzer et al. 2012). Convert the buffered areas to a raster and assign them a value of 4. Remove pixels that identified in the NLCD as developed high intensity, developed medium intensity, or open water.
- Identify classes in the TNC geophysical settings raster associated with grassland geology. We started by using the following classes in the CL_GEOSOIL field: 'Calcareous Sedimentary', 'Mafic/Intermediate Granitic', 'Silt/Clay over Limestone', 'Ultramafic'. This did not capture everything we needed, so we also used the following classes in the Full_Name class: 'Calcareous Sedimentary', 'Moderately Calcareous Sedimentary', 'Mid Elevation Acidic Sedimentary'. Classify all pixels that meet the above conditions as 1 and classify everything else as 0.
- In the Central Hardwoods region, the Ecological Potential Vegetation layer provides a better representation of grassland geology than TNC geophysical settings. Use as grassland geology pixels with the following values in the VEG_ORDER field: 1 = Prairie/Grassland, 2 = Prairie/Savanna (< 20% canopy), 3 = Prairie/Savanna (Barrens) (< 20% canopy), 4 = Glade/Savanna Mosaic (< 20% canopy), 5 = Oak Open Woodland (20-50% canopy), 7 = Pine/Bluestem Open Woodland (20-50% canopy). Classify all pixels that meet the above conditions as 1 and classify everything else as 0.
- In the area where Central Hardwoods Potential Ecological Vegetation layer overlaps with TNC resilient land settings, use only the Central Hardwoods layer. Use the Mosaic to New Raster function, using "first" as the mosaic operator, making sure that the Central Hardwoods layer is listed first. In the resulting raster, values of 1 are considered "grassland geology."
- Use the transmission lines to identify areas of potentially compatible grassland management. Convert these lines from vector to a 30 m raster.
- Use the RAP vegetation cover perennial forbs and grasses layer to identify additional areas of potentially compatible grassland management. Extract areas classified as >30% perennial forb and grass cover.
- Combine the transmission line and perennial forbs and grasses layers created above into single raster representing areas of potentially compatible grassland management.
- From the combined potentially compatible grassland management layer, remove some pixels using the NLCD. Expand by 1 pixel areas classified as the 3 highest urban classes (developed high intensity, developed medium intensity, or developed low intensity). Remove all areas

that overlap or are within one 30 m pixel of these urban classes. Next, further limit these potentially compatible management areas to landcover types in the NLCD we identified as restorable (developed open space, barren land, deciduous forest, evergreen forest, mixed forest, scrub/shrub, herbaceous, hay/pasture).

- In this reduced potentially compatible grassland management area, there are some isolated pixels. Remove all pixel clumps (using an 8-neighbor rule) that contain only 1 or 2 pixels.
- Where the potentially compatible management layer intersects the grassland geology layer, create a raster and assign those areas a value of 3.
- Where the potentially compatible management layer does not intersect the grassland geology layer, create a raster and give those areas a value of 2.
- Combine all 5 rasters produced above using a Cell Statistics "MAX" function that retains the maximum value for each pixel across all inputs. This results in a raster with 5 classes, seen in the final indicator values below.
- Clip the resulting layer to the unique indicator extent defined in the first step.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Known grassland
4 = Known grassland buffer
3 = Potentially compatible management within grassland geology (undeveloped powerline right-of-way or perennial forbs and grasses)
2 = Potentially compatible management outside of grassland geology (undeveloped powerline right-of-way or perennial forbs and grasses)
1 = Grassland geology
0 = Grassland less likely

Known Issues

- Some known grassland locations are omitted due to confidentiality concerns around potential poaching and disturbance of rare plant species.
- The powerline dataset does not include smaller powerline rights-of-way that can also be important grassland habitat. Important roadside grassland habitat often occurs in these smaller power line rights-of-way. We are continuing to look for data sources that depict these smaller power line rights-of-way across the full Southeast region.
- Other locations of disturbance that can help maintain grasslands, like sewer lines and pipelines, are not included in this indicator. We have been unable to find a multi-state data layer that depicts sewer line locations. A national dataset on pipeline locations does exist, but its terms of use prevent us from using it in an indicator.

- Locations of many managed grasslands, especially in the Central Hardwoods subregion, are not yet included in the known grassland class. We are working to obtain more spatial data on the locations of managed grasslands within the region scored in this indicator.
- While other grassland-specific indicators cover important areas not scored in this indicator, there is a gap in Northeast Oklahoma between the area scored in this indicator and where the complementary indicator, Great Plains Perennial Grasslands, takes over.
- Neither the powerline data nor the RAP perennial forbs and grasses layer differentiate between native and non-native grassland plant species. They also don't account for other non-compatible management practices that may occur, like non-selective herbicide application.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Mississippi Alluvial Valley Forest Birds - Protection

This indicator prioritizes areas for new land protection within the Mississippi Alluvial Valley (MAV) based on benefits to forest breeding birds that need large interior cores of bottomland hardwood habitat (Swainson's warbler, cerulean warbler, swallow-tailed kite). The model considers core size, the amount of existing protected land within a forest patch, proximity to reforestation priorities, and risk of conversion to agriculture based on flooding frequency. The highest scores go to drier, unprotected forest patches with cores at least 2,000 ha (~5,000 ac) in size that are adjacent to complementary reforestation priority areas also identified by the Lower Mississippi Valley Joint Venture (LMVJV). This indicator originates from the LMVJV MAV forest breeding bird protection priorities.

Reason for Selection

This indicator reflects the importance of conserving large forested tracts in the MAV that provide important habitat for interior forest breeding birds and other species. Agriculture and development have greatly reduced the extent of the bottomland hardwood forests that historically dominated the MAV, while changes in hydrology and forest management have altered the structure and composition of the remaining forests. This indicator also promotes consistency with the forest protection priorities of the Lower Mississippi Valley Joint Venture, which serve as a key resource for land trusts and other conservation partners in the MAV looking to advance bird conservation objectives through strategic forest protection.

Input Data

- Mississippi Alluvial Valley (MAV) Forest Protection Model from the Lower Mississippi Valley Joint Venture (LMVJV)

  This model identifies forest patches that are a priority for future protection "based on benefits to forest bird conservation afforded by forest patch area, geographic location, and hydrologic condition" (Elliott et al. 2020). It excludes already protected lands. The model first identifies as meriting protection existing forest patches in the MAV with interior cores (<250 m from a hostile edge) that are either ≥1,600 ha in size or adjacent to high priority areas from the complementary reforestation model. It then prioritizes based on the percent of the patch that is unprotected, also factoring in core size, proximity to reforestation priorities, and flood frequency. The model awards the highest scores to unprotected patches that are ≥2,000 ha (~5,000 acres), the least flood-prone (and therefore at higher risk of agricultural conversion), and adjacent to reforestation priorities.

The model characteristics are based on the habitat needed to support a source population of three species of interior forest breeding birds: Swainson's warbler, swallow-tailed kite, and cerulean warbler. These species received the highest overall priority score in [the 1999 Partners in Flight Plan for the MAV] based on their level of conservation concern. Each bird is used to represent an ecological suite of species with similar habitat needs. Swainson's warbler also represents prothonotary warbler, hooded warbler, wood thrush, and Acadian flycatcher; cerulean warbler also represents Kentucky warbler, summer tanager, yellow-billed cuckoo, and eastern wood-pewee; and swallow-tailed kite also represents red-shouldered hawk, broad-winged hawk, pileated woodpecker, and Cooper's hawk (Mini and Elliott 2022).

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Reproject the Mississippi Alluvial Valley (MAV) Forest Protection Model to NAD 1983 Contiguous USA Albers (EPSG 5070).
- Reclassify the LMVJV source data as seen in the legend below.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

10 = Highest priority forest breeding bird habitat patch for future protection (score >90-100)
9 = (score >80-90)
8 = (score >70-80)
7 = (score >60-70)
6 = (score >50-60)
5 = (score >40-50)
4 = (score >30-40)
3 = (score >20-30)
2 = (score >10-20)
1 = Lowest priority (score >0-10)
0 = Not a priority (score = 0)

Known Issues

- The forest bird protection model identifies large forest patches using 2011 Landsat data, which does not reflect more recent changes in landcover. As a result, this indicator may include patches fragmented by recent development that no longer meet the protection criteria. Conversely, this indicator may also overlook patches reforested in the last decade that now meet the protection criteria.
- Similarly, the forest bird protection model uses an older version of the Protected Areas Database of the United States (PAD-US 2.0) and therefore may miss more recently conserved lands. As a result, the indicator likely undervalues forest patches near newly protected areas, or protected areas added for the first time in the more recent versions of PAD-US (versions 2.1 and 3.0).
- Because birds are highly mobile and migratory, the forest bird protection model does not prioritize opportunities to improve the connectivity of the conservation estate. This dataset is not intended to identify high priority linkages between protected areas that may support isolated populations of less mobile species like black bear. The forest bird protection model also does not emphasize the value of creating new foundational protected areas in places that don't currently have any. As these opportunities are outside the scope of the source data, this indicator largely does not capture them.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Elliott AB, Mini AE, McKnight SK, Twedt DJ. Conservation–Protection of Forests for Wildlife in the Mississippi Alluvial Valley. Forests. 2020; 11(1):75. https://doi.org/10.3390/f11010075. [https://static1.squarespace.com/static/5bb3865d2727be6f94acf2fc/t/5e15ea9decbb473fb91c6d30/1597419918742/MAV+Forest+Protection].

Mini, Anne, and Blaine Elliott. March 17, 2022. Forest conservation priorities for landbirds in the Mississippi Alluvial Valley. Webinar hosted by the Southeast Conservation Adaptation Strategy. [https://www.youtube.com/watch?v=ggYjN3XdfMM&t=819s].

Mississippi Alluvial Valley Forest Birds - Reforestation

This indicator prioritizes areas for reforestation within the Mississippi Alluvial Valley (MAV) based on benefits to three species of forest breeding birds that need large interior cores of bottomland hardwood habitat (Swainson's warbler, cerulean warbler, swallow-tailed kite). The model considers the core size, number of cores, and percent of local forest cover that would result from reforestation, as well as risk of conversion to agriculture based on flooding frequency. The highest scores go to drier areas where reforestation would create new forest patches containing interior cores at least 2,000 ha (~5,000 ac) in size. It originates from the Lower Mississippi Valley Joint Venture MAV forest breeding bird reforestation priorities.

Reason for Selection

This indicator reflects the importance of restoring large forested tracts in the MAV to provide quality habitat for interior forest breeding birds and other species. Agriculture and development have greatly reduced the extent of the bottomland hardwood forests that historically dominated the MAV, while changes in hydrology and forest management have altered the structure and composition of the remaining forests. This indicator also promotes consistency with the reforestation priorities of the Lower Mississippi Valley Joint Venture (LMVJV), which serve as a key resource for land trusts and other conservation partners in the MAV looking to advance bird conservation objectives through strategic forest management and restoration.

Input Data

- MAV Forest Breeding Bird Reforestation Model from the Lower Mississippi Valley Joint Venture (LMVJV)

  This model prioritizes places where reforestation would reduce forest fragmentation and increase the area of interior forest cores (<250 m from a hostile edge). Its primary objective was to increase the number of forest patches containing interior cores >2,000 ha (~5,000 ac) in size, but it also sought to increase the number and size of cores >5,000 ha (~12,000 acres). At the same time, the model prioritized areas where reforestation would achieve at least 60% forest cover within local (320 km^2) landscapes. Finally, it prioritized higher-elevation bottomland hardwood forests that are less flood-prone and therefore at higher risk of agricultural conversion) (LMVJV 2015).

  The model characteristics are based on the habitat needed to support a source population of three species of interior forest breeding birds: Swainson's warbler, swallow-tailed kite, and cerulean warbler. These species received the highest overall priority score in the 1999 Partners in Flight Plan for the MAV based on their level of conservation concern. Each bird is used to represent an ecological suite of species with similar habitat needs. Swainson's warbler also represents prothonotary warbler, hooded warbler, wood thrush, and Acadian flycatcher; cerulean warbler also represents Kentucky warbler, summer tanager, yellow-billed cuckoo, and eastern wood-pewee; and swallow-tailed kite also represents red-shouldered hawk, broad-winged hawk, pileated woodpecker, and Cooper's hawk (Mini and Elliott 2022).

- Mississippi Alluvial Valley (MAV) Forest Protection Model from the Lower Mississippi Valley Joint Venture (LMVJV)
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Reproject the MAV Forest Breeding Bird Reforestation Model to NAD 1983 Contiguous USA Albers (EPSG 5070).

- Use the MAV Forest Protection Model to calculate the modeling extent of this indicator. The reforestation layer doesn't have zero values to indicate places that are within the modeling extent but are not a priority for reforestation because they are already forested. Assign a value of 0 to any pixel with a value ≥0 in the protection layer that did not already have a value in the reforestation layer. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

10 = Reforestation most likely to contribute to forest breeding bird habitat needs (≥90th percentile)

9 = Reforestation most likely to contribute to forest breeding bird habitat needs (80th to <90th percentile)

8 = Reforestation more likely to contribute to forest breeding bird habitat needs (70th to <80th percentile)

7 = Reforestation less likely to contribute to forest breeding bird habitat needs (60th to <70th percentile)

6 = Reforestation least likely to contribute to forest breeding bird habitat needs (50th to <60th percentile)

5 = Reforestation least likely to contribute to forest breeding bird habitat needs (40th to <50th percentile)

4 = Reforestation least likely to contribute to forest breeding bird habitat needs (30th to <40th percentile)

3 = Reforestation least likely to contribute to forest breeding bird habitat needs (20th to <30th percentile)

2 = Reforestation least likely to contribute to forest breeding bird habitat needs (10th to <20th percentile)

1 = Reforestation least likely to contribute to forest breeding bird habitat needs (<10th percentile)

0 = Not a priority for reforestation

Known Issues

- Most important areas in this indicator represent priorities for reforestation, as opposed to identifying areas currently in good or ideal ecological condition.
- While analysis by the LMVJV has found that it is most important to work in areas scoring higher than 8, we included the full dataset in this indicator.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Playas

This indicator represents the condition and location of playas, which are round, shallow depressions found primarily in the western Great Plains that serve as temporary wetlands by collecting water from rainfall and runoff. It defines a healthy playa as one that is not farmed, hydrologically modified, within a wind farm, or impacted by sediment accumulation due to agriculture. It also considers the increased benefits to wildlife provided by clusters of nearby playas, compared to more sparsely distributed playas. This indicator originates from the Playa Lakes Joint Venture probable playas dataset.

Reason for Selection

The unique wet-dry cycle that characterizes this important wetland ecosystem makes playas a biodiversity hotspot within the Great Plains. Playas support a rich community of wetland plants and invertebrates, providing habitat and food for migrating waterfowl, shorebirds, and resident prairie birds, as well as many mammal and amphibian species. Healthy playas “provide a sustainable water source for communities and rain-fed operations, water filtration, flood control, livestock forage, and recreation” (PLJV 2022). They play a particularly critical role in groundwater recharge and filtration that improve the quantity and quality of water in the region’s aquifers. Sediment accumulation due to agriculture in and around playas, as well as modification from construction and hydrologic alteration, have significantly degraded and continue to threaten the habitat and ecosystem services that playas provide (PLJV website).

Input Data

- Base Blueprint 2022 extent
- Playa Lakes Joint Venture probable playas dataset v5, accessed 5-25-2022

  This dataset is a regional compilation of several data sources including the National Wetlands Inventory, Soil Survey Geographic database, and satellite imagery. Specific details on methods are in the release notes. This dataset defines a healthy playa as one that is not farmed, has no hydrological modifications, is not within a wind farm, and is not sedimented. It defines playa clusters by identifying areas with either high playa density or high playa surface area, according to duck abundance data collected on playas.

- Playa Lakes Joint Venture (JV) boundary extracted from the North American Joint Venture Boundary dataset
- Southeast Blueprint 2023 extent

Mapping Steps

- From the Playa Lakes JV probable playas v5 data, convert polygons to raster and use the fields "healthy" and "cluster" to identify healthy playas and those that are part of a larger cluster.
- Assign zero values to all pixels not identified as a playa above. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Convert the Playa Lakes JV boundary to raster, giving it a value of 1.
- Limit the playas data (values of 0, 1, 2, and 3) to the Playa Lakes JV boundary by taking the playa raster times the JV raster.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

3 = Healthy playa and part of a larger cluster
2 = Healthy playa
1 = Other playa
0 = Not identified as a playa

Known Issues

- This indicator underrepresents playas, especially those smaller than 2 acres, in the eastern half of Beaver, Oklahoma. NWI data were missing from that area and the additional data sources used tend to underestimate playas, especially those less than 2 acres in size.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Playa Lakes Joint Venture. Playas of the high plains: Providing water for wildlife and people. [https://pljv.org/docs/What_Are_Playas.pdf].

Playa Lakes Joint Venture probable playas dataset v5. Playa Lakes Joint Venture. Accessed May 25, 2022. [https://pljv.org/playas/playa-tools/].

Playa Lakes Joint Venture website. 2022. Playas Benefit Wildlife and People. [https://pljv.org/playas/].

Resilient Terrestrial Sites

This indicator depicts an area's capacity to maintain species diversity and ecosystem function in the face of climate change. It measures two factors that influence resilience. The first, landscape diversity, reflects the number of microhabitats and climatic gradients created by topography, elevation, and hydrology. The second, local connectedness, reflects the degree of habitat fragmentation and strength of barriers to species movement. Highly resilient sites contain many different habitat niches that support biodiversity, and allow species to move freely through the landscape to find suitable microclimates as the climate changes. This indicator originates from The Nature Conservancy's Resilient Land data.

Reason for Selection

Resilience scores quantify a combination of landscape diversity and local connectedness, stratified by geophysical setting and ecoregion. These measures represent the number of microclimates available to species and the current state of the landscape. This builds on research from Anderson and Ferree (2010), who showed geophysical diversity and elevation range were associated with biodiversity in the Eastern United States. Resilience emphasizes diverse landscapes where species are likely to be able to move and adjust to changing conditions.

Input Data

- Base Blueprint 2022 extent
- The Nature Conservancy's (TNC) Resilient Land: download the data;(Terrestrial Resilience Score Only in geodatabase format - Resilient_Sites_National_CONUS_terrestrial.zip); read more about the analysis
- Southeast Blueprint 2023 extent

Mapping Steps

- Classify the VALUE field into the final indicator values as shown below. This translates the original continuous layer into the standard deviation-based classes that TNC uses to display the resilience data in their viewer.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

7 = Most resilient
6= More resilient
5 = Slightly more resilient
4 = Average/median resilience
3 = Slightly less resilient
2 = Less resilient
1 = Least resilient
0 = Developed

Known Issues

- This indicator does not account for the occurrence and timing of disturbance processes, particularly fire. Without fire, resilient sites in many terrestrial ecosystems will not serve as biodiversity hotspots. This is particularly problematic in pine and prairie ecosystems in the Piedmont and Coastal Plain.
- Resilience scores on indigenous lands are still under review and are not included in this indicator.
- This indicator is derived from an interim data product provided by TNC prior to its official release. The final version has since been publicly released. While we are not aware of any significant changes, it's possible there may be slight differences between the preliminary data used in this indicator and the final published data.
- TNC no longer runs the terrestrial resilience analysis in the coastal zone, coding some areas as NoData that they scored in past iterations of TNC Resilient Land. Areas within the coastal zone receive a NoData score in this indicator because TNC's analysis estimates coastal resilience only for areas that are currently marsh or expected to become marsh under various sea-level rise scenarios.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Anderson, M.G., A. Barnett, M. Clark, C. Ferree, A. Olivero Sheldon, J. Prince. 2016. Resilient Sites for Terrestrial Conservation in Eastern North America. The Nature Conservancy, Eastern Conservation Science.
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South Atlantic Amphibian & Reptile Areas

This indicator represents Priority Amphibian and Reptile Conservation Areas (PARCAs) in the South Atlantic. PARCA is an expert-driven, nonregulatory designation that includes places capable of supporting viable amphibian and reptile populations, places occupied by rare or imperiled species, and places rich in biodiversity or species unique to that geographic area (i.e., endemism).

Reason for Selection

The Southeast United States is a global biodiversity hotspot that supports many rare and endemic reptile and amphibian species (Barrett et al. 2014, EPA 2014). These species are experiencing dramatic population declines driven by habitat loss, pollution, invasive species, and disease (Sutherland and deMaynadier 2012, EPA 2014, CI 2004). Amphibians provide an early signal of environmental change because they rely on both terrestrial and aquatic habitats, are sensitive to pollutants, and are often narrowly adapted to specific geographic areas and climatic conditions. As a result, they serve as effective indicators of ecosystem health (CI et al 2004, EPA 2014). Their association with particular microhabitats and microclimates makes amphibians vulnerable to climate change, and Southeast amphibians are predicted to lose significant amounts of climatically suitable habitat in the future (Barrett 2014).

PARCAs also represent the condition and arrangement of embedded isolated wetlands. Many amphibians breed in temporary (i.e., ephemeral) wetlands surrounded by upland habitat, which are not well-captured by existing indicators in the Blueprint (Erwin 2016).

Input Data

- Southeast Blueprint 2023 extent
- Base Blueprint 2022 extent
- 2019 National Land Cover Database (NLCD)
- South Atlantic Blueprint 2021 extent

- South Atlantic Priority Amphibian and Reptile Conservation Areas

  PARCA is a nonregulatory designation established to raise public awareness and spark voluntary action by landowners and conservation partners to benefit amphibians and/or reptiles. Areas are nominated using scientific criteria and expert review, drawing on the concepts of species rarity, richness, regional responsibility, and landscape integrity. Modeled in part after the Important Bird Areas program developed by BirdLife International, PARCAs are intended to be nationally coordinated but locally implemented at state or regional scales. Importantly, PARCAs are not designed to compete with existing landscape biodiversity initiatives, but to complement them, providing an additional spatially explicit layer for conservation consideration.

  PARCAs are intended to be established in areas:

  - capable of supporting viable amphibian and reptile populations,
  - occupied by rare, imperiled, or at-risk species, and
  - rich in species diversity or endemism.

  Species used in identifying the PARCAs include: alligator snapping turtle, Barbour's map turtle, one-toed amphiuma, Savannah slimy salamander, Mabee's salamander, dwarf waterdog, Neuse river waterdog, chicken turtle, spotted turtle, tiger salamander, rainbow snake, lesser siren, gopher frog, Eastern diamondback rattlesnake, Southern hognose snake, pine snake, flatwoods salamander, gopher tortoise, striped newt, pine barrens tree frog, and indigo snake.

  There are four major implementation steps:

  - Regional PARC task teams or state experts can use the criteria and modify them when appropriate to designate potential PARCAs in their area of interest.
  - Following the identification of all potential PARCAs, the group then reduces these to a final set of exceptional sites that best represent the area of interest.
  - Experts and stakeholders in the area of interest collaborate to produce a map that identifies these peer-reviewed PARCAs.
  - Final PARCAs are shared with the community to encourage the implementation of voluntary habitat management and conservation efforts. PARCA boundaries can be updated as needed.

Mapping Steps

- Convert the PARCA polygon data from vector to a 30 m pixel raster using the ArcPy Feature to Raster function. Give PARCAs a value of 1.
- Reclassify the South Atlantic Blueprint 2021 extent, giving that area a value of 0. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Use cell statistics maximum to combine the two above rasters.

- Remove all areas in the resulting combined that are not covered by a value >0 in the 2019 NLCD. The purpose of this step is to remove deep marine areas, which are outside the scope of this terrestrial indicator.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

1 = Priority Amphibian and Reptile Conservation Area (PARCA)
0 = Not a Priority Amphibian and Reptile Conservation Area (PARCA)

Known Issues

- The mapping of this indicator is relatively coarse and doesn’t always capture differences in pixel-level quality in the outer edge of PARCAs.
- This indicator is binary and doesn’t capture the full continuum of value across the South Atlantic.
- The methods of combining expert knowledge and data in this indicator may have caused some poorly known and/or under-surveyed areas to be scored too low.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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South Atlantic Forest Birds

This indicator is an index of habitat suitability for twelve upland hardwood and forested wetland bird species (wood thrush, whip-poor-will, American woodcock, red-headed woodpecker, Chuck-will's widow, hooded warbler, Kentucky warbler, Acadian flycatcher, Northern parula, black-throated green warbler, prothonotary warbler, Swainson's warbler) based on patch size and other ecosystem characteristics such as proximity to water and proximity to forest and ecotone edge. It originates from Southeast Gap Analysis Program and Designing Sustainable Landscapes bird habitat models.

Reason for Selection

This indicator represents ecologically important thresholds in forest patch size and other characteristics, such as distance to forest and ecotone edge. Many species are sensitive to these features of the landscape, but forest birds' habitat relationships are the most extensively studied and have available habitat models. The needs of these forest bird species are increasingly restrictive at higher index values, reflecting better quality forested wetland and upland hardwood habitat.

Input Data

- South Atlantic Blueprint 2021 extent
- Southeast Blueprint 2023 extent
- 2019 National Land Cover Database (NLCD)
- Base Blueprint 2022 extent

- The following Southeast GAP species models:

  Chuck-will's widow (bCWWI)
  Red-headed woodpecker (bRHWO)
  Wood thrush (bWOTH)
  Whip-poor-will (bWPWI)
  American woodcock (bAMWO)
  Hooded warbler (bHOWA)
  Kentucky warbler (bKEWA)
  Acadian flycatcher (bACFL)
  Black-throated green warbler (bBTNW)
  Northern parula (bNOPA)
  Prothonotary warbler (bPROW)
  Swainson's warbler (bSWWA)

- Select models from the South Atlantic Migratory Bird Initiative (SAMBI) Designing Sustainable Landscapes (DSL) avian habitat project:

  Prothonotary warbler (bPROW)
  Swainson's warbler (bSWWA)

Mapping Steps

The index of forest birds is based on scores representing increasingly restrictive limitations of potential habitat for a suite of species. Species-based constraints are:

- If a pixel is identified in the wood thrush (1 ha minimum patch), whip-poor-will (no more than 250 m into forest interior), red-headed woodpecker (interior patch within 500 m of early successional habitat), Chuck-will's widow (interior patch within 500 m of early successional habitat), or American woodcock (within 125 m of ecotone edge) Southeast GAP models, give it a value of 1. If not, give it a value of 0.
- If a pixel is identified in the hooded warbler (15 ha minimum patch) or Kentucky warbler (17 ha minimum patch in wet hardwoods) Southeast GAP models, give it a value of 2. If not, it retains the value from step 1.
- If a pixel is identified in the Acadian flycatcher (40 ha minimum patch) Southeast GAP model, give it a value of 3. If not, it retains the value from step 2.
- If a pixel is identified in the Northern parula (70 ha minimum patch) Southeast GAP model, black-throated green warbler (100 ha minimum patch) Southeast GAP model, or the prothonotary warbler (70 ha minimum patch within 120 m of water) Southeast GAP or DSL model, give it a value of 4. If not, it retains the value from step 3.
- If a pixel is identified in the Swainson's warbler (350 ha minimum patch within 250 m of water) Southeast GAP or DSL model, give it a value of 5. If not, it retains the value from step 4.
- If a pixel is identified in the NLCD as low, medium, or high intensity developed, assign it a value of 0. If not, it retains the value from step 5.

- Clip to the spatial extent of the 2021 South Atlantic Blueprint. The data outside this area was not reviewed by the indicator team who created it, so we decided not to use those data.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Very large patches near water (potential for presence of Swainson's warbler)
4 = Large patches often near water (potential for presence of Northern parula, black-throated green warbler, or prothonotary warbler)
3 = Medium patches (potential for presence of Acadian flycatcher)
2 = Small patches often near water (potential for presence of hooded warbler or Kentucky warbler)
1 = Very small patches or near open areas (potential for presence of wood thrush, whip-poor-will, red-headed woodpecker, Chuck-will's widow, or American woodcock)
0 = Less potential for presence of forest bird index species

Known Issues

- This indicator predicts less habitat for Swainson's warbler and prothonotary warbler in the Apalachicola basin because one of the two models used for these species (DSL) does not cover this area.
- It overpredicts habitat in areas that have been converted to other land uses since the release of 2001 GAP landcover data.
- Thresholds used in this indicator focus primarily on species presence and larger patches are likely needed for source populations of any of these species.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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South Atlantic Low-Urban Historic Landscapes

This cultural resource indicator is an index of sites on the National Register of Historic Places surrounded by limited urban development. It identifies significant historic places that remain connected to their context in the natural world. It uses the National Land Cover Database and historic places data from the National Park Service and various state historic resource agencies.

Reason for Selection

Low-urban historic landscapes indicate significant cultural landscapes whose cultural context has been less impacted by urban development. Cultural landscapes are "properties [that] represent the combined works of nature and of man" (UNESCO 2012). Loss of natural habitat within these cultural landscapes reduces their overall historic and cultural value.

Input Data

- South Atlantic Blueprint 2021 extent
- Southeast Blueprint 2023 extent
- 2016 National Land Cover Database (NLCD)
- The following National Register of Historic Places data from the National Park Service and various State Historic Preservation Officers:

  The National Register of Historic Places, accessed March 2021: All point layers from the NRIS_CR_Standards_Public geodatabase, including historic buildings, districts, objects, sites and structures. We use this data only in Alabama and Georgia, where no improved state-specific layer is available.

  Some states maintain their own, improved versions of the National Register of Historic Places, while other states rely on the nationwide version maintained by the National Park Service. In Virginia, North Carolina, Florida, and South Carolina, we obtained the following state-specific point and polygon data for places on the National Register:

  - Virginia listed historic districts boundaries
  - Virginia listed site points
  - North Carolina local district boundaries
  - North Carolina NCHPO_NR_SL_DOE_Boundaries
  - North Carolina NCHPO points
  - Florida national register
  - South Carolina NRHP_Districts-Areas_Non-Restricted
  - SC_NRHP_Structures_points Non-Restricted

The National Register of Historic Places reflects what Americans value in their historic built environment. It is the collection of our human imprint on the landscape that records through time our changing relationship with the landscape, bridging between modern life and our history by providing, as closely as possible, experiences that evoke our empathy and understanding of previous eras.

Mapping Steps

- Define urban areas using the following classes from the 2019 NLCD - Developed, High Intensity; Developed, Medium Intensity; Developed, Low Intensity; Developed, Open Space. Classify all urban pixels as 1 and all other pixels as 0.
- Calculate the percent urban in a 270 m radius circle for each pixel using the Focal Statistics tool in ArcGIS. Since the NLCD data resolution is 30 m pixels, use 270 m (9 pixels) to approximate a 250 m radius. Retain all pixels that are <50% urban within a 270 m radius.
- Create a historic places layer as follows:
    - The North Carolina NCHPO points file contains points for both state-level and national-level historic places. To make these data comparable with data from other states, remove the state-specific points using information from the attribute table (remove any point that has a blank value for the YearNR field).
    - Merge together the state-specific point layers (NC, SC, and VA) and the National Park Service-maintained National Register of Historic Places point layers (AL and GA) and buffer by 100 m.
    - Merge all polygon data and buffered point data into one layer and convert to a 30 m raster.
- Use the historic places raster to remove areas that fall outside of the historic places.
- Reclassify the above raster into 3 classes, seen in the final indicator values below.
- Clip to the spatial extent of the South Atlantic Blueprint.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

2 = Historic place with nearby low-urban buffer
1 = Historic place with nearby high-urban buffer
0 = Not in the National Register of Historic Places

Known Issues

- There are spatial mapping errors for some of the historic areas.
- Some historic areas with cultural importance are not necessarily captured in the National Register of Historic Places.

- The approach to measuring urban growth doesn't capture degradation to historic places that were historically in larger cities (e.g., courthouses and other downtown buildings). It also doesn't distinguish between historic places that have always been urban and historic places that used to be low-urban.
- This layer underrepresents some historic areas in Georgia and Alabama because we only used the point data from the National Register of Historic Places maintained by the National Park Service. We omit the polygon layers because they contain many GIS errors and often overestimate the extent of historic sites.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Urban Park Size

This cultural resource indicator measures the size of parks larger than 5 acres in the urban environment. It originates from the Protected Areas Database of the United States, Census urban areas, and the National Land Cover Database.

Reason for Selection

Protected natural areas in urban environments provide urban residents a nearby place to connect with nature and offer refugia for some species. They help foster a conservation ethic by providing opportunities for people to connect with nature, and also support ecosystem services like offsetting heat island effects (Greene and Millward 2017, Simpson 1998), water filtration, stormwater retention, and more (Hoover and Hopton 2019). In addition, parks, greenspace, and greenways can help improve physical and psychological health in communities (Gies 2006). Urban park size complements the equitable access to potential parks indicator by capturing the value of existing parks.

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- Protected Areas Database of the United States (PAD-US) v2.1: Combined Fee/Easement
- 2010 Census Urban Area National (2017 version)
- 2019 National Land Cover Database (NLCD): Percent developed imperviousness

Mapping Steps

- Clip the Census urban area layer to the bounding box of NoData surrounding the extent of Base Blueprint 2022.
- Clip PAD-US 2.1 to the bounding box of NoData surrounding the extent of Base Blueprint 2022.
- Remove from PAD US 2.1 all School Trust Lands in Oklahoma and Mississippi (Loc Des = “School Lands” or “School Trust Lands”). These extensive lands are leased out and are not open to the public.
- Retain only selected attribute fields from PADUS to get rid of irrelevant attributes.
- The PAD US 2.1 Combined Fee Easement layer contains overlapping polygons. To remove overlapping polygons, use the Dissolve function.
- Process all multipart polygons (e.g., separate parcels within a National Wildlife Refuge) to single parts (referred to in Arc software as an “explode”).
- Select all polygons that intersect the Census urban extent within 0.5 miles. We chose 0.5 miles to represent a reasonable walking distance based on input and feedback from park access experts. Assuming a moderate intensity walking pace of 3 miles per hour, as defined by the U.S. Department of Health and Human Service’s physical activity guidelines, the 0.5 mi distance also corresponds to the 10-minute walk threshold used in the equitable access to potential parks indicator.
- Dissolve all the park polygons that were selected in the previous step.
- Process all multipart polygons to single parts (“explode”) again.
- Add a unique ID to the selected parks. This value will be used in a later step to join the parks to their buffers.
- Create a 0.5 mi (805 m) buffer ring around each park using the multiring plugin in QGIS. Ensure that “dissolve buffers” is disabled so that a single 0.5 mi buffer is created for each park.
- Assess the amount of overlap between the buffered park and the Census urban area using “overlap analysis”. This step is necessary to identify parks that do not intersect the urban area, but which lie within an urban matrix (e.g., Umstead Park in Raleigh, NC and Davidson-Arabia Mountain Nature Preserve in Atlanta, GA). This step creates a table that is joined back to the park polygons using the UniqueID.
- Remove parks that had ≤10% overlap with the urban areas when buffered. This excludes mostly non-urban parks that do not meet the intent of this indicator to capture parks that provide nearby access for urban residents. Note: The 10% threshold is a judgement call based on testing which known urban parks and urban National Wildlife Refuges are captured at different overlap cutoffs, and is intended to be as inclusive as possible.

- Calculate the GIS acres of each remaining park unit using the Add Geometry Attributes function.
- Join the buffer attribute table to the previously selected parks, retaining only the parks that exceeded the 10% urban area overlap threshold while buffered.
- Buffer the selected parks by 15 m. Buffering prevents very small and narrow parks from being left out of the indicator when the polygons are converted to raster.
- Reclassify the parks based on their area into the 6 classes seen in the final indicator values below. These thresholds were informed by park classification guidelines from the National Recreation and Park Association, which classify neighborhood parks as 5-10 acres, community parks as 30-50 acres, and large urban parks as optimally 75+ acres (Mertes and Hall 1995).
- Assess the impervious surface composition of each park using the NLCD 2019 impervious layer and the zonal statistics function. Retain only the “mean impervious” value for each park.
- Extract only parks with a mean impervious pixel value <80%. This step excludes parks that do not meet the intent of the indicator to capture opportunities to connect with nature and offer refugia for species (e.g., the Superdome in New Orleans, LA, the Astrodome in Houston, TX, and City Plaza in Raleigh, NC).
- Export the final vector file to a shapefile and import to ArcGIS Pro.
- Convert the resulting polygons to raster using the ArcPy Polygon to Raster function and the area class field.
- Reclassify to merge into the 0 class all <5 acre parks and all other pixels in the Base Blueprint extent not already identified as an urban park in the mapping steps above. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Use the NLCD 2019 to reclassify the marine environment as NoData using the Set Null function. This removes offshore marine areas from the 0 class of the indicator because they are outside the scope of the indicator.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = 75+ acre urban park
4 = 50 to <75 acre urban park
3 = 30 to <50 acre urban park
2 = 10 to <30 acre urban park
1 = 5 to <10 acre urban park
0 = <5 acre urban park or not identified as an urban park

Known Issues

- This indicator does not include park amenities that influence how well the park serves people and should not be the only tool used for parks and recreation planning. Park standards should be determined at a local level to account for various community issues, values, needs, and available resources.
- It does not include parks smaller than 5 acres (including pocket parks and mini-parks) that can still provide value for connecting people to nature in urban areas.
- This indicator includes some protected areas that are not open to the public and not typically thought of as "parks", like mitigation lands, private easements, and private golf courses. While we experimented with excluding them using the public access attribute in PAD, due to numerous inaccuracies, this inadvertently removed protected lands that are known to be publicly accessible. As a result, we erred on the side of including the non-publicly accessible lands.
- The NLCD percent impervious layer contains classification inaccuracies. As a result, this indicator may exclude parks that are mostly natural because they are misclassified as mostly impervious. Conversely, this indicator may include parks that are mostly impervious because they are misclassified as mostly natural. We tested many Southeast parks for misclassification issues, and the 80% average impervious threshold seemed to best capture edge cases like Old Fourth Ward Park in Atlanta, GA (where NLCD overestimates impervious) and City Plaza in Raleigh, NC (where NLCD underestimates impervious). However, some parks are likely still represented incorrectly in this indicator.
- Shortly after we created this indicator, USGS released a newer version of the Protected Areas Database (version 3.0). As a result, the indicator may miss newly protected areas, or protected areas added for the first time in PAD-US 3.0. We plan to update this indicator to PAD-US 3.0 in the future.

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West Coastal Plain & Ouachitas Forested Wetland Birds

This indicator is an index of habitat suitability for five forested wetland bird species (Acadian flycatcher, Kentucky warbler, yellow-throated warbler, prothonotary warbler, red-shouldered hawk) within bottomland hardwood forests and riparian areas in the West Gulf Coastal Plain/Ouachitas (WGCPO) Bird Conservation Region. It uses metrics like patch size, dispersal distance, and distance to water to assess the potential for habitat to support sustainable populations of these birds. This indicator originates from the Lower Mississippi Valley Joint Venture's forested wetland decision support model for the WGCPO region.

Reason for Selection

Some factors related to patch size and landscape composition that are important to forested wetland species are not well-represented by other indicators. Forested wetlands and associated bottomland hardwoods represent a unique and imperiled habitat in the region that supports birds and many other wildlife species. Maintaining the structure and integrity of these forested wetlands has conservation implications that extend beyond the West Gulf Coastal Plain/Ouachitas region due to the ecosystem's importance for birds migrating to and from Mexico, the West Indies, and Central and South America. This indicator also promotes consistency with the forest management and protection priorities of the Lower Mississippi Valley Joint Venture.

Input Data

- WGCPO Forested Wetland Decision Support Model; detailed description of methods is available under "Decision support model" in the West Gulf Coastal Plain/Ouachitas Forested Wetland Plan, Version 1.0

  This decision support model first characterized the landscape that was available to each forested wetland bird umbrella species for breeding. It identified landscapes with enough potentially suitable habitat to support a minimum viable population based on the amount of woody wetland landcover, minimum viable population size and area requirements, and natal dispersal distance. Then, it prioritized that potential breeding landscape based on each species' unique habitat needs: distance to water, percent forest cover, flood tolerance and flood preference, and presence of bald cypress-tupelo floodplain forest. Lastly, it combined each species-specific habitat suitability model into the final composite index used in this indicator.

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Reproject the WGCPO Forested Wetland Decision Support Model source data to NAD 1983 Contiguous USA Albers (EPSG 5070).
- Reclassify the source data as seen in the legend below. The WGCPO Forested Wetland Decision Support Model layer from the LMVJV has values ranging from 0 to 0.933365. Classify the data into five groups based on percentile priority within WGCPO regional boundary for the six umbrella species (Acadian flycatcher, Kentucky warbler, yellow-throated warbler, prothonotary warbler, red-shouldered hawk) as shown in the final indicator values below. Assign all pixels with an actual value of 0 in the WGCPO model a value of 0 in the indicator. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = High habitat suitability for forested wetland bird umbrella species (Acadian flycatcher, Kentucky warbler, yellow-throated warbler, prothonotary warbler, red-shouldered hawk) (score >80)
4 = Medium-high habitat suitability (score >60-80)
3 = Medium habitat suitability (score >40-60)
2 = Medium-low habitat suitability (score >20-40)
1 = Low habitat suitability for forested wetland bird umbrella species (score >0-20)
0 = Not suitable for forested wetland bird umbrella species (score = 0)

Known Issues

- The indicator does not account for important components of stand structure that impact habitat quality for these species. Key factors include: a) large tree diameter (>23 cm dbh), b) density of large trees (>40 trees >50 dbh/ha), c) low tree density (250-300/ha), d) mid-story cover (open), e) understory cover (open), f) understory cover (dense), g) moderate to well-developed canopy (60–70%), and h) small cavities (<10 inch diameter) or snag density of 5 snags/ha.
- The indicator does not account for variation in water quality.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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West Coastal Plain & Ouachitas Open Pine Birds

This indicator identifies areas with pine trees that, if managed for open condition, could support a population of three umbrella bird species (brown-headed nuthatch, Bachman's sparrow, red-cockaded woodpecker). It evaluates potential habitat in the West Gulf Coastal Plain/Ouachitas (WGCPO) Bird Conservation Region based on each species' habitat needs and population dynamics, prioritizing opportunities to restore and manage habitat to benefit open pine birds. Final scores reflect both the selectiveness of the species and whether an area meets the habitat requirements through one large patch, or clusters of smaller patches in sufficiently close proximity for breeding pairs to disperse. This indicator updates the Lower Mississippi Valley Joint Venture's open pine decision support model for the WGCPO region.

Reason for Selection

The three bird species used in this indicator (brown-headed nuthatch, Bachman's sparrow, red-cockaded woodpecker) represent the structure and function of open pine ecosystems in the West Gul Coastal Plain. Open pine and other grassland birds are experiencing significant declines and are currently off-track for meeting the SECAS 10% goal, so it is important that the Blueprint capture opportunities to restore open pine habitat. This indicator also promotes consistency with the priorities of the Lower Mississippi Valley Joint Venture.

Input Data

- Update to the WGCPO Open Pine Decision Support Model

  The Lower Mississippi Valley Joint Venture created the original data and methods in 2011 as the WGCPO Open Pine Decision Support Model. The original model used 2001 National Land Cover Database (NLCD) landcover as an input. This layer re-runs the model using the same methods, but an updated 2019 version of the NLCD. This model represents 3 species: brown-headed nuthatch (BHNU), Bachman's sparrow (BACS), and red-cockaded woodpecker (RCWO). It highlights patches of pine trees that are large enough to support a population of the umbrella species but are not necessarily in the open condition required to provide quality habitat. Its goal is to prioritize existing pine forests for open pine management actions.

  Additional information about model assumptions

  - The brown-headed nuthatch analysis assumed a density of 3 ha/pair, a minimum viable population of 28 pairs, a suitable habitat requirement of 84 ha, and a dispersal potential of 0.92 km (½ dispersal potential of 0.46 km).
  - The Bachman's sparrow analysis assumed a density of 3 ha/pair, a minimum viable population of 50 pairs, a suitable habitat requirement of 150 ha, and a dispersal potential of 3 km (½ dispersal potential of 1.5 km).
  - The red-cockaded woodpecker analysis assumed a density of 50 ha/pair, a minimum viable population of 20 pairs, a suitable habitat requirement of 1,000 ha, and a dispersal potential of 8 km (½ dispersal potential of 4 km).

Table 1. Model assumptions for each species in West Coastal Plains & Ouachitas open pine birds.

	D (ha/pair)	MVP (pairs)	Suitable habitat required (ha)	Dispersal potential (km)	½ Dispersal potential (km)
Red-cockaded woodpecker	50	20	1,000	8	4
Bachman's sparrow	3	50	150	3	1.5
Brown-headed nuthatch	3	28	84	0.92	0.46

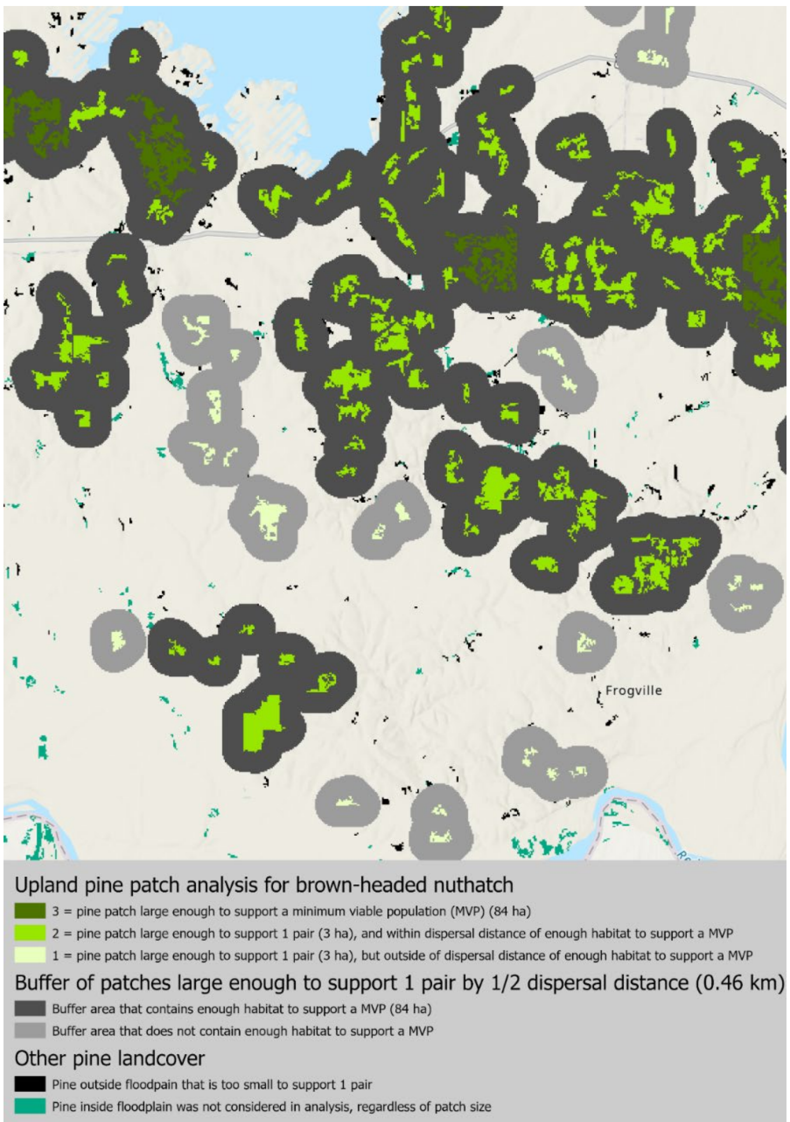

Figure 2. Example of analysis process on one of the umbrella species (brown-headed nuthatch).

- [2019 National Land Cover Database]() (NLCD)
- West Gulf Coastal Plain/Ouachitas floodplain map produced by the Lower Mississippi Valley Joint Venture (LMVJV) ([contact the LMVJV]() for access)
- West Gulf Coastal Plain/Ouachitas Bird Conservation Region (WGCPO BCR) (2010 version, [contact the LMVJV]() for access)
- [Base Blueprint 2022 extent]()
- [Southeast Blueprint 2023 extent]()

Mapping Steps

- Buffer the WGCPO BCR by 10 km to create the study area.
- Clip the 2019 NLCD to the study area.
- Pull out the evergreen and mixed forest classes from NLCD (values 42 and 43) to use as an estimate of the location of current pine forests.
- Remove all pine forests pixels that occur in the floodplain, using the West Gulf Coastal Plain/Ouachitas floodplain layer.
- Perform a patch analysis on the remaining pine pixels to determine the size of contiguous patches.
- Convert patch size from number of pixels to hectares.
- At this point, the model performs a series of the same analysis steps but modifies the thresholds to be specific for each species.
  - Remove all patches of forest that are not large enough to support at least one pair of birds. The BHNU and BACS analysis removed patches smaller than 3 ha, while the RCWO analysis removed patches smaller than 50 ha.
  - Buffer (enlarge) each patch by ½ the dispersal distance for that species. If the buffer of one patch intersects the buffer of another patch, then we assume the two patches are in close enough proximity that birds have the ability to disperse from one to another. The BHNU analysis buffered by 0.46 km, the BACS analysis buffered by 1.5 km, and the RCWO analysis buffered by 4 km.
  - Perform a new patch analysis on the buffers of the original patches. This identifies clusters of patches or areas that contain patches that are all close enough together that birds could disperse from one to another (to another, to another, etc.).
  - Analyze each cluster of patches to determine if they contain enough pine forest to support a minimum viable population (MVP) for the species. This analysis is done using the patches, so we exclude any patches of forest that aren't big enough to individually support one pair. The amount of forest needed to support an MVP was calculated by multiplying the hectares needed to support 1 pair by the number of pairs that represent an MVP of each species. The BHNU analysis used a minimum habitat amount of 84 ha (3 ha/pair times the MVP of 29 pairs = 84 ha), the BACS analysis used a minimum habitat amount of 150 ha (3 ha/pair times the MVP of 50 pairs = 150 ha), and the RCWO analysis used a minimum habitat amount of 1,000 ha (50 ha/pair times the MVP of 20 pairs = 1,000 ha).

    - If a cluster of patches contains enough pine forest to support at least one MVP, then all the original patches contained in that cluster of patches are identified as potential targets for open pine management.
- Reclassify the BHNU layer produced above so that:
    - 0 = Not an upland pine patch or an upland pine patch too small to support 1 pair
    - 1 = Patch large enough to support 1 pair, but outside of dispersal distance of enough habitat to support MVP
    - 2 = Patch is large enough to support 1 pair, and is within dispersal distance of enough habitat to support MVP
    - 3 = Patch alone is large enough to support MVP
- Reclassify BACS layer above so that:
    - 0 = Not an upland pine patch or an upland pine patch too small to support 1 pair
    - 10 = Patch large enough to support 1 pair, but outside of dispersal distance of enough habitat to support MVP
    - 20 = Patch is large enough to support 1 pair, and is within dispersal distance of enough habitat to support MVP
    - 30 = Patch alone is large enough to support MVP
- Reclassify RCWO layer above so that:
    - 0 = Not an upland pine patch or an upland pine patch too small to support 1 pair
    - 100 = Patch large enough to support 1 pair, but outside of dispersal distance of enough habitat to support MVP
    - 200 = Patch is large enough to support 1 pair, and is within dispersal distance of enough habitat to support MVP
    - 300 = Patch alone is large enough to support MVP
- Add three species layers above together using cell statistics "sum." The result is a raster with habitat values for BHNU in the hundreds place, BACS in the tens, and RCWO in the ones.
- Reclassify to create the legend values seen below:
    - 6 = 333
    - 5 = 331, 332
    - 4 = 312, 321, 322
    - 3 = 222
    - 2 = 122, 220, 221
    - 1 = 120, 121, 210
    - 0 = 0, 110
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

6 = Pine patch large enough to support a population of all 3 umbrella bird species (brown-headed nuthatch, Bachman's sparrow, red-cockaded woodpecker) if managed in open condition

5 = Pine patch large enough to support a population of 2 umbrella bird species if managed in open condition

4 = Pine patch large enough to support a population of 1 umbrella bird species if managed in open condition

3 = Pine patch part of a cluster of nearby patches able to support a population of all 3 umbrella bird species if managed in open condition

2 = Pine patch part of a cluster of nearby patches able to support a population of 2 umbrella bird species if managed in open condition

1 = Pine patch part of a cluster of nearby patches able to support a population of 1 umbrella bird species if managed in open condition

0 = Pine patch too small and isolated to support a population of any umbrella bird species or not an upland pine patch

Known Issues

- This indicator does not capture areas where planting new pine stands in existing agricultural areas would benefit open pine birds.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Lower Mississippi Valley Joint Venture. October 2011. West Gulf Coastal Plains/Ouachitas Open Pine Landbird Plan. [https://static1.squarespace.com/static/5bb3865d2727be6f94acf2fc/t/5bedd2650ebbe83079c0c7b1/1542312550791/WGCPO_Landbird_Open_Pine_Plan_Oct_2011.pdf].

Southeast Conservation Adaptation Strategy. 2021. Recent Trends in Southeastern Ecosystems (2021): Measuring Progress toward the SECAS Goal. [https://secassoutheast.org/pdf/SECAS-goal-report-2021.pdf].

U.S. Geological Survey (USGS). Published June 2021. National Land Cover Database (NLCD) 2019 Land Cover Conterminous United States. Sioux Falls, SD. [https://doi.org/10.5066/P9KZCM54].

Yang, L., Jin, S., Danielson, P., Homer, C., Gass, L., Case, A., Costello, C., Dewitz, J., Fry, J., Funk, M., Grannemann, B., Rigge, M. and G. Xian. 2018. A New Generation of the United States National Land Cover Database: Requirements, Research Priorities, Design, and Implementation Strategies, ISPRS Journal of Photogrammetry and Remote Sensing, 146, pp.108-123. [https://doi.org/10.1016/j.isprsjprs.2018.09.006].

West Gulf Coast Mottled Duck Nesting

This indicator depicts marshes and grasslands along the coast of Louisiana and Texas that are important for mottled duck nesting, based on key biological parameters such as patch size, land cover type, and distance to brood rearing habitat. It originates from a mottled duck decision support tool developed by the Gulf Coast Joint Venture.

Reason for Selection

The mottled duck is a non-migratory waterfowl species endemic to the Gulf coast that relies on a unique mix of coastal marshes and nearby grassland habitat for foraging, nesting, and raising young. The West Gulf Coast mottled duck population has declined significantly since the mid-1990s due to habitat loss from urban growth, agricultural development, saltwater intrusion, and invasive species (Moon et al. 2021, Krainyk et al. 2019, Moon et al. 2021). Mottled ducks are considered an indicator of coastal marsh health and function (Moon et al. 2015), and other indicators in the Blueprint were not capturing the important ecological role of grassland habitats near wetlands in the Western Gulf Coast.

Input Data

- Spatially Explicit Decision Support Tool for Guiding Habitat Conservation for Western Gulf Coast Mottled Ducks: Currently suitable nesting habitat

  Because mottled ducks use coastal marsh and agricultural landscapes somewhat differently, this model identified suitable nesting habitat in two different zones: agricultural and coastal. In agricultural areas, nesting cover is usually found in “fallow fields, low-intensity grazing systems, hay fields, native prairies, and other grasslands” with less than 30% woody cover (Krainyk et al. 2019). Here, the model defined suitable nesting habitat as patches of suitable agricultural or grassland land cover that are at least 40 acres in size, with a 0.025 m/m^2 edge-to-interior ratio, and no more than a mile from currently suitable brood-rearing habitat.

  In coastal marshes, “mottled ducks prefer nesting habitat characterized by tall, dense stands of grass, usually located in elevated sites within 150 meters of water” or “on narrow ridges or levees that are surrounded by marsh” (Krainyk et al. 2019). Here, the model defined suitable nesting habitat as patches of suitable agricultural, grassland, or wetland land cover that are at least 40 acres in size and no more than a mile from currently suitable brood-rearing habitat (very similar to the parameters used in the agricultural zone, but with the addition of wetland land cover and removal of the edge-to-interior ratio requirement).

- MODU_range_byInitiaveArea (contact Blair Tirpak for access at blair_tirpak@fws.gov)

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Divide the currently suitable nesting habitat layer into 10 equal area classes using the Slice tool in ArcPro.
- Create an extent raster with a value of 0 from the MODU_range_byInitiativeArea shapefile. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Mosaic the 10-class raster with the extent raster.
- Reclassify the resulting value field into the final indicator values seen below.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

10 = 90^{th}-100^{th} percentile of suitable mottled duck nesting habitat
9 = 80^{th}-90^{th} percentile of suitable mottled duck nesting habitat
8 = 70^{th}-80^{th} percentile of suitable mottled duck nesting habitat
7 = 60^{th}-70^{th} percentile of suitable mottled duck nesting habitat
6 = 50^{th}-60^{th} percentile of suitable mottled duck nesting habitat
5 = 40^{th}-50^{th} percentile of suitable mottled duck nesting habitat
4 = 30^{th}-40^{th} percentile of suitable mottled duck nesting habitat
3 = 20^{th}-30^{th} percentile of suitable mottled duck nesting habitat
2 = 10^{th}-20^{th} percentile of suitable mottled duck nesting habitat
1 = 0-10^{th} percentile of suitable mottled duck nesting habitat
0 = Not identified as suitable mottled duck nesting habitat (within TX and LA)

Known Issues

- This indicator represents a perspective on grasslands through the lens of a single species that requires grasslands to be in proximity to low salinity wetlands. As a result, it potentially excludes some larger blocks of intact grasslands.
- Mottled ducks also nest within some emergent coastal marshes; therefore, this indicator might include significant contiguous blocks of emergent wetlands in some areas, especially where the salinities don't exceed intermediate ranges.
- This indicator defines suitability for mottled duck based solely on landscape context and does not consider grassland condition (e.g., it does not differentiate overgrazed areas, grasslands dominated by exotics, etc.).

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Krainyk, Anastasia and Bart M. Ballard. 2014. Decision Support Tool: Prioritization of Mottled Duck (*Anas fulvigula*) Habitat for Conservation and Management in the Western Gulf Coast. Final report. [https://www.sciencebase.gov/catalog/item/547cb566e4b0bdc51793037c].

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Moon, Jena, D. Haukos, W. Conway. 2015. Mottled Duck *(Anas fulvigula)* Movements in the Texas Chenier Plain Region. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:255-261. [https://seafwa.org/sites/default/files/journal-articles/37%252520Moon%252520et%252520al%252520255-261.pdf].

Moon, J.A., Haukos, D.A. and Conway, W.C. (2017), Seasonal survival of adult female mottled ducks. Jour. Wild. Mgmt., 81: 461-469. [https://doi.org/10.1002/jwmg.21221].

Moon, J.A. and S.E. Lehnen, K.L. Metzger, M.A. Squires, M.G. Brasher, B.C. Wilson, W.C. Conway, D.A. Haukos, B.E. Davis, F.C. Rohwer, E.M. Wehland, B.M. Ballard. Projected impact of sea-level rise and urbanization on mottled duck (*Anas fulvigula*) habitat along the Gulf Coast of Louisiana and Texas through 2100. Ecological Indicators, Volume 132, 2021, 108276, ISSN 1470-160X, [https://doi.org/10.1016/j.ecolind.2021.108276].

Ringelman, K. M., Bonczek, E. S., Marty, J. R., Booth, A. R., & Dopkin, A. L. (2021). Survival of western Gulf Coast Mottled Ducks (*Anas fulvigula*) in the path of a Category 4 hurricane. Ecology and Evolution, 11, 15477– 15483. [https://doi.org/10.1002/ece3.8276].

Freshwater

Atlantic Migratory Fish Habitat

This indicator measures the condition of migratory fish habitat along the Atlantic coast within each catchment, using metrics of water quality, aquatic connectivity, habitat fragmentation, flow alteration, and more. Areas of excellent fish habitat are already in good condition and face few threats. Restoration opportunity areas are doing well in some respects, but restoration projects could significantly improve them. Degraded areas of opportunity face many challenges, and restoration projects are unlikely to increase available fish habitat unless particularly large in scope and scale. This indicator originates from the Atlantic Coast Fish Habitat Partnership's fish habitat conservation area mapping and prioritization project.

Reason for Selection

This indicator represents aquatic connectivity between fresh and salt water in Atlantic drainages. It incorporates both physical barriers to connectivity and indirect barriers related to habitat quality. It also promotes consistency with the priorities of the Atlantic Coast Fish Habitat Partnership.

Input Data

- Atlantic Coast Fish Habitat Partnership (ACFHP) Fish Habitat Conservation Area Mapping and Prioritization Project: South Atlantic and Mid-Atlantic Diadromous Analysis
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Convert the South Atlantic Diadromous Analysis from vector to 30 m raster using the FINALSCORE field.
- Convert the Mid-Atlantic Diadromous Analysis from vector to 30 m raster using the TotalPoints field.
- Combine the above rasters using the ArcPy Spatial Analyst Cell Statistics "MAX" function.
- Reclassify the above raster into 8 classes, seen in the final indicator values below.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

8 = Final score of 80 (areas of excellent fish habitat)
7 = Final score of 70 (areas of excellent fish habitat)
6 = Final score of 60 (restoration opportunity areas)
5 = Final score of 50 (restoration opportunity areas)
4 = Final score of 40 (restoration opportunity areas)
3 = Final score of 30 (restoration opportunity areas)
2 = Final score of 20 (restoration opportunity areas)
1 = Final score of 10 (degraded areas of opportunity)
0 = Final score of 0 (degraded areas of opportunity)

Known Issues

- This indicator under and overrepresents migratory fish habitat in some areas. The South Atlantic and Mid-Atlantic Diadromous Analysis did not include fish presence and fishing data because of inconsistent sampling methods across the study area and because this data was unavailable in many shallow water habitats.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Martin, Erik, Kat Hoenke, and Lisa Havel. Atlantic Coast Fish Habitat Partnership. Fish Habitat Conservation Area Mapping and Prioritization Project: A Prioritization of Atlantic Coastal, Estuarine, and Diadromous Fish Habitats for Conservation. August 2020. [https://www.atlanticfishhabitat.org/wp-content/uploads/2020/08/ACFHP-Mapping-and-Prioritization-Final-Report.pdf].

Gulf Migratory Fish Connectivity

This indicator captures how far upstream migratory fish in the Gulf of Mexico have been observed. How far upstream migratory fish can travel reflects not just the presence of dams and other barriers, but also the presence of measures like fish ladders that allow specific species to access habitat upstream of dams. This indicator originates from The Nature Conservancy's Southeast Aquatic Connectivity Assessment Project and U.S. Fish and Wildlife Service critical habitat data. It applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood).

Reason for Selection

Migratory fish presence reflects uninterrupted connections between freshwater, estuarine, and marine ecosystems. Aquatic connectivity benefits diadromous fish and is considered a high priority for the integrity of aquatic ecosystems. Larger diadromous fish, like sturgeon, are often more sensitive to disruptions in aquatic connectivity. Smaller fish can make better use of fish ladders and other fish passage measures than larger fish.

Input Data

- Southeast Aquatic Connectivity Assessment Project (SEACAP); see the final report for more information

  SEACAP developed linear spatial data on the presence of priority diadromous species. These layers are modified versions of the NHDPlus Version 2. These data were altered to contain presence of Alabama shad using data from the Atlantic States Marine Fisheries Commission (produced for the ASMFC by the Biodiversity and Spatial Information Center at North Carolina State University, Alexa McKerrow), and expert knowledge of the SEACAP Workgroup.

  SEACAP also developed a functional river network layer (final SEACAP report, page 9). A functional river network is defined by those stream reaches that are accessible to a hypothetical fish within that network. The functional river network is defined by lines (streams). SEACAP also calculated "functional catchments," which are polygons that represent the catchment area that is associated with each of those functional networks.

  Note: A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics. To learn more about catchments and how they're defined, check out these resources:

  - An article from USGS explaining the differences between various NHD products
  - The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

- National Oceanic and Atmospheric Administration (NOAA) Gulf Sturgeon Critical Habitat

- Estimated Floodplain Map of the Conterminous U.S. from the Environmental Protection Agency's (EPA) EnviroAtlas; see this factsheet for more information; download the data

  The EPA Estimated Floodplain Map of the Conterminous U.S. displays "...areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood). These data are based on the Federal Emergency Management Agency (FEMA) 100-year flood inundation maps with the goal of creating a seamless floodplain map at 30-m resolution for the conterminous United States. This map identifies a given pixel's membership in the 100-year floodplain and completes areas that FEMA has not yet mapped" (EPA 2018).

- U.S. Geological Survey (USGS) Watershed Boundary Dataset (WBD), accessed 8-11-2020: HUC6s, HUC12s; download the data
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Combine all the linework for Gulf Sturgeon using the ArcPy Data Management Merge function. This includes line data from SEACAP and the NOAA critical habitat. Add and calculate a field showing that these are sturgeon lines.
- Combine all the linework for the Alabama shad, American shad, or striped bass from SEACAP using the ArcPy Data Management Merge function. Add and calculate a field showing these lines represent the above species.
- Assign the values from the two sets of linework above to HUC12s using two separate ArcPy Analysis Spatial Join functions.
- Add and calculate a new field. If it intersects a sturgeon line, give it a value of 2. Otherwise, if it intersects the other species linework, give it a value of 1.
- Covert the HUC12s from polygons to a 30 m raster using the field above.
- Convert the polygon layers from the Gulf sturgeon critical habitat to 30 m rasters and give those pixels a value of 2.
- Combine the two rasters above using the ArcPy Spatial Analyst Cell Statistic "MAX" function.
- Clip the resulting layer to the EPA estimated floodplain.
- Use the HUC6 layer to remove from the resulting raster areas outside the Gulf drainage where those 4 species ranges occur. The Atlantic drainages are represented in the Blueprint by the Atlantic Migratory Fish Habitat Indicator.
- Use the HUC6 layer to add zero values to the above raster representing the Gulf range of the 4 species listed above. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the spatial extent of Base Blueprint 2023.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

2 = Presence of Gulf sturgeon
1 = Presence of Alabama shad, American shad, or striped bass
0 = Not identified as Gulf migratory fish habitat (east of the Mississippi River)

Known Issues

- This indicator does not account for smaller dams/culverts that serve as barriers to fish passage.
- Where the SEACAP linear spatial data interests a dam, the indicator can extend to reservoirs that are not accessible to fish due to fish passage barriers (e.g., Ross R. Barnett Reservoir in MS).
- The EPA Estimated Floodplain layer sometimes misses the small, linear connections made by artificial canals, especially when they go through areas that wouldn't naturally be part of the floodplain. As a result, some areas (like lakes) that are connected via canals may appear to be disconnected, but still receive high scores.
- While this indicator generally includes the open water area of reservoirs, some open water portions of reservoirs are missing from the estimated floodplain dataset.
- Estuaries where Gulf sturgeon are not present are often underprioritized because data for the other species do not extend into the estuaries.
- This indicator does not account for instream habitat quality, which can also be a barrier to fish passage.
- This indicator likely underestimates the value of some areas for American eel. That species is not included in the indicator due to a lack of integrated regionwide data depicting how far upstream American eels have been observed.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Martin, E. H, Hoenke, K., Granstaff, E., Barnett, A., Kauffman, J., Robinson, S. and Apse, C.D. 2014. SEACAP: Southeast Aquatic Connectivity Assessment Project: Assessing the ecological impact of dams on Southeastern rivers. The Nature Conservancy, Eastern Division Conservation Science, Southeast Aquatic Resources Partnership. [https://secassoutheast.org/pdf/SEACAP_Report.pdf].

EPA EnviroAtlas. 2018. Estimated Floodplain Map of the Conterminous U.S. [https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/Supplemental/EstimatedFloodplains.pdf].

Imperiled Aquatic Species

This indicator measures the number of aquatic animal Species of Greatest Conservation Need (SGCN) observed within each 12-digit HUC subwatershed, including fish, mussels, snails, crayfish, and amphibians. SGCN are identified in State Wildlife Action Plans as most in need of conservation action. This indicator originates from state Natural Heritage Program data collected by the Southeast Aquatic Resources Partnership and applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood).

Reason for Selection

According to the Southeastern Freshwater Biodiversity Conservation Strategy, "the Southeastern United States is a global hotspot of freshwater biodiversity, supporting almost two-thirds of the country's fish species, over 90% of the US total species of mussels and nearly half of the global total for crayfish species. More than a quarter of this region's species are found nowhere else in the world. Unfortunately, this region is also a hotspot for imperilment. The number of imperiled freshwater fish species in the Southeast has risen 125% in the past 20 years" (RBC and TNACI).

This indicator identifies areas with abundant rare and endemic aquatic species that would benefit from conservation action. It captures patterns of rare and endemic species diversity not well-represented by other freshwater indicators.

Input Data

- Base Blueprint 2022 extent
- Southeast Aquatic Resources Partnership (SARP) SGCN HUC12 summaries

  The Southeast Aquatic Resources Partnership provided these summaries on April 19, 2023 as an Excel spreadsheet geodatabase containing the ID number for each HUC12 watershed and an attribute for the number of aquatic animal SGCNs observed in that watershed. This dataset is based on state Natural Heritage Program occurrence records for fishes, mussels, snails, crayfish, and amphibians. It was last updated in February 2023. More information on this dataset is available in Appendix A.

- Estimated Floodplain Map of the Conterminous U.S. from the Environmental Protection Agency's (EPA) EnviroAtlas; see this factsheet for more information; download the data

  The EPA Estimated Floodplain Map of the Conterminous U.S. displays "...areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood). These data are based on the Federal Emergency Management Agency (FEMA) 100-year flood inundation maps with the goal of creating a seamless floodplain map at 30-m resolution for the conterminous United States. This map identifies a given pixel's membership in the 100-year floodplain and completes areas that FEMA has not yet mapped" (EPA 2018).

- National Hydrography Dataset Plus (NHDPlus) Version 2.1 medium resolution catchments (note: V2.1 is just the current sub-version of the dataset generally called NHDPlusV2); view the user guide

  Catchments

  A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

  To learn more about catchments and how they're defined, check out these resources:

  - An article from USGS explaining the differences between various NHD products
  - The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

- U.S. Geological Survey (USGS) Watershed Boundary Dataset (WBD), accessed 12-2-2021: HUC12s; download the data
- 2023 U.S. Census TIGER/Line state boundaries, accessed 5-15-2023; download the data
- Southeast Blueprint 2023 extent

Mapping Steps

- Join the SGCN count table to the HUC12 spatial data.
- Convert to a 30 m raster, where the values represent the number of SGCN.
- Reclassify the species count values to the 1-9 indicator values below.
- Mask the resulting raster to the EPA estimated floodplain. Assign a value of 0 to all areas outside the EPA floodplain. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Mask the resulting floodplain-masked raster to the NHDPlus medium resolution catchments layer to remove values in the nearshore environment.
- Using the TIGER/Line state boundary, assign a value of NoData to areas in West Virginia, since the SARP data does not cover West Virginia.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

9 = 8+ aquatic animal Species of Greatest Conservation Need (SGCN) observed
8 = 7 aquatic animal SGCN observed
7 = 6 aquatic animal SGCN observed
6 = 5 aquatic animal SGCN observed
5 = 4 aquatic animal SGCN observed
4 = 3 aquatic animal SGCN observed
3 = 2 aquatic animal SGCN observed
2 = 1 aquatic animal SGCN observed
1 = 0 aquatic animal SGCN observed
0 = Not identified as a floodplain (excluding West Virginia)

Known Issues

- As this indicator is based on occurrence records, poorly surveyed areas may be scored too low. Therefore, this data does not imply absence of species.
- While this indicator generally includes the open water area of reservoirs, some open water portions of reservoirs (e.g., Kerr Lake in NC/VA) are missing from the estimated floodplain dataset.
- Small headwaters and creeks are not included in this indicator because the EPA estimated floodplain dataset does not include them.
- This indicator may underprioritize areas important for aquatic plants. As most Southeast states do not identify plants as SGCNs, it includes aquatic animal species only.
- This indicator draws from data provided by SARP, which does not cover the full state of West Virginia. To fill that gap, we developed the West Virginia imperiled aquatic species indicator using a different data source. While states that neighbor West Virginia (Kentucky and Virginia) submitted species observations to SARP for HUC12s that cross over into West Virginia, we erased the values within West Virginia since we lacked complete information for those HUCs and the West Virginia imperiled aquatic species indicator already covered those areas in a more consistent way. In future Blueprint updates, we are working to expand the full imperiled aquatic species indicator to West Virginia to avoid the need for a separate indicator.
- In the area just south of Guadalupe Mountains National Park in West Texas, this indicator depicts the floodplain as a series of linear lines that poorly match the actual floodplain. This is due to an error in the EPA floodplain map used in this indicator.
- The catchment boundaries are inconsistent in how far they extend toward the ocean. As a result, this indicator does not consistently apply to estuaries, coastal areas, and barrier islands.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Natural Landcover in Floodplains

This indicator measures the amount of natural landcover in the estimated floodplain of rivers and streams within each catchment. It assesses the stream channel and its surrounding riparian buffer, measuring the percent of unaltered habitat like forests, wetlands, or open water (rather than agriculture or development). This indicator originates from the National Land Cover Database and applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood).

Reason for Selection

Habitat near rivers and streams is strongly linked to water quality and instream flow (Naiman 1997), is easy to monitor and model, and is widely used and understood by diverse partners. Intact vegetated buffers within the floodplain of rivers and streams provide aquatic habitat, improve water quality, reduce erosion and flooding, recharge groundwater, and more (WeConservePA 2014). Natural floodplain landcover is often described as "the first line of defense" for aquatic systems.

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- Estimated Floodplain Map of the Conterminous U.S. from the Environmental Protection Agency's (EPA) EnviroAtlas; see this factsheet for more information; download the data

The EPA Estimated Floodplain Map of the Conterminous U.S. displays "...areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood). These data are based on the Federal Emergency Management Agency (FEMA) 100-year flood inundation maps with the goal of creating a seamless floodplain map at 30-m resolution for the conterminous United States. This map identifies a given pixel's membership in the 100-year floodplain and completes areas that FEMA has not yet mapped" (EPA 2018).

- 2019 National Land Cover Database (NLCD)
- National Hydrography Dataset Plus (NHDPlus) Version 2.1 medium resolution catchments (note: V2.1 is just the current sub-version of the dataset generally called NHDPlusV2); view the user guide

Catchments

A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

To learn more about catchments and how they're defined, check out these resources:

- An article from USGS explaining the differences between various NHD products
- The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

Mapping Steps

- Clip the 2019 NLCD to the EPA estimated floodplain layer. This limits the indicator values to the floodplain areas, where they are most relevant.
- Reclassify the clipped 2019 NLCD to identify natural landcover using the following classes: open water, barren land, deciduous forest, evergreen forest, mixed forest, scrub/shrub, grassland/herbaceous, woody wetlands, and emergent wetlands.
- Select the NHDPlus V2.1 medium resolution catchments that intersect the vector boundary of the Base Blueprint 2022 extent.
- Calculate the percent of riparian natural landcover inside each NHDPlus catchment using ArcPy Spatial Analyst Zonal Statistics "MEAN" function.
- Reclassify the above raster into the 1-5 classes seen in the final indicator values below.
- Clip the above raster back to the EPA estimated floodplain layer. It is necessary to do this again since the zonal statistics function outputs pixel values for the entire catchment. During this step, assign a value of 0 to areas outside the EPA floodplain. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = >90% natural landcover within the estimated floodplain, by catchment
4 = >80-90%
3 = >70-80%
2 = >60-70%
1 = ≤60% natural landcover within the estimated floodplain, by catchment
0 = Not identified as a floodplain

Known Issues

- Small headwaters and creeks are not included in this indicator because the EPA estimated floodplain dataset does not include them.
- This indicator does not account for the accumulated impacts of upstream riparian buffers. Buffers at the headwaters are treated the same as those downstream.
- This indicator does account for the river or stream size in relation to the estimated floodplain. Aquatic habitat needs may differ based on the river size class. For example, smaller headwater streams may need more natural landcover than larger rivers to maintain aquatic health. It also does not account for variation in buffer quality within the floodplain at a scale below the catchment. This means that within the estimated floodplain, loss of natural habitat adjacent to the river is treated the same as loss farther away.
- While this indicator generally includes the open water area of reservoirs, some open water portions of reservoirs (e.g., Kerr Lake in NC/VA) are missing from the estimated floodplain dataset.
- The catchment boundaries are inconsistent in how far they extend toward the ocean. As a result, this indicator does not consistently apply to estuaries, coastal areas, and barrier islands.
- In the area just south of Guadalupe Mountains National Park in West Texas, this indicator depicts the floodplain as a series of linear lines that poorly match the actual floodplain. This is due to an error in the EPA floodplain map used in this indicator.
- The catchment boundaries cross the United States/Mexico border, but the NLCD impervious data does not; as a result, the values along the United States/Mexico border are only based on the portion of the catchment where there are NLCD impervious values.
- Due to an issue with the selection of the NHD+ medium resolution catchments layer, we inadvertently excluded some catchments from the indicator. As a result, there are holes in the data in Lake Pontchartrain, LA. These areas are underprioritized in the indicator, but this did not meaningfully influence the final Blueprint priorities.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

EPA EnviroAtlas. 2018. Estimated Floodplain Map of the Conterminous U.S. [https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/Supplemental/EstimatedFloodplains.pdf].

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Network Complexity

This indicator depicts the number of connected stream size classes in a river network between dams or waterfalls. It originates from the Southeast Aquatic Resources Partnership and applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood).

Reason for Selection

River networks with a variety of connected stream size classes are more likely to have a wide range of available habitat to support a greater number of species. This will help retain aquatic biodiversity in a changing climate by allowing species to access climate refugia and move between habitats (Morelli et al. 2016).

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- Southeast Aquatic Resources Partnership's Network Complexity metric

  The Southeast Aquatic Resources Partnership (SARP) developed metrics for their Southeast Aquatic Barrier Prioritization Tool. On June 7, 2023, Brendan Ward with Astute Spruce (software developer working on behalf of SARP) shared high resolution NHDPlus flowlines with attributes depicting the network complexity attribute for each functional network (see definition of "functional network" below). The network complexity attribute calculates the total number of different stream size classes within each functional network. SARP assigned stream and river reaches to size classes based on total drainage area:

  - 1a: Headwaters (<3.861 sq mi)
  - 1b: Creeks (≥3.861 and <8.61 sq mi)
  - 2: Small Rivers (≥38.61 and <200 sq mi)
  - 3a: Medium Tributary Rivers (≥200 and <1,000 sq mi)
  - 3b: Medium Mainstem Rivers (≥1,000 and <3,861 sq mi)
  - 4: Large Rivers (≥3,861 and <9,653 sq mi)
  - 5: Great Rivers (≥9,653 sq mi)

  Functional Network

  SARP compiles the Southeast Aquatic Barrier Inventory from national, regional, state, and local partner databases across the Southeast region. These include the National Inventory of Dams (2018), National Anthropogenic Barrier Dataset (2012), databases from state dam safety programs and other state agencies, information from local partners, and dam locations estimated by SARP. Waterfalls are compiled from national datasets and local partners.

  Dams and waterfalls are snapped to hydrologic networks extracted from the National Hydrography Dataset (NHD) - High Resolution Beta version. All dams and waterfalls are treated as "hard" barriers for network connectivity analysis. Aquatic networks are cut at the location of each barrier. All network "loops" (non-primary flowlines) are omitted from the analysis.

  An upstream functional network is constructed by traversing upstream from each barrier through all tributaries to the upstream-most origination point or upstream barrier, whichever comes first. Additional functional networks are defined from downstream-most non-barrier termination points, such as marine areas or other downstream termination points.

  The total length of all network segments within a functional network is summed to calculate the total network length of each functional network. Each flowline segment within the NHD is assigned to a size class based on total drainage area. This was used to calculate the number of unique size classes per functional network.

- Estimated Floodplain Map of the Conterminous U.S. from the Environmental Protection Agency's (EPA) EnviroAtlas; see this factsheet for more information; download the data

  The EPA Estimated Floodplain Map of the Conterminous U.S. displays "...areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood). These data are based on the Federal Emergency Management Agency (FEMA) 100-year flood inundation maps with the goal of creating a seamless floodplain map at 30-m resolution for the conterminous United States. This map identifies a given pixel's membership in the 100-year floodplain and completes areas that FEMA has not yet mapped" (EPA 2018).

- National Hydrography Dataset Plus High Resolution (NHDPlus HR) National Release catchments, accessed 11-30-2022; download the data; view the user guide
- NHDPlus Version 2.1 medium resolution catchments (note: V2.1 is just the current sub-version of the dataset generally called NHDPlusV2); view the user guide

  Catchments

  A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

  To learn more about catchments and how they're defined, check out these resources:

  - An article from USGS explaining the differences between various NHD products
  - The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

Mapping Steps

- Merge the functional network lines from the 11 subregions delivered by SARP into one feature class.
- Convert the combined SARP network complexity values from the NHDPlus HR flowlines to a 30 m raster.
- Clip to the Base Blueprint 2022 extent.
- Apply the network complexity values to the high resolution NHDPlus HR catchments using the ArcPy Zonal Statistics "MAJORITY" function. This results in a raster where each catchment is given the majority network complexity value that intersects the catchment. Most catchments have only one intersecting line, but for catchments with interior dams, the analysis uses the majority network complexity value. This creates a raster with network complexity value assigned to catchments.
- To define the analysis extent of the indicator, make a copy of the NHDPlus HR catchments and convert it to raster, assigning it a value of 1.

- Clip the network complexity raster to the EPA floodplain layer. During this step, assign a value of 0 to areas outside the EPA floodplain. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Some areas of the floodplain are not scored in the resulting layer because they are missing SARP network complexity values. This is due to the fact that some small reaches, such as braids and loops in the stream network, are not assigned a network complexity value. SARP has to remove loops and braided streams in order to calculate network complexity because the analysis can only accommodate a one-way flow of water. Identify these holes in the floodplain and fill them in by looking at the network complexity value of the surrounding pixels and assigning the maximum value to the missing catchments in the floodplain. Note: This explanation simplifies a complex series of analysis steps. For more specifics, please consult the code.
- Select the NHDPlus V2.1 medium resolution catchments that intersect the vector boundary of the Base Blueprint 2022 extent. Then, clip the network complexity raster to those catchments. This removes values in the nearshore environment that are outside the intended scope of this indicator, particularly on the NC coast.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

7 = 7 connected stream classes
6 = 6 connected stream classes
5 = 5 connected stream classes
4 = 4 connected stream classes
3 = 3 connected stream classes
2 = 2 connected stream classes
1 = 1 connected stream class
0 = Not identified as a floodplain

Known Issues

- It does not include other smaller scale attributes of complexity (e.g., sinuosity, mixtures of riffles/pools/runs) that influence the habitat quality of the connections.
- The EPA Estimated Floodplain layer sometimes misses the small, linear connections made by artificial canals, especially when they go through areas that wouldn't naturally be part of the floodplain. As a result, some areas (like lakes) that are connected via canals may appear to be disconnected, but still receive high scores.
- Small headwaters and creeks are not included in this indicator because the EPA estimated floodplain dataset does not include them.

- This indicator does not account for the habitat quality of the connections.
- While this indicator generally includes the open water area of reservoirs, some open water portions of reservoirs (e.g., Kerr Lake in NC/VA) are missing from the estimated floodplain dataset.
- This indicator likely overestimates the number of connected stream classes in some areas due to missing barriers in the inventory, such as smaller dams or road-stream crossings. It could also underestimate the number of connected stream classes, given the extensive ongoing restoration work to improve aquatic connectivity across the SECAS geography. If you identify a missing barrier or a removed barrier, please let SARP know by emailing Kat Hoenke at kat@southeastaquatics.net. You can learn more about the current inventory of dams and road-stream crossings by visiting https://connectivity.sarpdata.com/.
- SARP did a lot of work to snap the dam locations to the line network, but there are likely still dams (including some large ones) that didn't get snapped correctly due to the large distance between the centerpoint of the dam and the nearest flowline. If you see any of these cases when reviewing the data, please let SARP know (the giveaway is networks that look longer than they should on a map).
- In the area just south of Guadalupe Mountains National Park in West Texas, this indicator depicts the floodplain as a series of linear lines that poorly match the actual floodplain. This is due to an error in the EPA floodplain map used in this indicator.
- Due to issues with the national NHDPlus HR catchments layer, there are a handful of missing catchments (e.g., northwest TX, coastal LA, and eastern NC). These places receive a value of NoData in the indicator and are therefore underprioritized. We are investigating ways to resolve this in future updates.
- Due to an issue with the selection of the NHDPlus medium resolution catchments layer, we inadvertently excluded some catchments from the indicator. As a result, there are holes in the data in Lake Pontchartrain, LA. These areas are underprioritized in the indicator, but this did not meaningfully influence the final Blueprint priorities.
- This indicator may slightly overvalue network complexity in WV compared to other Southeast states because the coverage of dams and barriers data is not as comprehensive. While the dams and barriers data coverage improved sufficiently for us to use the network complexity indicator across the entire state of WV in 2023 for the first time (whereas it was only used in the southern part of the state in 2022), there is still room for improvement and we anticipate significant progress in the next Blueprint update.

Disclaimer: Comparing with Older Indicator Versions

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Literature Cited

Moore, R.B., McKay, L.D., Rea, A.H., Bondelid, T.R., Price, C.V., Dewald, T.G., and Johnston, C.M., 2019, User's guide for the national hydrography dataset plus (NHDPlus) high resolution: U.S. Geological Survey Open-File Report 2019– 1096, 66 p., [https://doi.org/10.3133/ofr20191096].

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Permeable Surface

This indicator measures the average percent of non-impervious cover within each catchment. It originates from the National Land Cover Database.

Reason for Selection

Impervious cover is easy to monitor and model and is widely used and understood by diverse partners. It is also strongly linked to water quality, estuary condition, eutrophication, and freshwater inflow. Impervious surface affects not only aquatic habitats and biodiversity, but also human communities. High levels of impervious surface cause more frequent flooding by increasing the volume of stormwater runoff, reduce the amount of available drinking water by preventing groundwater recharge, and pollute waterways where people swim and fish (Chesapeake 2023, USGS 2018, EPA 2018).

The 90% permeable surface threshold (i.e., 10% impervious) is a well-documented signal of major negative changes to aquatic ecosystems (Schueler et al. 2009). The 95% permeable surface threshold (i.e., 5% impervious) has been documented to impact Piedmont fish [tricolor shiner *(Cyprinella trichroistia)*, bronze darter *(Percina palmaris)*, Etowah darter *(Etheostoma etowahae)*] (Wenger et al. 2008) and estuarine species [blue crab *(Callinectes sapidus)*, white perch *(Morone americana)*, striped bass *(M. Saxatilis)* and spot *(Leiostomus xanthurus)*] (Uphoff Jr. et al. 2011).

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- 2019 National Land Cover Database (NLCD): Percent developed imperviousness
- National Hydrography Dataset Plus (NHDPlus) Version 2.1 medium resolution catchments (note: V2.1 is just the current sub-version of the dataset generally called NHDPlusV2); view the user guide

Catchments

A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

To learn more about catchments and how they're defined, check out these resources:

- An article from USGS explaining the differences between various NHD products
- The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

Mapping Steps

- Select the NHDPlus V2.1 medium resolution catchments that intersect the vector boundary of the Base Blueprint 2022 extent.
- Calculate percent impervious for each NHDPlus catchment using the NLCD 2019 impervious surface layer and the ArcPy Spatial Analyst Zonal Statistics "MEAN" function. The Zonal Statistics Mean calculates the average of the impervious surface values in each catchment and assigns that value to all the cells inside that catchment.
- Convert percent impervious to percent permeable using the formula [percent permeable = 100 - percent impervious] to maintain consistent scoring across Southeast indicators (high values indicate better ecological condition).
- Reclassify the above raster into 4 classes, seen in the final indicator values below.
- As a final step, clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = >95% of catchment permeable (likely high water quality and supporting most sensitive aquatic species)
3 = >90-95% of catchment permeable (likely declining water quality and supporting most aquatic species)
2 = >70-90% of catchment permeable (likely degraded water quality and not supporting many aquatic species)
1 = ≤70% of catchment permeable (likely degraded instream flow, water quality, and aquatic species communities)

Known Issues

- This indicator may not account for differences in permeability between different types of soils and land uses.
- The catchment boundaries are inconsistent in how far they extend toward the ocean. As a result, this indicator does not consistently apply to estuaries, coastal areas, and barrier islands in different parts of the Southeast.

- The catchment boundaries cross the United States/Mexico border, but the NLCD impervious data does not; as a result, the values along the United States/Mexico border are only based on the portion of the catchment where there are NLCD impervious values.
- The NLCD percent impervious layer contains classification inaccuracies that may cause this indicator to overestimate or underestimate the amount of permeable surface in some catchments.
- Due to an issue with the selection of the NHDPlus medium resolution catchments layer, we inadvertently excluded some catchments from the indicator. As a result, there are holes in the data in Lake Pontchartrain, LA. These areas are underprioritized in the indicator, but this did not meaningfully influence the final Blueprint priorities.

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Literature Cited

Chesapeake Bay Program. 2023. Stormwater Runoff. Accessed September 7, 2023. [https://www.chesapeakebay.net/issues/threats-to-the-bay/stormwater-runoff].

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West Virginia Imperiled Aquatic Species

This indicator counts the number of aquatic species within each 12-digit HUC subwatershed in West Virginia that are listed as G1 (globally critically imperiled), G2 (globally imperiled), or threatened/endangered under the U.S. Endangered Species Act. It originates from the Environmental Protection Agency's EnviroAtlas data.

Reason for Selection

According to the Southeastern Freshwater Biodiversity Conservation Strategy, "the Southeastern United States is a global hotspot of freshwater biodiversity, supporting almost two-thirds of the country's fish species, over 90% of the US total species of mussels and nearly half of the global total for crayfish species. More than a quarter of this region's species are found nowhere else in the world. Unfortunately, this region is also a hotspot for imperilment. The number of imperiled freshwater fish species in the Southeast has risen 125% in the past 20 years" (RBC and TNACI).

This indicator identifies areas with abundant rare and endemic aquatic species that would benefit from conservation action. It captures patterns of rare and endemic species diversity not well-represented by other freshwater indicators. It complements the other imperiled aquatic species indicator, which uses aquatic Species of Greatest Conservation Need, but does not yet cover West Virginia.

Input Data

- Total number of at-risk aquatic animal species observed by HUC12 from the Environmental Protection Agency's (EPA) EnviroAtlas

  The data come from a NatureServe analysis that includes all non-plant (i.e., animal) aquatic species ranked as Imperiled (G1/G2) by NatureServe or listed as threatened or endangered under the U.S. Endangered Species Act. More details are available in the associated EnviroAtlas factsheet.

- Estimated Floodplain Map of the Conterminous U.S. from the Environmental Protection Agency's (EPA) EnviroAtlas; see this factsheet for more information; download the data

  The EPA Estimated Floodplain Map of the Conterminous U.S. displays "...areas estimated to be inundated by a 100-year flood (also known as the 1% annual chance flood). These data are based on the Federal Emergency Management Agency (FEMA) 100-year flood inundation maps with the goal of creating a seamless floodplain map at 30-m resolution for the conterminous United States. This map identifies a given pixel's membership in the 100-year floodplain and completes areas that FEMA has not yet mapped."

- Base Blueprint 2022 extent
- U.S. Geological Survey (USGS) Watershed Boundary Dataset (WBD), accessed 12-2-2021: HUC12s
- 2023 U.S. Census TIGER/Line state boundaries, accessed 5-15-2023; download data
- Southeast Blueprint 2023 extent

Mapping Steps

- Download the EnviroAtlas at-risk aquatic animal species observed dataset in Esri FileGeodatabse format and join the tabular data to the WBD HUC12 spatial data.
- Use the field with the total number of G1/G2 or threatened/endangered aquatic species to convert the vector HUC12 layer to a raster with 30 m cell size using the ArcGIS Polygon to Raster tool with a cell assignment type of cell center.
- Reclassify the species count values to the 1-9 indicator values seen below.
- Mask the resulting raster to the EPA estimated floodplain. Assign a value of 0 to all areas outside the EPA floodplain. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Remove all areas outside of West Virginia using the TIGER/Line state boundary.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = 4+ aquatic imperiled (G1/G2) or threatened/endangered animal species observed
4 = 3 aquatic imperiled (G1/G2) or threatened/endangered animal species observed
3 = 2 aquatic imperiled (G1/G2) or threatened/endangered animal species observed
2 = 1 aquatic imperiled (G1/G2) or threatened/endangered animal species observed
1 = 0 aquatic imperiled (G1/G2) or threatened/endangered animal species observed
0 = Not identified as a floodplain

Known Issues

- This indicator uses a different definition of "imperiled" compared to the full imperiled aquatic species indicator that covers the rest of the Southeast. The West Virginia indicator defines imperiled as G1 (globally critically imperiled), G2 (globally imperiled), or threatened/endangered under the U.S. Endangered Species Act, while the full imperiled aquatic species indicator defines "imperiled" as a Species of Greatest Conservation Need (SGCN). We are investigating ways to add aquatic SGCN data for WV to improve the consistency of the underlying data and eliminate the need for this separate indicator.
- For the HUC12 watersheds that intersect with the Kentucky and Virginia state lines, this indicator took precedence over the full imperiled aquatic species indicator because this indicator was more accurate at those state boundaries.
- As this indicator is based on occurrence records, poorly surveyed areas may be scored too low. Therefore, this data does not imply absence of species.
- The data in this indicator was last updated in 2011. Subwatersheds with new imperiled species discovered after 2011 would be scored too low. Compared to the more recent data from the Southeast Aquatic Resources Partnership on aquatic Species of Greatest Conservation Need, which is used across the rest of the Southeast in the full imperiled aquatic species indicator, this WV-specific indicator likely underestimates imperiled aquatic species values.
- While this indicator generally includes the open water area of reservoirs, some open water portions of reservoirs are missing from the estimated floodplain dataset.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Coastal & Marine

Atlantic Coral and Hardbottom

This indicator predicts the presence of coral and hardbottom in the Atlantic Ocean based on direct observations, known locations of human-created structures like artificial reefs, and distribution models. The models use hardbottom observations and a suite of environmental predictors including measures of depth, seafloor topography and substrate, oceanography, and geography. This indicator combines data from The Nature Conservancy's South Atlantic Bight Marine Assessment and multiple National Oceanic and Atmospheric Administration datasets (deep-sea coral observations, shipwrecks, artificial reefs, and two projects predicting hardbottom distribution).

Reason for Selection

Hardbottom provides an anchor for important seafloor habitats such as deep-sea corals, plants, and sponges. Hardbottom and these associated communities provide important habitat structure for many invertebrate and fish species (NOAA 2018). Hardbottom areas serve as fish nursery, spawning, and foraging grounds, supporting commercially valuable fisheries like snapper and grouper (NCDEQ 2016). According to Dunn and Halpin (2009), "hardbottom habitats support high levels of biodiversity and are frequently used as a surrogate for it in marine spatial planning." Human-created hardbottom (e.g., artificial reefs) is also known to provide additional habitat that is quickly colonized to provide a suite of ecosystem services commonly associated with naturally occurring hardbottom (Wu et al. 2019).

Input Data

- Southeast Blueprint 2023 extent
- Southeast Blueprint 2023 subregions: Atlantic marine, marine (combined Atlantic & Gulf of Mexico)
- National Oceanic and Atmospheric Administration (NOAA) Characterizing Spatial Distributions of Deep-sea Corals and Hardbottom Habitats in the U.S. Southeast Atlantic; read the final report; data shared prior to official release on 2-4-2022 by Dr. Matt Poti with the NOAA National Centers for Coastal Ocean Science (NCCOS) (matthew.poti@noaa.gov)
- Predictive Modeling and Mapping of Hardbottom Seafloor Habitats off the Southeast U.S: unpublished NOAA data and draft final report entitled *Assessment of Benthic Habitats for Fisheries Management* provided on 1-28-2021 by Dr. Matt Poti with NOAA NCCOS (matthew.poti@noaa.gov)
- Mapping and Geomorphic Characterization of the Vast Cold-Water Coral Mounds of the Blake Plateau; data provided prior to official release on 6-14-2023 by Dr. Derek Sowers with Ocean Exploration Trust (derek@oceanexplorationtrust.org); read more about the mapping expedition, read an abstract describing this work from the 2024 Ocean Sciences Meeting; read a white paper about the survey
- The Nature Conservancy's (TNC) South Atlantic Bight Marine Assessment; chapter 3 of the final report provides more detail on the seafloor habitats analysis

- NOAA artificial reefs, accessed 6-21-2023 on the Marine Cadastre, provided by the NOAA Office for Coastal Management
- NOAA Electronic Navigational Chart (ENC) Wrecks, accessed 6-9-2023; download the data
- NOAA deep-sea coral locations, accessed 6-21-2023 on the NOAA Deep-Sea Coral & Sponge Map Portal

Mapping Steps

- Buffer the Southeast Blueprint 2023 Atlantic marine subregion by 100 km. Convert to raster, giving all areas inside the buffer a value of 0. This buffer distance attempts to capture how far upstream brackish water typically extends along the Atlantic coast and is informed by a 1978 water quality study of the estuarine James River in Virginia (Neilson and Ferry 1978). This is intended to approximate part of the analysis extent of the indicator.
- Extract "Hardbottom_Final_Logistic_Prediction.tif" from the older NOAA hardbottom data for shallower waters and "Hardbottom_Median_Prediction.tif" from the newer NOAA hardbottom data for deeper waters. Reclassify both NOAA hardbottom datasets into 5 quantiles.
- Combine the two NOAA hardbottom datasets and use the newer data from the "Characterizing Spatial Distributions of Deep-sea Corals and Hardbottom Habitat in the U.S. Southeast Atlantic" project where pixels overlap. Snap and project the result based on the Southeast Blueprint 2023 marine subregion.
- Add to the buffer created in the first step to ensure that the southern "tail" of the NOAA probabilities is not cut off in the Florida Keys. Reclassify the combined NOAA probability raster to give all values >0 a value of 1, convert it to a polygon, and buffer it by 100 m. Then union the result with the buffered Atlantic marine extent from the first step and convert it back to a raster. This now more fully represents the analysis extent of the indicator.
- From the Blake Plateau dataset, pull out peaks, ridges, and slopes from the landform data and assign them all a value of 6.
- Combine all anthropogenic hardbottom points (shipwrecks and artificial reefs). Buffer the points by 150 m and convert to raster, assigning all buffered points a value of 7. The buffer distance used here, and later for coral locations, follows guidance from the Army Corps of Engineers for setbacks around artificial reefs and fish havens (Riley et al. 2021).
- From the deep-sea coral point locations, select points with a Vernacular field value of either 'stony coral (branching)', 'stony coral (cup coral)', 'stony coral (unspecified)', 'black coral', or 'gorgonian coral'. These vernacular name categories best correspond to the taxa included in the NOAA hardbottom and deep-seal coral models mentioned above. Then buffer the selected point locations by 150 m, convert to raster, and assign them a value of 8.
- From the TNC SABMA data, pull out observed hardbottom polygons that contain a value of "01. mapped hardbottom area" in the TEXT_DESC field. Convert to a raster and assign a value of 7.
- Combine all the layers produced above using the cell statistics tool with the overlay statistic maximum.
- Use the 2019 NLCD to remove all land from the above raster, where this marine indicator does not apply. Assign a value of 0 to all pixels that are not a value of 0 or 11 in the NLCD.

- Remove all areas outside of the 100 km buffer around the Atlantic marine subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

8 = Confirmed coral
7 = Confirmed natural or human-created hardbottom (shipwrecks, artificial reefs)
6 = Predicted cold-water coral mounds (Blake Plateau)
5 = Highest probability of hardbottom (>80th percentile)
4 = High probability of hardbottom (>60th-80th percentile)
3 = Medium probability of hardbottom (>40th-60th percentile)
2 = Low probability of hardbottom (>20th-40th percentile)
1 = Lowest probability of hardbottom (≤20th percentile)
0 = Not identified as hardbottom

Known Issues

- This indicator underprioritizes confirmed natural hardbottom. We intended for the top class of the indicator (class 8) to include confirmed coral and natural hardbottom, but due to a processing error, inadvertently assigned confirmed natural hardbottom to class 7. We discovered this too late to fix in this update cycle, but updated the legend accordingly so it accurately reflects the actual mapping steps used. We intend to fix this in our next update to this indicator. It is unlikely to meaningfully impact the Blueprint priorities.
- This indicator likely underpredicts hardbottom suitability in shallow waters. While this indicator includes new hardbottom suitability models based on recent hardbottom observations for deep waters (depths of 50 m or below), the underlying NOAA data available for shallow waters were developed in 2014.
- While this layer has a 30 m resolution, both NOAA hardbottom datasets were coarser than that. We downsampled 100 m pixels and 92 m pixels to 30 m.
- This indicator underestimates shallower hardbottom habitat (<200 m depth) north of the NC/VA state line because the study area of the shallower hardbottom suitability dataset was restricted only to the South Atlantic marine environment and did not cover the northern portion of the SECAS marine area. The indicator also underestimates deeper hardbottom habitat north of approximately 37.5°N latitude because the study area of the deeper hardbottom suitability dataset does not perfectly align with the SECAS marine area and leaves an area of NoData.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Atlantic Deep-Sea Coral Richness

This indicator measures the number of deep-sea coral genera predicted to occur in the Atlantic Ocean at depths of approximately 50 m or below. It is based on coral observations and a suite of environmental predictors including measures of depth, seafloor topography and substrate, oceanography, and geography. This indicator combines probability models for 24 deep-sea coral genera to predict overall richness. Deep-sea corals provide valuable habitat structure that supports a wide range of invertebrate and fish species, and higher coral diversity typically creates more complex habitats occupied by more species. This indicator originates from a National Oceanic and Atmospheric Administration project characterizing the spatial distributions of deep-sea corals and hardbottom habitats in the U.S. Southeast Atlantic.

Reason for Selection

Many deep-sea corals form tree-like shapes and complex reefs that provide valuable three-dimensional habitat structure for many fish and invertebrate species. The presence of more coral genera typically creates more complex habitats that support more species. In tropical coral reef communities, higher levels of coral diversity and topographic complexity have been shown to promote higher diversity of fish species (Komyakova et al. 2013). Deep-sea corals support commercially important fisheries such as grouper, snapper, sea bass, rockfish, shrimp, and crab. Because most deep-sea corals grow very slowly, they are highly vulnerable to damage from trawling and energy development, as well as ocean acidification due to climate change (NOAA 2018).

Input Data

- Southeast Blueprint 2023 subregions: Marine (combined Atlantic & Gulf of Mexico)
- Southeast Blueprint 2023 extent
- National Oceanic and Atmospheric Administration (NOAA) Characterizing Spatial Distributions of Deep-sea Corals and Hardbottom Habitats in the U.S. Southeast Atlantic; read the final report; data shared prior to official release on 2-4-2022 by Dr. Matt Poti with the NOAA National Centers for Coastal Ocean Science (matthew.poti@noaa.gov)

This dataset provides probability models for 24 deep-sea coral genera *(Eunicella, Enallopsammia, Cladocora, Chrysogorgia, Callogorgia, Bathypathes, Antipathes, Anthothela, Acanthogorgia, Acanella, Thesea, Tanacetipathes, Stylasteridae, Stichopathes, Solenosmilia, Plumarella, Paramuricea, Paragorgia, Oculina, Nicella, Muricea, Madrepora, Lophelia, Leiopathes),* as well as a combined genus richness layer that counts the average number of unique genera predicted to occur in each 100 m pixel. Dr. Poti provided a summarized vector version of the continuous genus richness raster layer that mirrors the way the Bureau of Safety and Environmental Enforcement displays the Gulf version of these data. This classification is based on natural breaks in the data distribution and used 10 bins. We further collapsed the bins from 10 to 5 for simplicity.

Mapping Steps

- Convert the categorical text descriptions in the provided genus richness shapefile into the indicator values.
- Reclassify to collapse the 10 classes into 5 by combining the “0-0.5” and “0.5-1” classes and assigning a value of 1, combining the “1-1.5” and “1.5-2” classes and assigning a value of 2, combining the “2-2.5” and “2.5-3” classes and assigning a value of 3, combining the “3-3.5” and “3.5-4” classes and assigning a value of 4, and combining the “4-5” and “>5” classes and assigning a value of 5.
- Convert the shapefile to a raster.
- Clip to the Southeast Blueprint 2023 marine subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Highest predicted average genus richness (>4)
4 = High predicted average genus richness (>3-4)
3 = Medium predicted average genus richness (>2-3)
2 = Low predicted average genus richness (>1-2)
1 = Lowest predicted average genus richness (0-1)

Known Issues

- While this layer has a 30 m resolution, the NOAA deep-sea coral models were coarser than that. We downsampled 100 m pixels to 30 m.
- This indicator underprioritizes areas with low survey effort for the variables used to predict deep-sea corals. This is especially true for seafloor geology, curvature, and aspect. Sharp linear features and shapes in this indicator, when not aligned with a shelf break, are a symptom of places with low survey effort for these variables.

- The source data does not consistently cover all areas deeper than 50 m within the Blueprint marine subregion. According to the final report for the NOAA project, "The study area included waters between 50–3,500 m depth within BOEM's Straits of Florida, South Atlantic, and Mid-Atlantic Planning Areas and extended from Florida to Delaware. Locations of underwater visual surveys used to compile the presence-absence database for this study did not span this entire depth range across the study area. Therefore, the depth range of the study area extent varied with latitude. Offshore of south Florida (the Straits of Florida, the Miami and Pourtalès Terraces, and the adjacent escarpment) presence-absence data were not located shallower than approximately 150 m, so the study area was restricted to waters from 150–3,500 m depth south of 26.5 °N latitude. Similarly, the study area was restricted to continental slope waters from 200–3,500 m depth north of 34.5 °N because presence-absence data north of Cape Lookout, North Carolina, were located only on the continental slope (in submarine canyons and inter-canyons areas) and not on the continental shelf (<200 m depth)."

Other Things to Keep in Mind

- Atlantic and Gulf deep-sea coral richness are intended to serve as complementary indicators and are based on very similar NOAA source data. Because of the different deep-sea coral communities present in the Atlantic and the Gulf, the data provider recommended different thresholds for what level of genus richness qualifies as highest, high, medium, etc. to ensure the Blueprint captures the most important deep-sea coral areas within each region.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Atlantic Estuarine Fish Habitat

This indicator measures the condition of estuarine fish habitat along the Atlantic coast using metrics of water quality, marsh edges, seagrass and oyster reefs, fragmentation, human development, and more. Areas of excellent fish habitat are already in good condition and face few threats. Restoration opportunity areas are doing well in some respects, but restoration projects could significantly improve them. Degraded areas of opportunity face many challenges, and restoration projects are unlikely to increase available fish habitat unless particularly large in scope and scale. This indicator originates from the Atlantic Coast Fish Habitat Partnership's fish habitat conservation area mapping and prioritization project.

Reason for Selection

This indicator captures many factors influencing Atlantic estuarine fish habitat quality and promotes consistency with the priorities of the Atlantic Coast Fish Habitat Partnership. Estuarine habitat provides critical food resources and serves as a refuge from predators for many recreational and commercial fish, crabs and small animals (Naturally Resilient Communities 2017). Submerged aquatic vegetation in coastal and estuarine ecosystems is a food source for waterfowl and, along with marsh edges and seagrass, serves as important nursery habitat for many species (Dennison et al. 1993). Oyster reefs and beds also help to improve surrounding water quality, buffer coasts from waves, and reduce erosion (Naturally Resilient Communities 2017).

Input Data

- Atlantic Coast Fish Habitat Partnership (ACFHP) Fish Habitat Conservation Area Mapping and Prioritization Project: South Atlantic, Mid-Atlantic, and South Florida Estuarine Analysis
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Convert the South Atlantic Estuarine Analysis from vector to a 30 m raster using the FINALSCORE field.
- Convert the Mid-Atlantic Estuarine Analysis from vector to a 30 m raster using the TotalPoints field.
- Convert the South Florida Estuarine Analysis from vector to a 30 m raster using the FINALSCORE field.
- Combine the above rasters using the ArcPy Spatial Analyst Cell Statistics "MAX" function.
- Reclassify the above raster into 9 classes, seen in the final indicator values below.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

8 = Final score of 80 (areas of excellent fish habitat)
7 = Final score of 70 (areas of excellent fish habitat)
6 = Final score of 60 (restoration opportunity areas)
5 = Final score of 50 (restoration opportunity areas)
4 = Final score of 40 (restoration opportunity areas)
3 = Final score of 30 (restoration opportunity areas)
2 = Final score of 20 (restoration opportunity areas)
1 = Final score of 10 (degraded areas of opportunity)
0 = Final score of 0 (degraded areas of opportunity)

Known Issues

- This indicator underestimates scores in parts of Georgia and North Florida that weren't well-surveyed for oyster reefs at the time of the ACFHP assessment.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Atlantic Marine Birds

This indicator identifies important areas in the Atlantic Ocean for birds that feed exclusively or mainly at sea. It uses seasonal predictions of relative abundance for 19 species of marine birds (Audubon's shearwater, band-rumped storm petrel, black-capped petrel, black scoter, Bonaparte's gull, bridled tern, brown pelican, common loon, common tern, Cory's shearwater, great shearwater, Manx shearwater, Northern gannet, parasitic jaeger, red-throated loon, royal tern, sooty shearwater, sooty tern, white-winged scoter) based on sightings from boat-based surveys and marine environmental data like fronts, primary productivity, and ocean currents. This indicator originates from Duke University's Marine-life Data and Analysis Team marine bird models.

Reason for Selection

Marine birds help identify key areas of ocean productivity and overall ocean health. According to Parsons et al. 2008, seabirds are often considered useful ecological indicators for the marine environment because they "essentially represent the top of the food chain" and therefore are likely to signal changes in lower trophic levels and the surrounding environment. Seabird populations also respond to anthropogenic pressures such as "overexploitation of their food resources and pollution from industrial discharge." Long-term monitoring has "generated high-quality data on population counts and demographic parameters" and seabirds "are considered to be of international importance and have high resonance with the public and policy-makers" (Parsons et al. 2008). This indicator complements the Atlantic marine mammals indicator by providing finer spatial resolution and stronger connections to forage fish productivity.

Input Data

- Southeast Blueprint 2023 extent
- 2019 National Land Cover Database (NLCD)
- Seasonal avian abundance models (Version 2.0) from Duke University's Marine-life Data and Analysis Team (Avian abundance ZIP), accessed 6-8-2021

  These models use aggregated survey information and oceanographic variables to predict the relative abundance of marine birds across the entire U.S. Atlantic. Potential species to include in this indicator began with Tier 1 and Tier 2 priority species in Bird Conservation Region 27 (the Southeastern Coastal Plain) in the Southeast United States Regional Waterbird Conservation Plan. This plan did not include waterfowl species, so additional waterfowl were added from priority species identified by the Northwest Atlantic Birds at Sea Conservation Cooperative (now the Atlantic Marine Bird Cooperative). We narrowed down this larger combined list in two ways. First, we removed species from the list that didn't have spatial models available. Then, we removed species that had models with poor predictive performance and/or large spatial errors.

Species with seasonal models used in this indicator are: Audubon's shearwater (fall, spring, summer), band-rumped storm-petrel (summer), black-capped petrel (spring, summer, winter), black scoter (fall, spring, winter), Bonaparte's gull (spring, winter), bridled tern (fall, summer), brown pelican (fall), common loon (spring, summer, winter), common tern (fall, spring, summer), Cory's shearwater (fall, spring, summer), great shearwater (fall, spring, summer), Manx shearwater (fall, spring, summer), Northern gannet (spring, summer, winter), parasitic jaeger (fall, spring, summer), red-throated loon (spring, winter), royal tern (fall, spring, summer), sooty shearwater (fall, spring, summer), sooty tern (spring, summer) and white-winged scoter (fall, spring, winter).

Mapping Steps

- To identify important areas for each species, use the core area algorithm (CAZMAX) in Zonation 5. Include each seasonal abundance layer as a separate input and weight them equally. To account for boundary effects, run all the models across the full extent of the input data (entire U.S. Atlantic).
- Reproject the resulting data to Albers Equal Area.
- Resample the data to 30 m cell size using the nearest neighbor method (the source data is 2 km cells).
- Convert from a floating point raster with a range of 0-1 to an integer raster ranging from 0-100.
- Reclassify to values of 1-10 based on increments of 10 to produce the indicator values seen below.
- Add a zero class for land by reclassifying the NLCD to identify areas of land included in the marine mammal models, which are outside the scope of this indicator. Assign a value of 0 to all pixels that are not a value of 0 or 11 in the NLCD.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

10 = >90th percentile of importance for marine bird index species (across the full East Coast study area)
9 = >80th-90th percentile of importance
8 = >70th-80th percentile of importance
7 = >60th-70th percentile of importance
6 = >50th-60th percentile of importance
5 = >40th-50th percentile of importance
4 = >30th-40th percentile of importance
3 = >20th-30th percentile of importance
2 = >10th-20th percentile of importance
1 = ≤10th percentile of importance
0 = Land

Known Issues

- Models are likely underpredicting the importance of areas in the eastern part of the Atlantic marine ecosystem. Survey effort was very low in that area and many input models did not extend their predictions into the eastern area.
- This indicator does not capture fine resolution patterns nearshore. Model predictions are fairly coarse and do not capture finer variations in relative abundance nearshore and near estuaries.
- This indicator does not cover the estuarine ecosystem. Many of these marine bird species could also be excellent indicators in the open water portion of the estuarine ecosystem; however, spatial models covering the full area of the estuarine ecosystem are not available at this time.
- While this layer has a 30 m resolution, the source data was coarser than that. We downsampled 2 km pixels to 30 m.
- There are a small number of pixels on the eastern edge of the Atlantic marine subregion, east of central and southern Florida, where the Duke models have no data. As a result, those areas are not scored in this indicator.

Other Things to Keep in Mind

- We ran the Zonation analysis across the full East Coast study area because some of the important areas for some species during some months were mostly in an area north of the Blueprint area and just barely extended into the northernmost tip of the Southeast Blueprint marine area. If we ran Zonation only within the Southeast Blueprint Atlantic marine subregion, the indicator would have overprioritized those areas, since they would appear to be very rare features, when in actuality they are common features that just more frequently occur further north. While doing the Zonation run across the full East Coast study area addressed this problem, it means that the percentile calculations are for the full East Coast study area, which included areas outside the extent of the final indicator. As a result, the various classes within the indicator do not cover equal areas within the indicator's extent, as you might expect with a percentile-based indicator—they cover equal areas within the full East Coast study area, and then are clipped down to produce the indicator.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Atlantic Marine Mammals

This indicator identifies important areas in the Atlantic Ocean for dolphins, whales, and seals. It incorporates density predictions for 20 marine mammals species or species groups (Atlantic spotted dolphin, Atlantic white-sided dolphin, Clymene dolphin, common bottlenose dolphin, Cuvier's beaked whale, dwarf and pygmy sperm whales, fin whale, harbor porpoise, humpback whale, mesoplodont beaked whales, North Atlantic right whale, pantropical spotted dolphin, pilot whales, Risso's dolphin, rough-toothed dolphin, seals, short-beaked common dolphin, sperm whale, striped dolphin, unidentified beaked whales) based on sightings from boat-based and aerial surveys and data on oceanographic conditions. It uses marine mammal models developed by the Duke Marine Lab.

Reason for Selection

Marine mammals help identify key areas of ocean productivity and overall ocean health, are regularly monitored, and resonate with a variety of audiences. Marine mammals are often used as ocean health indicators due to their long lifespans, feeding at high trophic levels, and large blubber stores that can serve as repositories for anthropogenic chemicals and toxins (Bossart 2011). This indicator complements the Atlantic marine birds indicator by identifying important habitats in areas too deep for marine birds to reach.

Input Data

- Southeast Blueprint 2023 extent
- 2019 National Land Cover Database (NLCD)
- Habitat-based Marine Mammal Density Models for the U.S. Atlantic (last updated 6-20-2022), accessed 12-12-2023

  These models use aggregated survey information, distance-sampling, and oceanographic variables to predict cetacean density throughout the region. We used data for all available species with the exception of blue whale, common minke whale, false killer whale, Fraser's dolphin, killer whale, melon-headed whale, Northern bottlenose whale, pygmy killer whale, sei whale, spinner dolphin, and white-beaked dolphin. Those species had significant spatial problems in the Southeast.

  The indicator used monthly predictions for 11 species: Atlantic spotted dolphin, Atlantic white-sided dolphin, common bottlenose dolphin, fin whale, harbor porpoise, humpback whale (2009-2019), North Atlantic right whale (2003-2019), Risso's dolphin, seals, short-beaked common dolphin, and sperm whale. It used yearly predictions for 9 rarer species/species groups: Clymene dolphin, Cuvier's beaked whale, dwarf and pygmy sperm whales, mesoplodont beaked whales, pantropical spotted dolphin, pilot whales, rough-toothed dolphin, striped dolphin, and unidentified beaked whales.

Mapping Steps

- To identify important areas for each species, use the core area algorithm (CAZMAX) in Zonation 5. Include each monthly density layer for each marine mammal species as a separate input and weight them equally. To account for boundary effects, run all the models across the full extent of the input data (entire U.S. Atlantic).
- Reproject the resulting source data to Albers Equal Area.
- Resample to a 30 m cell size using the nearest neighbor method (the source data is 5 km by 5 km cells).
- Convert from a floating point raster with a range of 0-1 to an integer raster ranging from 0-100.
- Reclassify to values from 1-10 based on increments of 10.
- Add in a zero class for land by reclassifying NLCD to identify areas of land included in the marine mammal models, which are outside the scope of this indicator. Assign a value of 0 to all pixels that are not a value of 0 or 11 in the NLCD.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

10 = >90th percentile of importance for marine mammal index species (across the full East Coast study area)
9 = >80th-90th percentile of importance
8 = >70th-80th percentile of importance
7 = >60th-70th percentile of importance
6 = >50th-60th percentile of importance
5 = >40th-50th percentile of importance
4 = >30th-40th percentile of importance
3 = >20th-30th percentile of importance
2 = >10th-20th percentile of importance
1 = ≤10th percentile of importance
0 = Land

Known Issues

- While this layer has a 30 m resolution, the source data was coarser than that. We downsampled 5 km pixels to 30 m.
- There are a small number of pixels on the eastern edge of the Atlantic marine subregion just south of southern Florida where the Duke models have no data. As a result, those areas are not scored in this indicator.

Other Things to Keep in Mind

- We ran the Zonation analysis across the full East Coast study area because some of the important areas for some species during some months were mostly in an area north of the Blueprint area and just barely extended into the northernmost tip of the Southeast Blueprint marine area. If we ran Zonation only within the Southeast Blueprint Atlantic marine subregion, the indicator would have overprioritized those areas, since they would appear to be very rare features, when in actuality they are common features that just more frequently occur further north. While doing the Zonation run across the full East Coast study area addressed this problem, it means that the percentile calculations are for the full East Coast study area, which included areas outside the extent of the final indicator. As a result, the various classes within the indicator do not cover equal areas within the indicator's extent, as you might expect with a percentile-based indicator—they cover equal areas within the full East Coast study area, and then are clipped down to produce the indicator.

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Coastal Shoreline Condition

This indicator assesses shoreline condition based on the presence of hardened structures like jetties, groins, and riprap, as well as other human development. Natural shorelines in harder-to-develop coastal areas receive the highest shoreline condition scores, while hardened shorelines receive the lowest scores. This indicator originates from the National Oceanic and Atmospheric Administration's Environmental Sensitivity Index dataset.

Reason for Selection

Human development along shorelines, along with jetties, groins, seawalls, revetments, and other structures, provide a measure of overall habitat alteration and shoreline condition. Human infrastructure along shorelines generally stabilizes barrier islands, impeding natural beach migration and barrier island rollover processes. Groins, seawalls, jetties, and revetments have resulted in narrowing of beaches, or greater beach loss, compared to unstructured beaches (Dugan et al. 2008, Hall and Pilkey 1991, Mohanty et al. 2012, Pilkey and Wright III 1988). Jetties also alter sand transport and may result in downdrift erosion (Bruun 1995). Hardened structures landward of tidal wetlands can cause "coastal squeeze" by accelerating erosion during storms and preventing inland migration in response to sea-level rise (Gittman 2015).

In addition, hardened shorelines, particularly seawalls, generally support lower levels of biodiversity (Gittman et al. 2015, 2016). Studies funded by NOAA's National Centers for Coastal Ocean Science found that shoreline hardening has a negative impact on amounts of submerged aquatic vegetation (SAV) and on fish density and egg-laying (NOAA NCOS 2015, 2013).

Input Data

- National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index (ESI) National Shoreline dataset: This dataset classifies shorelines into types of natural habitat and hardened structures to identify coastal resources that are at risk if an oil spill occurs nearby.
- Spatial designations of the Coastal Barrier Resources System (CBRS), as a result of the Coastal Barrier Resources Act (1982) and subsequent amendments (last updated 3-15-2019), accessed 1-31-2022

  The CBRS was used to set boundaries of relatively undeveloped coastal areas that are more difficult to develop. The Act incentivizes the conservation of mostly intact coastal barrier landforms—such as barrier islands, beaches and dunes, fringing mangroves, and others—to protect valuable natural resources and minimize the loss of human life and property due to hurricanes. It restricts federal expenditures that encourage development in these areas, such as flood insurance.

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

Mapping Steps

- Convert the CBRS polygons to a 30 m raster. Partially armored and natural shoreline pixels will receive a bump in their score if they fall within a CBRS polygon.
- From the ESI data, extract saline estuarine shorelines, where LINE field is not ‘H’ and ENVIR field is ‘E’.
- The GENERALIZED_ESI_TYPE field contains 1-3 shoreline types, listed landward to seaward. If the field contains only ‘1: Armored’, consider it fully armored and assign it the lowest value (0) in the indicator.
- If GENERALIZED_ESI_TYPE contains multiple shoreline types and any of them are armored, consider it partially armored. Assign these pixels a value of 1 (if they are outside the CBRS) or 2 (if they are inside the CBRS) in the indicator.
- Consider all other GENERALIZED_ESI_TYPE fields as natural shoreline. Assign them values of 3 (if they are outside the CBRS) or 4 (if they are inside the CBRS) in the indicator.
- Convert the entire ESI linework to a 30 m raster.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available [in the Southeast Blueprint 2023 Data Download]() under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = Natural and harder to develop
3 = Natural
2 = Partially armored and harder to develop
1 = Partially armored
0 = Armored

Known Issues

- This indicator overestimates shoreline condition in areas near hardened structures. It only predicts low values in places that are currently hardened and not in nearby areas that can also be impacted by that hardening.
- This indicator overestimates shoreline condition in areas with active beach renourishment. Beach renourishment negatively affects some beach and dune species but is not captured by this indicator.
- This indicator does not take into account protected natural areas (e.g., National Wildlife Refuges such as St. Marks in Florida) that are unlikely to be developed but are not within the CBRS.

- In areas where source data is outdated, this indicator sometimes overestimates shoreline condition because it does not capture more recent shoreline alteration (such as the addition of new residential docks and boat slips along the Texas coast). This dataset is a compilation of individual state inputs that vary in age, ranging back to 1996. Some states, like Florida and Texas, maintain their own ESI data separate from the national NOAA ESI, but differences in data structure and formatting made it difficult to combine those with the national ESI data this year. We hope to incorporate more recent state data in future Blueprint updates.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Estuarine Coastal Condition

This indicator combines measures of water quality, sediment quality, contaminants in fish tissue, and benthic community condition to create an overall index of coastal estuarine condition. It originates from the Environmental Protection Agency's National Coastal Condition Assessment data.

Reason for Selection

This index measures the condition of the nation's estuaries following standard national methodologies and is synthesized by the U.S. Environmental Protection Agency (EPA) roughly every five years. Estuaries serve as important nursery habitat for wildlife, including many species of fish and shellfish eaten as seafood. They also improve water quality by filtering out sediments and pollutants, provide recreational opportunities, and support coastal economies (NOAA 2019).

The estuaries and surrounding coastal habitats of the Southeast coast "serve as important stopovers for migratory birds along the Atlantic Flyway as well as nurseries for fish and other animals. The highly productive ecosystems of Southeast estuarine waters contribute to commercial and recreational fishing. The Southeast Coast provides a wealth of economic and ecosystem services that sustain local economies and quality of life. These services include storm-surge and sea-level protection, maritime transportation and trade, commercial and recreational fisheries, and tourism."

Input Data

- Environmental Protection Agency (EPA) National Coastal Condition Assessment (NCCA): 2010 data and 2015 data; download NCCA data

  The NCCA surveys the estuaries and nearshore waters of the Great Lakes using various indicators of ecological condition and human health risk. We use four ecological indicators (USEPA 2015, 2021):

  1. The water quality/eutrophication index - includes measures of phosphorus, nitrogen, water clarity, chlorophyll a, and dissolved oxygen
  2. The sediment quality index - includes sediment contaminant levels and sediment toxicity to live organisms
  3. The benthic/biological condition index – measures the condition of the community of macroinvertebrates (worms, mollusks and crustaceans) living in the sediment, based on diversity, abundance and sensitivity to pollution
  4. The fish tissue contaminants/ecological fish tissue quality index - measures the concentrations of metals and organic contaminants in fish and estimates potential harm to the wildlife that eat them

  This indicator is scored in the same way as EPA's scoring: 1 = poor, 3 = fair, and 5 = good. The 2015 assessment reported no strong regional trends in coastal condition between 2010 and 2015, so we combined both assessments to increase the density of the point data used to create the interpolation.

- NOAA coastal relief model: Shallow water bathymetry derived by extracting the area with depths from 0-10 m; we converted this spatial extent to a shapefile and used it to constrain the interpolation of the mean estuarine condition index
- Southeast Blueprint 2023 extent

Mapping Steps

- The 2010 and 2015 point data contain separate fields for the water quality index, the sediment quality index, the fish tissue index, and the benthic index. Assign numeric values based on EPA's scoring system. If a point scores poor in these fields, assign it a value of 1. If a point scores fair in these fields, assign it a value of 3. If a point scores good in these fields, assign it a value of 5.
- Add and calculate a field to contain the average of the four indices for all sites sampled in either 2010 or 2015. Note: Sites are drawn randomly so are not usually sampled in both timesteps.
- Import the tabular data into ArcPro and join to the table of EPA sampling locations.

- Interpolate the mean EPA coastal condition index value using Spline with Barriers. To avoid interpolating estuarine scores over land areas, use as the barriers input the shallow water extent from the NOAA coastal relief model. If a shallow water bathymetry polygon does not contain an EPA sampling location, that polygon is classified as 0 in a later step because we don't know anything about its condition. Note: This operation had to be accomplished in two steps (Gulf and Atlantic regions) because of file size limitations.
- Merge the Gulf and Atlantic outputs and clip the resulting raster to the 0-10 m shallow water layer from the NOAA coastal relief model.
- Reclassify the above raster into the 5 classes seen in the final indicator values below:
    - 0.3087-2 = 1 (Note: 0.3087 is the minimum value over the entire raster)
    - 2-2.4 = 2
    - 2.4-3.7 = 3
    - 3.7-4 = 4
    - 4-5 = 5
- Intersect the shallow water bathymetry polygon with the EPA sampling locations. If a shallow water extent polygon does not contain an EPA sampling location, use the Calculate Field function to classify that polygon as 0 because we don't know anything about its condition. Assign a value of 1 to all other polygons that do contain EPA sampling locations.
- Convert the resulting vector layer to raster.
- Multiply this new raster by the mean coastal condition index raster to produce a result that shows the mean coastal condition index where that value is known, and 0 for shallow estuaries lacking an EPA condition score. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Good
4 = Fair to good
3 = Fair
2 = Poor to fair
1 = Poor
0 = Shallow estuary not assessed for condition

Known Issues

- The CCA was designed to support regional interpretations of coastal condition, not site-level interpolation as used in this indicator. As a result, estimates for areas far from NCCA sampling sites are highly uncertain.
- This indicator uses only two snapshots in time in a highly dynamic system.

- There is typically a significant time lag between the year the data is collected, and the year the data is published (allowing time for analysis, quality assurance, compiling the report, etc.). As a result, even the most recent available NCCA data (collected in 2015) is somewhat outdated.
- There is an error in the interpolation off the coast of Pensacola, FL that creates an unusual spatial pattern in the indicator. However, this pattern is not reflected in the final Blueprint as the entire area scores highest priority.

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Gulf Coral and Hardbottom

This indicator predicts the presence of coral and hardbottom in the Gulf of Mexico based on direct observations, acoustic surveys, designated Coral Habitat Areas of Particular Concern, and known locations of human-created structures like artificial reefs. It combines data from multiple sources, including Bureau of Ocean Energy Management seismic water bottom anomalies, usSEABED sediment data, several National Oceanic and Atmospheric Administration datasets, and more.

Reason for Selection

Hardbottom provides an anchor for important seafloor habitats such as deep-sea corals, plants, and sponges. Hardbottom is also sometimes associated with chemosynthetic communities around cold seeps or deep-sea hydrothermal vents where bacteria convert chemicals into energy and form the base of complex food webs (Love et al. 2013). Hardbottom and associated species provide important habitat structure for many fish and invertebrates (NOAA 2018). Hardbottom areas serve as fish nursery, spawning, and foraging grounds, supporting commercially valuable fisheries like snapper and grouper (NCDEQ 2016). According to Dunn and Halpin (2009), "hardbottom habitats support high levels of biodiversity and are frequently used as a surrogate for it in marine spatial planning." Human-created hardbottom (e.g., artificial reefs) is also known to provide additional habitat that is quickly colonized to provide a suite of ecosystem services commonly associated with naturally occurring hardbottom (Wu et al. 2019, Schulze et al. 2020).

Input Data

- Southeast Blueprint 2023 extent
- Southeast Blueprint 2023 subregions: Gulf of Mexico
- usSEABED Gulf of Mexico sediments, accessed 4-21-2023; download the data; view and read more about the data on the National Oceanic and Atmospheric Administration (NOAA) Gulf of Mexico Atlas (select Physical --> Marine geology --> 1. Dominant bottom types and habitats)
- Bureau of Ocean Energy Management (BOEM) Gulf of Mexico seismic water bottom anomalies, accessed 4-4-2023
- NOAA artificial reefs, accessed 6-9-2023 on the Marine Cadastre, provided by the NOAA Office for Coastal Management
- NOAA Electronic Navigational Chart (ENC) Wrecks, accessed 6-9-2023; download the data
- Oil and natural gas platforms, accessed 6-9-2023 from the Homeland Infrastructure Foundation-Level Data portal
- NOAA deep-sea coral locations, accessed 6-9-2023 on the NOAA Deep-Sea Coral & Sponge Map Portal
- Gulf of Mexico Coral Habitat Areas of Particular Concern (HAPC) designated by the Gulf of Mexico Fishery Management Council, accessed 6-23-2023

Mapping Steps

- From the BOEM .lpk data, extract the following shapefiles: anomaly_confirmed_relic_patchreefs.shp, anomaly_Cretaceous.shp, anomaly_relic_patchreefs.shp, seep_anomaly_confirmed_buried_carbonate.shp, seep_anomaly_confirmed_carbonate.shp, seep_anomaly_confirmed_organisms.shp, seep_anomaly_positives.shp, seep_anomaly_positives_confirmed_gas.shp, seep_anomaly_positives_confirmed_oil.shp, seep_anomaly_positives_possible_oil.shp, seep_anomaly_confirmed_corals.shp, seep_anomaly_confirmed_hydrate.shp.

- To create a class of confirmed BOEM features, combine anomaly_confirmed_relic_patchreefs.shp, seep_anomaly_confirmed_organisms.shp, seep_anomaly_confirmed_corals.shp, and seep_anomaly_confirmed_hydrate.shp and convert to raster.
- To create a class of predicted BOEM features, use the remaining extracted shapefiles and convert to raster.
- From usSEABED data, use the field "gom_domnc" to classify polygons into 3 categories: rock (dominant and subdominant), gravel (dominant and subdominant), and all other sediments. Convert to raster.
- From oil and natural gas platform data, select points where STATUS = 'REMOVED' to extract only decommissioned platforms.
- Merge point locations for shipwrecks, artificial reefs, and decommissioned oil and natural gas platforms (which have a status of "removed" in the source data). Buffer them by 150 m and convert to raster. The buffer distance used here, and later for coral locations, follows guidance from the Army Corps of Engineers for setbacks around artificial reefs and fish havens (Riley et al. 2021).
- From the deep-sea coral point locations, select points with a Vernacular field value of either 'stony coral (branching)', 'stony coral (cup coral)', 'stony coral (unspecified)', 'black coral', or 'gorgonian coral'. Then buffer the selected point locations by 150 m and convert to raster. Note: These vernacular name categories match the taxa included in the Atlantic version of this indicator and represent the major types of hard deep-sea corals in the Gulf of Mexico. Flower Garden Banks National Marine Sanctuary provides helpful descriptions of the taxa that inhabit the Deep Coral Zone.
- From the Coral HAPC data, merge the following files: Coral9NoRegs.shp, Coral9Regs, ExistingWithOutRegs.shp, and ExistingWithRegs.shp. Convert to raster.
- Add zero values to help users better understand the extent of this indicator and to make this indicator layer perform better in online tools. Buffer the Southeast Blueprint 2023 Gulf of Mexico marine subregion by 100 km to make a continuous buffer along the coast, with no gaps. Use this to create a raster of zeros within this buffer to approximate the analysis extent of the indicator. This buffer distance matches the one used in the Atlantic version of this indicator, which attempts to capture how far upstream brackish water typically extends along the Atlantic coast and is informed by a 1978 water quality study of the estuarine James River in Virginia (Neilson and Ferry 1978).
- Combine all input data and the raster of zeros to create the final indicator categories seen below.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

6 = Confirmed hardbottom-associated species (corals, patch reef, chemosynthetic communities, or other organisms)
5 = Confirmed human-created hardbottom (shipwrecks, artificial reefs, decommissioned oil and gas platforms)
4 = Predicted hardbottom (fine resolution)
3 = Coral Habitat Area of Particular Concern (HAPC)
2 = Rock (coarse resolution)
1 = Gravel (coarse resolution)
0 = Not identified as hardbottom

Known Issues

- While active oil and gas platforms also provide artificial hardbottom habitat that supports diverse marine life (Claisse et al. 2014), we did not include active drilling sites in this first version of the indicator. This decision reflects an attempt to balance the positive structural habitat value of oil and gas platforms with the negative impacts of climate change caused by fossil fuel combustion (e.g., coral bleaching and ocean acidification) (NOAA 2023) and the negative impacts of a potential oil spill (Daley 2019). We intend to further investigate these tradeoffs in future revisions.
- The confirmed human-created hardbottom class may include sites where the previous oil or gas platform has been fully removed and no longer provides habitat structure. It may also include sites where the decommissioned rig was moved to an alternative location to be repurposed as a reef. In future updates, we hope to better pinpoint the locations of decommissioned offshore rigs that have been specifically repurposed as artificial reefs.
- The confirmed human-created hardbottom class does not account for variation in the condition of artificial habitat structures, such as harmful leaks from capped oil and gas wells or “black reef” phenomena caused by pollution and invasive species growth around contaminated shipwrecks (Degnarain 2020).
- Multiple important habitat areas associated with decommissioned oil and gas platforms are under- and overprioritized in this indicator because there are significant issues with the oil and gas platform dataset. While some data have been updated recently, the status field used to differentiate between active and removed platforms has not been recently validated for many platforms and is significantly outdated. We are looking into improving the oil and gas platform-related data with state data in a future update.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Gulf Deep-Sea Coral Richness

This indicator measures the number of different deep-sea coral genera predicted to occur in the Gulf of Mexico at depths of 50 m or below. It is based on coral observations and a suite of environmental predictors including measures of depth, seafloor topography and substrate, oceanography, and geography. This indicator combines probability models for 28 deep-sea coral genera to predict overall richness. It originates from a National Oceanic and Atmospheric Administration project characterizing the spatial distributions of deep-sea corals and chemosynthetic communities in the U.S. Gulf of Mexico.

Reason for Selection

Many deep-sea corals form tree-like shapes and complex reefs that provide valuable three-dimensional habitat structure for many fish and invertebrate species. They support commercially important fisheries such as grouper, snapper, sea bass, rockfish, shrimp, and crab. The presence of more diverse types of coral typically creates more complex habitats that support more species. Because most deep-sea corals grow very slowly, they are highly vulnerable to damage from trawling and energy development, as well as ocean acidification due to climate change (NOAA 2018).

Input Data

- Southeast Blueprint 2023 subregions: Marine (combined Atlantic & Gulf of Mexico)
- Southeast Blueprint 2023 extent
- National Oceanic and Atmospheric Administration (NOAA) Characterizing Spatial Distributions of Deep-sea Corals and Chemosynthetic Communities in the U.S. Gulf of Mexico; read the final report; data shared prior to official release on 2-1-2023 by Dr. Matt Poti with the NOAA National Centers for Coastal Ocean Science (matthew.poti@noaa.gov).

This dataset provides probability models for 28 deep-sea coral genera *(Acanella, Antipathes, Bathypathes, Bebryce, Caliacis, Callogorgia, Cheliodonisis, Enallopsammia, Hypnogorgia, Keratoisis, Leiopathes, Lepidisis, Lophelia, Madracis, Madrepora, Nicella, Oculina, Paramuricea, Placogorgia, Plumapathes, Scleracis, Solenosmilia, Stauropathes, Stichopathes, Swiftia, Tanacetipathes, Thesea, Villogorgia)*, as well as a combined genus richness layer that counts the average number of unique genera predicted to occur in each 100 m pixel. Dr. Poti provided a summarized vector version of the continuous genus richness raster layer that mirrors the way the Bureau of Safety and Environmental Enforcement displays these data. This classification is based on natural breaks in the data distribution and used 10 bins. We further collapsed the bins from 10 to 5 for simplicity.

Mapping Steps

- Reclassify to collapse the 10 classes in the provided genus richness shapefiles into 5 by combining the “0-0.5” and “0.5-1” classes and assigning a value of 1, combining the “1-2” and “2-3” classes and assigning a value of 2, combining the “3-4” and “4-5” classes and assigning a value of 3, combining the “5-6” and “6-7” classes and assigning a value of 4, and combining the “7-8” and “>8” classes and assigning a value of 5.
- Convert the provided genus richness shapefile from vector to raster.
- Clip to the Southeast Blueprint 2023 marine subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Highest predicted average genus richness (>7)
4 = High predicted average genus richness (>5-7)
3 = Medium predicted average genus richness (>3-5)
2 = Low predicted average genus richness (>1-3)
1 = Lowest predicted average genus richness (0-1)

Known Issues

- While this layer has a 30 m resolution, the NOAA deep-sea coral models were coarser than that. We downsampled 100 m pixels to 30 m.
- Areas with low survey effort for the variables used to predict deep-sea corals are underprioritized. This is especially true for seafloor geology, curvature, and aspect. Sharp linear features and shapes in this indicator, when not aligned with a shelf break, are a symptom of places with low survey effort for these variables.

Other Things to Keep in Mind

- Atlantic and Gulf deep-sea coral richness are intended to serve as complementary indicators based on similar NOAA source data. Because of the different deep-sea coral communities present in the Atlantic and the Gulf, the data provider recommended different thresholds for what level of genus richness qualifies as highest, high, medium, etc. to ensure the Blueprint captures the most important deep-sea coral areas within each region.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

Goyert HF, Bassett R, Christensen J, Coleman, H, Coyne M, Etnoyer PJ, Frometa J, Hourigan, TF, Poti M, Salgado EJ, Williams, B, Winship AJ. 2020. Characterizing spatial distributions of deep-sea corals and chemosynthetic communities in the US Gulf of Mexico through data synthesis and predictive modeling. New Orleans (LA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-027. 317 p. [https://espis.boem.gov/final%20reports/BOEM_2021-027.pdf].

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Gulf Marine Mammals

This indicator identifies important areas in the Gulf of Mexico for dolphins and whales. It incorporates monthly density predictions for 13 marine mammal species or species groups (Atlantic spotted dolphin, beaked whales, blackfish [which includes killer whale, melon-headed whale, false killer whale, pygmy killer whale], bottlenose dolphin, Bryde's whale, clymene dolphin, pantropical spotted dolphin, pilot whales, pygmy/dwarf sperm whales, Rice's whale, Risso's dolphin, sperm whale, spinner dolphin) based on sightings from boat-based and aerial surveys and data on oceanographic conditions. It uses marine mammal models developed by the National Oceanic and Atmospheric Administration as part of the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS).

Reason for Selection

Marine mammals help identify key areas of ocean productivity and overall ocean health in the Gulf of Mexico, are regularly monitored, and resonate with a variety of audiences. Marine mammals are often used as ocean health indicators due to their long lifespans, feeding at a high trophic levels, and large blubber stores that can serve as repositories for anthropogenic chemicals and toxins (Bossart 2011).

Input Data

- Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS): GoMMAPPS marine mammal spatial density model outputs (version 2.2), accessed 12-14-2022

  Based on ship-based and aerial line-transect surveys conducted in the U.S. waters of the Gulf of Mexico between 2003 and 2019, the National Oceanic and Atmospheric Administration (NOAA) Southeast Fisheries Science Center developed spatial density models (SDMs) for cetacean and sea turtle species for the entire Gulf of Mexico. SDMs were developed using a generalized additive modeling framework to determine the relationship between species abundance and environmental variables (monthly averaged oceanographic conditions during 2015-2019).

- 2019 National Land Cover Database (NLCD)
- Southeast Blueprint 2023 subregions: Marine (combined Atlantic & Gulf of Mexico)
- Southeast Blueprint 2023 extent

Mapping Steps

- Replace all values of -9999 with 0.
- Convert to monthly rasters for each species/species group using the following fields: "Jan_n", "Feb_n", "Mar_n", "Apr_n", "May_n", "Jun_n", "Jul_n", "Aug_n", "Sep_n", "Oct_n", "Nov_n", and "Dec_n". The pygmy/dwarf sperm whale model only includes data for April through November. The rest of the species/species group models include data for all months. Use the Southeast Blueprint 2023 marine subregion for pixel size and snap.
- Use the beaked whale data and the NLCD to create a mask to define the extent of the Zonation analysis. The beaked whale data represents the full sample area for the other species in GoMMAPPS. The area covered by the marine mammal models overlaps with land in a few areas. This mask removes from the analysis all landcover classes that are not open water (not a value of 11 in the NLCD) within the extent of the NLCD. The resulting Zonation mask covers open water areas where there is both modeled data for marine mammals and NLCD data to remove land.

- To identify important areas for each species, use the core area algorithm (CAZMAX) in Zonation 5. First, include all species but do separate runs by season: Spring (Mar, Apr, May), Summer (Jun, Jul, Aug), Fall (Sep, Oct, Nov), and Winter (Dec, Jan, Feb). We did this for two reasons: 1) Some conservation decisions in the marine environmental are seasonal and 2) Computational limitations prevented a full run for all species and months. Then do a final Zonation run with the seasonal results as inputs. This creates a single layer that accounts for different species and monthly variation while also producing seasonal intermediary products to help with specific marine decisions.
- Reproject the Zonation results to Albers Equal Area.
- Convert from a floating point raster with a range of 0-1 to an integer raster ranging from 0-100.
- Reclassify to values of 1-10 based on increments of 10 to produce the indicator values seen below.
- Use the NLCD and the modeling extent of the source data to identify areas of land not used in the analysis and assign those pixels a value of 0, since they are outside the scope of this marine indicator.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

10 = >90th percentile of importance for marine mammal index species (across larger analysis area)
9 = >80th-90th percentile of importance
8 = >70th-80th percentile of importance
7 = >60th-70th percentile of importance
6 = >50th-60th percentile of importance
5 = >40th-50th percentile of importance
4 = >30th-40th percentile of importance
3 = >20th-30th percentile of importance
2 = >10th-20th percentile of importance
1 = ≤10th percentile of importance
0 = Land

Known Issues

- While this layer has a 30 m resolution, the source data was coarser than that. We downsampled hexagons with an area of 40 km^2 to 30 m pixels.
- The indicator may underrepresent striped dolphin habitat. While model results are available for this species, there were processing issues that prevented the use of models for this species in the indicator.

- Some important areas for Rice’s whale may be underprioritized. The Blueprint currently covers habitat predicted by the GoMMAPPS model for Rice’s whale, but NOAA core distribution polygons cover a much larger area.

Other Things to Keep in Mind

- We ran the Zonation analysis across open water areas where there were both marine mammal models and NLCD data present to discriminate between land and water. We did this for multiple reasons. We didn’t run Zonation across the full area covered by the GoMMAPPS data because the full files were very large and required long processing times. We also anticipated that Zonation would not have been able to computationally handle the full area. We extended the Zonation run beyond U.S. waters to try to account for areas of high mammal density just south of the Blueprint’s Gulf marine boundary. As a result, the various classes within the indicator do not cover equal areas within the indicator’s extent, as you might expect with a percentile-based indicator—they cover equal areas within the full analysis area, and then are clipped down to produce the indicator.

Disclaimer: Comparing with Older Indicator Versions

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Literature Cited

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Moilanen, A., Lehtinen, P., Kohonen, I., Virtanen, E., Jalkanen, J. and Kujala, H. 2022. Novel methods for spatial prioritization with applications in conservation, land use planning and ecological impact avoidance. Methods in Ecology and Evolution. [https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.13819].

Gulf Sea Turtles

This indicator identifies important areas in the Gulf of Mexico for sea turtles. It incorporates monthly density predictions for four species (green, Kemp’s ridley, leatherback, and loggerhead sea turtles) based on sightings from boat-based and aerial surveys and data on oceanographic conditions. It uses sea turtle models developed by the National Oceanic and Atmospheric Administration as part of the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS).

Reason for Selection

As a keystone species, even at diminished population levels, sea turtles play an important role in ocean ecosystems by maintaining healthy seagrass beds and coral reefs, providing key habitat for other marine life, helping to balance marine food webs, and facilitating nutrient cycling from water to land (Wilson 2010). Sea turtles use large areas of the ocean for feeding and reproduction, making them a good indicator of ocean productivity and overall ocean health. For example, Kemp's ridley sea turtles nesting in southern Texas consistently forage in areas near the Yucatán Peninsula, the Gulf coast of Florida, the Mississippi River Delta, and the Texas-Louisiana shelf (Gredzens and Shaver 2020).

Input Data

- Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) - [GoMMAPPS sea turtle spatial density model outputs]() (version 2.2)

  Based on ship-based and aerial line-transect surveys conducted in the U.S. waters of the Gulf of Mexico between 2003 and 2019, the NOAA Southeast Fisheries Science Center developed spatial density models (SDMs) for cetacean and sea turtle species for the entire Gulf of Mexico. SDMs were developed using a generalized additive modeling framework to determine the relationship between species abundance and environmental variables (monthly averaged oceanographic conditions during 2015-2019).

- [Southeast Blueprint 2023 subregions]() – marine (combined Atlantic & Gulf of Mexico)
- [Southeast Blueprint 2023 extent]()
- [2019 National Land Cover Database]() (NLCD)

Mapping Steps

- Replace all values of -9999 with 0.
- Convert to monthly rasters for each species using the following fields: "Jan_n", "Feb_n", "Mar_n", "Apr_n", "May_n", "Jun_n", "Jul_n", "Aug_n", "Sep_n", "Oct_n", "Nov_n", and "Dec_n". Use the marine subregion for pixel size, snap, and extent.
- Use the loggerhead sea turtle data and the NLCD to create a mask to define the extent of the Zonation analysis. The loggerhead data represents the full sample area for the other species in GoMMAPPS. The area covered by the sea turtle models overlaps with land in a few areas. This mask removes from the analysis all landcover classes that are not open water (not a value of 11 in the NLCD) within the extent of NLCD. The resulting Zonation mask covers open water areas where there is both modeled data for sea turtles and NLCD data to remove land.
- To identify important areas for each species, use the core area algorithm (CAZMAX) in Zonation 5. Include each monthly density layer as a separate input and weight them equally.
- Reproject the Zonation results data to Albers Equal Area.
- Convert from a floating point raster with a range of 0-1 to an integer raster ranging from 0-100.
- Reclassify to produce the indicator values seen below so that 0-60 is 1, 61-70, 71-80 is 3, 81-90 is 4, and 91-100 is 5. The variation in values from Zonation below 60 was less helpful than the other higher classes so we classified all values from 60 and below as 1.

- Use the NLCD and the modeling extent of the source data to identify areas of land not used in the analysis and assign those pixels a value of 0, since they are outside the scope of this marine indicator.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = >90th percentile of importance for sea turtle index species (across larger analysis area)
4 = >80th-90th percentile of importance
3 = >70th-80th percentile of importance
2 = >60th-70th percentile of importance
1 = ≤60th percentile of importance
0 = Land

Known Issues

- While this layer has a 30 m resolution, the source data was coarser than that. We downsampled hexagons with an area of 40 km^2 to 30 m pixels.
- There is a small linear artifact in the “2 = >60th-70th percentile of importance” class at the southernmost edge of the indicator, south of Dry Tortugas National Park in FL. This artifact was produced in the Zonation run used to create the indicator, and the indicator slightly overprioritizes this area as a result. It does not meaningfully influence the Blueprint priorities, likely because the area is still low-scoring relative to the other indicator classes.

Other Things to Keep in Mind

- We ran the Zonation analysis across open water areas where there were both sea turtle models and NLCD data present to discriminate between land and water. We did this for multiple reasons. We didn’t run Zonation across the full area covered by the GoMMAPPS data because the full files were very large and required long processing times. We also anticipated that Zonation would not have been able to computationally handle the full area. We extended the Zonation run beyond U.S. waters to try to account for areas of high mammal density just south of the Blueprint’s Gulf of Mexico subregion. As a result, the various classes within the indicator do not cover equal areas within the indicator’s extent, as you might expect with a percentile-based indicator—they cover equal areas within the full analysis area, and then are clipped down to produce the indicator.

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Literature Cited

Gredzens C, Shaver DJ. 2020. Satellite tracking can inform population-level dispersal to foraging grounds of post-nesting Kemp's ridley sea turtles. Frontiers in Marine Science, section Marine Megafauna, Special Theme Issue Research Topic: Advances in Understanding Sea Turtle Use of the Gulf of Mexico. [https://doi.org/10.3389/fmars.2020.00559].

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Moilanen A, Lehtinen P, Kohonen I, Virtanen E, Jalkanen J, Kujala H. 2022. Novel methods for spatial prioritization with applications in conservation, land use planning and ecological impact avoidance. Methods in Ecology and Evolution. [https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.13819].

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Island Habitat

This indicator represents important habitat for coastal island-dependent species across the Southeast. The highest scores go to island critical habitat for six threatened and endangered animal and plant species: piping plover, loggerhead sea turtle, Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, and Bartram's hairstreak butterfly. This indicator uses U.S. Fish and Wildlife Service critical habitat data and island boundaries from the U.S. Geological Survey and Esri.

Reason for Selection

Islands provide important habitat for many species, including birds, sea turtles, mammals, insects, and plants. Their relative isolation from disturbance and mainland predators can make them important breeding habitat for coastal birds and sea turtles (as represented by piping plover and loggerhead sea turtle). Their unique ecology and isolation can also make them important habitat for some mammals, plants and insects that are only found on islands (as represented by Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, and Bartram's hairstreak butterfly). As a barrier that can protect the mainland from major storms, they also help protect ecosystems and human communities from extreme weather events.

The critical habitat included in this indicator refers to areas with specific physical or biological features that are essential to conserving a federally threatened or endangered species and may require special management or protection.

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- Island boundaries from the Global Island Explorer provided by the U.S. Geological Survey and Esri, accessed 5-13-2022
- Critical habitat provided by the U.S. Fish and Wildlife Survey, accessed 6-23-2022

Mapping Steps

- Clip the Global Island Explorer data to the Base Blueprint 2022 extent and merge small and large islands.
- From the critical habitat data (CRITHAB_POLY.shp), select the following species based on 'comname': piping plover, loggerhead sea turtle, Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, Bartram's hairstreak butterfly.
- Clip the critical habitat for the selected species to the merged islands layer.
- Convert the islands and selected species data to raster and clip to the spatial extent of Base Blueprint 2022.
- Add zero values to help users better understand the extent of this indicator and to make it perform better in online tools. Buffer the island shapefile by 40 km to make a continuous buffer along the coast, with no gaps. Use this to create a raster of zeros for that buffer.
- Combine rasters so parts of islands with selected species critical habitat get a value of 2, other island pixels get a value of 1, and all other areas in the buffer described above get a value of 0.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

2 = Island critical habitat for any of six threatened and endangered species (piping plover, loggerhead sea turtle, Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, or Bartram's hairstreak butterfly)

1 = Other island area

0 = Not a coastal island

Known Issues

- This indicator underestimates piping plover critical habitat in parts of the Chandeleur Islands off the coast of Louisiana. Locations of barrier islands can be highly dynamic, and the island boundaries and critical habitat data did not agree on the locations of some parts of the islands.

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Literature Cited

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Marine Highly Migratory Fish

This indicator identifies important foraging and spawning areas for highly migratory fish in the Atlantic Ocean and Gulf of Mexico. It uses physical capture and satellite tag observations, remote sensing of environmental variables, and physical oceanographic data to analyze the habitat preferences of three species (skipjack tuna, bluefin tuna, and blue shark) at various life stages. The indicator originates from European Commission Joint Research Centre global fish models.

Reason for Selection

Highly migratory fish species travel long distances and often cross domestic and international boundaries (NOAA Fisheries). They are often the focus of sport and commercial fishing, and the management of their populations can have far-reaching impacts. As top predators in the marine food chain, highly migratory fish are good indicators for areas of high ocean productivity. In particular, sharks and tunas play an important role in marine food webs by helping regulate populations of lower-level predators that, if left unchecked, could compromise the integrity of marine ecosystems across the Gulf and Atlantic (Baum 2009). In effect, the places where these species feed and spawn are also important for other types of marine life.

Input Data

- Southeast Blueprint 2023 extent
- Southeast Blueprint 2023 subregions: Marine (combined Atlantic & Gulf of Mexico)

- European Commission global fish models, accessed 6-14-2023: Bluefin tuna (adult feeding, adult spawning, juvenile feeding), skipjack tuna (adult feeding), blue shark (adult female foraging, adult male foraging, large juvenile female foraging, large juvenile male foraging, small juvenile foraging)

  Note: While these data are global in scope, they use large amounts of data from U.S. Atlantic and Gulf waters and include a spawning model specific to the Gulf of Mexico.

Mapping Steps

- Clip all global input data to the Southeast Blueprint 2023 marine subregion.
- Reproject the blue shark data to match the tuna data.
- Use the Southeast Blueprint 2023 marine subregion to make a Zonation mask for tuna and blue shark. The species data are global, and we wanted to limit the analysis just to the Southeast Blueprint marine subregion.
- To identify important areas for tunas and blue shark, use the core area algorithm (CAZMAX) in Zonation 5. For bluefin and skipjack tuna, include each monthly density layer for each tuna species and life stage for 2015, 2016, and 2017 and weight them equally. For blue shark, include each monthly density layer for each life stage for 2015, 2016, and 2017 and weight them equally. We did two separate runs, one for tunas and one for blue shark, due to differences in the input datasets. We chose 2015-2017 so we had matching years across the species and focused on more recent conditions to reduce the overall impact of climate change on the estimates.
- Reproject the Zonation results to Albers Equal Area and resample to 30 m pixels.
- Convert the tuna and blue shark layers from floating point rasters with a range of 0-1 to integer rasters ranging from 0-100.
- Reclassify each raster to produce the indicator values seen below so that 0-30 is 1, 31-40 is 2, 41-50 is 3, 51-60 is 4, 61-70 is 5, 71-80 is 6, 81-90 is 7, and 91-100 is 8. The variation in values from Zonation below 30 was less helpful than the other higher classes so we classified all values from 30 and below as 1. This was primarily due to large low probability areas for tuna in part of the Atlantic that all had the same low value.
- Combine the reclassified tuna and blue shark rasters into a single indicator by using the maximum value in CellStatistics.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

8 = >90th percentile of importance for bluefin and skipjack tuna or blue shark
7 = >80th-90th percentile of importance
6 = >70th-80th percentile of importance
5 = >60th-70th percentile of importance
4 = >50th-60th percentile of importance
3 = >40th-50th percentile of importance
2 = >30th-40th percentile of importance
1 = ≤30th percentile of importance

Known Issues

- While this layer has a 30 m resolution, the source data was coarser than that. We downsampled 1/24° pixels (~4 km) to 30 m.
- This indicator doesn't fully represent the specialized habitat requirements of other highly migratory fish not used in the indicator. The indicator focuses on highly productive currents and eddies. While these are important for many highly migratory species, especially for feeding, this approach likely misses important areas for some species.

Other Things to Keep in Mind

- We weren't able to run all the tuna and blue shark data together in Zonation, so we ran them separately and took the maximum value of the two resulting outputs. As a result, the various classes within the indicator do not cover equal areas within the indicator's extent, as you might expect with a percentile-based indicator—they cover equal areas within the underlying tunas run and shark run and are then combined.
- While these are global models, we did the Zonation run just within the Blueprint marine subregion. We could explore running them over a larger ecological region in the future. For this year, given we were already running into processing challenges and didn't have an alternative subglobal subregion in mind for these species, we stuck with the Blueprint marine subregion.

Disclaimer: Comparing with Older Indicator Versions

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Resilient Coastal Sites

This indicator depicts the capacity of coastal habitats to migrate to adjacent lowlands in order to sustain biodiversity and natural services under increasing inundation from sea-level rise. It is based on the physical and condition characteristics of current tidal complexes, their predicted migration space, and surrounding buffer areas. These characteristics include marsh complex size, shared edge with migration space, sediment balance, water quality, natural landcover, landform diversity, and more. This indicator originates from The Nature Conservancy's Resilient Coastal Sites project.

Reason for Selection

The resilient coastal sites indicator seeks to capture features of salt marshes that are important for salt marsh species and ecosystem function both now and in the future. Many of these characteristics, like water quality and landform diversity, also serve as indicators of a site's potential future habitat quality once the salt marsh is fully inundated and transitions to a new estuarine or marine habitat.

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent

- This indicator combines data from the following TNC projects:
  - TNC Resilient Coastal Sites for Conservation in the South Atlantic
  - TNC Resilient Coastal Sites for Conservation in the Gulf of Mexico
  - TNC Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic

From the South Atlantic and Gulf of Mexico Resilient Coastal Sites projects, we used:

- The “RESILB1stC” field of the “Tidal_Complex_Resilience_Score_SLR65” layers: Final resilience score within existing tidal complexes in a 6.5 ft of SLR scenario.
- The “RESILB1stC” field of the “Migration_Space” layers ending in _SLR15, _SLR30, _SLR40, and _SLR65: Final resilience score within the migration space associated with each tidal complex in 1.5, 3, 4, and 6.5 ft of SLR scenarios. Migration space consists of low-lying areas adjacent to current tidal complexes that may support future tidal habitats as current habitats migrate due to SLR.
- The “RESILB1stC” field of the “Additional_Migration_Space” layers ending in _SLR15, _SLR30, _SLR40, and _SLR65: Final resilience score within additional migration space units in 1.5, 3, 4, and 6.5 ft of SLR scenarios. Additional migration space units capture portions of the migration space that do not spatially intersect current tidal marshes but may provide additional landscape context.

From the Northeast and Mid-Atlantic Resilient Coastal Sites projects, we used:

- The “RESILssBZ” field of the “slr06_stratified_resilience” layer: Final resilience score within existing tidal complexes in a 6 ft of SLR scenario.

Mapping Steps

To capture the resilience of existing tidal complexes in the highest SLR scenario (6.5 ft for South Atlantic and Gulf of Mexico, 6 for Northeast and Mid-Atlantic):

- Convert the South Atlantic and Gulf of Mexico “Tidal_Complex_Resilience_Score_SLR65” layers from vector to a 30 m raster data using the “RESILB1stC” field.
- Convert the Northeast and Mid-Atlantic “slr06_stratified_resilience” layers from vector to a 30 m raster using the “RESILssBZ” field. Areas that overlapped with the South Atlantic were removed from this input.

To capture the resilience of the migration space and additional migration space associated with each tidal complex across all SLR scenarios (1.5 ft, 3 ft, 4 ft, and 6.5 ft):

- Convert all of the South Atlantic and Gulf of Mexico “Migration_Space” and “Additional_Migration_Space” layers for each SLR scenario (ending in _SLR15, _SLR30, _SLR40, and _SLR65) from vector to a 30 m raster using the “RESILB1stC” field. Note: The Northeast and Mid-Atlantic data does not provide resilience scores for migration space or additional migration space.

To create a combined coastal resilience layer:

- Combine the coastal resilience layers produced in the previous steps using the Cell Statistics "MAX" function in ArcGIS. This creates a layer depicting the highest possible resilience score for each pixel from the above sea- level rise layers.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

7 = Most resilient
6= More resilient
5 = Slightly more resilient
4 = Average/median resilience
3 = Slightly less resilient
2 = Less resilient
1 = Least resilient

Known Issues

- Resilience scores on some indigenous lands are still under review and are not included in this indicator.
- This indicator does not account for the occurrence and timing of disturbance processes, like prescribed fire, which impact resilience.
- Accretion rates were not incorporated into the marsh migration data.
- The source data from TNC assesses costal resilience and sea-level rise slightly differently in a portion of coastal Virginia that falls into the Northeast and Mid-Atlantic region, where TNC conducted its first coastal resilience assessment. In the Northeast and Mid-Atlantic, TNC data only assessed coastal resilience within the existing tidal complex and did not score migration space as it does in in the Gulf of Mexico and South Atlantic regions. Therefore, migration space along the North Virginia coast will appear as NoData.
- Also, TNC assessed sea-level rise in the Northeast and Mid-Atlantic region in 1 ft increments (ranging from 1-6 ft) as opposed to 1.5 ft increments (ranging from 1.5-6.5 ft) in the Gulf and South Atlantic regions. As a result, this indicator likely underestimates the extent of resilient areas in this portion of coastal Virginia.
- Because resilience was only assessed for tidal marsh and its migration space, there will be areas of NoData in the coastal zone. Places that do not receive a resilience score are urban areas or non-marsh habitat in the coastal zone, but outside of the migration space.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Seagrass

This indicator represents the presence of seagrass in the Atlantic Ocean and Gulf of Mexico. It originates from the National Oceanic and Atmospheric Administration’s Marine Cadastre.

Reason for Selection

Seagrasses provide food and habitat for a range of marine and estuarine wildlife, including fish, sea turtles, shrimp, crabs, oysters, and more. They also produce oxygen, filter water, sequester carbon, control erosion, and buffer storms. Seagrasses serve as an important indicator of the overall health of coastal ecosystems because they are sensitive to water quality and require sufficiently clear water for sunlight to penetrate (NPS 2021, NOAA 2021, NWF 2021). In addition, seagrass meadows are being increasingly recognized for their value as a carbon sink in the face of climate change (McKenzie et al. 2020).

Input Data

- Southeast Blueprint 2023 extent
- Base Blueprint 2022 extent
- NOAA seagrass layer, accessed 5-30-2023 on the Marine Cadastre, provided by the NOAA Office for Coastal Management

Mapping Steps

- Convert the polygons from the Marine Cadastre seagrass layer to raster, snapping to the 2022 Base Blueprint extent.
- The data were originally classified into various biotic subclasses of “Aquatic Vascular Vegetation” and “Benthic Macroalgae.” Because these classes were not applied consistently across different states, collapse these categories into a single category of seagrass presence.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

1 = Seagrass present

Known Issues

- Because the data used in this indicator were opportunistically collected based on available state data, this indicator underestimates seagrass presence in some areas and misses some known seagrass locations (e.g., the north shore of Lake Pontchartrain in LA and areas farther offshore of central FL in the Gulf of Mexico).
- Due to the variety of data sources combined in this indicator, there is significant variation across the Southeast in how rigorously seagrass data is validated. Water turbidity can also influence the quality of validation. NOAA characterizes the level of validation in NC as good, the east coast of FL (particularly the St. John’s River Water Management District) as excellent, the west coast of FL (particularly the Southwest Florida Water Management District) as good, the Big Bend of FL as more challenging due to turbidity, the area immediately surrounding the FL Keys as good, other parts of Florida Bay as challenging due to turbidity, Mobile Bay in AL as good, LA as less consistent, Matagorda in TX as somewhat good, and Laguna Madre in TX as excellent. This indicator is more reliable in areas with strong validation.
- Similarly, variation in the minimum mapping unit used by each data provider causes differences in the size of seagrass patches captured in different parts of the Southeast. For example, some surveys map patches as small as 20 m^2, while others do not map patches smaller than 1 acre. As a result, this indicator may underpredict small seagrass patches in areas where survey efforts used a coarse minimum mapping unit.

- In estuarine areas near river deltas (e.g., portions of Mobile Bay in AL), this indicator captures freshwater species of submerged aquatic vegetation in addition to true seagrass.
- Because the source data does not provide any information about the extent of surveyed areas, this indicator cannot distinguish between places where seagrass was surveyed and not found (true absences) vs. places that were not surveyed. Ideally, we would prefer to depict areas where seagrass was surveyed and not found as zeroes and unsurveyed areas as NoData.

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South Atlantic Beach Birds

This indicator is an index of habitat suitability for four shorebird species (American oystercatcher, Wilson’s plover, least tern, piping plover) in the South Atlantic, based on observed abundance. It assesses beaches and nearby onshore habitats. This indicator combines bird data from the U.S. Geological Survey and state waterbird biologists in FL, GA, SC, and NC.

Reason for Selection

The relative use of beach habitat by shorebird species for nesting, foraging, and breeding is an indicator of beach health and quality. Shorebird populations are highly responsive to threats like sea-level rise, changes in freshwater inflow, shoreline alteration and loss, human disturbances, and contaminants. In particular, the American oystercatcher "has been proposed as a 'sentinel' bio-indicator of ecosystem integrity because of the depth of life history information available, its specialized dependence on oysters and associated marine invertebrates, and known reproductive responses to a variety of natural and anthropogenic pressures" (Ogden et al. 2014). As a result of these pressures, North American shorebird populations are experiencing "consistent, steep population loss" (Ronenberg et al. 2019). The species included in this index are already monitored by state and Federal agencies and collectively represent a variety of coastal ecosystem features (e.g., nesting habitat availability and quality, fish and marine invertebrate populations).

Input Data

- South Atlantic Blueprint 2021 extent
- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- 2019 National Land Cover Database (NLCD)
- 2023 U.S. Census TIGER/Line state boundaries, accessed 5-15-2023; download the data
- The following beach bird datasets:

Wilson's plover and American oystercatcher

Betsy Von Holle (University of Central Florida) led a project that included state waterbird biologists in the South Atlantic: Tim Keyes, Felicia Sanders, Sara Schweitzer, and Janell Brush. They mapped habitat suitability based on nest, or breeding pair, density per beach segment, as was used for Von Holle et al.'s sea turtle research. The approach is documented in Von Holle et al. 2018.

The following nesting years were used for the analysis:

- American oystercatcher: FL (2005-2011), GA (2010-2011), SC (2008), NC (2007)
- Wilson's plover: FL (2005-2011), GA (2010-2011), SC (2009-2011), NC (2007)

Piping plover and least tern

A previous post-doctoral researcher, Bradley Pickens, processed the following datasets by ranking least tern nest abundance and piping plover individuals by quantile (0-6). They were exported as 90 m rasters.

Least tern

The point locations and number of least tern nests, or breeding pairs, were provided by waterbird biologists from each state's natural resource department (Tim Keyes, Felicia Sanders, Sara Schweitzer, and Janell Brush). All least tern locations were buffered by 1 km.

Although least tern do not actively forage on the beach itself, the buffer characterizes habitat selected by least tern (i.e., beach width, predator abundance, etc.) and accounts for interannual variability in nesting locations. Among years, data showed least tern often shifted the location of nests in the general vicinity of previous years.

Piping plover (winter distribution)

The 2011 winter population census of piping plover was provided by the U.S. Geological Survey, as the international census is repeated every five years. Locations were buffered with a 2 km radius. Although home range estimates exist for piping plover (Cohen et al. 2008, Drake et al. 2001), these measures depict primarily linear habitats. We used a 2 km buffer, as this is similar to the mean linear distance of 4.2 km that piping plover moved during winter in Texas (Drake et al. 2001). The resulting buffer was also substantiated by maps in Cohen et al. (2008).

Mapping Steps

- Von Holle et al. used a categorical habitat suitability ranking based on six quantiles of nest density, or breeding pair density, for each species on the Atlantic Coast. Convert to numeric scores by assigning a value of 0 to polygons rated as “none”, a value of 1 to those rated as “low”, a value of 2 to those rated as “moderate”, a value of 3 to those rated as “moderately high”, a value of 4 to those rated as “high”, a value of 5 to those rated as “very high”, and a value of 6 to those rated “extremely high”. Convert the polygons to a separate raster for each species (Wilson’s plover and American oystercatcher), assigning those numeric values.
- Resample and reproject the least tern and piping plover source data from 90 m pixels to 30 m pixels so it can be used in Zonation in a later step.
- Create a mask to define the extent of the Zonation run that will be used to create this indicator. Use cell statistics to combine all 4 bird rasters (the two Von Holle rasters created in the previous step, and the 90 m piping plover and least tern rasters) with the output statistic maximum value. Include in the mask all pixels with a value >0 on any of the bird rasters.
- To create the beach bird index, use the software program Zonation v4 with the core-area algorithm and without the edge removal option (removal rule = 1, edge removal = 0, warp = 1). Input the mask and the rasters for all four species. Zonation produces a continuous ranking of all pixels within the mask based on their importance for the 4 beach-nesting bird species.
- Reclassify the output Zonation rank raster into 5 classes, seen in the final indicator values below. This layer represents the relative use of habitat for beach nesting birds in the South Atlantic. Generally, areas with higher values in this layer are considered to have greater relative abundance of beach nesting birds than areas with lower values.
- To create an analysis extent for the indicator, buffer the polygons provided by Von Holle by 25 km. Assign a value of 0 to all pixels within the analysis extent that do not already receive a score elsewhere in the indicator. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the South Atlantic Blueprint 2021 extent.

- Further limit the extent of the zero class by removing pixels from Virginia, because the source data did not cover Virginia. Also, remove deep marine areas that are not covered by a value of 0 or greater in the 2019 NLCD, where this terrestrial indicator does not apply.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = >80th percentile of importance for bird index species (American oystercatcher, Wilson's plover, least tern, and piping plover)
4 = >60th-80th percentile of importance
3 = >40th-60th percentile of importance
2 = >20th-40th percentile of importance
1 = ≤20th percentile of importance
0 = Open water or not identified as a priority for bird index species

Known Issues

- Beach bird survey data are summarized by beach segment and do not account for variations in density within those segments.
- Volunteers often collect beach bird data in discrete time frames and survey effort may differ by location. Some areas may not have been surveyed or nests may have been missed. Therefore, this data does not imply absence of species.
- Red knot is not included due to lack of data.
- This indicator may underestimate beach bird use of dune areas inland of beach segments because of inconsistencies in the extent of the various bird models.
- The spatial resolution of the source data for least tern and piping plover has been degraded. While the indicator has a 30 m resolution, it was not created directly from the spatially precise input data for those two birds. Here, we resampled the 90 m resolution data used in the previous version of the indicator back down to 30 m resolution so that we could use it in Zonation.
- The indicator has an extraneous "tail" of zero values at its southern edge. This is an artifact of how the buffer of zero values was created. Since zero values do not influence Zonation, this does not affect the final Blueprint priorities. It was discovered too late to fix in this update cycle. We hope to make a larger improvement to this indicator in the future to better depict important areas for beach birds across more of the region's coastline.

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South Atlantic Maritime Forest

This indicator depicts the maritime forest currently present in the South Atlantic. It originates from LANDFIRE landcover.

Reason for Selection

Overall acreage of existing maritime forest provides an indicator of whether maritime forest being inundated by sea-level rise is being replaced or restored somewhere else. Since maritime forest has been substantially reduced from its historic extent, protecting the remaining acreage is important (Bellis 1995). This ecosystem supports a unique suite of plants that tolerate wind, salt, and flooding, as well as many species of birds, mammals, and reptiles. It also helps buffer the coastline from storms (NOAA 2021). Maritime forest is also well monitored and resonates with a diversity of audiences.

Input Data

- Base Blueprint 2022 subregions
- Southeast Blueprint 2023 extent
- 2016 LANDFIRE Existing Vegetation Type (EVT), accessed 3-31-2021

Mapping Steps

- Extract the LANDFIRE existing vegetation type classes with the following names, which are considered maritime forest: Central Atlantic Coastal Plain Maritime Forest, East Gulf Coastal Plain Maritime Forest, Southern Atlantic Coastal Plain Maritime Forest, Southern Atlantic Coastal Plain Dune and Maritime Grassland.
- Add zero values to help users better understand the extent of this indicator and to make this indicator layer perform better in online tools. Use the expand tool to buffer the maritime forest pixels by 40 km. We chose this distance because it was large enough to make a continuous buffer along the coast, with no gaps. Shrink the expanded areas back down by 30 km. We added this step to better reflect that maritime forest exists near the marine shoreline.
- Clip to the 'Atlantic Coastal Plain' and East Gulf Coastal Plain' subregions. LANDFIRE depicts maritime forest classes that also cover parts of Louisiana, Alabama, and Florida that are not represented in this indicator, but the data has not yet been vetted in those areas. Since the original indicator was developed for the South Atlantic region, expert review for other regions is needed before they are used in the Blueprint.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

1 = Maritime forest
0 = Not identified as maritime forest

Known Issues

- The LANDFIRE existing vegetation map underpredicts the extent of maritime forest in several known locations, including Kitty Hawk Woods and Nags Head Woods in the Outer Banks of North Carolina.
- We include the Southern Atlantic Coastal Plain Dune and Maritime Grassland existing vegetation classes from LANDFIRE because some known maritime forests in the South Atlantic are misclassified as this type. This may result in overpredicting maritime forest in some dune and grassland areas.
- This indicator underpredicts maritime forest along the Gulf Coast of Florida.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Stable Coastal Wetlands

This indicator uses remote sensing to calculate the unvegetated-vegetated ratio of tidal wetlands, which compares how much of a wetland is not covered by plants (e.g., sediment, rocks, open water) to how much is covered by plants. Marshes that maintain a higher proportion of vegetation tend to be more stable and resilient to threats like sea-level rise, erosion, and coastal development. This indicator originates from a U.S. Geological Survey project on an unvegetated to vegetated ratio for coastal wetlands.

Reason for Selection

Threats like sea-level rise, erosion, and development are driving widespread salt marsh loss. Tidal marshes protect coastlines from storms, filter pollution to improve water quality, and provide important habitat for birds, fish, and shellfish. Studies show that the unvegetated-vegetated ratio (UVVR) of tidal marshes serves as a good surrogate for marsh degradation processes like sediment loss and conversion to open water (Ganju 2017, Wasson et al. 2019). In general, "...marshes with high vegetative cover and lower open-water area tend to trap and retain sediment, while marshes that are losing plant cover will further lose sediment and convert to open water" (Wasson et al. 2019).

Examining snapshots of the UVVR and how it changes over time can differentiate between relatively stable and more vulnerable marshes. This can help land managers determine which marshes are the best candidates for restoration to help them persist in the face of changing conditions (USGS 2017). Recent research also shows that UVVR correlates with elevation measurements that detect vertical changes due to accretion, subsidence, or compaction—meaning that stable marshes with high vegetative cover tend to better keep pace with sea-level rise. This suggests that marshes with low vegetative cover and an unstable UVVR tend to be "both horizontally and vertically vulnerable". It also shows that "horizontal integrity is a prerequisite for vertical stability: a marsh can only maintain elevation if the plain is intact with minimal unvegetated area" (Ganju et al. 2023).

Input Data

- Base Blueprint 2022 extent
- Southeast Blueprint 2023 extent
- National Wetlands Inventory
- An unvegetated to vegetated ratio (UVVR) for coastal wetlands

  This dataset computes the UVVR for coastal wetlands using Landsat data from 2014-2018. The average and standard deviation of the UVVR across that five-year period can be used to characterize both a marsh's overall stability and its variability from year to year. The figure on the following page, from Ganju et al. 2022, identifies the threshold used in this indicator to define stable, low uncertainty tidal marshes (<0.15 average UVVR and <0.15 standard deviations from the average UVVR).

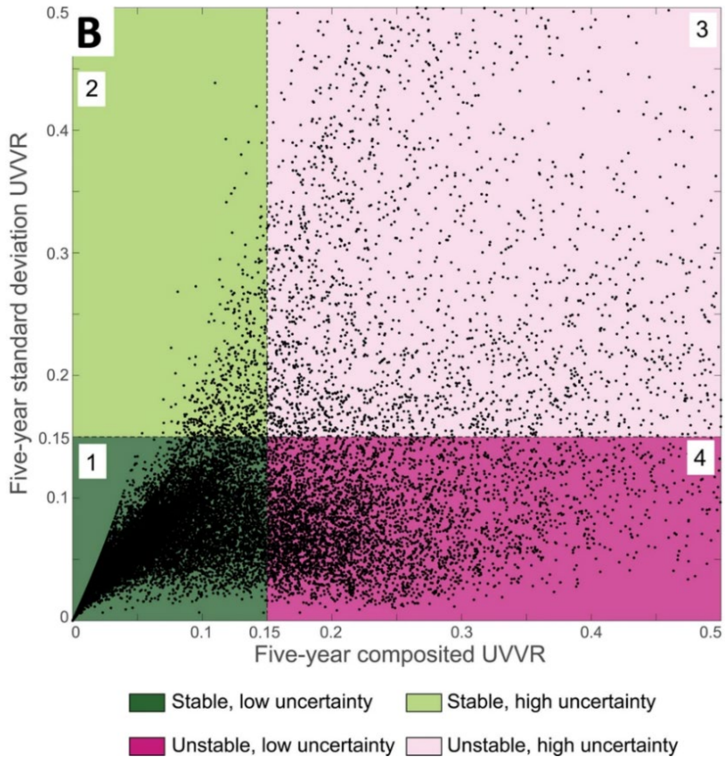

Figure 3. Scatterplot of five-year composited and standard deviation of UVVR, used to identify areas that have crossed the nominal 0.15 stability threshold. 1) Indicates stable, low uncertainty pixels that are consistently below the stability threshold of 0.15 (i.e., good) and don't fluctuate much; 2) indicates stable, high uncertainty pixels that are below the stability threshold of 0.15, but there are big annual outliers (e.g., overwash event, dieback); 3) indicates unstable, high uncertainty pixels that are above the stability threshold of 0.15 (i.e., bad) and there are large annual fluctuations (water levels, controlled burn); and 4) indicates unstable, low uncertainty pixels that are consistently above the stability threshold of 0.15, and they don't fluctuate much (Ganju 2022).

Mapping Steps

- Calculate the mean and standard deviation of the UVVR 2014-2018 imagery.
- Extract areas with mean and standard deviation values <0.15, which represent stable vegetated areas. Reclassify the resulting raster to assign stable coastal wetlands a value of 2.
- Extract fresh and saline tidal wetlands from NWI (note: because of the complex way the NWI is classified, the query to extract these classes is too long to include here, so consult the code for more specifics). Buffer by 30 m and covert to raster. Clip the stable vegetated areas produced in the previous step to the NWI tidal wetlands.
- Reclassify the standard deviation rasters produced in the first step to assign a value of 0 to the study area. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Cip the study area raster to the NWI raster to create a coastal wetland extent raster and reclassify to assign it a value of 1.

- Use the Cell Statistics “MAX” function to combine the rasters produced above. This produces a new raster with the indicator values seen below, where each pixel is assigned the highest value it received in any of the previous steps.
- Clip to the spatial extent of Base Blueprint 2022.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

2 = Stable coastal wetlands
1 = Other coastal wetlands
0 = Not identified as coastal wetlands

Known Issues

- The age of the NWI data is inconsistent across the Gulf and Atlantic coast.
- Newly created wetlands, such as the Wax Lake Delta in Louisiana, are missing from this indicator.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Caribbean

Terrestrial

Caribbean Greenways & Trails

This cultural resource indicator measures both the natural condition and connected length of greenways and trails in the U.S. Caribbean to characterize the quality of the recreational experience. Natural condition is based on the amount of impervious surface surrounding the path. Connected length captures how far a person can go without leaving a dedicated path, based on common distances for walking, running, and biking. This indicator originates from OpenStreetMap data and the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program landcover.

Reason for Selection

This indicator captures the recreational value and opportunities to connect with nature provided by greenways and trails. Greenways and trails provide many well-established social and economic benefits ranging from improving human health, reducing traffic congestion and air and noise pollution, increasing property values, and generating new jobs and business revenue (ITRE 2018). The locations of greenways and trails are regularly updated through the open-source database OpenStreetMap.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- 2012 NOAA Coastal Change Analysis Program (C-CAP) land cover files for the U.S. Virgin Islands (St. Thomas, St. John, and St. Croix are provided as separate rasters), accessed 11-10-2022; learn more about C-CAP high resolution land cover and change products
- 2010 NOAA C-CAP land cover files for Puerto Rico, accessed 11-10-2022; learn more about C-CAP high resolution land cover and change products
- OpenStreetMap data "lines" layer, accessed 2-26-2023

  A line from this dataset is considered a potential greenway/trail if the "highway" tag attribute is eitherbridleway, cycleway, footway, or path. In OpenStreetMap, a highway refers to "any road, route, way, or thoroughfare on land which connects one location to another and has been paved or otherwise improved to allow travel by some conveyance, including motorized vehicles, cyclists, pedestrians, horse riders, and others (but not trains)". OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

Mapping Steps

The greenways and trails indicator score reflects both the natural condition and connected length of the greenway/trail.

Natural condition

Natural condition is based on the amount of impervious surface surrounding the greenway/trail. Since perceptions of a greenway's "naturalness" are influenced both by the immediate surroundings adjacent to the path, and the greater viewshed, natural condition is calculated by averaging two measurements: local impervious and nearby impervious.

Local impervious is defined as the percent impervious surface of the 30 m pixel that intersects the trail. Nearby impervious is defined as the average impervious surface within a 300 m radius circle surrounding the path (note: along a 300 m stretch of trail, we only count the impervious surface within a 45 m buffer on either side of the trail, since pixels nearer the trail have a bigger impact on the greenway/trail experience). The natural classes are defined as follows:

3 = Mostly natural: average of local and nearby impervious is ≤1%
2 = Partly natural: average of local and nearby impervious is >1 and <10%
1 = Developed: average of local and nearby impervious is ≥10%

- To create a percent impervious layer, start by converting the C-CAP land cover rasters for Puerto Rico (2 m resolution) and the U.S. Virgin Islands (separate downloads for St. Thomas, St. John, and St. Croix with 2.4 m resolution) from .img format to .tif using the Copy Raster function.
- For each individual C-CAP layer, use the ArcPy Conditional function to make a binary raster assigning the impervious class a value of 100 (representing fully impervious) and all other classes a value of 0 (representing fully permeable). This mimics the data format of the 2019 National Land Cover Database (NLCD) used in the continental Southeast permeable surface indicator, which provides a continuous impervious surface value ranging from 0 to 100. Use focal statistics to calculate the percent of cells in a 30 m square that are identified as impervious in the C-CAP data, then reproject and resample the result to a 30 m resolution.
- Use the Cell Statistics "MAX" function to combine the resulting four 30 m C-CAP impervious rasters. This creates an approximation of the percent developed impervious score from the 2019 NLCD.

Connected length

The connected length of the path is calculated using the entire extent of the potential greenways/trails dataset. A trail is considered connected to another trail if it is within 2 m of the other trail. Length thresholds are defined by typical lengths of three common recreational greenway activities: walking, running, and biking. The 40 km threshold for biking is based on the standard triathlon biking segment of 40 km (~25 mi). Because a 5K is the most common road race distance, the running threshold is set at 5 km (~3.1 mi) (Running USA 2017). The 1.9 km (1.2 mi) walking threshold is based on the average walking trip on a summer day (U.S. DOT 2002).

- Using the statistics software R, download the OpenStreetMap data for Puerto Rico and the US Virgin Islands.
- Select all lines from the OpenStreetMap data that have a highway tag of either footway, cycleway, bridleway, or path. These are all considered potential trails.
- Removed all lines marked as private.
- Identify lines from the potential trails that are tagged as sidewalks. Assign them a value of 1 in the indicator.

Final scores

If the potential greenway/trail was tagged as a sidewalk in the "other tags" field, it is given a value of 1 to separate sidewalks from what most people think of as a trail or greenway. If a pixel does not intersect a potential greenway/trail but is covered by the C-CAP landcover data, it is coded with a value of 0. Clip to the Caribbean Blueprint 2023 subregion. As a final step, clip to the spatial extent of Southeast Blueprint 2023.

		Trail length				**Sidewalk**
		L ≥ 40 km	40 km > L ≥ 5 km	5 km > L ≥ 1.9 km	L < 1.9 km	
Average of local and nearby impervious	Imp ≤ 1%	7	6	5	4	1
	1% < Imp < 10%	6	5	4	3	
	Imp ≥ 10%	5	4	3	2	
Sidewalk		1				

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

6 = Mostly natural and connected for 5 to <40 km or partly natural and connected for ≥40 km
5 = Mostly natural and connected for 1.9 to <5 km, partly natural and connected for 5 to <40 km, or developed and connected for ≥40 km
4 = Mostly natural and connected for <1.9 km, partly natural and connected for 1.9 to <5km, or developed and connected for 5 to <40 km
3 = Partly natural and connected for <1.9 km or developed and connected for 1.9 to <5km
2 = Developed and connected for <1.9 km
1 = Sidewalk
0 = Not identified as a trail, sidewalk, or other path

Known Issues

- This indicator sometimes misclassifies sidewalks as greenways and trails because they are not tagged as a sidewalk in the OpenStreetMap data.
- This indicator occasionally misclassifies driveways as “sidewalks and other paths” in places where they are not correctly tagged as private in OpenStreetMap. These typically appear as isolated pixels receiving a score of 1 on the indicator.
- OpenStreetMap does not provide a complete inventory of greenways and trails in the U.S. Caribbean. Paths that are missing from the source data will be underprioritized in this indicator. For example, some trails are missing within National Wildlife Refuges.
- This indicator includes trails and sidewalks from OpenStreetMap, which is a crowdsourced dataset. While members of the OpenStreetMap community often verify map features to check for accuracy and completeness, there is the potential for spatial errors (e.g., misrepresenting the path of a greenway) or incorrect tags (e.g., mislabeling a path as a footway that is actually a road for vehicles). However, using a crowdsourced dataset gives on-the-ground experts, Blueprint users, and community members the power to fix errors and add new greenways and trails to improve the accuracy and coverage of this indicator in the future.
- This indicator sometimes underestimates greenway length when connections route under bridges or along abandoned dirt roads. Some of these issues have been fixed through active testing and improvement, but some likely remain.
- Some greenways and trails continue along roadways that allow motorized vehicles, which are excluded from this indicator. As a result, certain trails may appear incomplete because the indicator only captures the sections dedicated for cyclists, pedestrians, and horseback riders.
- When calculating nearby impervious for one greenway, if there’s another greenway within 300 m, impervious surface from the different but overlapping greenway buffer area is also used to compute natural condition. This is an unintended issue with the analysis methods. Investigation into potential fixes is ongoing.
- The indicator doesn’t currently include areas where future greenways are planned.
- This indicator doesn’t include Mona Island, even though there are important and popular trails, due to the lack of landcover data.

Disclaimer: Comparing with Older Indicator Versions

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Caribbean Habitat Patch Size (Large Islands)

This indicator represents the size of natural habitat patches on large islands in the U.S. Caribbean that are unfragmented by roads, urban development, or agriculture. It uses LANDFIRE landcover and road data, mimicking Esri's intact habitat cores approach from their green infrastructure data.

Reason for Selection

Large areas of intact natural habitat are favorable for conservation of numerous species, including reptiles and amphibians, birds, and large mammals. Historically, many Caribbean islands experienced dramatic habitat alteration across much of their land mass from intensive colonial agriculture (such as sugar cane cultivation) and later by urbanization and other anthropogenic modifications (Fitzpatrick et al. 2007, CEPF 2023). As a result, contiguous natural habitat patches are particularly important for supporting native species, restoring native vegetation, and maintaining ecosystem services. This indicator roughly follows the same approach for evaluating patch size used by the intact habitat cores indicator in the continental part of the Southeast Blueprint, but lowers the highest patch size threshold, recognizing that the maximum patch size on small Caribbean islands is lower than in the continental Southeast and on large islands (Esri 2017).

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Caribbean island extent and size
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) and Operational Roads (Roads) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas

Mapping Steps

- Reclassify the LANDFIRE EVT data into natural and unnatural classes. All classes in "EVT_NAME" that start with "Quarries", "Developed", or "Agriculture" are considered unnatural. "Caribbean bush fruit and berries", which captures sun coffee plantations, is also considered unnatural, while "tropical agroforestry plantation", which captures shade coffee, is considered natural. Water is classified as "natural".
- Reclassify the Caribbean island extent layer to assign all islands a value of 1 and assign the ocean a value of NoData.
- Multiply the reclassified LANDFIRE natural/unnatural layer and island extent data. This makes the ocean NoData, but retains freshwater, smaller salt ponds, and enclosed brackish water areas, as well as terrestrial areas on the islands.
- Reclassify primary, secondary, and tertiary roads in the LANDFIRE roads layer as barriers.
- Combine the natural/unnatural raster and roads raster to identify natural areas without roads.
- Use region group to find the size of patch that each pixel belongs to.
- Reclassify based on the final indicator values seen below.

- Use the island extent layer to limit indicator to only large islands, excluding small and medium islands, which are captured in a different indicator.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Very large patch (>10,000 acres)
4 = Large patch (>1,000-10,000 acres)
3 = Medium patch (>100-1,000 acres)
2 = Small patch (>10-100 acres)
1 = Very small patch (≤10 acres)
0 = Developed or agriculture

Known Issues

- Some small dirt roads serve as hard boundaries for habitat cores. While this makes sense for some species, this indicator likely underestimates the effective size of the patch for some more mobile animals.
- This indicator doesn't account for variation in habitat condition within the patch.
- Some docks are overprioritized due landcover misclassification. LANDFIRE sometimes misclassifies docks as forests, so they can get included in habitat patches for this indicator.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Caribbean Habitat Patch Size (Small Islands)

This indicator represents the size of natural habitat patches on small islands in the U.S. Caribbean that are unfragmented by roads, urban development, or agriculture. It uses LANDFIRE landcover and road data, mimicking Esri's intact habitat cores approach from their green infrastructure data.

Reason for Selection

Large areas of intact natural habitat are favorable for conservation of numerous species, including reptiles and amphibians, birds, and large mammals. Historically, many Caribbean islands, especially smaller ones, experienced dramatic habitat alteration across much of their land mass from intensive colonial agriculture (such as sugar cane cultivation) and later by urbanization and other anthropogenic modifications (Fitzpatrick et al. 2007, CEPF 2023). As a result, contiguous natural habitat patches are particularly important for supporting native species, restoring native vegetation, and maintaining ecosystem services. This indicator roughly follows the same approach for evaluating patch size used by the intact habitat cores indicator in the continental part of the Southeast Blueprint (Esri 2017), but lowers the highest patch size threshold, recognizing that the maximum patch size on small Caribbean islands is lower than in the continental Southeast and on large islands.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Caribbean island extent and size
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) and Operational Roads (Roads) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas

Mapping Steps

- Reclassify the LANDFIRE EVT data into natural and unnatural classes. All classes in “EVT_NAME” that start with “Quarries”, “Developed”, or “Agriculture” are considered unnatural. “Caribbean bush fruit and berries”, which captures sun coffee plantations, is also considered unnatural, while “tropical agroforestry plantation”, which captures shade coffee, is considered natural. Water is classified as “natural”.
- Reclassify the Caribbean island extent layer to assign all islands a value of 1 and assign the ocean a value of NoData.
- Multiply the reclassified LANDFIRE natural/unnatural layer and island extent data. This makes the ocean NoData, but retains freshwater, smaller salt ponds, and enclosed brackish water areas, as well as terrestrial areas on the islands.
- Reclassify primary, secondary, and tertiary roads in the LANDFIRE roads layer as barriers.
- Combine the natural/unnatural raster and roads raster to identify natural areas without roads.
- Use region group to find the size of patch that each pixel belongs to.
- Reclassify based on the final indicator values seen below.
- Make a small island mask using the island extent layer for “small” and “medium” islands. Use this mask to include only habitat patches within that mask, excluding large islands, which are captured in a different indicator.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = Large patch (>1,000 acres)
3 = Medium patch (>100-1,000 acres)
2 = Small patch (>10-100 acres)
1 = Very small patch (≤10 acres)
0 = Developed or agriculture

Known Issues

- Some small dirt roads serve as hard boundaries for habitat cores. While this makes sense for some species, this indicator likely underestimates the effective size of the patch for some more mobile animals.
- This indicator doesn’t account for variation in habitat condition within the patch.
- Some docks are overprioritized due landcover misclassification. LANDFIRE sometimes misclassifies docks as forests, so they can get included in habitat patches for this indicator.

- In Eastern St. Croix, where it's particularly dry, this indicator can underestimate or overestimate patch size. LANDFIRE has trouble differentiating pasture from natural thornscrub in this area. Pasture isn't considered natural in this indicator, so any areas of thornscrub misclassified as pasture would underestimate patch size, while areas of pasture classified as thornscrub would overestimate patch size.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Caribbean Island Habitat

This indicator represents the importance of island habitat in the U.S. Caribbean for federally listed and other imperiled species based on the presence of imperiled and invasive animals. This indicator uses species data from Island Conservation's Threatened Island Biodiversity Database, U.S. Fish and Wildlife Service critical habitat, and the Puerto Rico and U.S. Virgin Islands Gap Analysis Program.

Reason for Selection

Islands provide important habitat for many species of birds, reptiles, amphibians, mammals, insects, and plants. Due to their isolation, islands tend to be ecologically unique, making them hotspots for species diversity. In addition, the relative isolation of islands from disturbance and mainland predators can make them important breeding habitat for coastal birds and sea turtles. However, these factors also increase islands' vulnerability to invasive species (IUCN 2018).

According to Bernie 2015, "islands warrant a unique level of attention for biodiversity conservation because they make up only a small percentage of land area but are known for their many endemic species." This rich diversity is also disproportionately threatened, with "61% of all extinct species and 37% of all critically endangered species confined to islands" (Bernie 2015).

The critical habitat included in this indicator refers to areas with specific physical or biological features that are essential to conserving a federally threatened or endangered species and may require special management or protection.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Caribbean island extent and size
- Southeast Blueprint 2023 extent
- Critical habitat provided by the U.S. Fish and Wildlife Survey, accessed 6-23-2022; download the data
- Threatened Island Biodiversity (TIB) Database, accessed 11-29-2022

  This database includes terrestrial vertebrate species that breed on islands and appear on the IUCN Red List as either Critically Endangered or Endangered. It also includes seabird species listed as Vulnerable and terrestrial vertebrates listed as Extinct in the Wild.

- Puerto Rico Gap Analysis Project (GAP) predicted vertebrate species distributions: data provided by Dr. Bill Gould with the Caribbean Climate Hub on 4-4-2022 (contact william.a.gould@usda.gov for more information); read the final report
- U.S. Virgin Islands GAP predicted vertebrate species distributions: data and report appendices provided by Dr. Bill Gould with the Caribbean Climate Hub on 2-6-2023 (contact william.a.gould@usda.gov for more information); read the final report

Mapping Steps

- From the TIB Database, in the "Invasive Species on Island" sheet, select islands where "Region_Archipelago" is "Greater Antilles (Puerto Rican Islands)", "US Virgin Islands", "US Virgin Islands (St. Croix Islands)", or "US Virgin Islands (St. Thomas Islands)".
- Count the number of invasives species records per island, ignoring any row where "Common_Name" is "NONE".

- From the TIB Database, in the “Threatened Species on Island” sheet, select islands where “Region_Archipelago” is “Greater Antilles (Puerto Rican Islands)”, “US Virgin Islands”, “US Virgin Islands (St. Croix Islands)”, or “US Virgin Islands (St. Thomas Islands)”.
- Count the number of threated species records per island where “Present_Breeding_Status” is “Confirmed” or “Potential Breeding”.
- Combine the invasive and threatened species data using “Island_GID_Code” and fill in invasive or threatened species counts with 0 if islands didn’t have a record in either of the sheets.
- Include only islands < 50 km^2 (smaller than St. Thomas) using the “Corrected_Area_KM2” field. The input data on imperiled species and invasive animals did not include species distributions within individual islands. That was less of an issue on smaller islands but made the source data less informative for larger islands.
- Extract “Corrected_Latitude” and “Corrected_Longitude” of islands from the “Invasive Species on Islands” sheet, then create shapefile of the summarized data.
- Spatially join the summarized data from TIB Database to the Caribbean island extent layer.
- Many species in the island biodiversity database have habitat on large islands, but the database doesn’t provide sufficiently detailed species distribution information within those islands to be used as an indicator. To address this, use predicted habitat models from Puerto Rico and U.S. Virgin Islands GAP for species listed in the TIB Database that live on large islands (i.e., >50 $km^{2)}$. These species were: Puerto Rican parrot, Culebra Island giant anole, Puerto Rican nightjar, Mottled coqui, Cricket coqui, Hedrick’s coqui, Golden coqui, Locust coqui, Forest coqui, Richmond’s coqui, Wrinkled coqui, Virgin Island tree boa, and Desecheo dwarf gecko.
- To prepare the GAP data, begin by fixing issues in two species layers. For Puerto Rican nightjar (*Caprimulgus noctitherus*), convert NoData to 0 to fill in a square of NoData in the center of Puerto Rico. For forest coqui (*Eleutherodactylus portoricensis*), add 1 to the values to make them consistent with the values used in the other layers for presence and absence.
- Sum the values of the species models and subtract by the total number of species to get species counts for each pixel. GAP uses 2 to indicate presence and 1 to indicate absence.
- Combine the Puerto Rico and U.S. Virgin Islands GAP species counts into a single raster. Then snap and reproject based on the Caribbean Blueprint subregion.
- Clip the critical habitat to the Caribbean islands extent layer and convert to raster. Include all critical habitat in the area except for yellow-shoulder blackbird. The large area of poor-quality habitat covered by critical habitat for this species was causing significant overprioritization in this indicator and local reviewers recommended removing it. This still results in important areas for the species being included based on models for other species, but greatly reduces overall overprioritization in many places.
- Combine data from the TIB database, critical habitat, and Puerto Rico and U.S. Virgin Islands GAP as shown in the final indicator values below.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

7 = Island area with critical habitat for a threatened or endangered species
6 = Island area with no invasive animals and 2+ imperiled species
5 = Island area with no invasive animals and 1 imperiled species
4 = Island area with no invasive animals
3 = Island area with invasive animals and 2+ imperiled species
2 = Island area with invasive animals and 1 imperiled species
1 = Island area with invasive animals
0 = Not an island

Known Issues

- This indicator underestimates habitat values for some small islands due to a lack of data in the Threatened Island Biodiversity Database. For some areas on large islands, like Vieques National Wildlife Refuge, it underestimates habitat values due to a lack of detailed distribution models for some species.
- This indicator likely underpredicts important habitat for federally listed species. Not all federally listed species have critical habitat designated, and not all of the critical habitat data designated by the U.S. Fish and Wildlife Service is available from the data source used.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Caribbean Karst Habitat

This indicator for the U.S. Caribbean represents natural karst areas with limited human alteration from activities such as urban development and intensive agriculture. Karst is a geologically unique landscape where the movement of water through easily dissolved bedrock, particularly limestone, produces distinctive features like caves, sinkholes, and underground rivers. This indicator combines LANDFIRE land cover with karst datasets from the Puerto Rico Department of Natural and Environmental Resources, National Park Service, and U.S. Geological Survey.

Reason for Selection

"Karst is a type of landscape where the dissolving of the bedrock has created sinkholes, sinking streams, caves, springs, and other characteristic features. Karst is associated with soluble rock types such as limestone, marble, and gypsum. In general, a typical karst landscape forms when much of the water falling on the surface interacts with and enters the subsurface through cracks, fractures, and holes that have been dissolved into the bedrock. After traveling underground, sometimes for long distances, this water is then discharged from springs, many of which are cave entrances" (NPS 2022).

The Caribbean region has one of the most significant karst landscapes in the world and is recognized by the International Union for Conservation of Nature (IUCN) World Commission of Protected Areas as in need of protection (Day 2010). In Puerto Rico, the unique karst landscape provides habitat for many endemic and rare species, such as the Puerto Rican boa, the Puerto Rican skink, Puerto Rican sharp-shinned hawk, and many federally listed plants (Lugo et al. 2001). In addition, the Puerto Rico karst belt contains the island's largest mature forests, coastal wetlands, estuaries, and underground cave systems. The northern limestone region supplies 22% of Puerto Rico's public drinking water (Lugo et al. 2001).

On St. Croix, the karst landscape supports the largest aquifer in the U.S. Virgin Islands, which covers approximately 25 mi^2 and produces about 67% of the total groundwater withdrawn in the U.S. Virgin Islands (Zack 1986; Dr. Olassee Davis - Ecologist and Extension Specialist with the University of the Virgin Islands, personal communication, July 6, 2023). Caribbean karst is also an important cultural landscape. For example, caves served as refuges for Maroons during colonization (Day 2010). Cave systems within this landscape also provide opportunities for low-impact nature-based tourism (Hall 2014).

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas
- U.S. Geological Survey Karst in the United States: A digital map compilation and database, last modified 8-1-2014, accessed 5-18-2023
- National Park Service Digital Geologic Map of St. Croix and Buck Island Reef National Monument, U.S. Virgin Islands (published 4-28-2008), accessed 6-22-2023
- Puerto Rico Karst Restricted Zone shapefile, shared on 6-15-2023 by Rossana Vidal Rodriguez with the Puerto Rico Department of Natural and Environmental Resources (PR DNER) (rvidal@drna.pr.gov)

  This is an improved version of the Karst Conservation Zone layer (also known as "zona_amortiguamiento_carso" layer) found in the 2018 Puerto Rico Natural Areas database. The Karst Conservation Zone layer is a 50 m buffer around the Karst Restricted Zone. The delimitation of the Karst Restricted Zone originated from the PR DNER's 2008 Study of Karst .

Mapping Steps

- Create a karst shapefile for St. Thomas and St. John by selecting all features in the USGS Karst file VIcarbonates.shp except where UNIT_NAME = 'Kingshill Marl'. That geologic unit appears in St. Croix and we exclude it because we have better data for St. Croix from the National Park Service.
- Create a karst shapefile for St. Croix from the National Park Service St. Croix geology map by selecting GLG_SYM = 'Mikh' from buisglg.shp. MIkh is the code for Kingshill Marl.

- Merge the karst shapefiles created for St. John, St. Thomas, and St. Croix with the Puerto Rico Karst Restricted Zone and Karst Conservation Zone buffer shapefiles, then convert to raster. This creates a combined karst layer for the U.S. Virgin Islands and Puerto Rico.
- Reclassify the LANDFIRE EVT data into 3 alteration classes where 3 is natural, 2 is altered, and 1 is heavily altered. Assign a value of 1 to all pixels with a value in the EVT_NAME field of “Developed-High Intensity” or “Developed-Medium Intensity”. Assign a value of 2 to all pixels with a value in the EVT_LF field of “Developed”, “Agriculture”, or “Barren”, or a value in the EVT_NAME field of “Agriculture-Pasture and Hay” or “Caribbean Bush fruit and berries”. Assign a value of 3 to everything else. Classify pixels with a value in the EVT_NAME field of “Open Water” as NoData. Note: The Caribbean bush fruit and berries LANDFIRE class is intended to represent sun-grown coffee, while tropical agroforestry plantation is intended to capture shade-grown coffee (LANDFIRE help desk, personal communication, 2-22-23). As a result, we considered Caribbean bush fruit and berries to be in the middle alteration class and considered tropical agroforestry plantation to be natural for the purposes of this indicator.
- Combine the karst raster with the reclassified LANDFIRE EVT data to produce the final indicator values shown below.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

3 = Karst with natural landcover
2 = Karst with pasture, crops, or open space in developed area
1 = Karst with developed landcover
0 = Not identified as karst

Known Issues

- Some karst areas are underprioritized in Puerto Rico because they are not included in the Karst Restricted Zone. While the Karst Restricted Zone focuses on the most sensitive karst areas, it does not include all karst on the island.
- Some areas are both under- and overprioritized in St. Thomas. The USGS karst data are not as fine-resolution as other data in this indicator and are likely under- and overpredicting karst in areas along the boundary of the polygons used.
- This indicator likely misses some karst areas in the U.S. Caribbean that are not captured in the input datasets.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Caribbean Landscape Condition

This indicator for the U.S. Caribbean represents natural areas with limited human alteration while also considering the natural landcover of the surrounding landscape. Examples of human alteration include urban development and intense agricultural use. The degree of naturalness across the landscape is a key ecological condition for sustaining species and ecosystem services that are sensitive to habitat fragmentation at multiple scales. This indicator uses LANDFIRE landcover and ideas from the Florida Critical Lands and Waters Identification Project's approach for evaluating landscape integrity.

Reason for Selection

A high degree of naturalness across the landscape benefits species diversity as well as ecosystem services such as pollinator habitat, increased water infiltration, and reduced soil erosion. Though many Caribbean habitats have experienced human alternation at some point, natural landcover across the wider landscape provides many benefits. It allows species to disperse during different life stages, better adapt to a changing climate by accessing refugia, and freely move between different habitats. Natural landscapes can also complement existing protected areas and help increase resilience to extreme weather events such as flooding and hurricanes (Kremen and Merenlender 2018).

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Caribbean island extent and size
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas

Mapping Steps

- Reclassify the LANDFIRE EVT data into 3 alteration classes where 3 is natural, 2 is altered, and 1 is heavily altered. Assign a value of 1 to all pixels with a value in the EVT_NAME field of "Developed-High Intensity" or "Developed-Medium Intensity". Assign a value of 2 to all pixels with a value in the EVT_LF field of "Developed", "Agriculture", or "Barren", or a value in the EVT_NAME field of "Agriculture-Pasture and Hay" or "Caribbean Bush fruit and berries". Assign a value of 3 to everything else. Classify pixels with a value in the EVT_NAME field of "Open Water" as 3. Note: The Caribbean bush fruit and berries LANDFIRE class is intended to represent sun-grown coffee, while tropical agroforestry plantation is intended to capture shade-grown coffee (LANDFIRE help desk, personal communication, 2-22-23). As a result, we considered Caribbean bush fruit and berries to be in the middle alteration class, and considered tropical agroforestry plantation to be natural for the purposes of this indicator.
- Reclassify the Caribbean island extent layer to assign all islands a value of 1 and assign the ocean a value of NoData.

- Multiply the reclassified LANDFIRE natural/altered layer and island extent data. This makes the ocean NoData, but retains freshwater, smaller salt ponds, and enclosed brackish water areas, as well as terrestrial areas on the islands.
- Many species and ecological processes operate at multiple scales. To account for this, estimate the average amount of alteration using a moving window (or neighborhood) analysis at 4 different scales: single pixel, approximately 10 acres; approximately 100 acres; and approximately 1,000 acres. Then average the values across all scales. This results in continuous values from 1 to 3.
- Bin the continuous values into the following categories seen in the final indicator values below: 1 (heavily altered): 1 to <1.5; 2 (altered): 1.5 to <2; 3 (partly natural): 2 to <2.5; 4 (mostly natural): 2.5 to <2.9; 5 (natural): 2.9 to 3.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available [in the Southeast Blueprint 2023 Data Download]() or [Caribbean-only Southeast Blueprint 2023 Data Download]() under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Natural landscape
4 = Mostly natural landscape
3 = Partly natural landscape
2 = Altered landscape
1 = Heavily altered landscape

Known Issues

- This indicator overestimates landscape condition in some marinas and nearby areas because LANDFIRE often classifies marinas as ruderal forests (i.e., a forest type made up of native and non-native early successional species that are the first to colonize a disturbed area).
- This indicator does not account for variation in habitat condition due to invasive species.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Kremen, Claire, and Adina M. 2018. Merenlender. Landscapes that work for biodiversity and people. Science 362.6412. Eaau6020. [https://www.science.org/doi/10.1126/science.aau6020].

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Caribbean Low-Urban Historic Landscapes

This cultural resource indicator is an index of sites on the National Register of Historic Places and other historic sites surrounded by limited urban development in the U.S. Caribbean. It identifies significant historic places that remain connected to their context in the natural world. This indicator uses LANDFIRE landcover and historic places data from the Puerto Rico State Historic Preservation Office, OpenStreetMap, and the University of the Virgin Islands.

Reason for Selection

Low-urban historic landscapes indicate significant cultural landscapes whose cultural context has been less impacted by urban development. Cultural landscapes are “properties [that] represent the combined works of nature and of man” (UNESCO 2012). Loss of natural habitat within these cultural landscapes reduces their overall historic and cultural value.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas
- The following The National Register of Historic Places data for Puerto Rico provided by Eduardo Cancio, Information Systems Specialist with the Puerto Rico State Historic Preservation Office (SHPO) on 2-21-2023 (contact ecancio@prshpo.pr.gov for more information):
    - NRHP_PR_individual_properties.shp
    - NRHP_PR_lineal_districts.shp
    - NRHP_PR_polygonal_districts.shp

  The National Register of Historic Places reflects what Americans value in their historic built environment. It is the collection of our human imprint on the landscape that records through time our changing relationship with the landscape, bridging between modern life and our history by providing, as closely as possible, experiences that evoke our empathy and understanding of previous eras.

- OpenStreetMap data "multipolygons" layer, accessed 3-14-2023

  A polygon from this dataset is considered a historic site if the "historic" tag is not null. In OpenStreetMap, a historic feature refers to "features that still exist or of which traces are observable, and that are of historic interest, or where the feature class is generally of historical interest". We only used historic polygons if the name tag is also not null. OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

- Select USVI historic districts: Polygon boundaries for the Christiansted National Historic District on St. Thomas and Charlotte Amalie Historic and Architectural Historic District on St. Croix, provided by Nikita Beck with the University of the Virgin Islands on 3-6-2023 (contact nikita.beck@uvi.edu for more information)

Mapping Steps

- Identify urban areas using the following classes from 2020 LANDFIRE EVT: Developed-High Intensity, Developed-Low Intensity, Developed-Medium Intensity, Developed-Open Space, Developed-Roads. Classify all urban pixels as 1 and all other pixels as 0.
- Calculate the percent urban in a 270 m radius circle for each pixel using the Focal Statistics tool in ArcGIS. Since the LANDFIRE data resolution is 30 m, 270 m (9 pixels) approximates a 250 m radius. Retain all pixels that are <50% urban within a 270 m radius.
- Create a historic places layer by combining the following vector datasets as follows:
  - Buffer National Register point data from the Puerto Rico SHPO by 100 m.
  - Combine National Register polygons from the Puerto Rico SHPO, select USVI historic districts, and OpenStreetMap polygons. Only use OpenStreetMap polygons if both the historic and name columns are null. Buffer the polygons by 30 m.
  - Buffer line data from the Puerto Rico SHPO by 30 m.
  - Merge all buffered point, polygon, and line data into one layer and convert to a 30 m raster representing historic places.
- Use the historic places raster to remove areas that fall outside of the historic places.
- Reclassify the above raster into 3 classes, seen in the final indicator values below.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

2 = Historic place with nearby low-urban buffer
1 = Historic place with nearby high-urban buffer
0 = Not identified as a historic place

Known Issues

- There are likely spatial mapping errors for some of the historic areas.
- Some historic areas with cultural importance are not captured in the National Register of Historic Places.
- The approach to measuring urban development doesn't capture degradation to historic places that were historically in larger cities (e.g., courthouses and other downtown buildings). It also doesn't distinguish between historic places that have always been urban and historic places that used to be low-urban.
- This layer likely underrepresents some historic areas in the U.S. Virgin Islands compared to Puerto Rico because we were unable to incorporate historic places data from the USVI SHPO during the timeline of this Blueprint update. As a result, some sites on the National Register of Historic Places are not depicted in this indicator.
- OpenStreetMap is a crowdsourced dataset. While members of the OpenStreetMap community often verify map features to check for accuracy and completeness, there is the potential for spatial errors (e.g., misrepresenting the boundary of a historic site) or incorrect tags (e.g., labelling an area as a historic site that does not have historic value). However, using a crowdsourced dataset gives on-the-ground experts, Blueprint users, and community members the power to fix errors and add new historic sites to improve the accuracy and coverage of this indicator in the future.
- Because open water is considered a non-urban landcover for the purposes of this analysis, this indicator is likely overprioritizing some urbanized historic areas that are close to water, such as marinas and bridges.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Caribbean Reforestation Potential

This indicator prioritizes areas to increase tree cover in the U.S. Caribbean based on current land uses and potential benefits for local drinking water supplies. It includes opportunities to improve water quality and species habitat by transitioning sun-grown coffee production to shade-grown; enhancing the overstory of shade-grown coffee areas; and reforesting open space in developed areas, pasture, and agricultural lands. The highest scores represent coffee plantations in watersheds with reservoirs. This indicator uses LANDFIRE landcover and U.S. Geological Survey watershed boundaries.

Reason for Selection

This indicator reflects the importance of restoring forests in the Caribbean to provide quality habitat for species and protect local drinking water supplies. Agriculture, timber harvesting, and development have greatly reduced the extent of Caribbean forests, resulting in habitat loss for many species and declines in water quality due to increased nutrient runoff and sedimentation (Newkirk II 2018, Brash 1987, Lyons and Gartner 2017). In watersheds that contain reservoirs used for local drinking water, reducing sedimentation is particularly important. Not only does sediment accumulation in reservoirs cause "loss in storage capacity of the dam, but it may also lead to many negative effects both within and downstream of reservoirs which may include high turbidity, loss of flood-carrying capacity and reduction in water quality" (Adeogun et al. 2018). These negative impacts can incur high financial and environmental costs (Kawashima 2007).

Protecting drinking water and improving the environmental sustainability of coffee production is a major focus of reforestation efforts in the Caribbean by partners like the Natural Resources Conservation Service (NRCS) (Frank Velazquez – Assistant State Conservationist for the NRCS Caribbean Area State Office, personal communication, 2-9-2023). The intent of this indicator is not to eliminate coffee production, but rather to support farmers in maintaining and enhancing forest cover in coffee plantations to "protect, enhance, and conserve soil, water, and wildlife habitat" (NRCS 2019).

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas
- U.S. Geological Survey Watershed Boundary Dataset (WBD), accessed 1-5-2023: HUC12s; download the data

Mapping Steps

- Export the HUC12 watersheds in the Caribbean from the WBD using states = 'VI' or states = 'PR'.
- Make a raster of coffee locations with LANDFIRE using the classes "Tropical agroforestry plantation" and "Caribbean bush fruit and berries". The Caribbean bush fruit and berries LANDFIRE class is intended to represent sun-grown coffee, while tropical agroforestry plantation is intended to capture shade-grown coffee (LANDFIRE help desk, personal communication, 2-22-23).
- Make a raster of potential reforestation areas with LANDFIRE using coffee areas from the step above, plus the Developed-Open Space class and agriculture classes (Pasture and Hay, Cultivated Crops and Irrigated Agriculture).
- From the WBD, identify HUC12 watersheds with reservoirs. A watershed is assumed to contain a reservoir if it contains the word "Dam" in the "name" attribute.
- Convert HUC12 watersheds with reservoirs from polygon to raster.
- Combine the above rasters and reclassify to produce the final indicator values seen below.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = Highest reforestation potential (coffee production in watershed with reservoir)
3 = Very high reforestation potential (other coffee production)
2 = High reforestation potential (open space in developed area, pasture, or crops in watershed with reservoir)
1 = Medium reforestation potential (other open space in developed area, pasture, or crops)
0 = Low reforestation potential (already natural or developed)

Known Issues

- This indicator does not account for differences in canopy cover among existing coffee plantations. It assigns the same level of priority to both sun-grown and shade-grown coffee. While sun-grown coffee is often considered a higher priority for reforestation (Almodovar 2013, NRCS 2019), even plantations that are considered shade-grown can vary in their level of canopy cover and would benefit from management or restoration to maintain or enhance the overstory.

- The methods used to identify watersheds that contain reservoirs do not distinguish between reservoirs used for drinking water and reservoirs used for other purposes, such as recreation or flood control. While drinking water quality is a major driver of this indicator, not all reservoirs identified in this indicator are necessarily used for drinking water.
- This indicator underprioritizes reforestation in some areas that are classified as natural but have significantly fewer trees than they should. Some ecosystems in the Caribbean (e.g., thorn scrub in eastern St. Croix), do not have many trees due to climate and geology. However, other areas classified as natural are lacking trees due to invasive species, grazing, or other human disturbance.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

Literature Cited

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Caribbean Urban Park Size

This cultural resource indicator measures the size of parks and beaches in the urban environment in the U.S. Caribbean. It uses several protected areas and beach datasets (e.g., the Protected Areas Database of the United States, OpenStreetMap) and Census urban areas.

Reason for Selection

Protected natural areas in urban environments provide urban residents a nearby place to connect with nature and offer refugia for some species. Because beaches in Puerto Rico and the U.S. Virgin Islands are open to the public, beaches also provide important outdoor recreation opportunities for urban residents, so we include beaches as parks in this indicator.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Coastal Relief Model, accessed 11-22-2022
- Protected Areas Database of the United States (PAD-US) 3.0: VI, PR, and Marine Combined Fee Easement
- Puerto Rico Protected Natural Areas 2018 (December 2018 update): Terrestrial and marine protected areas (PACAT2018_areas_protegidasPR_TERRESTRES_07052019.shp, PACAT2018_areas_protegidasPR_MARINAS_07052019.shp)
- 2020 Census Urban Areas from the Census Bureau's urban-rural classification; download the data, read more about how urban areas were redefined following the 2020 census

- OpenStreetMap data "multipolygons" layer, accessed 3-14-2023

  A polygon from this dataset is considered a park if the "leisure" tag attribute is either "park" or "nature_reserve" and considered a beach if the value in the "natural" tag attribute is "beach". OpenStreetMap describes leisure areas as "places people go in their spare time" and natural areas as "a wide variety of physical geography, geological and landcover features". Data were downloaded in .pbf format and translated to an ESRI shapefile using R code. OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

- TNC Lands - Public Layer, accessed 3-8-2023
- U.S. Virgin Islands beaches layer (separate vector layers for St. Croix, St. Thomas, and St. John) provided by Joe Dwyer with Lynker/the NOAA Caribbean Climate Adaptation Program on 3-3-2023 (contact jdwyer@lynker.com for more information)

Mapping Steps

- Most mapping steps were completed using QGIS (v 3.22) Graphical Modeler.
- Fix geometry errors in the PAD-US PR data using Fix Geometry. This must be done before any analysis is possible.
- Merge the terrestrial PR and VI PAD-US layers.
- Use the NOAA coastal relief model to restrict marine parks (marine polygons from PAD-US and Puerto Rico Protected Natural Areas) to areas shallower than 10 m in depth. The deep offshore areas of marine parks do not meet the intent of this indicator to capture nearby opportunities for urban residents to connect with nature.
- Merge into one layer the resulting shallow marine parks from marine PAD-US and the Puerto Rico Protected Natural Areas along with the combined terrestrial PAD-US parks, OpenStreetMap, TNC Lands, and USVI beaches. Omit from the Puerto Rico Protected Areas layer the "Zona de Conservación del Carso", which has some policy protections and conservation incentives but is not formally protected.
- Fix geometry errors in the resulting merged layer using Fix Geometry.
- Intersect the resulting fixed file with the Caribbean Blueprint subregion.
- Process all multipart polygons to single parts (referred to in Arc software as an "explode"). This helps the indicator capture, as much as possible, the discrete units of a protected area that serve urban residents.
- Clip the Census urban area to the Caribbean Blueprint subregion.
- Select all polygons that intersect the Census urban extent within 1.2 miles (1,931 m). The 1.2 mi threshold is consistent with the average walking trip on a summer day (U.S. DOT 2002) used to define the walking distance threshold used in the greenways and trails indicator. Note: this is further than the 0.5 mi distance used in the continental version of the indicator. We extended it to capture East Bay and Point Udall based on feedback from the local conservation community about the importance of the park for outdoor recreation.

- Dissolve all the park polygons that were selected in the previous step.
- Process all multipart polygons to single parts (“explode”) again.
- Add a unique ID to the selected parks. This value will be used to join the parks to their buffers.
- Create a 1.2 mi (1,931 m) buffer ring around each park using the multiring buffer plugin in QGIS. Ensure that “dissolve buffers” is disabled so that a single 1.2 mi buffer is created for each park.
- Assess the amount of overlap between the buffered park and the Census urban area using overlap analysis. This step is necessary to identify parks that do not intersect the urban area, but which lie within an urban matrix. This step creates a table that is joined back to the park polygons using the UniqueID.
- Remove parks that had ≤2% overlap with the urban areas when buffered. This excludes mostly non-urban parks that do not meet the intent of this indicator to capture parks that provide nearby access for urban residents. Note: In the continental version of this indicator, we used a threshold of 10%. In the Caribbean version, we lowered this to 2% in order to capture small parks that dropped out of the indicator when we extended the buffer distance to 1.2 miles.
- Calculate the GIS acres of each remaining park unit using the Add Geometry Attributes function.
- Join the buffer attribute table to the previously selected parks, retaining only the parks that exceeded the 2% urban area overlap threshold while buffered.
- Buffer the selected parks by 15 m. Buffering prevents very small parks and narrow beaches from being left out of the indicator when the polygons are converted to raster.
- Reclassify the polygons into 7 classes, seen in the final indicator values below. These thresholds were informed by park classification guidelines from the National Recreation and Park Association, which classify neighborhood parks as 5-10 acres, community parks as 30-50 acres, and large urban parks as optimally 75+ acres (Mertes and Hall 1995).
- Export the final vector file to a shapefile and import to ArcGIS Pro.
- Convert the resulting polygons to raster using the ArcPy Polygon to Raster function. Assign values to the pixels in the resulting raster based on the polygon class sizes of the contiguous park areas.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

6 = 75+ acre urban park
5 = >50 to <75 acre urban park
4 = 30 to <50 acre urban park
3 = 10 to <30 acre urban park
2 = 5 to <10 acre urban park
1 = <5 acre urban park
0 = Not identified as an urban park

Known Issues

- This indicator does not include park amenities that influence how well the park serves people and should not be the only tool used for parks and recreation planning. Park standards should be determined at a local level to account for various community issues, values, needs, and available resources.
- This indicator includes some protected areas that are not open to the public and not typically thought of as “parks”, like mitigation lands, private easements, and private golf courses. While we experimented with excluding them using the public access attribute in PAD, due to numerous inaccuracies, this inadvertently removed protected lands that are known to be publicly accessible. As a result, we erred on the side of including the non-publicly accessible lands.
- This indicator includes parks and beaches from OpenStreetMap, which is a crowdsourced dataset. While members of the OpenStreetMap community often verify map features to check for accuracy and completeness, there is the potential for spatial errors (e.g., misrepresenting the boundary of a park) or incorrect tags (e.g., labelling an area as a park that is not actually a park). However, using a crowdsourced dataset gives on-the-ground experts, Blueprint users, and community members the power to fix errors and add new parks to improve the accuracy and coverage of this indicator in the future.

Other Things to Keep in Mind

- This indicator calculates the area of each park using the park polygons from the source data. However, simply converting those park polygons to raster results in some small parks and narrow beaches being left out of the indicator. To capture those areas, we buffered parks and beaches by 15 m and applied the original area calculation to the larger buffered polygon, so as not to inflate the area by including the buffer. As a result, when the buffered polygons are rasterized, the final indicator has some areas of adjacent pixels that receive different scores. While these pixels may appear to be part of one contiguous park or suite of parks, they are scored differently because the park polygons themselves are not actually contiguous.

- The Caribbean version of this indicator uses a slightly different methodology than the continental Southeast version. It includes parks within a 1.2 mi distance from the Census urban area, compared to 0.5 mi in the continental Southeast. We extended it to capture East Bay and Point Udall based on feedback from the local conservation community about the importance of the park for outdoor recreation. Similarly, this indicator uses a 2% threshold of overlap between buffered parks and the Census urban areas, compared to a 10% threshold in the continental Southeast. This helped capture small parks that dropped out of the indicator when we extended the buffer distance to 1.2 miles. Finally, the Caribbean version does not use the impervious surface cutoff applied in the continental Southeast because the landcover data available in the Caribbean does not assess percent impervious in a comparable way.
- The Caribbean version of this indicator uses more recent data than the continental Southeast version because it was updated more recently (2020 Census urban areas vs. 2010 Census urban areas and PAD-US 3.0 vs. PAD-US 2.1). We intend to update the continental Southeast version to match in the next Blueprint revision cycle.
- The Caribbean version of this indicator includes nearshore marine parks and an additional park dataset that is available in the continental Southeast area, OpenStreetMap. We intend to explore whether to expand the scope of the continental Southeast version to include nearshore marine parks, and assess whether OpenStreetMap fills important park gaps in that area as well.

Disclaimer: Comparing with Older Indicator Versions

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Freshwater

Caribbean Natural Landcover in Floodplains

This indicator measures the amount of natural landcover in the estimated floodplain of rivers and streams within each catchment in the U.S. Caribbean. It assesses the stream channel and its surrounding riparian buffer, measuring the percent of unaltered habitat like forests, wetlands, or open water (rather than agriculture or development) in the floodplain. This indicator originates from LANDFIRE land cover. It applies to the floodplain predicted to be inundated by a 100-year flood (also known as the 1% annual chance flood), derived from the Federal Emergency Management Agency's National Flood Hazard Layer, and buffered flowlines representing other streams.

Reason for Selection

Habitat near rivers and streams is strongly linked to water quality and instream flow (Naiman 1997), is easy to monitor and model, and is widely used and understood by diverse partners. Intact vegetated buffers within the floodplain of rivers and streams provide aquatic habitat, improve water quality, reduce erosion and flooding, recharge groundwater, and more (WeConservePA 2014). Natural floodplain landcover provides a "front line defense" for aquatic systems.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas
- National Hydrography Dataset Plus High Resolution (NHDPlus HR) National Release catchments and flowlines, accessed 11-30-2022; download the data
- Federal Emergency Management Agency (FEMA) National Flood Hazard Layer flood zones for Puerto Rico and the U.S. Virgin Islands, accessed 10-22-2022; to download the data, visit the FEMA Flood Map Service Center, search by jurisdiction (Puerto Rico or Virgin Islands), download all FIRM (Flood Insurance Rate Maps) panels, and locate the "S_FLD_HAZ_AR" shapefile in each download package.

  We used the "FLD_ZONE" attribute of the S_FLD_HAZ_AR shapefile to define an estimated floodplain depicting areas predicted to be inundated by a 100-year flood (also known as the 1% annual chance flood). To create the estimated floodplain for Puerto Rico and the U.S. Virgin Islands, we combined all areas with flood zone codes beginning with the letter "A". These zones represent the inland (non-coastal) portions of FEMA Special Flood Hazard Areas considered at high risk of flooding. This excludes coastal areas where the high risk of flooding stems from storm waves, areas of moderate-low flood risk, and areas with possible but undetermined flood hazards where no hazard analysis has been conducted. For more details on FEMA flood zones, read this FEMA blog or visit the FEMA glossary (detailed definitions are under "Z" for "zones").

Catchments

A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

To learn more about catchments and how they're defined, check out these resources:

- An article from USGS explaining the differences between various NHD products
- The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

Mapping Steps

- Convert the FEMA floodplain polygons to a 30 m raster, giving floodplain areas a value of 1.
- Extract the stream and river lines from the NHDPlus HR flowlines (ftype IN (460, 558)). Convert extracted stream and river lines to a 30 m raster. Use the ArcPy Spatial Analysis Expand function to "buffer" the streams by 1 cell. This is the method that SARP uses to create a total stream width of approximately 90 m.
- Combine the FEMA floodplains and buffered flowlines using the Mosaic function to make an enhanced floodplain layer.
- Clip the 2020 LANDFIRE EVT to the enhanced floodplain layer. This limits the indicator values to the floodplain areas, where they are most relevant.
- Reclassify the clipped 2020 LANDFIRE EVT to identify natural landcover. The following classes were considered not natural: Quarries-Strip Mines-Gravel Pits-Well and Wind Pads, Developed-Low Intensity, Developed-Medium Intensity, Developed-High Intensity, Developed-Roads, Developed-Open Space, Agriculture-Pasture and Hay, Agriculture-Cultivated, Crops and Irrigated Agriculture, Caribbean Bush fruit and berries. All other classes were considered natural.
- The original NHDPlus HR catchment data was missing coverage of a small area on the west coast of Puerto Rico (just east of Parcelas Aguas Claras). Create an additional catchment polygon for this missing area so that the indicator covers the entire island of Puerto Rico.
  - The missing area is essentially outlined by extremely thin catchment polygons. To fill the gap, make a new rectangular feature class covering the missing area, then union it together with the original NHDPlus HR catchments. From that output, select the newly created polygon that fills in the hole.
  - The resulting polygon is a multipart feature, so use the explode tool to separate out just the missing catchment. Export it as a shapefile.
  - Union together the missing catchment with the other NHDPlus HR catchments and use that combined output as the catchment layer for the rest of the mapping steps.
- Calculate the percent of riparian natural landcover inside each NHDPlus catchment using ArcPy Spatial Analyst Zonal Statistics "MEAN" function.
- Reclassify the above raster into the 1-5 classes seen in the final indicator values below.

- Clip the resulting raster back to the enhanced floodplain layer. It is necessary to do this again since the zonal statistics function outputs pixel values for the entire catchment. During this step, assign a value of 0 to areas outside the enhanced floodplain. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = >90% natural landcover within the estimated floodplain, by catchment
4 = >80-90%
3 = >70-80%
2 = >60-70%
1 = ≤60% natural landcover within the estimated floodplain, by catchment
0 = Not identified as a floodplain

Known Issues

- This indicator does not account for the accumulated impacts of upstream riparian buffers. Buffers at the headwaters are treated the same as those downstream.
- This indicator does account for river or stream size in relation to the estimated floodplain. Aquatic habitat needs may differ based on the river size class. For example, smaller headwater streams may need more natural landcover than larger rivers to maintain aquatic health. It also does not account for variation in buffer quality within the floodplain at a scale below the catchment. This means that within the estimated floodplain, loss of natural habitat adjacent to the river is treated the same as loss farther away.
- The NHDPlus flowlines in the headwaters could represent intermittent or ephemeral streams. They were not excluded, so the indicator could be overprioritizing headwater areas relative to second-, third-, or fourth-order streams.
- The National Hydrography Dataset digitizes surface water systems at the 1:24,000 resolution. It does not digitize every small, ephemeral stream. As a result, some stream channels that contribute excess sediment to downstream streams or the ocean are not included in this indicator.
- NHDPlus HR contains multiple catchments that are very small. The reduced size of these catchments may result in exaggerating their values in the indicator.

Other Things to Keep in Mind

- Headwater streams are important to freshwater systems but are not always well-captured in the FEMA floodplain dataset. To better represent headwater streams in this indicator, we chose to buffer flowlines and include them as additional floodplain areas to give those areas the opportunity to be included in the Blueprint.
- You may notice stream sections in this indicator that appear to be unconnected to other stream networks. These occur because the National Hydrography Dataset digitizes surface water streams that are not always connected to downstream stream segments. We assume that in these cases, the surface water streams sink into karst areas (e.g., in northwest Puerto Rico around Quebrada). We still included these stream segments in this indicator because they could provide freshwater water habitat for aquatic species.

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Literature Cited

LANDFIRE, Earth Resources Observation and Science Center (EROS), U.S. Geological Survey. Published August 1, 2022. LANDFIRE 2020 Existing Vegetation Type (EVT) Puerto Rico US Virgin Islands. LF 2020, raster digital data. Sioux Falls, SD. [https://www.landfire.gov].

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Caribbean Network Complexity

This indicator depicts the number of connected stream size classes in a river network between dams or waterfalls in the U.S. Caribbean. It originates from the Southeast Aquatic Resources Partnership. It applies to the estimated floodplain, which spatially defines areas predicted to be inundated by a 100-year flood (also known as the 1% annual chance flood), based on the Federal Emergency Management Agency's National Flood Hazard Layer, and buffered flowlines representing other streams.

Reason for Selection

River networks with a variety of connected stream size classes are more likely to have a wide range of available habitat to support a greater number of species. This will help retain aquatic biodiversity in a changing climate by allowing species to access climate refugia and move between habitats (Morelli et al. 2016).

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- Southeast Aquatic Resources Partnership's Network Complexity metric

  The Southeast Aquatic Resources Partnership (SARP) developed metrics for their Southeast Aquatic Barrier Prioritization Tool. In February 2023, Brendan Ward with Astute Spruce (software developer working on behalf of SARP) shared high resolution NHDPlus flowlines with attributes depicting the network complexity attribute for each functional network (see definition of "functional network" below). The network complexity attribute calculates the total number of different stream size classes within each functional network. SARP assigned stream and river reaches to size classes based on total drainage area:

  - 1a: Headwaters (<3.861 sq mi)
  - 1b: Creeks (≥3.861 and <8.61 sq mi)
  - 2: Small Rivers (≥38.61 and <200 sq mi)
  - 3a: Medium Tributary Rivers (≥200 and <1,000 sq mi)
  - 3b: Medium Mainstem Rivers (≥1,000 and <3,861 sq mi)
  - 4: Large Rivers (≥3,861 and <9,653 sq mi)
  - 5: Great Rivers (≥9,653 sq mi)

  #### *Functional network*

  SARP compiles the Southeast Aquatic Barrier Inventory from national, regional, state, and local partner databases across the Southeast region. These include the National Inventory of Dams (2018), National Anthropogenic Barrier Dataset (2012), databases from state dam safety programs and other state agencies, information from local partners, and dam locations estimated by SARP. Waterfalls are compiled from national datasets and local partners.

Dams and waterfalls are snapped to hydrologic networks extracted from the National Hydrography Dataset (NHD) - High Resolution Beta version. All dams and waterfalls are treated as “hard” barriers for network connectivity analysis. Aquatic networks are cut at the location of each barrier. All network “loops” (non-primary flowlines) are omitted from the analysis.

An upstream functional network is constructed by traversing upstream from each barrier through all tributaries to the upstream-most origination point or upstream barrier, whichever comes first. Additional functional networks are defined from downstream-most non-barrier termination points, such as marine areas or other downstream termination points.

The total length of all network segments within a functional network is summed to calculate the total network length of each functional network. Each flowline segment within the NHD is assigned to a size class based on total drainage area. This was used to calculate the number of unique size classes per functional network.

- Federal Emergency Management Agency (FEMA) National Flood Hazard Layer flood zones for Puerto Rico and the U.S. Virgin Islands, accessed 10-22-2022; to download the data, visit the FEMA Flood Map Service Center, search by jurisdiction (Puerto Rico or Virgin Islands), download all FIRM (Flood Insurance Rate Maps) panels, and locate the “S_FLD_HAZ_AR” shapefile in each download package.

  We used the “FLD_ZONE” attribute of the S_FLD_HAZ_AR shapefile to define an estimated floodplain depicting areas predicted to be inundated by a 100-year flood (also known as the 1% annual chance flood). To create the estimated floodplain for Puerto Rico and the U.S. Virgin Islands, we combined all areas with flood zone codes beginning with the letter “A”. These zones represent the inland (non-coastal) portions of FEMA Special Flood Hazard Areas considered at high risk of flooding. This excludes coastal areas where the high risk of flooding stems from storm waves, areas of moderate-low flood risk, and areas with possible but undetermined flood hazards where no hazard analysis has been conducted. For more details on FEMA flood zones, read this FEMA blog or visit the FEMA glossary (detailed definitions are under “Z” for “zones”).

- National Hydrography Dataset Plus High Resolution (NHDPlus HR) National Release catchments and flowlines, accessed 11-30-2022; download the data

  Catchments

  A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

To learn more about catchments and how they're defined, check out these resources:

- An article from USGS explaining the differences between various NHD products
- The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

Mapping Steps

- Convert the SARP network complexity values from the NHDPlus HR flowlines to a 30 m raster.
- The original NHDPlus HR catchment data was missing coverage of a small area on the west coast of Puerto Rico (just east of Parcelas Aguas Claras). Create an additional catchment polygon for this missing area so that the indicator covers the entire island of Puerto Rico.
    - The missing area is essentially outlined by extremely thin catchment polygons. To fill the gap, make a new rectangular feature class covering the missing area, then union it together with the original NHDPlus HR catchments. From that output, select the newly created polygon that fills in the hole.
    - The resulting polygon is a multipart feature, so use the explode tool to separate out just the missing catchment. Export it as a shapefile.
    - Union together the missing catchment with the other NHDPlus HR catchments and use that combined output as the catchment layer for the rest of the mapping steps.
- Apply the network complexity values to the NHDPlus HR catchments using the ArcPy Zonal Statistic "MAJORITY" function. This results in a raster where each catchment is given the majority network complexity value that intersects the catchment. Most catchments have only one intersecting line, but for catchments with interior dams, the analysis uses the majority network complexity value. This creates a raster with network complexity value assigned to catchments.
- Convert the FEMA floodplain polygons to a 30 m raster, giving floodplain areas a value of 1.
- Extract the stream and river lines from the NHDPlus HR flowlines (ftype IN (460, 558)). Convert extracted stream and river lines to a 30 m raster. Use the ArcPy Spatial Analysis Expand function to "buffer" the streams by 1 cell. This is the method that SARP uses to create a total stream width of approximately 90 m.
- Combine the FEMA floodplains and buffered flowlines using the Mosaic function to make an enhanced floodplain layer.
- Clip the raster with network complexity values assigned to catchments to the enhanced floodplain layer. This limits the indicator values to the floodplain areas, where they are most relevant.

- Some areas of the floodplain are not scored in the resulting layer because they are missing SARP network complexity values. This is due to the fact that some small reaches, such as braids and loops in the stream network, are not assigned a network complexity value. SARP has to remove loops and braided streams in order to calculate network complexity because the analysis can only accommodate a one-way flow of water. Identify these holes in the floodplain and fill them in by looking at the network complexity value of the surrounding pixels and assigning the maximum value to the missing catchments in the floodplain. Note: This explanation simplifies a complex series of analysis steps. For more specifics, please consult the code.
- Assign zero values to all areas that are covered by the NHDPlus HR catchments, but that are outside the enhanced floodplain layer. Zero values are intended to help users better understand the extent of this indicator and make it perform better in online tools.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = 4 connected stream classes
3 = 3 connected stream classes
2 = 2 connected stream classes
1 = 1 connected stream class
0 = Not identified as floodplain

Known Issues

- This indicator does not include other smaller scale attributes of complexity (e.g., sinuosity, mixtures of riffles/pools/runs) that influence the habitat quality of the connections.
- This indicator likely overestimates the number of connected stream classes in some areas due to missing barriers in the inventory, such as smaller dams or road-stream crossings. It could also underestimate the number of connected stream classes, given the extensive ongoing restoration work to improve aquatic connectivity across the SECAS geography. If you identify a missing barrier or a removed barrier, please let SARP know by emailing Kat Hoenke at kat@southeastaquatics.net. You can learn more about the current inventory of dams and road-stream crossings by visiting https://connectivity.sarpdata.com/.
- SARP did a lot of work to snap the dam locations to the line network, but there are likely still dams (including some large ones) that didn't get snapped correctly due to the large distance between the centerpoint of the dam and the nearest flowline. If you see any of these cases when reviewing the data, please let SARP know (the giveaway is networks that look longer than they should on a map).

- The NHDPlus flowlines in the headwaters could represent intermittent or ephemeral streams. They were not excluded, so the indicator could be overprioritizing headwater areas relative to second-, third-, or fourth-order streams.
- The National Hydrography Dataset digitizes surface water streams that are not always connected to downstream stream segments. We assume that in these cases, the surface water streams sink into karst areas (e.g., in northwest Puerto Rico around Quebrada). We still included these stream segments in this indicator because they could provide freshwater water habitat for aquatic species.
- The FEMA Floodplain layer sometimes misses the small, linear connections made by artificial canals, especially when they go through areas that wouldn't naturally be part of the floodplain. As a result, some areas (like lakes) that are connected via canals may appear to be disconnected, but still receive high scores.
- The National Hydrography Dataset digitizes some surface water streams that are not always connected to downstream stream segments. We assume that some of these areas have surface water streams but sink into karst areas. An example of this is in the northwest portion of Puerto Rico around Quebrada. We still included these stream segments in this indicator because they could provide freshwater water habitat for aquatic species.
- NHDPlus HR contains multiple catchments that are very small. The reduced size of these catchments may result in exaggerating their values in the indicator.

Other Things to Keep in Mind

- You may notice stream sections in this indicator that appear to be unconnected to other stream networks. These occur because the National Hydrography Dataset digitizes surface water streams that are not always connected to downstream stream segments. We assume that in these cases, the surface water streams sink into karst areas (e.g., in northwest Puerto Rico around Quebrada). We still included these stream segments in this indicator because they could provide freshwater water habitat for aquatic species.
- Headwater streams are important to freshwater systems but are not always well-captured in the FEMA floodplain dataset. To better represent headwater streams in this indicator, we chose to buffer flowlines and include them as additional floodplain areas to give those areas the opportunity to be included in the Blueprint.
- We considered using different indicator values that would account for varying island sizes and the natural complexity of freshwater systems on each island. By using consistent indicator values across all islands, regardless of their maximum aquatic connectivity potential, this indicator essentially assigns lower scores to smaller islands, despite the fact that they will never reach the same level of network complexity as larger islands. Ultimately, we decided to use the same classes across all islands because more complex and connected aquatic systems on larger islands do provide more climate refugia and available habitat to aquatic species, and therefore should have higher scores.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Caribbean Permeable Surface

This indicator measures the average percent of non-impervious cover within each catchment in the U.S. Caribbean. High levels of impervious surface degrade water quality and alter freshwater flow, impacting both aquatic species communities and ecosystem services for people, like the availability of clean drinking water. It originates from the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program land cover.

Reason for Selection

Impervious cover is easy to monitor and model and is widely used and understood by diverse partners. It is also strongly linked to water quality, estuary condition, eutrophication, and freshwater inflow. Impervious surface affects not only aquatic habitats and biodiversity, but also human communities. High levels of impervious surface cause more frequent flooding by increasing the volume of stormwater runoff, reduce the amount of available drinking water by preventing groundwater recharge, and pollute waterways where people swim and fish (Chesapeake 2023, USGS 2018, EPA 2018).

The 90% permeable surface threshold (i.e., 10% impervious) is a well-documented signal of major, negative changes to aquatic ecosystems (Schueler et al. 2009). The 95% permeable surface threshold (i.e., 5% impervious) has been documented to impact Piedmont fish [tricolor shiner *(Cyprinella trichroistia)*, bronze darter *(Percina palmaris)*, Etowah darter *(Etheostoma etowahae)*] (Wenger et al. 2008) and estuarine species [blue crab *(Callinectes sapidus)*, white perch *(Morone americana)*, striped bass *(M. Saxatilis)* and spot *(Leiostomus xanthurus)*] (Uphoff Jr. et al. 2011).

While most of these species do not occur in Puerto Rico and the U.S. Virgin Islands, we kept these thresholds in the Caribbean for consistency with the continental version of the indicator.

Input Data

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent
- 2012 National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover files for the U.S. Virgin Islands (St. Thomas, St. John, and St. Croix are provided as separate rasters) accessed 11-10-2022; learn more about C-CAP high resolution land cover and change products
- 2010 NOAA C-CAP land cover files for Puerto Rico, accessed 11-10-2022; learn more about C-CAP high resolution land cover and change products
- National Hydrography Dataset Plus High Resolution (NHDPlus HR) National Release catchments, accessed 11-30-2022; download the data

  Catchments

  A catchment is the local drainage area of a specific stream segment based on the surrounding elevation. Catchments are defined based on surface water features, watershed boundaries, and elevation data. It can be difficult to conceptualize the size of a catchment because they vary significantly in size based on the length of a particular stream segment and its surrounding topography—as well as the level of detail used to map those characteristics.

  To learn more about catchments and how they're defined, check out these resources:

  - An article from USGS explaining the differences between various NHD products
  - The glossary at the bottom of this tutorial for an EPA water resources viewer, which defines some key terms

- NOAA Continuously Updated Shoreline Product (CUSP), accessed 1-11-2023; read a 1-page factsheet about CUSP; view and download CUSP data in the NOAA Shoreline Data Explorer (to download, select "Download CUSP by Region" and select Southeast Caribbean)

Mapping Steps

- NHDPlus HR catchments are currently only available for the islands of Puerto Rico, Vieques, Culebra, St. Croix, St. John, and St. Thomas. Because the catchments don't cover many of the smaller islands, use CUSP to add islands larger than 900 m^2 (the area of a 30 m pixel). Start by converting CUSP shoreline lines to polygons.
- Dissolve interior waterbodies on islands to represent each island with only one polygon.
- To eliminate alignment issues between the CUSP and catchment polygons, remove most island areas that overlap with or are near (<10 m from) the NHDPlus HR catchments, ensuring that all of Culebra is retained.
- The original NHDPlus HR catchment data was missing coverage of a small area on the west coast of Puerto Rico (just east of Parcelas Aguas Claras). Create an additional catchment polygon for this missing area so that the indicator covers the entire island of Puerto Rico.
    - The missing area is essentially outlined by extremely thin catchment polygons. To fill the gap, make a new rectangular feature class covering the missing area, then union it together with the original NHDPlus HR catchments. From that output, select the newly created polygon that fills in the hole.
    - The resulting polygon is a multipart feature, so use the explode tool to separate out just the missing catchment. Export it as a shapefile.
    - Union together the missing catchment with the other NHDPlus HR catchments and use that combined output as the catchment layer for the rest of the mapping steps.
- Remove islands created from the CUSP dataset that are less than 900 m^2.
- Merge the remaining CUSP islands with the NHDPlus catchments to create a single set of polygons in which to calculate average permeable surface.
- Convert the C-CAP land cover rasters for Puerto Rico (2 m resolution) and the U.S. Virgin Islands (separate downloads for St. Thomas, St. John, and St. Croix with 2.4 m resolution) from .img format to .tif using the Copy Raster function.
- For each individual C-CAP layer, use the ArcPy Conditional function to make a binary raster assigning the impervious class a value of 100 (representing fully impervious) and all other classes a value of 0 (representing fully permeable). This mimics the data format of the 2019 National Land Cover Database used in the continental Southeast permeable surface indicator, which provides a continuous impervious surface value ranging from 0 to 100.
- Using the ArcPy Mosaic to New Raster function, mosaic all 4 rasters into 1 raster. Reproject to match the Blueprint projection and the 2 m cell size of the original Puerto Rico C-CAP data.
- Calculate the average percent of impervious surface for each NHDPlus catchment or CUSP island using the ArcPy Spatial Analyst Zonal Statistics "MEAN" function, assigning the average impervious surface value to each catchment or island.
- Convert percent impervious to percent permeable using the formula [percent permeable = 100 - percent impervious] to maintain consistent scoring across Southeast Blueprint indicators (where high values indicate better ecological condition).
- Reclassify the above raster into 4 classes, seen in the final indicator values below.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = >95% of catchment or small island permeable (likely high water quality and supporting most sensitive aquatic species)
3 = >90-95% of catchment or small island permeable (likely declining water quality and supporting most aquatic species)
2 = >70-90% of catchment or small island permeable (likely degraded water quality and not supporting many aquatic species)
1 = ≤70% of catchment or small island permeable (likely degraded instream flow, water quality, and aquatic species communities)

Known Issues

- This indicator may not account for differences in permeability between different types of soils and land uses.
- The C-CAP impervious layer used in this indicator contains classification inaccuracies that may cause this indicator to overestimate or underestimate the amount of permeable surface in some catchments.
- C-CAP dates from 2010 for Puerto Rico and 2012 for the U.S. Virgin Islands. As a result, this indicator likely overestimates permeable surface values in areas that have been developed since the data was collected.
- C-CAP landcover is not available for some islands over 900 m^2. While these islands exceeded the size threshold for inclusion in this indicator, they are therefore scored as NoData. This indicator only covers areas where C-CAP landcover is present, and either NHDPlus HR catchments or islands over 900 m^2 that were generated using CUSP data are also present.
- NHDPlus HR contains multiple catchments that are very small. The reduced size of these catchments may result in exaggerating their values in the indicator.

Other Things to Keep in Mind

- The impervious surface in the C-CAP data has impervious surface as one class in the landcover, which differs from the 2019 NLCD percent developed impervious layer used in the continental Southeast version of the permeable surface indicator. NLCD 2019 is served up as a continuous raster ranging from 0-100% impervious.
- We used the Caribbean island size and extent layer for this indicator and not others because landcover data was available for small islands that were not covered by catchments, which otherwise would have been excluded. This was not the case for other indicators. For example, while we use catchments in natural landcover in floodplains, the floodplains and flowlines did not occur on small islands, anyway, so we did not leave any data out by using the catchments only and not supplementing with the islands layer.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Coastal & Marine

Caribbean Beach Habitat

This indicator evaluates beach habitat for six species of birds and sea turtles that nest on beaches in the U.S. Caribbean (Wilson's plover, American oystercatcher, and hawksbill, leatherback, green, and loggerhead sea turtles). It includes beach locations, sea turtle nest observations, and predicted suitable habitat for birds and sea turtles. This indicator combines multiple datasets from the Gap Analysis Program, State of the World's Sea Turtles, OpenStreetMap, and more.

Reason for Selection

Beaches in Puerto Rico and the U.S. Virgin Islands support a wide array of shorebirds, colonial seabirds, and sea turtles (ACJV et al. 2015, USFWS 2022). However, their limited spatial extent makes beaches an ecosystem of special concern for conservation (ACJV et al. 2015). In addition, coastal dunes and beaches are some of the Caribbean ecosystems facing the greatest threat from disturbance and development (ACJV et al. 2015). This indicator focuses on a suite of bird and sea turtle species that nest on beaches, though it includes beach habitat used for other activities like foraging and breeding, in addition to nesting.

Input Data

- Puerto Rico Gap Analysis Project predicted vertebrate species distributions: data provided by Dr. Bill Gould with the Caribbean Climate Hub on 4-4-2022 (contact william.a.gould@usda.gov for more information); read the final report

  In Puerto Rico, we used the following GAP species models:
  - Wilson's plover

- Puerto Rico Gap Analysis Project landcover; download the data; read the final report
- U.S. Virgin Islands Gap Analysis Project predicted vertebrate species distributions and landcover; data and report appendices provided by Dr. Bill Gould with the Caribbean Climate Hub on 2-6-2023 (contact william.a.gould@usda.gov for more information); read the final report

  In the USVI, we used the following GAP species models:
  - Wilson's plover
  - American oystercatcher
  - Hawksbill sea turtle
  - Leatherback sea turtle
  - Green sea turtle

- State of the World's Sea Turtles (SWOT) nest locations for hawksbill, leatherback, green, and loggerhead sea turtles; download the data using the download icon on the left side of the SWOT mapping application. Note: loggerhead was only observed in USVI, while the other species were observed in both PR and USVI.
- OpenStreetMap data, accessed 6-28-2023

  A polygon from this dataset is considered a beach if the value in the "nature" attribute is beach. OpenStreetMap describes natural areas as "a wide variety of physical geography, geological and landcover features". Data were downloaded in .pbf format using R code. OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

- U.S. Virgin Islands beaches layer (separate vector layers for St. Croix, St. Thomas, and St. John) provided by Joe Dwyer with Lynker/the NOAA Caribbean Climate Adaptation Program on 3-3-2023 (contact jdwyer@lynker.com for more information)
- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent

Mapping Steps

- Buffer by 15 m the beach polygons from OpenStreetMap and the USVI beaches layer. This is consistent with the methodology used in the urban park size indicator to avoid the loss of narrow beaches when converting to raster. Project and convert to raster.
- Extract from GAP landcover the relevant beach classes and resample to a 30 m pixel. In Puerto Rico, the beaches include two classes: "Gravel beaches and stony shoreline" and "Fine to coarse sandy beaches, mixed sand and gravel beaches". In the U.S. Virgin Islands, the beaches include three classes: "Fine to Medium Grained Sandy Beaches," "Gravel Beaches" and "Mixed Sand and Gravel Beaches".
- Extract the predicted habitat class from the GAP predicted habitat rasters for species that nest on beaches. These include Wilson's plover, American oystercatcher, and hawksbill, leatherback, and green sea turtles. Note: Only Wilson's plover was predicted in Puerto Rico. Project and resample the rasters to 30 m.
- Extract from the SWOT data nest all point locations for hawksbill, leatherback, green and loggerhead sea turtles and convert them to 30 m rasters.
- Merge together the SWOT and GAP predicted habitat rasters for each species and identify each pixel that contains at least one species. Then clip the resulting raster to the beach extent.
- To define individual beaches, run a region group on beach extent.
- Run the Zonal Statistics "MAX" function to apply species presence to the entirety of each beach.
- Reclassify to 0 the beach extent layer created above.

- To create the final indicator values seen below, mosaic together three rasters: the beaches containing at least one species, the beach extent, and the Caribbean Blueprint 2023 extent. This adds back in a 0 value for areas not identified as beaches and a 1 value for beaches that did not contain any species predictions or observations. Zero values better represent the extent of the source data and make the indicator perform better in online tools.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

2 = Beach with 1+ nesting species predicted or observed
1 = Other beach
0 = Not identified as a beach

Known Issues

- This indicator likely underprioritizes beaches in Puerto Rico due to disparities in both beach extent and species data coverage between Puerto Rico and the U.S. Virgin Islands. USVI has a comprehensive hand-digitized beach layer that is not available in Puerto Rico. GAP models only one beach-nesting species in Puerto Rico, compared to five in the U.S. Virgin Islands (though the additional species are known to occur in Puerto Rico as well). In addition, the SWOT sea turtle observations better aligned with the beach polygons in USVI. We will explore additional datasets and methods for addressing these disparities in future revisions. To help mitigate this issue for this year, we set the maximum species richness as 1+ rather than using the full range of species richness values, since Puerto Rico had a maximum species richness of 3 in the available data, compared to a maximum value of 6 in USVI.
- This indicator includes beaches from OpenStreetMap, which is a crowdsourced dataset. While members of the OpenStreetMap community often verify map features to check for accuracy and completeness, there is the potential for spatial errors (e.g., misrepresenting the boundary of a beach) or incorrect tags (e.g., labelling an area as a beach that is not actually a beach). However, using a crowdsourced dataset gives on-the-ground experts, Blueprint users, and community members the power to fix errors and add new parks to improve the accuracy and coverage of this indicator in the future.
- This indicator may exclude some small beaches that aren't captured in the source data. We encourage interested partners and citizens to add any missing beaches to OpenStreetMap so we can better capture them in future updates.
- This indicator does not account for other factors that influence the quality of beach habitat, such as distance to roads, light pollution, and vulnerability to erosion and sea-level rise.

Other Things to Keep in Mind

- The species chosen for this indicator are birds and sea turtles that nest on beaches. However, the indicator also includes beach habitat used for activities other than nesting, like foraging and breeding.
- This indicator does not always align with Caribbean coastal shoreline condition. Some areas identified as important beach habitat in this indicator, especially those coming from the GAP Wilson's plover model, are scored as armored in coastal shoreline condition (e.g., the Hyatt Regency Grand Hotel in Río Grande, Puerto Rico). This often occurs where riprap is present along narrow beaches, or occasionally near bulkheads. There is often a section of beach present behind the riprap or bulkhead that could still provide habitat, or the riprap is sporadically placed on a long stretch of beach to protect inland structures. In these cases, the mismatch reflects the different intent of these complementary indicators. In some cases, hardened structures may be actually misclassified as beach. Inconsistencies in alignment and classification likely result from the older age and coarser resolution of the GAP data (10 m raster based on 2001 landcover) compared to the more recent and fine-scale CUSP shorelines (vectors dating primarily from 2014-2021) and challenges in distinguishing the unique remote sensing signature of beach vs. riprap and other hardened structures. Because of the 30 m resolution of the Blueprint and underlying data, a single pixel may contain a mix of beach habitat and hardened structures and be reflected differently in each of these two indicators due to their different functions.

Disclaimer: Comparing with Older Indicator Versions

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Caribbean Coastal Shoreline Condition

This indicator assesses shoreline alteration based on the presence of hardened structures like seawalls, groins, and riprap at the dynamic interface between land and water along the U.S. Caribbean coast. It originates from the National Oceanic and Atmospheric Administration's Continuously Updated Shoreline Product.

Reason for Selection

Armoring along shorelines, such as jetties, groins, seawalls, revetments, and other structures, provide a measure of habitat alteration at the dynamic interface between land and water along the coast. Human infrastructure along shorelines generally stabilizes the coastline, impeding natural beach migration processes. Groins, seawalls, jetties, and revetments have resulted in narrowing of beaches, or greater beach loss, compared to unstructured beaches (Dugan et al. 2008, Hall and Pilkey 1991, Mohanty et al. 2012, Pilkey and Wright III 1988). Jetties also alter sand transport and may result in downdrift erosion (Bruun 1995). Hardened structures landward of tidal wetlands can cause "coastal squeeze" by accelerating erosion during storms and preventing inland migration in response to sea-level rise (Gittman 2015).

In Puerto Rico, shoreline stabilization intended to stop shoreline erosion has made beaches narrower and steeper, resulting in "dramatic loss of beach recreational quality and ease of beach access" (Bush et al. 2009).

In addition, hardened shorelines, particularly seawalls, generally support lower levels of biodiversity (Gittman et al. 2015, 2016). Studies funded by the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Coastal Ocean Science found that shoreline hardening has a negative impact on amounts of submerged aquatic vegetation and on fish density and egg-laying (NOAA NCOS 2015, 2013).

Input Data

- National Oceanic and Atmospheric Administration (NOAA) Continuously Updated Shoreline Product (CUSP), accessed 1-11-2023; read a 1-page factsheet about CUSP; view and download CUSP data in the NOAA Shoreline Data Explorer (to download, select "Download CUSP by Region" and select Southeast Caribbean)
- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent

Mapping Steps

- If the "Attribute" field in the CUSP dataset contained the word "natural", assign the feature a value of 1. Assign a value of 0 to all other features.
- Convert the entire CUSP linework to a 30 m raster.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

1 = Natural
0 = Armored

Known Issues

- This indicator overestimates shoreline condition in areas near hardened structures or urban development. It only assigns a low value to places that are currently hardened and not to nearby areas that can also be impacted by that hardening.
- This indicator overestimates shoreline condition in areas with active beach renourishment. Beach renourishment negatively affects some beach and dune species but is not captured by this indicator.

Other Things to Keep in Mind

- This indicator uses a simplified approach compared to its counterpart for the continental Southeast. The continental indicator gives a slightly higher score to partially armored and natural shorelines that fall within the Coastal Barrier Resource System (CBRS). These areas are not eligible for federal flood insurance and can therefore be considered “harder to develop”. We dropped the CBRS from the Caribbean indicator because these areas can still be developed through non-federal investments and will not necessarily remain in a more natural condition. In addition, using just the CBRS does not give a score bump to shorelines in protected conservation lands that are much less likely to develop. We considered giving a higher score to protected shorelines to fix that issue but determined that making already protected shorelines a higher priority for conservation action in the final Blueprint was inconsistent with the intent of the Blueprint and the approach used for other similar indicators. We plan to update the continental version to match in the next Blueprint update.
- This indicator also uses a different data source compared to the continental version. The Caribbean version uses CUSP shoreline data, while the continental uses ESI. Since CUSP is more recent, we plan to update the continental version to match in the next Blueprint update.
- This indicator does not always align with Caribbean beach habitat. Some areas identified as armored in this indicator are scored as important habitat beach habitat, especially in areas where the beach habitat data comes from the GAP Wilson’s plover model (e.g., the Hyatt Regency Grand Hotel in Río Grande, Puerto Rico). This often occurs where riprap is present along narrow beaches, or occasionally near bulkheads. There is often a section of beach present behind the riprap or bulkhead that could still provide habitat, or the riprap is sporadically placed on a long stretch of beach to protect inland structures. In these cases, the mismatch reflects the different intent of these complementary indicators. In some cases, hardened structures may be actually misclassified as beach. Inconsistencies in alignment and classification likely result from the older age and coarser resolution of the GAP data (10 m raster based on 2001 landcover) compared to the more recent and fine-scale CUSP shorelines (vectors dating primarily from 2014-2021) and challenges in distinguishing the unique remote sensing signature of beach vs. riprap and other hardened structures. Because of the 30 m resolution of the Blueprint and underlying data, a single pixel may contain a mix of beach habitat and hardened structures and be reflected differently in each of these two indicators due to their different functions.

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Caribbean Fish Hotspots

This indicator represents areas of high predicted fish density and diversity in the U.S. Caribbean based on the presence of mangroves, seagrass, and coral in close proximity to one another. It draws from research in Puerto Rico that examines fish density and the number of fish species present at different distances from various habitat types (Pittman et al. 2007). It uses benthic habitat data from The Nature Conservancy and landcover from the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program.

Reason for Selection

Nearshore waters where mangroves, seagrass, and coral are all present and within close proximity to one another are likely to support higher densities and diversity of fish species (Pittman et al. 2007). The co-occurrence of these three habitats supports healthy coastal ecosystems and connected seascapes (Gillis et al. 2017). While the movement and dispersal patterns for different fish species can vary widely, mangroves, seagrass, and coral provide key ecological services and functions for many species. For example, mangroves and seagrass beds serve as important nursery habitats, especially for fish species that, as adults, also depend on coral reefs (Nagelkerken et. al 2001). Many fish species, like mangrove snapper and yellowtail snapper, move through all three habitat types within their home ranges (Pittman et al. 2007).

The 300 m and 600 m distance thresholds used in this indicator draw on personal communication with Dr. Simon Pittman (1-25-2023) and several studies examining seascape structure and the number and diversity of fish species present at different distances from various habitat types. Research in southwest Puerto Rico shows that the positive impact of co-occurring mangrove, seagrass, and coral reef habitat on fish abundance is species-specific and strongest at 100 m but ranges between 50 and 600 m (Pittman et al. 2007). In a decision support framework developed for the U.S. Virgin Islands, "coral reefs were deemed strongly connected where they existed within 300 m of seagrasses, mangroves and other reefs" (Pittman et al. 2018). These findings align with research in Australia and the western Pacific that considered habitats within 250-500 m of one another to be highly connected (Olds et al. 2012; Martin et al. 205), and a study in the United Arab Emirates that used a 500 m buffer to prioritize relationships between mangrove, seagrass, and reefs (Pittman et al. 2022).

Input Data

- The Nature Conservancy's (TNC) Caribbean benthic habitat maps; read a press release about the data; read a scientific journal article about the data; request to download the data
- 2012 National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover files for the U.S. Virgin Islands (St. Thomas, St. John, and St. Croix are provided as separate rasters) accessed 4-26-2022; learn more about C-CAP high resolution land cover and change products
- 2010 NOAA C-CAP land cover files for Puerto Rico, accessed 4-26-2022; learn more about C-CAP high resolution land cover and change products
- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent

Mapping Steps

- Mosaic the benthic data for Puerto Rico and the U.S. Virgin Islands.
- Mosaic the C-CAP landcover data for Puerto Rico and the U.S. Virgin Islands.
- Reproject and do a majority resample of the TNC benthic data to 30 m pixels.
- Reproject and do a majority resample of the C-CAP data to 30 m pixels.
- Create a seagrass raster by reclassifying the TNC benthic data so that "dense seagrass" is 1, all other data is 0, and NoData is 1,000. The NoData value helps later in the analysis to remove land and deal with differences in NoData between the C-CAP and TNC benthic data.
- Create a coral raster by reclassifying the TNC benthic data so that "Reef Crest", "Fore Reef", "Back Reef", "Coral/Algae", and "Spur and Groove Reef" are 1, all other classes are 0, and NoData is 0.
- Create a mangrove raster by reclassifying the C-CAP data so that "Estuarine forested wetland" is 1, all other classes are 0, and NoData is 0.
- Combine the mangrove and seagrass data to make a water mask to remove land (including mangroves) from the final indicator.
- 600 m analysis: For each habitat raster (mangrove, seagrass, and coral), use a 20 cell radius circle and maximum in focal statistics to identify areas with at least one pixel of those habitats. Sum these rasters together and multiply by the presence of mangrove (0/1) to get habitat diversity. This step calculates how many of the distinct habitat types occur within a 600 m radius. It also removes the actual mangrove pixels, as this indicator targets the estuarine and marine habitats near mangroves.
- 300 m analysis: Repeat the same steps from the 600 m analysis but use a 10 cell radius.
- Combine the 600 m analysis and 300 m analysis to get final indicator classes.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

4 = Highest predicted fish density/diversity (mangrove, coral, and dense seagrass all present within 300 m)
3 = Very high predicted fish density/diversity (either mangrove and coral, mangrove and dense seagrass, or coral and dense seagrass present within 300 m)
2 = High predicted fish density/diversity (mangrove, coral, and dense seagrass all present within 600 m)
1 = Medium predicted fish density/diversity (either mangrove and coral, mangrove and dense seagrass, or coral and dense seagrass present within 600 m)
0 = Low predicted fish density/diversity (no coral, mangrove, or dense seagrass present within 600 m of one other)

Known Issues

- For some pixels at the edge of the Caribbean subregion, less than half of the 30 m pixel is covered by the finer resolution TNC benthic data. These cells are classified as NoData in the indicator.
- The distances used in this indicator are primarily based on a study conducted in southwest Puerto Rico (Pittman et al. 2007), a decision support framework developed for the U.S. Virgin Islands, and personal communication with the principal investigator of those projects, Dr. Simon Pittman (1-25-2023). While other similar studies in Australia, the western Pacific, and the United Arab Emirates support the distance thresholds chosen for this analysis (Olds et al. 2012, Martin et al. 2015, Pittman et al. 2022), different distances may be more appropriate for other parts of the U.S. Caribbean.
- This indicator may overestimate the fish habitat value of some terrestrial areas that were evaluated by the TNC benthic habitat dataset (e.g., areas near Limetree Bay Refinery in the southern part of St. Croix, USVI).

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Caribbean Fish Nursery Habitat

This indicator represents nursery and spawning habitat or other concentration areas for fish in the U.S. Caribbean. It captures places like mangrove lagoons, bays, estuaries, and some coral reefs. These areas serve as important nursery habitat for many fish species including snook, tarpon, snapper, great barracuda, grunt, mojarra, mullet, jack, bonefish, and more. This data originates from the National Oceanic and Atmospheric Administration's Environmental Sensitivity Index.

Reason for Selection

Areas that provide nursery habitat for juvenile fish, as well as areas where fish spawn and otherwise congregate, are important for ensuring the persistence of abundant and diverse fisheries. Many fish use these habitats during multiple life stages and throughout all seasons. For example, many coastal fish lay their eggs in estuarine habitats because of the combination of food availability for juveniles and protection from predators (Sheaves 2015).

Input Data

- National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index (ESI) data for Puerto Rico and Virgin Islands; download ESI maps and data (PuertoRico_2000_GDB and VirginIsl_2000_GDB, last modified October 10, 2012); read NOAA's definitions of the biological resource classes

  The ESI biological resources data is intended to represent species that are particularly vulnerable to the impacts of oil spills. NOAA classifies these species into seven general categories, referred to as "elements": birds, fish, invertebrates, habitats, marine mammals, terrestrial mammals, and reptiles. NOAA further divides the elements into sub-elements by grouping species with similar characteristics (e.g., taxonomy, morphology, life history, and/or oil spill sensitivity). NOAA compiled the biological resources data with the assistance of biologists from the U.S. Fish and Wildlife Service and other organizations.

  In this indicator, we use polygons associated with the fish element and two sub-elements: estuarine nursery fish and estuarine resident fish. ESI defines the estuarine nursery fish class as "spawning, nursery, or other concentration areas". ESI defines the estuarine resident fish polygons as "spawning or other concentration areas; locations of threatened, endangered, or rare species". The estuarine nursery fish polygons represent habitat for the following estuarine nursery fish: tarpon (*Megalops atlanticus*), mutton snapper (*Lutjanus analis*), yellowtail snapper (*Ocyurus chrysurus*), great barracuda (*Sphyraena barracuda*), common snook (*Centropomus undecimalis*), bonefish (*Albula vulpes*), mojarras (*Diapterus* spp.), mullet (*Mugil* spp.), jacks, grunts, other snappers, and other species generally classified as "nursery fish". The estuarine resident fish polygons represent habitat for mangrove molly (*Poecilia orri*).

  Many of these areas also provide habitat for other species of diadromous, freshwater, marine benthic, and marine pelagic fish. ESI also classifies the e_nursery sub-element fish polygons used in this indicator as associated with the following diadromous fish: sirajo goby (*Sicydium plumieri*), hog-nosed mullet (J*oturus pichardi*), mountain mullet (*Agonostomus monticola*), and other species generally classified as "native stream fish"; the following freshwater fish: largemouth bass (*Micropterus salmoides*), redear sunfish (*Lepomis microlophus*), channel catfish (*Ictalurus punctatus*), peacock bass (*Cichla ocellaris*), and tilapia (*Tilapia* spp.); the following marine benthic fish: red hind (*Epinephelus guttatus*), permit (*Trachinotus falcatus*), butterfly fish (*Chaetodon* spp.), damselfish (*Chromis* spp.), groupers, parrotfish, wrasses, and other species generally classified as "reef fish"; and the following pelagic fish: species generally classified as "pelagic fish".

- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas
- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent

Mapping Steps

- From the ESI geodatabase for Puerto Rico and the U.S. Virgin Islands, select the "fish_polygon" vector layer and the associated "biofile" table. Join the biofile table to the fish polygons using the attribute "RARNUM". Note: be sure to use a one-to-many join because many of the fish polygons are coded to multiple sub-elements.
- Merge the Puerto Rico and USVI fish polygon data into a single layer.
- From the merged fish polygon layer, select by attributes where SUBELEMENT = 'e_nursery' or SUBELEMENT = 'e_resident' and extract the selected polygons.
- Convert the extracted nursery polygons from vector to raster.
- Using the LANDFIRE EVT data, remove all pixels with a value in the EVT_NAME field of "Developed-High Intensity", "Developed-Medium Intensity", "Developed-Low Intensity", "Developed-Roads", "Developed-Open Space" or "Quarries-Strip Mines-Gravel Pits-Well and Wind Pads". This removes areas from the fish nursery polygons that have been urbanized since the ESI data was created.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

1 = Fish spawning, nursery, or other concentration area
0 = Not identified as a fish spawning, nursery, or other concentration area

Known Issues

- The indicator source data was published in 2001. As a result, this indicator may overestimate fish nursery habitat value in areas that have been altered by storms, urbanized, or converted to agriculture since the data was collected. We attempted to remove areas that have been developed using 2020 LANDFIRE EVT landcover. We left in agricultural areas because they may still provide some fish nursery habitat value if inundated.
- The 2020 LANDFIRE EVT landcover misclassifies some parking lots as wet areas due to aerial imagery. These areas may be overprioritized in the indicator.

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Caribbean Seagrass

This indicator represents the presence and density of seagrass at various depths in the U.S. Caribbean. It uses benthic habitat data from The Nature Conservancy and bathymetry data from the National Oceanic and Atmospheric Administration.

Reason for Selection

Seagrass provides food and habitat for a range of marine and estuarine wildlife, including fish, sea turtles, octopuses, and more (NWF 2021). Seagrass in shallow water (<13 m) and very shallow water (<5 m) is particularly important for many species like manatee and queen conch (Marshak et al. 2006, Drew et al. 2012). Most manatee grazing occurs in waters <5 m deep (Drew et al. 2012). Seagrass also produces oxygen, filters water, controls erosion, and buffers storms. It serves as an important indicator of the overall health of coastal ecosystems because it is sensitive to water quality and requires sufficiently clear water for sunlight to penetrate (NPS 2021, NWF 2021). In addition, seagrass meadows are being increasingly recognized for their value as a carbon sink in the face of climate change (McKenzie et al. 2020).

Input Data

- The Nature Conservancy's (TNC) Caribbean benthic habitat maps, accessed 12-21-2022; read a press release about the data; read a scientific journal article about the data; request to download the data

- National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Coastal Relief Model (Vol.9 - Puerto Rico), accessed 11-22-2022

  This layer was preprocessed to create a Caribbean Blueprint bathymetry raster layer. The coastal relief data is in netCDF format. The netCDF layer was imported into ArcPro using the Make NetCDF Raster Layer function in the Multidimensions Toolbox, then saved as a .tif. The horizontal datum was converted to EPSG 5070 and the vertical datum is in meters representing depth.

- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent

Mapping Steps

- Mosaic together TNC's benthic data for Puerto Rico and the Virgin Islands.
- Reclassify the Caribbean bathymetry layer to identify land (0 m and above), very shallow waters (down to 5 m), shallow waters (5-13 m), and deeper waters (below 13 m).
- Reproject and do a majority resample of the benthic data to 30 m pixels.
- Reproject and do a majority resample of the bathymetric data to 30 m pixels.
- Reclassify the benthic data to assign "Dense Seagrass" a value of 2, "Sparse Seagrass" a value of 1, and all other classes a value of 0.
- Combine the benthic and bathymetric data and reclassify into the final indicator values below. The bathymetric data are coarser than 30 m, which results in some nearshore areas being incorrectly classified as land based on the finer resolution benthic data. In these cases, include benthic data classified as "land" as part of shallow water.
- Clip to the Blueprint 2023 Caribbean subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

6 = Very shallow and dense seagrass
5 = Very shallow and sparse seagrass
4 = Shallow and dense seagrass
3 = Shallow and sparse seagrass
2 = Deep and dense seagrass
1 = Deep and sparse seagrass
0 = Not seagrass

Known Issues

- For some pixels at the edge of the Caribbean subregion, less than half of the 30 m pixel is covered by the finer resolution benthic data. These cells are classified as NoData.
- Seagrass depth classes are over and underestimated in some areas—especially nearshore and in the very shallow depth class. The bathymetry data is coarser than 30 m resolution, which results in more coarse estimates of depth.
- Seagrass deeper than 13 m can be hard to differentiate from algae with the Planet Dove imagery used in the TNC benthic map source data. It's likely some areas classified as deep seagrass are actually algae or a mix of algae and seagrass.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Caribbean Shallow Hardbottom & Coral

This indicator measures the presence of hardbottom habitat and coral in the U.S. Caribbean. It also predicts the ability of coral to survive the impacts of climate change based on reef locations, past and future thermal conditions, hurricane impacts, and coral larval connectivity. This indicator combines benthic habitat and coral climate refugia data from The Nature Conservancy.

Reason for Selection

Coral reefs and hardbottom serve as important habitat for much of the marine biodiversity in the Caribbean. They also provide important economic and cultural goods and services that benefit nearby coastal communities, such as supporting fisheries, filtering seawater, and buffering the impacts of storms (NOAA 2020). In addition, coral reefs can serve as environmental indicators of water quality because of their narrow temperature, salinity, and water clarity requirements (EPA 2005).

While climate change will affect all habitats in the Caribbean, coral reefs are likely to face the largest impacts. According to The Nature Conservancy, "...in recent decades, coral cover throughout the region has declined by almost 60 percent. Remaining reefs are threatened by warmer waters, harsher storms, disease, overfishing and pollution" (2019).

In this indicator, we score hardbottom with sparse algae higher than hardbottom with dense algae because algae negatively impact coral colonization and resilience. According to Bonaldo et al., "macroalgae can suppress the settlement, growth and survivorship of corals, thereby limiting the capacity of coral populations to recover following disturbances" (2017).

Input Data

- The Nature Conservancy's (TNC) Caribbean benthic habitat maps, accessed 12-21-2022; read a press release about the data; read a scientific journal article about the data; request to download the data
- TNC coral climate refugia; read a journal article about the data
- Southeast Blueprint 2023 subregions: Caribbean
- Southeast Blueprint 2023 extent

Mapping Steps

- Convert the coral refugia data from vector to raster.
- Reclassify the coral refugia ranks to above and below average values using the field "rank_PRU". Lower values in the rank_PRU class correspond to higher resilience. Values ranging from 1-775 are considered above average, and values ranging from 776-1552 are considered below average. The rank of 0 is not assessed in the Puerto Rico/U.S. Virgin Islands portion of the coral refugia analysis, so treat it as NoData.
- Mosaic together The Nature Conservancy's benthic data for Puerto Rico and the Virgin Islands.
- Reproject and do a majority resample of the benthic data to 30 m pixels.
- Reclassify the benthic data to assign "Reef Crest" (1), "Fore Reef" (2), "Back Reef" (3), "Coral/Algae" (4) and "Spur and Groove Reef" (5) a value of 3; "Hardbottom Sparse Algae" (6) a value of 2, "Hardbottom Dense Algae" (7) a value of 1; and all other classes a value of 0. While conceptually "Boulders and Rocks" (11) would score more highly than the hardbottom sparse and dense algae classes, because algae have a negative impact on coral settlement, no boulders and rocks pixels occur in the TNC benthic data in Puerto Rico and the U.S. Virgin Islands.
- Combine the above rasters and reclassify into the final indicator values seen below.
- Clip to the Caribbean Blueprint 2023 subregion.
- As a final step, clip to the spatial extent of Southeast Blueprint 2023.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Final indicator values

Indicator values are assigned as follows:

5 = Coral with above average climate resilience
4 = Coral with unknown climate resilience
3 = Coral with below average climate resilience
2 = Hardbottom with sparse algae
1 = Hardbottom with dense algae
0 = Not coral or hardbottom

Known Issues

- While the benthic data was at a finer resolution than 30 m, the coral climate refugia analysis was at a 1 km^2 resolution. This likely resulted in this indicator undervaluing or overvaluing a number of 30 m pixels at the edge of the 1 km^2 squares.
- For some pixels at the edge of the Caribbean Blueprint 2023 subregion, less than half of each 30 m pixel is covered by the finer resolution benthic data. These cells are classified as NoData in the final indicator.

Disclaimer: Comparing with Older Indicator Versions

There are numerous problems with using Southeast Blueprint indicators for change analysis. Please consult Blueprint staff if you would like to do this (email hilary_morris@fws.gov).

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Running Zonation

Defining Subregions

We break down the Southeast Blueprint into subregions to reduce processing time and help with balancing weights across indicators in such a large and varied region. The subregions are also used to create ecologically relevant indicators as described in the indicator mapping steps. The [Southeast Blueprint 2023 subregions]() are available on [the Blueprint page of the SECAS Atlas]().

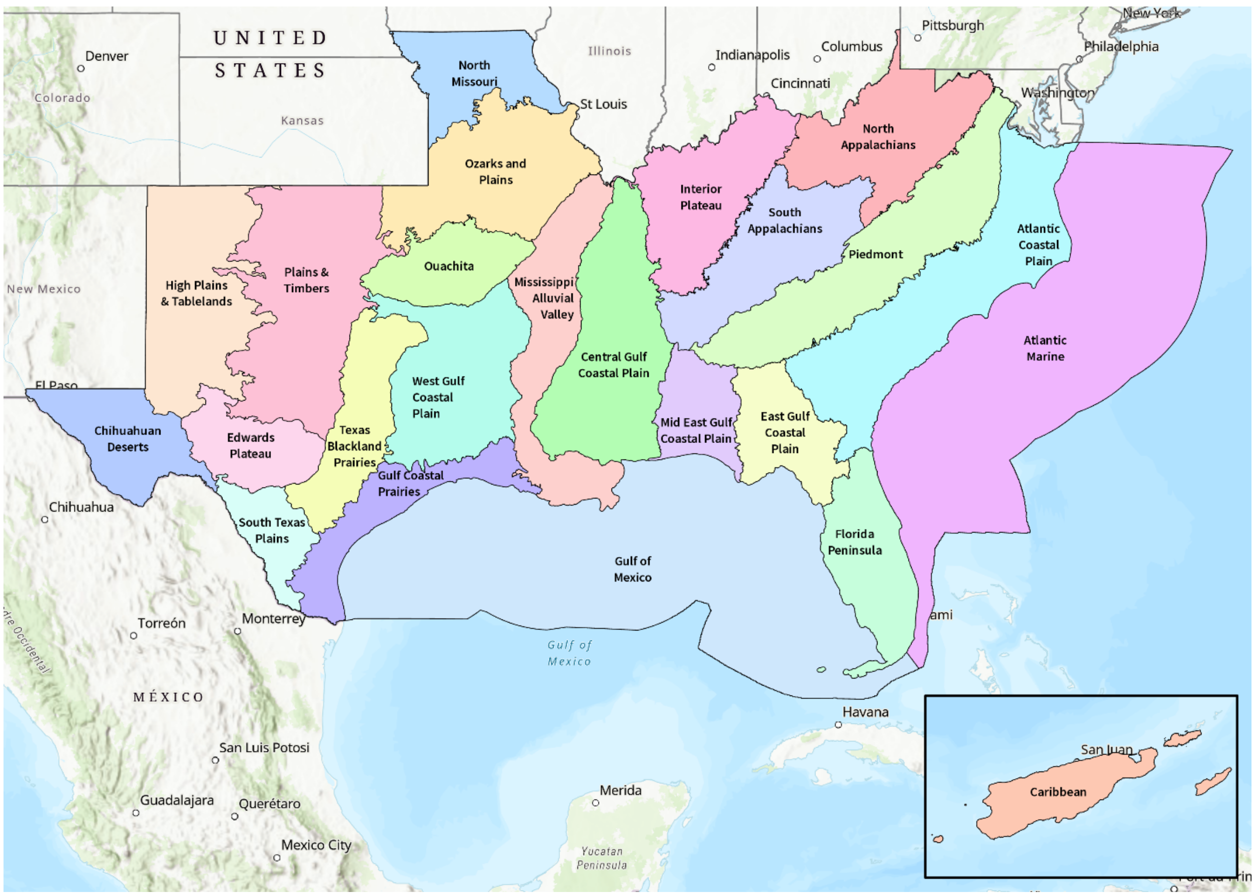

Figure 4. The subregions used in Southeast Blueprint 2023. These are all used to define the extent of the Zonation runs, with the exception of Atlantic Marine and Gulf of Mexico, which are run in Zonation as one combined marine subregion.

Continental

The continental portion of the Southeast Blueprint is composed of 15 Southeast states and the surrounding marine environment to the end of U.S. waters in the Atlantic Ocean and Gulf of Mexico. We further subdivide the continental area into inland and marine subregions as described below.

Inland Subregions

Input Data

- U.S. Environmental Protection Agency (EPA) Level IV Ecoregions shapefile with state boundaries (EPA L4), accessed 12-8-2021
- U.S. Geological Survey (USGS) Watershed Boundary Dataset (WBD), accessed 12-8-2021: HUC4s; download the data
- Marine Ecoregions Level III from the Commission for Environmental Cooperation North American Environmental Atlas, accessed 12-8-2021
- 2021 Census TIGER/Lines State boundary, accessed 12-8-2021

Mapping Steps

For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code. Generally, we used the following mapping steps:

- Identify the non-coastal state boundaries of subregions using the state boundaries from the EPA Level IV ecoregions.
- Define the coastal edges of the subregions using the coastal extent of the HUC4 watersheds.
- Do some initial grouping of the EPA ecoregions to make larger ecoregions. Usually, we grouped by Level III ecoregions; sometimes we went down to the Level IV ecoregions to make smoother, larger ecoregions.
- The EPA ecoregions include some “islands” where part of an ecoregion is not contiguous with the rest. Because we need contiguous subregions to use in running Zonation, identify those “islands” and assign them to the contiguous ecoregion that surrounds them. In addition, some ecoregions have long, finger-like, “peninsulas” that protrude from the ecoregion. Sometimes we assigned these to the surrounding ecoregion to make smoother edges.
- Union together the modified EPA ecoregions and HUC4 watershed layers and reclassify to assign subregions to unique combinations of EPA ecoregions and HUC4 watersheds.
- For the “islands” and “peninsulas” mentioned above, we made exceptions to the above rules and assigned those polygons to the subregion that surrounds them.
- Use the Census TIGER/Lines state boundaries to remove HUC4 areas that extend beyond the Southeast Blueprint extent. This removes some coastal water areas in the Northeast United States that were outside the Southeast Blueprint area.

Inland Subregion Descriptions

Table 2. Definitions of subregions used in the Blueprint. Particularly large SubRgn_I boundaries were subdivided into smaller SubRgn_II boundaries. The larger SubRgn_I boundaries were used to run Zonation in the final Blueprint wherever possible. Smaller SubRgn_II boundaries were used primarily for testing, and only used in the final Blueprint where SubRgn_I boundaries proved too large to be computationally feasible. Green shading and italicized text indicate the boundary used in the final Blueprint.

SubRgn_I	**SubRgn_II**	**Extent**
Atlantic Coastal Plain	North Atlantic Coastal Plain	Defined based on the VA state boundary and the following EPA ecoregions and HUC4s: • EPA L3s: Middle Atlantic Coastal Plain-Code 63, Southeastern Plains-Code 65 • HUC4s: Delaware-Mid Atlantic Coastal-0204, Potomac-0207, Lower Chesapeake-0208, Chowan-Roanoke-0301, Neuse-Pamlico-0302
	Central Atlantic Coastal Plain	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Middle Atlantic Coastal Plain-Code 63, Southeastern Plains-Code 65, Southern Coastal Plain-Code 75 • HUC4s: Cape Fear-0303, Pee Dee-0304 • It also includes a small “peninsula” of EPA L4 Northern Outer Piedmont-Code 45f.
	South Atlantic Coastal Plain	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Southeastern Plains-Code 65, Middle Atlantic Coastal Plain-Code 63, Southern Coastal Plain-Code 75 • HUC4s: Edisto-Santee-0305, Ogeechee-Savannah-0306, Altamaha-St. Marys-0307

SubRgn_I	SubRgn_II	Extent
Piedmont	North Piedmont	Defined based on the VA state boundary and the following EPA ecoregions and HUC4s: • EPA L3s: Piedmont-Code 45, Northern Piedmont-Code 64 • HUC4s: Potomac-0207, Lower Chesapeake-0208, Chowan-Roanoke-0301, Neuse-Pamlico-0302, Cape Fear-0303, Pee Dee-0304 • It also includes several small “islands” and “peninsulas” of EPA L3 Blue Ridge-Code 66.
	South Piedmont	Defined based on the following EPA ecoregion and HUC4s: • EPA L3: Piedmont-Code 45 • HUC4s: Edisto-Santee-0305, Ogeechee-Savannah-0306, Altamaha-St. Marys-0307, Apalachicola-0313, Alabama-0315 • It also includes a few small “islands” and “peninsulas” of EPA L3 Blue Ridge-Code 66.
Appalachians	*North Appalachians*	Defined based on the state boundaries of VA, WV, and KY, as well as the following EPA ecoregions and HUC4s: • EPA L3s: Blue Ridge-Code 66, Ridge and Valley-Code 67, Central Appalachians-Code 69, Western Allegheny Plateau-Code 70, • HUC4s: Potomac-0207, Lower Chesapeake-0208, Chowan-Roanoke-0301, Pee Dee-0304, Monongahela-0502, Upper Ohio-0503, Kanawha-0505, Scioto-0506, Big Sandy-Guyandotte-0507, Middle Ohio-0509, Kentucky-Licking-0510

SubRgn_I	SubRgn_II	Extent
Appalachians	*South Appalachians*	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Blue Ridge-Code 66, Ridge and Valley-Code 67, Southwestern Appalachians-Code 68, Central Appalachians-Code 69, Western Allegheny Plateau-Code 70 • HUC4s: Edisto-Santee-0305, Ogeechee-Savannah-0306, Apalachicola-0313, Alabama-0315, Mobile-Tombigbee-0316, Cumberland-0513, Upper Tennessee-0601, Middle Tennessee-Hiwassee-0602, Middle Tennessee-Elk-0603
Interior Plateau	*Interior Plateau*	Defined based on the state boundary of KY and the following EPA ecoregions: • EPA L3s: Interior Plateau-Code 71, Interior River Valleys and Hills-Code 72 • It also includes a few small "islands" and "peninsulas" of EPA L3 Southwestern Appalachians-Code 68.

SubRgn_I	SubRgn_II	Extent
East Gulf Coastal Plain	*Central Gulf Coastal Plain*	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Southeastern Plains-Code 65, Mississippi Valley Loess Plains-Code 74, Southern Coastal Plain-Code 75 • HUC4s: Mobile-Tombigbee-0316, Pascagoula-0317, Pearl-0318, Middle Tennessee-Elk-0603, Lower Tennesee-0604, Lower Mississippi-Hatchie-0801, Lower Mississippi-Yazoo-0803, Lower Mississippi-Big Black-0806, Lower Mississippi-Lake Maurepas-0807, Lower Mississippi-0809
	Mid East Gulf Coastal Plain	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Southeastern Plains-Code 65, Southern Coastal Plain-Code 75 • HUC4s: Choctawhatchee-Escambia-0314, Alabama-0315
	East Gulf Coastal Plain	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Southeastern Plains-Code 65, Southern Coastal Plain-Code 75 • HUC4s: Suwannee-0311, Ochlockonee-0312, Apalachicola-0313
Florida Peninsula	*Florida Peninsula*	Defined based on the following EPA ecoregions and HUC4s: • EPA L3s: Southern Coastal Plain-Code 75, Southern Florida Coastal Plain-Code 76 • HUC4s: St. Johns-0308, Southern Florida-0309, Peace-Tampa Bay-0310

SubRgn_I	SubRgn_II	Extent
Mississippi Alluvial Valley	*Mississippi Alluvial Valley*	Defined based on the MO state boundary and the following EPA ecoregion: • EPA L3: Mississippi Alluvial Plain-Code 73 • It also includes a few “islands” of EPA L3 South Central Plains-Code 35 and Mississippi Valley Loess Plains-Code 74, as well as a “peninsula” of EPA L3 Interior River Valleys and Hills-Code 72.
West Gulf Coastal Plain	*West Gulf Coastal Plain*	Defined based on the following EPA ecoregion: • EPA L3: South Central Plains-Code 35
Gulf Coastal Prairies	*Gulf Coastal Prairies*	Defined based on the following EPA ecoregion: • EPA L3: Western Gulf Coastal Plain-Code 34 • It also contains an “island” of EPA L3 Mississippi Alluvial Plain-Code 73.
South Texas Plains	*South Texas Plains*	Defined based on the following EPA ecoregion: • EPA L3: Southern Texas Plains-Code 31
Texas Blackland Prairies	*Texas Blackland Prairies*	Defined based on the following EPA ecoregions: • EPA L3s: Texas Blackland Prairies-Code 32, East Central Texas Plains-Code 33
Edwards Plateau	*Edwards Plateau*	Defined based on the following EPA ecoregion: • EPA L3: Edwards Plateau-Code 30

SubRgn_I	SubRgn_II	Extent
Chihuahuan Deserts	*Chihuahuan Deserts*	Defined based on the TX state boundary and the following EPA ecoregion: • EPA L3: Chihuahuan Desert-Code 24 • It also contains a “peninsula” of EPA L3 Arizona/New Mexico Mountains-Code 23.
High Plains and Tablelands	North High Plains and Tablelands	Defined based on the TX state boundary and the following EPA ecoregions and HUC4s: • EPA L3: High Plains-Code 25, Southwestern Tablelands-Code 26 • HUC4: Upper Cimarron-1104, Lower Cimarron-1105, Arksansas-Keystone-1106, Lower Canadian-1109, Red Headwaters-1112, Red-Washita-1113, North Canadian-1110 • It also contains an “island” of EPA L3 Edwards Plateau-Code 30.
	South High Plains and Tablelands	Defined based on the TX state boundary and the following EPA ecoregions and HUC4s: • EPA L3: High Plains-Code 25, Southwestern Tablelands-Code 26 • HUC4: Brazos Headwaters-1205, Middle Brazos-1206, Upper Colorado-1208, Lower Colorado-San Bernard Coastal-1209, Lower Pecos-1307

SubRgn_I	SubRgn_II	Extent
Plains and Timbers	*Plains and Timbers*	Defined based on the TX state boundary and the following EPA ecoregions and HUC4s: • EPA L3s: Central Great Plains-Code 27, Cross Timbers-Code 29 • HUC4: Upper Cimarron-1104, Lower Cimarron-1105, Arksansas-Keystone-1106, Neosho-Verdigris-1107, Lower Canadian-1109, North Canadian-1110, Lower Arkansas-1111, Red Headwaters-1112, Red-Washita-1113, Red Sulphur-1114, Trinity-1203, Brazos Headwaters-1205, Middle Brazos-1206, Lower Brazos-1207, Upper Colorado-1208, Lower Colorado-San Bernard Coastal-1209 • It also contains a “peninsula” of EPA L3 Flint Hills-Code 28.
Ouachita	*Ouachita*	Defined based on the following EPA ecoregions: • EPA L3s: South Ouachita Mountains-Code 36, Arkansas Valley-Code 37, Boston Mountains-Code 38

SubRgn_I	SubRgn_II	Extent
Ozarks and Plains	*Ozarks and Plains*	Defined based on the OK and MO state boundaries and the following EPA ecoregions and HUC4s: • EPA L3s: Ozark Highlands-Code 39, Central Irregular Plains-Code 40, Interior River Valleys and Hills-Code 72 • HUC4s: Upper Mississippi-Salt-0711, Upper Mississippi-Kaskaskia-Meramec-0714, Lower Mississippi-St. Francis-0802, Chariton-Grand-1028, Gasconade-Osage-1029, Lower Misssouri-1030, Upper White-1101, Neosho-Verdigris-1107, Lower Canadian-1109, North Canadian-1110, Lower Arkansas-1111
North Missouri	*North Missouri*	Defined based on the MO state boundary and the following EPA ecoregions and HUC4s: • EPA L3s: Central Irregular Plains-Code 40, Western Corn Belt Code 47, Interior River Valleys and Hills-Code 72 • HUC4s: Des Moines-0710, Upper Mississippi-Salt-0711, Missouri-Nishnabotna-1024, Kansas-1027, Chariton-Grand-1028, Gasconade-Osage-1029, Lower Missouri-1030

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Marine Subregion

For the purposes of Zonation, we do not further subdivide the marine subregion, although the steps below do create finer Atlantic and Gulf marine layers that are used in the development of several marine continental indicators and are shown in Figure 4 above.

Input Data

- National Oceanic and Atmospheric Administration (NOAA) U.S. Maritime Limits and Boundaries, accessed 11-22-2022
- Base Blueprint 2022 extent

Mapping Steps

- For both the Atlantic and the Gulf of Mexico, define the inshore extent by the Base Blueprint 2022 extent.
- Hand-digitize the offshore extent using the “trace” editing feature and the offshore Exclusive Economic Zone (EEZ) boundary from the U.S. Maritime Limits and Boundaries layer.
- Extend the northernmost extent of the offshore Atlantic marine boundary by-hand editing following the Base Blueprint 2022 extent and a SW to NE extension guided by the EEZ boundaries.
- In the absence of any other supporting justification, impose an artificial break to split the Gulf and the Atlantic marine zones near Key Largo, FL. This separation is an approximate extension of US Hwy 1.
- Convert the final vector dataset to raster using the GDAL Vector to Raster utility in QGIS and snap to the extent and cell size of the 2022 Base Blueprint.

Literature Cited

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Caribbean

The Caribbean portion of the Southeast Blueprint is composed of Puerto Rico, the U.S. Virgin Islands, and a subset of the surrounding marine environment. It was intended to cover as broad a swath as possible of the terrestrial, freshwater, and marine environments of Puerto Rico and the U.S. Virgin Islands given the data available.

Caribbean Subregion

We did not further subdivide the Caribbean subregion because the area is small enough that it is computationally feasible to run the analysis across the entire area.

Input Data

- The Nature Conservancy's (TNC) Caribbean benthic habitat maps, accessed 12-21-2022: read a press release about the data; read a scientific journal article about the data; request to download the data
- National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Coastal Relief Model (Vol.9 - Puerto Rico), accessed 11-22-2022
- NOAA U.S. Maritime Limits and Boundaries, accessed 11-22-2022
- NOAA Continuously Updated Shoreline Product (CUSP), accessed 1-18-2023; read a 1-page factsheet about CUSP; view and download CUSP data in the NOAA Shoreline Data Explorer (to download, select "Download CUSP by Region" and select Southeast Caribbean)
- LANDFIRE 2020 (version 2.2.0) Puerto Rico, US Virgin Islands: Existing Vegetation Type (EVT)

Mapping Steps

- Processing steps were performed in the QGIS v3.22 graphical modeler.
- Prepare the TNC benthic data by merging together the U.S. Virgin Islands and Puerto Rico layers into one dataset using the DGDAL Merge utility. Using the Reclassify utility, reclassify the TNC benthic classes into a single class representing the extent of the TNC benthic analysis.
- Prepare the coastal relief data by importing the netCDF file using the Import NetCDF function. Reclassify the coastal relief data to assign a value of 0 to elevations ranging from -10,000-0 and a value of 1 to elevations ranging from 0.0001 to 1,500. This separates out all land areas, which have an elevation >0.
- Prepare the U.S. maritime limits and boundaries data by selecting the marine boundaries for Puerto Rico and the U.S. Virgin Islands. Select all lines with a REGION field value of "Puerto Rico and U.S. Virgin Islands". Hand-edit the marine boundary lines to create marine boundary polygons.

- Fill in the holes in the marine boundary polygons, which represent land areas, using the Delete Holes utility. This creates a layer representing the combined land and sea jurisdiction of Puerto Rico and the U.S. Virgin Islands.
- Clip the processed coastal relief data to the Puerto Rico and the U.S. Virgin Islands land and sea jurisdiction layer using the GDAL Clip utility. This step removes data in the British Virgin Islands, creating an elevation layer that distinguishes land and sea areas within Puerto Rico and the U.S. Virgin Islands.
- Combine the U.S. Caribbean elevation layer with the TNC benthic data to create a preliminary extent using the Raster Boolean OR utility. The resulting layer includes all land pixels with an elevation >0 in NOAA's coastal relief model and all sea pixels assessed in TNC's benthic habitat layer.
- Convert that layer to vector using the GRASS Raster to Vector utility and extract the desired TNC benthic and land areas from the background values using Select by Attribute.
- The resulting layer has gaps in coverage between the land and TNC benthic ocean values. Remove holes <1,000,000 m^2 (247 acres) using the Delete Holes utility.
- Use hand-digitizing to further modify the extent to include areas captured in the CUSP shoreline dataset. Use the CUSP line data to create a polygon covering Isla Desecheo, which was not included in the coastal relief model.
- Cricket Rock, Dutchcap Key, Cockroach Island, Mona Island and Isla Monita were all excluded from the coastal relief model but did have a marine extent included in the benthic habitat data. Guided by the CUSP shoreline data, hand-edit each of the polygons for these small islands to fill in the land areas.
- Convert the final vector dataset to raster using the GDAL Vector to Raster utility in QGIS and snap to the extent and cell size of the LANDFIRE 2020 EVT raster.

Literature Cited

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Defining Extent

The exterior boundary of the collection of subregions described above represents the Southeast Blueprint 2023 extent. For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code. The final step of the code used to create the subregions exports the extent layer. The Southeast Blueprint 2023 extent is available on the Blueprint page of the SECAS Atlas.

Overall Zonation Approach

The Southeast Blueprint indicators were modeled at a 30 m resolution, tested and reviewed, and used as inputs to identify priority areas for a connected network of lands and waters. The indicators then served as inputs into Zonation, a conservation planning framework and software program that produces a hierarchical prioritization of the landscape.

We ran Zonation within 23 subregions (see Figure 4 above). Zonation ranks the pixels in each subregion according to their indicator scores, using a modeling approach that tries to conserve high-value representations of all indicators collectively. Pixels that rank higher in Zonation become higher priority in the Blueprint.

Inland Continental

In the inland continental Southeast subregions, we used Zonation version 4.

Removing Highly Altered Areas

Reasoning

In Zonation version 4, removing highly altered areas before running helps the algorithm start removing pixels at the edges of the most altered areas. This creates a more connected network of lands and waters in the resulting priorities and speeds up overall runtime.

We removed three types of places: 1) select roads, 2) select developed areas, and 3) reservoirs. Generally, these areas would not be prioritized in the Blueprint anyway. However, some developed areas, such as vacant lots, may be targets for creation of parks that provide equitable access for communities that currently lack park access.

To better include those areas, we only removed the two highest NLCD urban classes (medium and high intensity). This left in some additional areas that may be vacant lots, but it also left in many roads, which are not available for creation of parks. To address this, we then went back and removed select roads. We are exploring methods in the future that will not require the removal of these highly developed areas.

Reservoirs, while highly altered systems, do still have conservation value. Unfortunately, the current set of indicators do not do a good job of capturing important parts of those reservoirs. The indicators do, however, capture the value of areas surrounding reservoirs, and those areas are not removed. The areas around reservoirs are also where most conservation actions occur to improve reservoir condition.

Input Data

- USGS National Hydrography Database (High Resolution) in FileGDB 10.1 format (published 08-30-2021) - NHDWaterbody and NHDFlowlines, accessed 10-14-2021
- National Inventory of Dams (NID), accessed 10-15-2021; download the data
- 2019 National Land Cover Database (NLCD)
- Floodplain Inundation Frequency Southeast version: available on request by emailing yvonne_allen@fws.gov
- OpenStreetMap data "roads" layer, accessed 3-11-2021

  OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

- Base Blueprint 2022 extent

Mapping Steps

Reservoirs

- Make copies of the NHDWaterbody and NHDFlowlines layers for editing.
- Extract features identified as either "LakePond" or "Reservoir" from the NHDWaterbody layer. Most reservoirs in the Southeast region are coded as "LakePond" in this dataset.
- Make a geospatial layer of the National Inventory of Dams (NID) from the source .csv file.
- Select NHD waterbodies that are within 200 m of NID locations.
- Add to the selection all NHD waterbodies that are within 5 m of the selection generated in the previous step to ensure that all parts of a single waterbody are selected.
- Select NHD flowlines that are within 50 m of NID locations.
- Select NHD waterbodies that are within 50 m of the selection generated in the previous step.

- At this stage, we did some hand-editing to add in obvious large reservoirs (especially in Texas) that were omitted from the above selections because the NID did not capture the dam locations. We used Inundation Frequency and the 2019 NLCD to assist in this step. In addition, the NHD contains some misclassified reservoirs (e.g., reservoirs classified as swamp/marsh or stream/river) that we manually added in. Note: The NID is also missing many dam locations associated with small farm ponds, which are too numerous to add by hand.
- Convert to raster using the ArcPy Polygon to Raster function and clip to the spatial extent of Base Blueprint 2022.

Roads and highly developed areas

- Identify large roads from the OpenStreetMap data using the fclass field. Roads that had a value of motorway, motorway_link, trunk, trunk_link, primary, primary_link in the fclass field were considered large roads.
- Convert large roads from the OpenStreetMap data to a 30 m raster.
- Identify medium roads from the OpenStreetMap data using the fclass field. Roads that had a value of secondary, secondary_link, tertiary, or tertiary_link in the fclass field were considered medium roads.
- Covert medium roads from the OpenStreetMap data to a 10 m raster and then resample to a 30 m raster using the nearest resampling technique. This was done because many of these roads are less than 30 m wide and converting straight to a 30 m raster made them too prominent.
- Identify areas with values of medium intensity developed or high intensity developed in the 2019 NLCD. These were considered highly developed areas.
- Combine the large road raster, the medium road raster, and the highly developed areas raster.

Combining reservoirs and highly developed areas

- Remove the roads, highly developed areas, and the reservoirs from the Zonation analysis extent for each subregion.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Zonation Run Settings

Determining Indicator Weights

We developed indicator weighting rules to ensure that:

- Spatially limited indicators were not overprioritized
- Significantly outdated indicator data has less of an influence

Spatially limited indicators

With equal weights, the entire area of many indicators that cover a limited part of the subregion (e.g., South Atlantic beach birds, greenways and trails) is identified as a high priority. To address this issue, we weighted indicators based on the proportion of their total area with values ≥1.

For indicators where the proportion of ≥1 values was between 0.5 and 0.1, we set their weights equal to that proportion. For example, we set the imperiled aquatic species indicator weight to approximately0.22 in the Atlantic Coastal Plain because that was the proportion of pixels analyzed by Zonation in that subregion with a value ≥1. For indicators where the proportion of ≥1 values was ≤0.1, we set their weights equal to that proportion multiplied by 3. We found that indicators in this range began to be underprioritized when only using the unadjusted proportion.

For indicators where the proportion of ≥1 values was 0.5 and higher, we set their weight to 1.0 unless they were covered by the exceptions discussed below.

Significantly outdated indicator data

One of our indicators is based on relatively old data: South Atlantic forest birds. This indicator identified some areas as high priority that no longer made sense given the current condition of those places. After applying the rule discussed above in "spatially limited indicators", we further reduced the weights of this indicator by multiplying its weight by 0.1.

Other exceptions

Intact habitat cores

We only weighted the intact habitat cores indicator where the proportion of ≥1 values was less than 0.3. Applying the "spatially limited indicators" weighting rule in subregions where the proportion of ≥1 values ranged from 0.3-0.5 resulted in many important areas for conservation not being prioritized in the Blueprint.

Network complexity within Florida Peninsula subregion

Within the Florida Peninsula subregion, this indicator overestimates connectivity in artificial suburban ponds, resulting in overprioritization of these areas. After applying the rule discussed above in the "spatially limited indicators" section, we further reduced the weight of this indicator by multiplying its weight by 0.1 within the Florida Peninsula subregion.

Imperiled aquatic species within High Plains & Tablelands subregion

Within the High Plains and Tablelands subregion, applying the standard weighting rules to imperiled aquatic species underprioritized areas important for that indicator. Adding a zero class to this indicator in 2023 changed the indicator weight from the previous year. To address this, we modified the "spatially limited indicators" rule described above to apply to ≥2 values instead of ≥1. This increased the weight for the indicator in this subregion.

Natural landcover in floodplains within Ouachita subregion

In 2023, this indicator in this subregion fell on the other side of an indicator weighting threshold compared to the previous year, which lowered its weight significantly. Sometimes priorities in certain subregions can be particularly sensitive to those thresholds. To maintain consistency with the 2022 Blueprint, we applied the spatially limited indicators weighting rule for indicators where the proportion of ≥1 values is ≤0.1, instead of the one where the proportion of ≥1 values is 0.5 to 0.1.

Interior Southeast Grasslands within North Appalachians, South Appalachians, Piedmont, and Ozarks & Plains subregions

In these four subregions, where the top indicator class (known grassland) covers less than 0.03% of the area, lower indicator values were having too strong of an impact on the subregion's priorities. To address this, we multiplied the weight of Interior Southeast Grasslands by 0.5 in those subregions.

Removal Rule

1 (basic core-area Zonation): In basic core-area Zonation (commonly CAZ), cell removal is done in a manner that minimizes biological loss by picking the cell that has the smallest occurrence for the most valuable overall biodiversity features in the cell. In other words, the cell gets a high value if even one indicator has a relatively important occurrence there.

Boundary Length Penalty

0 (not used): Boundary length penalty (BLP) is a method to induce aggregation of high priority areas. Using a BLP, the hierarchy of cell removal is based upon the conservation value of the cell and the increase/decrease of boundary length that results from the removal of a cell.

Warp Factor

10,000: The warp factor defines how many cells are removed at a time per iteration. A lower warp factor provides a finer solution but requires a longer model run time. A higher warp factor reduces the time required to run a model but results in a coarser solution. To improve speed and model performance, we chose a warp factor of 10,000 for all inland subregions and 1,000 for all marine subregions.

Edge Removal

1: Determines whether the program removes cells from the edges of remaining landscape (value = 1) or anywhere from the landscape (value = 0).

Zonation Inputs & Weights for Each Subregion

To see the weights used for each indicator in each inland continental subregion, see the Zonation feature list files see the Zonation feature list files available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Rebalancing Zonation Results

Rebalancing the Results for Each Subregion

The Zonation software outputs a raster layer with values ranging from a very small fraction close to 0 to 1 (the actual minimum value depends on the size of the input area). The values in the Zonation output represent the percent of the input area ranked from highest priority to lowest priority, according to the indicators. So, if we take the values in the Zonation output that range between 0.9 and 1, this represents the best 10% of the input area.

In the inland continental subregions, we removed highly altered areas before we ran Zonation (described in the Removing Highly Altered Areas section above). As a result, the outputs from Zonation represent a subset of each subregion's area, and not the entire subregion. So, we need to convert the Zonation output values into the percent of the whole subregion (currently, they are the percent of the portion of the subregion we gave it, which excludes highly altered areas).

To account for this, we rescaled the Zonation outputs using a linear rescale. The goal is to have the top 10% of each subregion score "highest priority," the next 15% score "high priority," and the next 20% score "medium priority."

First, we calculated the percentage of each subregion that was left out of Zonation (highly altered areas). Then we used the ArcPy linear Rescale function to convert every pixel from the original Zonation output to a new value, so that the new minimum is equal to the percent of the subregion that was left out of Zonation and the new maximum value is 100. The linear rescale both shifts the values up and condenses the values (because the percent of subregion area covered by each pixel is smaller now that we have a bigger denominator). Then we added back in the areas that were left out of Zonation (highly altered areas) and gave them a value of 0 (this puts them in the bottom of the stack and ensures they don't interfere with any of the other values when we add in the 5% of the area covered by corridors later).

The result is that we have more priority areas in the linear rescale output than we had in the Zonation output, because we have made the "highest priority" class cover 10% of the entire subregion and not just 10% of a portion of the subregion.

These methods treat reservoirs the same as the select roads and highly developed areas. This allows priorities that would have gone to reservoirs, select roads, or highly developed areas (if they had ranked highly enough to get prioritized in Zonation based on their indicator scores) to be applied to other areas inside the subregion. So, even if a subregion has a lot of reservoirs and/or development taking up space, it still gets 10% of the total subregion as highest priority, 15% as high priority, and 20% as medium priority.

The resulting Blueprint output matches the result we would get if we had given Zonation all the reservoirs and developed areas, and they just had very low indicator scores.

In the future, we want to develop indicators that specifically measure the value or importance of reservoirs. Since we do not have those indicators for Blueprint 2022, we cannot score reservoirs relative to each other. Considering this lack of information, we decided this was the best option for Blueprint 2022, as it does not punish subregions that have a lot of reservoirs by limiting the total amount of priority areas those subregions are allotted.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Marine Continental

In the marine continental subregion, we used Zonation version 5. The overall approach for the marine differs from the inland in that we do not remove highly altered areas or use edge removal.

Zonation Run Settings

Determining Indicator Weights

We developed indicator weighting rules to ensure that:

- Spatially limited indicators were not overprioritized
- Priorities were relatively balanced between Gulf and Atlantic areas

Spatially limited indicators

With equal weights, the entire area of many indicators that cover a limited part of the subregion (e.g., estuarine coastal condition, Atlantic estuarine fish habitat) is identified as a high priority. To address this issue, we weighted indicators based on the proportion of their total area with values ≥1.

For indicators where the proportion of ≥1 values was between 0.5 and 0.1, we set their weights equal to that proportion. For example, we set the gulf coral and hardbottom indicator weight to approximately 0.256 because that was the proportion of pixels analyzed by Zonation in the marine subregion with a value ≥1. For indicators where the proportion of ≥1 values was ≤0.1, we set their weights equal to that proportion multiplied by 3. We found that indicators in this range began to be underprioritized when only using the unadjusted proportion.

For indicators where the proportion of ≥1 values was 0.5 and higher, we set their weight to 1.0 unless they were covered by the exceptions discussed below.

Balancing Atlantic & Gulf priorities

The marine subregion includes many indicators that only cover either the Atlantic or the Gulf. In order to better balance priorities across those areas, we made two modifications to the indicator weighting rules. The first modification was only weighting bird, mammal, and turtle indicators when the proportion of ≥1 values was less than 0.3. The second change was increasing the weight of two indicators that were getting significantly under-represented in the Blueprint priorities (Atlantic coral and hardbottom, Gulf deep-sea coral richness) from 0.3 to 0.75.

Marginal Loss Rule

CAZMAX: This setting is consistent with basic core-area Zonation (commonly CAZ) in Zonation 4. It tries to always cover high-value locations for all indicators, even if this comes with the cost of achieving lower average coverage across all indicators.

Zonation Inputs & Weights

To see the weights used for each indicator in the marine continental subregion, see the Zonation feature list files available [in the Southeast Blueprint 2023 Data Download] under > 6_Code.

Caribbean

In the Caribbean subregion, we used [Zonation version 5]. The overall approach for the Caribbean is consistent with the marine continental but differs from the inland continental in that we do not remove highly altered areas or use edge removal.

Zonation Run Settings

Determining Indicator Weights

We developed indicator weighting rules to ensure that:

- Spatially limited indicators were not overprioritized

Spatially limited indicators

With equal weights, the entire area of many indicators that cover a limited part of the subregion (e.g., Caribbean beach habitat, Caribbean greenways and trails) is identified as a high priority. To address this issue, we weighted indicators based on the proportion of their total area with values ≥1.

For indicators where the proportion of ≥1 values was between 0.5 and 0.1, we set their weights equal to that proportion. For example, we set the Caribbean karst habitat indicator weight to approximately 0.228 because that was the proportion of pixels analyzed by Zonation in the Caribbean subregion with a value ≥1. For indicators where the proportion of ≥1 values was ≤0.1, we set their weights equal to that proportion multiplied by 3. We found that indicators in this range began to be underprioritized when only using the unadjusted proportion.

For indicators where the proportion of ≥1 values was 0.5 and higher, we set their weight to 1.0.

Removal Rule

CAZMAX: This setting is consistent with basic core-area Zonation (commonly CAZ) in Zonation 4. It tries to always cover high-value locations for all indicators, even if this comes with the cost of achieving lower average coverage across all indicators.

Zonation Inputs & Weights

To see the weights used for each indicator in the Caribbean subregion, see the Zonation feature list files available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Combining Caribbean & Continental Results

Next, we mosaiced together the rebalanced Zonation results for the inland continental subregions, the marine continental subregion, and the Caribbean subregion. In this mosaiced, rebalanced Zonation results layer, each pixel in the Southeast Blueprint geography has a continuous value ranging from 0 to 100 according to its rank by the Zonation prioritization, rebalanced by linear rescale. The output of this step, the combined Zonation results for the Southeast Blueprint, is available on the Blueprint page of the SECAS Atlas.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

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Connectivity

The Southeast Blueprint uses a least-cost path connectivity analysis to identify connections between priority areas. A program called Linkage Mapper defines corridors that link hubs across the shortest distance possible, while also routing through as much Blueprint priority as possible. The results of the connectivity analysis, the Southeast Blueprint 2023 hubs and corridors, are available on the Blueprint page of the SECAS Atlas.

Continental

In the continental geography, inland corridors connect large patches of highest priority Blueprint areas and/or protected lands. Marine/estuarine corridors connect large estuaries and/or large patches of highest priority Blueprint areas, within broad marine mammal and turtle movement areas. We split the inland and marine/estuarine analyses to overcome data and methodological issues with running them together. In future versions of the Blueprint, we hope to run them together in an integrated analysis.

Inland Hubs & Corridors

Inland Resistance Raster

This is the resistance raster or cost surface used in the Linkage Mapper-based connectivity analysis for the inland continental portion of Blueprint 2023.

Input Data

- 2023 Southeast Blueprint subregions
- U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), accessed 3-4-2021
- 2023 combined Zonation results
- The Nature Conservancy's (TNC) Terrestrial Resilience - Local Connectedness (Anderson et al. 2016)
- Florida Wildlife Road crossings, last updated 12-7-2020
- Select North Carolina wildlife road crossings

  Eastern NC crossings were provided by Gary Jordan at the Raleigh, NC U.S. Fish and Wildlife Service Ecological Services field office on 7-22-2021; Gary received these data from Travis Wilson at the North Carolina Wildlife Resources Commission. Other wildlife road crossings in NC were provided by Alex Vanko from the Wildlands Network and Steve Goodman from the National Parks Conservation Association. Some of these are dedicated crossing structures and some are bridge replacements that were specifically widened to accommodate wildlife; this is not a census of all widened bridge replacements.

- OpenStreetMap data “roads” layer, accessed 2-23-2022

  OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). Additional credit to OSM contributors. Read more on the OSM copyright page.

- 2019 National Land Cover Database (NLCD)
- U.S. Geological Survey (USGS) Watershed Boundary Dataset (WBD), accessed 12-2-2021: HUC2s; download the data

Mapping Steps

Define inland/nearshore extent of resistance raster

- Dissolve all the inland/nearshore polygons from the Southeast Blueprint 2023 subregions into one polygon.
- Buffer the inland/nearshore polygons by 26.1 km. The distance of 26.1 km is based on dispersal distances of subadult black bears (White et al. 2000), a species that disperses from within the Southeast Blueprint geography into neighboring areas.
- Use the WBD HUC2 boundaries to remove buffer area in the marine environment.
- Convert to a 30 m raster that represents the inland continental subregions. This still includes estuarine areas that will be removed later.

Combine the TNC Local Connectedness and combined Zonation results

- Use the local connectedness layer from TNC’s Resilient Land project to fill in a buffer area around the inland continental Southeast Blueprint geography. This allows corridors to connect from inside the inland continental Southeast Blueprint geography into neighboring landscapes.
- Clip TNC local connectedness to the buffered inland/nearshore area.
- Using the ArcPy Rescale-Linear function, rescale the local connectedness layer to assign values ranging from 1 to 100. Also, flip the high and low values so that areas with high local connectedness are easier to move through (i.e., lower resistance) than areas of low local connectedness.
- Similarly, flip the combined Zonation results so that areas that rank higher in Zonation are easier to move through.
- Mosaic together the resulting local connectedness layer and Zonation layer, only using the local connectedness in places where there are no Zonation results.

Remove deep estuarine/marine areas from the resistance raster

- Use the National Wetlands Inventory (NWI) data to remove deep estuarine/marine areas for the purposes of the connectivity analysis. Select the Estuarine and Marine Deepwater NWI class, and covert those areas to a raster. Reclassify the raster so that the deepwater estuaries and marine have a value of NoData and everything else has a value of 1. This creates a mask representing estuaries that we want to remove from the inland corridor analysis.
- Remove the estuaries from the inland resistance raster by taking the deepwater estuary mask times the mosaiced Zonation results and TNC local connectedness raster created above. This removes deepwater estuaries and marine areas, limiting the resistance raster to the inland corridor extent.
- Take the Southeast Blueprint 2023 inland continental subregions times the deepwater estuary mask to define the extent of the inland corridor analysis, which will be used later.

Burn NLCD urban into resistance raster

- To get the Linkage Mapper connectivity analysis to run successfully across the whole area, we had to resample the resistance raster from 30 m to 90 m. During this process, developed areas often get resampled out. To make sure that the connectivity analysis has sufficient information to move around developed areas, select the high and medium developed classes from the NLCD, resample them to 90 m, and burn them into the resistance raster with a high resistance value (150).

Make known wildlife road crossings easy to move through

We obtained a small sample of known wildlife road crossings for North Carolina and Florida. This served as a test to route corridors through these crossings. We would like to get more spatial data for wildlife road crossings in the future.

- Buffer known wildlife road crossings by 210 m and convert them to raster with a low resistance value (1) that makes it easy for corridors to route through.
- Select roads surrounding known wildlife road crossings from the OpenStreetMap data. We do not want corridors to go across these roads except at the designated crossings, so we needed to make the resistance very high in these areas. Buffer the roads by 180 m and convert to raster with a very high resistance value (150).
- In testing, the methods above weren’t enough to encourage corridors to route through the crossings, so we buffered the crossings again, this time by 900 m, erased the road areas from the larger buffered crossings (so the roads remained a high value) and converted to a raster with value that is easier to move through (10).
- Combine the roads with the combined Zonation results, using a maximum value so that these roads are very hard to cross.
- Combine the above raster with the two buffered road crossing layers, using a minimum value so that the areas with wildlife road crossings get the lower value from the buffered road crossing layers or Zonation results.

Resample to 90 m

- Using the ArcPy Resample-Bilinear function, resample the resistance layer from 30 m to 90 m to allow it to run successfully in Linkage Mapper. The result is the final inland continental resistance raster.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Inland Hubs

These are the hubs used in the Linkage Mapper-based connectivity analysis for the inland continental portion of Blueprint 2023.

Input Data

- Southeast Blueprint 2023 extent
- 2023 Southeast Blueprint subregions
- 2023 combined Zonation results
- The Nature Conservancy's (TNC) Terrestrial Resilience - Local Connectedness (Anderson et al. 2016)
- Protected Areas Database of the United States (PAD-US) 2.1: Combined Fee Easement
- U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), accessed 3-4-2021
- Reservoirs used to remove highly altered areas in inland continental subregions (available in the Southeast Blueprint 2023 Ancillary Data Download)
- Southeast Blueprint 2023 inland corridor extent (created above in the inland resistance raster analysis by removing marine/estuarine areas from the Southeast Blueprint 2023 subregions)

Mapping Steps

- Start with the combined Zonation results, which are the rebalanced Zonation results for each subregion, mosaiced together into one raster. Identify as potential hubs the highest scoring 10% of the inland 2023 Southeast Blueprint subregions (based on the combined Zonation results).
- Outside of the 2023 inland continental Southeast Blueprint subregions, use local connectedness from TNC's Resilient Land project. Identify as potential hubs areas ≥1 standard deviation above average.
- Select polygons from PAD-US 2.1 and remove areas with Location Designations of 'School Trust Land', 'School Lands', 'State Land Board', or '3201'. These are state Land Board lands. This is consistent with the methods used in the urban park size indicator.
- Combine potential hubs from the combined Zonation results, TNC Resilient Land, and PAD-US.
- Remove from the potential hubs areas identified as reservoirs to match our approach to reservoirs in the rest of the inland continental portion of Blueprint 2023.

- Convert this polygon layer to a raster with a cell size of 90 m using the default Esri method (nearest neighbor). Since we have to run Linkage Mapper at 90 m to overcome computational limitations, when Linkage Mapper converts the 30 m hubs to a 90 m raster, it breaks up long linear features into small pieces, creating many small hubs. This produced errors that prevented Linkage Mapper from running successfully. Converting the hubs to 90 m before running Linkage Mapper removes any long narrow protuberances from the cores.
- Keep as hubs contiguous patches greater than 2,000 ha (5,000 acres) in size. Identify these patches using the ArcGIS Spatial Analyst-Region Group function (8-neighbor). This size threshold from Hoctor et. al (2000) is also used in the Florida Conservation Blueprint for connectivity purposes.
- Convert the raster patches to polygons.
- Use as inland hubs in the Linkage Mapper analysis all resulting polygons either within the 2023 Southeast Blueprint extent or within 26.1 km of the Blueprint extent. The distance of 26.1 km is based on dispersal distances of subadult black bears (White et al. 2000), a species that disperses from within the Southeast Blueprint geography into neighboring areas.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Prepare Inland Hubs & Resistance Raster for Linkage Mapper

Due to the large size of the inland continental area, we have to break it into 11 hexagons to run the inland continental connectivity analysis in Linkage Mapper. This requires breaking both the inland hubs and the inland resistance raster into hexagons.

Input Data

- Inland continental resistance raster (created above)
- Inland continental hubs (created above)

Mapping Steps

- Use the Generate Tessellation tool to create hexagons with an area of 500 km^2. This size was the largest we could feasibly run in Linkage Mapper.
- To eliminate edge effects, buffer each hexagon by 200 km.
- For each buffered hexagon, clip the inland continental resistance raster to the buffered hexagon and select all inland continental hub polygons that intersect each buffered hexagon.
- Use these layers as the inputs to the Linkage Mapper run for each buffered hexagon.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

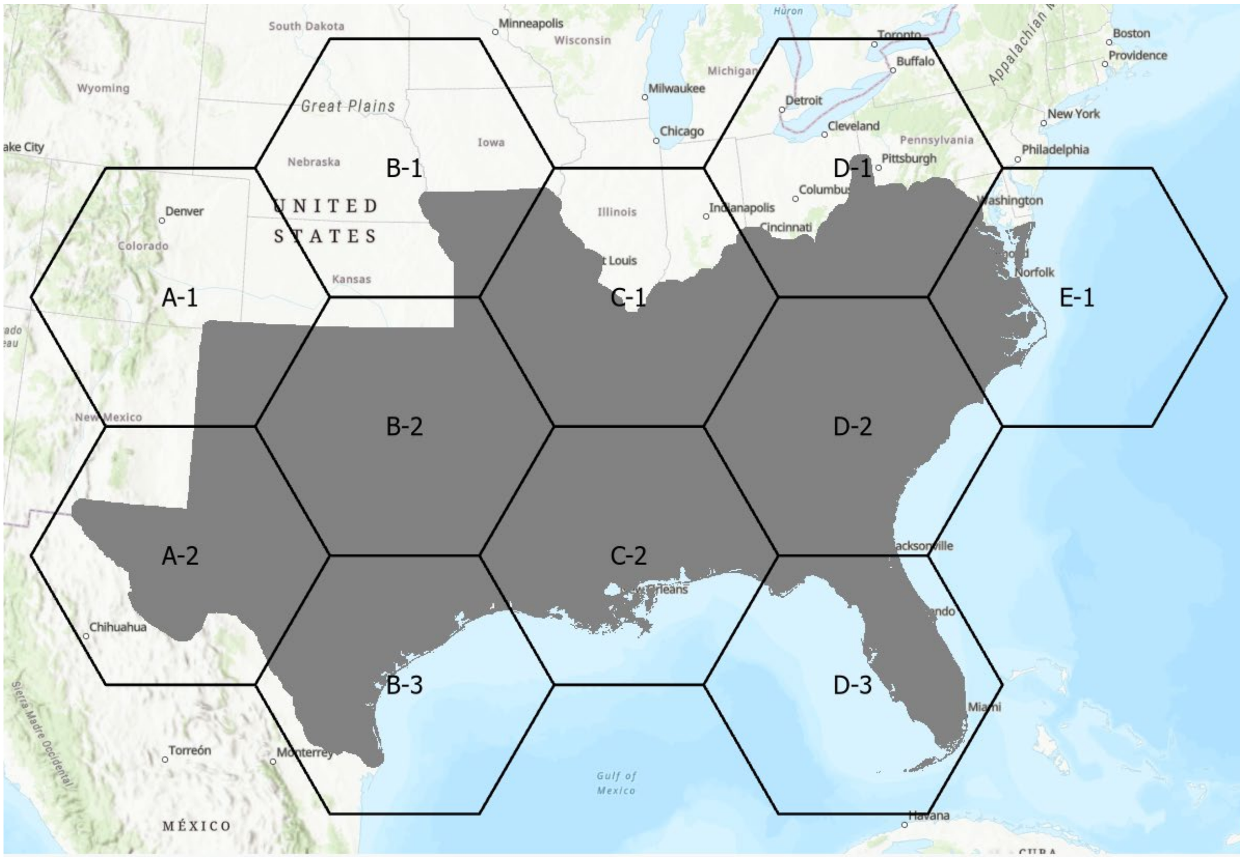

Figure 5. Illustration of hexagons used for the Linkage Mapper connectivity analysis.

Run Inland Corridor Analysis

Running the inland corridor analysis creates a continuous corridor surface for each buffered hexagon.

Input Data

- Inland continental resistance raster within each buffered hexagon (created above)
- Inland continental hubs that intersect each buffered hexagon (created above)

Mapping Steps

- Perform a Linkage Mapper corridor analysis for each buffered hexagon in ArcGIS Pro V 3.1.2 using the settings seen in this example log file from one of the buffered hexagon runs:

LINKAGE MAPPER LOG FILE
Start time: 00:38 2023-08-19
Version: 3.1.0
Tool used: Linkage Mapper

SYSTEM AND DATA INFORMATION
Operating system: Windows-10-10.0.19045-SP0
Processor type: Intel64 Family 6 Model 151 Stepping 2, GenuineIntel
Total & available RAM: 63.6 GB & 46.0 GB

ARCGIS INFORMATION
Product name & version: ArcGISPro 3.1.2
Build number: 41833
Product license: ArcInfo
Spatial Analyst status: Available

MODEL INPUTS

Parameter	Value
---------	-----
PROJ_DIR	C:\La1
CORE_LYR	C:\La1\A1in.gdb\Hubs_A_1
CORE_FLD	UID
RESIS_LYR	C:\La1\A1in.gdb\Resist_A_1
STEP1	true
STEP2	true
S2_ADJ_METHOD	Cost-Weighted & Euclidean
S2_EUCDIST_FILE	C:\La1\Hubs_dists.txt
STEP3	true
S3_DROP_LCCS	true
STEP4	true
S4_MAX_NN	4
S4_NN_UNIT	Cost-Weighted
S4_CONNECT	true
STEP5	true
S5_TRUNC_RAST	true
S5_CWD_THRESH	200000
CUS_BUF_DIST	200000
CUS_MAX_CWD	#
CUS_MAX_EUCDIST	#
CUS_OUTPUT_MB	#
CUS_SET_FILE	#

Custom Settings

CALCNONNORMLCCS	False
MINCOSTDIST	None
MINEUCDIST	None
SAVENORMLCCS	True
SIMPLIFY_CORES	True

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Merge Outputs of Corridor Analysis

The corridor analysis outputs 11 buffered Linkage Mapper runs. This step merges them together into a seamless continuous corridor surface for the inland continental area.

Input Data

- Outputs of all 11 buffered hexagon Linkage Mapper runs (created above)
- Hexagons used to subset inland area (created above)
- Inland continental resistance raster (90 m version)

Mapping Steps

- After running all 11 buffered hexagon Linkage Mapper runs, combine the outputs to create a corridor surface covering the whole area.
- Clip each Linkage Mapper output raster back down to the original hexagon and mosaic them all together. This ended up leaving a one cell empty space in some areas, so we went back and buffered the hexagons by just 90 m and used that to clip down instead so there were no cells "lost" on the line between two hexagons.
- Snap to the 90 m version of the inland continental resistance raster to avoid a cell shift.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Make Final Inland Corridors

This step extracts the final corridors for the inland continental area from the combined continuous corridors surface. It creates the corridor raster used in the inland continental portion of the Southeast Blueprint 2023 area.

Input Data

- 2023 combined Zonation results
- Full inland continental corridor continuous surface (created above)

Mapping Steps

- The above steps produce a corridor raster with a continuous surface covering the entire inland continental Southeast Blueprint area.
- To turn the continuous corridor output into corridors, we have to find a cutoff value in the output. We do this by combining it with the Zonation results, with the goal of making the corridor class cover 5% of the inland continental area.

- We tested different cutoffs and found that keeping all pixels <61,000 created corridors that cover approximately 5% of the area of the inland continental Southeast Blueprint region (that were not already covered by highest, high, and medium).
- Remove corridors that run through reservoirs, to be consistent with how we treated reservoirs in the rest of the Blueprint. This result is the full inland corridor layer for the continental portion of Southeast Blueprint 2023. Inland corridor pixels not already identified as highest, high or medium priority were incorporated into the priority connections class of the Southeast Blueprint. We chose the 61,000 cutoff because it resulted in a priority connections area of approximately 5% of the inland continental region (not already covered by highest, high, or medium priority pixels).

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Marine & Estuarine Hubs & Corridors

Marine Mammal & Turtle Movement Areas Mask

To ensure the marine/estuarine corridors reflect connectivity for marine mammals and sea turtles, we created a marine mammal and turtle movement areas mask using spatial density models.

Input Data

- Habitat-based Marine Mammal Density Models for the U.S. Atlantic (last updated 6-20-2022), accessed 12-12-2023

  These models use aggregated survey information, distance-sampling, and oceanographic variables to predict cetacean density throughout the region.

- Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) - GoMMAPPS marine mammal and sea turtle spatial density model outputs (version 2.2), accessed 12-14-2022

  Based on ship-based and aerial line-transect surveys conducted in the U.S. waters of the Gulf of Mexico between 2003 and 2019, the National Oceanic and Atmospheric Administration (NOAA) Southeast Fisheries Science Center developed spatial density models (SDMs) for cetacean and sea turtle species for the entire Gulf of Mexico. SDMs were developed using a generalized additive modeling framework to determine the relationship between species abundance and environmental variables (monthly averaged oceanographic conditions during 2015-2019).

Mapping Steps

- We selected 3 species for the Atlantic (North Atlantic right whale, humpback whale, and pilot whale) and 4 species for the Gulf (Rice's whale, pilot whale, Kemp's ridley sea turtle, and loggerhead sea turtle). The movement areas for these species also cover most of the major movement areas used by other marine mammals and sea turtle species.
- For each of the marine mammal and sea turtle species, sum the monthly abundance rasters across all months. The only exception to this is pilot whales in the Atlantic, where the data were yearly and did not need to be summed.
- Use the following thresholds for summed species data to ensure movement areas are connected and represent a wide range of species.
    - For Rice's whale, pilot whale (Atlantic), North Atlantic right whale, and Kemp's ridley sea turtle, use the top 70% of values based on a 10-class quantile classification.
    - For more cohesive and selective areas for pilot whale (Gulf), use the top 60% of values based on a 10-class quantile classification.
    - For more cohesive and selective areas for loggerhead sea turtles, use the top 50% of values based on a 10-class quantile classification.
    - For more cohesive and selective areas for humpback whales, use a manually identified threshold (0.04). For context, this threshold is slightly less than the top 85% of values based on a 10-class quantile classification.
- Combine all species movement areas into a single layer identifying whether a pixel is in at least one movement area.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Marine & Estuarine Resistance Raster

This is the resistance raster or cost surface used in the Linkage Mapper-based connectivity analysis for the marine/estuarine continental portion of Blueprint 2023. The resistance raster is limited to the marine mammal and turtle movement mask created above, as well as large estuaries. Constraining the resistance raster to these areas allows Linkage Mapper to model marine/estuarine least-cost paths only within those estuaries and marine mammal and sea turtle movement areas.

Input Data

- 2023 combined Zonation results
- U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), accessed 3-4-2021
- 2023 Southeast Blueprint subregions
- Inland corridors extent from inland corridor analysis – created above in the inland resistance raster analysis by removing marine/estuarine areas from the continental Southeast Blueprint 2023 subregions
- Marine mammal and turtle movement areas mask (created above)

Mapping Steps

Define the marine/estuarine continental corridor extent

- From the 2023 Southeast Blueprint subregions, select all continental subregions (i.e., exclude the Caribbean).
- Remove the inland corridor extent from the extent of the continental Southeast Blueprint 2023 subregions. What remains is the marine/estuarine continental corridor extent.

Make resistance raster

- Flip the Zonation results so that areas that rank higher in Zonation are easier to move through, and mask to the marine/estuarine continental corridor extent.
- Bring in the marine mammal and turtle movement areas mask, which will be used to limit the corridor analysis. The mask assigns potential corridors a value of 1. However, it excludes estuaries from the potential corridors because estuaries scored low in the marine mammal and turtle spatial density models. To correct this so the corridors can connect to the estuarine hubs (created in the next section), add estuaries to the marine mammal and sea turtle mask to make them potential corridors.
- Extract the Estuarine and Marine Deepwater class from NWI (WETLAND_TY = 'Estuarine and Marine Deepwater'). Make a copy of the vector deep estuaries layer, add and calculate a field with the value of 1, and convert to a raster using that new field.
- Combine the marine mammal and turtle movement areas with the reclassified estuaries layer using the ArcPy Spatial Analyst Cell Statistics "MAXIMUM" function.
- Reclassify the merged deep estuaries and marine mammal and turtle movement areas mask to turn the 0 values to NoData.
- Clip the flipped Zonation results to the modified marine mammal and turtle movement areas mask, which now includes deep estuaries.
- Using the ArcPy Resample-Bilinear function, resample the resistance layer from 30 m to 90 m to allow it to run successfully in Linkage Mapper. The result is the final marine/estuarine continental resistance raster.

Note: For more details on the mapping steps, code used to create this layer is available [in the Southeast Blueprint 2023 Data Download] under > 6_Code.

Marine & Estuarine Hubs

These are the hubs used in the [Linkage Mapper]-based connectivity analysis for the marine/estuarine portion of Blueprint 2023.

Input Data

- 2023 combined Zonation results
- U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), accessed 3-4-2021
- 2023 Southeast Blueprint subregions
- Marine/estuarine continental corridor extent (created above)

Mapping Steps

- To identify open water estuaries, select estuarine and marine deepwater areas from the NWI. (WETLAND_TY = 'Estuarine and Marine Deepwater' And ATTRIBUTE <> 'M1UBL'). "M1UBL" is an attribute referring to "permanently flooded, open ocean deepwater habitat". Add and calculate a field to use to convert the resulting layer to raster.
- Convert to raster to create a deep estuaries layer. All deep estuaries are considered potential hubs.
- Identify the highest scoring 10% of the marine area from the combined Zonation results). These will also be considered potential marine/estuarine hubs.
- Combine the deep estuarine hubs and the marine Zonation-based hubs using the ArcPy Cell Statistics "MAXIMUM" function.
- Convert the resulting layer to a 90 m raster. This step was necessary in the inland continental hubs to deal with some thin linear hub features. We kept this step in the marine/estuarine continental connectivity analysis as a precaution.
- Use the ArcPy Spatial Analyst-Region Group function (8-neighbor) to identify patches of marine/estuarine hubs. Contiguous patches greater than 2,000 ha were kept as hubs. This is consistent with the inland hubs approach and also within the 2-10 km width recommended by Krueck et al (2017) for marine reserve sizes to protect coral reef fishes.
- Convert the raster patches to polygons to use as hubs in Linkage Mapper.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Prepare Marine/Estuarine Hubs & Resistance Raster for Linkage Mapper

Due to the large size of the marine/estuarine continental area, we have to break it into 2 subregions to run the marine/estuarine continental connectivity analysis in Linkage Mapper. This requires breaking both the marine/estuarine hubs and the marine/estuarine resistance raster into subregions.

Input Data

- 2023 Southeast Blueprint subregions: Atlantic Marine, Gulf of Mexico
- Marine/estuarine resistance raster (created above)
- Marine/estuarine hubs (created above)

Mapping Steps

- Pull out the Gulf of Mexico subregion, buffer by 200 km to eliminate edge effects, and clip the marine/estuarine resistance raster to the buffered Gulf of Mexico area. This resistance raster will be used for the Gulf of Mexico marine/estuarine Linkage Mapper run.
- Pull out the Atlantic Marine subregion, buffer by 200 km to eliminate edge effects, and clip the marine/estuarine resistance raster to the buffered Atlantic area. This resistance raster will be used for the Atlantic Linkage marine/estuarine Mapper run.
- Pull out the Gulf of Mexico subregion, buffer by 200 km to eliminate edge effects, and select the hubs that intersect the buffered Gulf of Mexico area. These hubs are used for the Gulf of Mexico marine/estuarine Linkage Mapper run.
- Pull out the Atlantic Marine subregion, buffer by 200 km to eliminate edge effects, and select the hubs that intersect the buffered Atlantic area. These hubs will be used for the Atlantic marine/estuarine Linkage Mapper run.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Run Marine & Estuarine Corridor Analysis

Running the marine/estuarine corridor analysis creates a continuous corridor surface for each buffered marine subregion.

Input Data

- Marine/estuarine resistance raster within each buffered subregion (created above)
- Marine/estuarine hubs that intersect each buffered subregion (created above)

Mapping Steps

- Perform a Linkage Mapper corridor analysis for each buffered subregion in ArcGIS Pro V 3.1.2 using the settings seen in this example log file from one of the buffered marine subregions:

LINKAGE MAPPER LOG FILE
Start time: 13:36 2023-09-07
Version: 3.1.0
Tool used: Linkage Mapper

SYSTEM AND DATA INFORMATION
Operating system: Windows-10-10.0.19045-SP0
Processor type: Intel64 Family 6 Model 151 Stepping 2, GenuineIntel
Total & available RAM: 63.6 GB & 40.7 GB

ARCGIS INFORMATION
Product name & version: ArcGISPro 3.1.2
Build number: 41833
Product license: ArcInfo
Spatial Analyst status: Available

MODEL INPUTS

Parameter	Value
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PROJ_DIR	C:\LMa
CORE_LYR	C:\LMa\Ea_ConMarine_LM_Input.gdb\HubsA
CORE_FLD	UID
RESIS_LYR	C:\LMa\Ea_ConMarine_LM_Input.gdb\ResistanceA
STEP1	true
STEP2	true
S2_ADJ_METHOD	Cost-Weighted & Euclidean
S2_EUCDIST_FILE	C:\LMa\Hubs_dists.txt
STEP3	true
S3_DROP_LCCS	true
STEP4	true
S4_MAX_NN	4
S4_NN_UNIT	Cost-Weighted
S4_CONNECT	true
STEP5	true
S5_TRUNC_RAST	true
S5_CWD_THRESH	200000
CUS_BUF_DIST	200000
CUS_MAX_CWD	#
CUS_MAX_EUCDIST	#
CUS_OUTPUT_MB	#
CUS_SET_FILE	#

Custom Settings

CALCNONNORMLCCS	False
MINCOSTDIST	None
MINEUCDIST	None
SAVENORMLCCS	True
SIMPLIFY_CORES	True

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Merge Outputs of Corridor Analysis

The corridor analysis outputs two Linkage Mapper runs, one for the buffered Gulf of Mexico subregion and another for the buffered Atlantic subregion. This step merges them together into a seamless continuous corridor surface for the marine/estuarine continental area.

Input Data

- Output of buffered Gulf of Mexico Linkage Mapper run (created above)
- Output of buffered Atlantic Linkage Mapper run (created above)

Mapping Steps

- Because the estuarine/marine resistance raster extends outside of the Gulf of Mexico and Atlantic Marine subregions, we weren't able to clip the results down to those regions like we do with the inland hexagons without losing data.
- To combine the outputs, we mosaiced together the full buffered outputs using the ArcPy Mosaic to New Raster "MAXIMUM" function. This may have created some slight errors in the buffer zone.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Make Final Marine & Estuarine Corridors

This step extracts the final corridors for the marine/estuarine continental area from the combined continuous corridors surface. It creates the corridor raster used in the marine/estuarine continental portion of the Southeast Blueprint 2023 area.

Input Data

- 2023 combined Zonation results
- Full marine/estuarine continental corridor continuous surface (created above)

Mapping Steps

- The above steps produce a corridor raster with a continuous surface covering the entire marine/estuarine continental area.
- To turn the continuous corridor output into corridors, we have to find a cutoff value in the output. We do this by combining it with the Zonation results, with the goal of making the corridor class cover 5% of the marine/estuarine continental area.

- We tested different cutoffs and found that keeping all pixels <360,000 created corridors that cover approximately 5% of the area of the marine/estuarine continental Southeast Blueprint region (that were not already covered by highest, high, and medium).
- This result is the full marine/estuarine corridor layer for Southeast Blueprint 2023. Marine/estuarine corridor pixels not already identified as highest, high or medium priority were incorporated into the priority connections class of the Southeast Blueprint. We chose the 360,000 cutoff because it resulted in a priority connections area of approximately 5% of the marine/estuarine continental region (not already covered by highest, high, or medium priority pixels).

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download under > 6_Code.

Caribbean

In the Caribbean geography, corridors connect large patches of highest priority Blueprint areas and/or protected lands. Running a combined inland and marine connectivity analysis greatly simplifies the process and better accounts for species and ecological processes that connect both land and water.

Hubs & Corridors

Caribbean Resistance Raster

This is the resistance raster or cost surface used in the Linkage Mapper-based connectivity analysis for the Caribbean portion of Southeast Blueprint 2023.

Input Data

- 2023 combined Zonation results
- 2020 LANDFIRE Existing Vegetation Type (EVT) (v2.2.0) for Puerto Rico and the U.S. Virgin Islands; access the data for U.S. Insular Areas
- Southeast Blueprint 2023 subregions: Caribbean

Mapping Steps

- Flip the Zonation results so that areas that rank higher in Zonation are easier to move through.
- Burn the LANDFIRE urban classes into the resistance raster, giving urban pixels the highest resistance value (500), making them harder for corridors to move through. Pixels with an EVT_NAME value of 'Developed-Low Intensity', 'Developed-Medium Intensity', 'Developed-High Intensity', 'Developed-Roads' or 'Developed-Open Space' were considered urban.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Caribbean Hubs

These are the hubs used in the Linkage Mapper-based connectivity analysis for the Caribbean portion of Southeast Blueprint 2023.

Input Data

- 2023 combined Zonation results
- Protected Areas Database of the United States (PAD-US) 3.0: Fee, Easement

Mapping Steps

- Use a conditional statement to pull out the top 10% (value >90) from the combined Zonation results and clip to the Caribbean extent. Reclassify to turn values of NoData to 0.
- Bring in protected areas as additional hubs. Union together the Fee and Easement layers from PAD-US 3.0. Add a field to convert to a raster and assign it a value of 1. Use that field to convert to a raster.
- Combine the top 10% of the Caribbean Zonation results with the protected areas using the ArcPy Cell Statistics “MAXIMUM” function.
- Keep as hubs contiguous patches greater than 200 ha (500 acres) in size. Identify these patches using the ArcGIS Spatial Analyst-Region Group function (8-neighbor). This size threshold is 10% of the threshold used for hubs in the continental part of the Blueprint. When compared to the continental part of the Blueprint, many key species in the Caribbean have adapted to use the significantly smaller areas of habitat. The reduced threshold allowed for many important hub areas discussed during Caribbean workshops, especially in the U.S. Virgin Islands, to be potentially identified as hubs in the analysis.
- Convert the raster patches to polygons.
- Use all resulting polygons as hubs in the Caribbean Linkage Mapper analysis.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Run Caribbean Corridor Analysis

Running the Caribbean corridor analysis creates a continuous corridor surface for the Caribbean subregion of Southeast Blueprint 2023.

Input Data

- Caribbean resistance raster (created above)
- Caribbean hubs (created above)

Mapping Steps

- Perform a Linkage Mapper corridor analysis ArcGIS Pro V 3.1.2 using the settings seen in this log file:

  LINKAGE MAPPER LOG FILE
  Start time: 13:45 2023-09-06
  Version: 3.1.0
  Tool used: Linkage Mapper

  SYSTEM AND DATA INFORMATION
  Operating system: Windows-10-10.0.19045-SP0
  Processor type: Intel64 Family 6 Model 151 Stepping 2, GenuineIntel
  Total & available RAM: 63.6 GB & 36.1 GB

  ARCGIS INFORMATION
  Product name & version: ArcGISPro 3.1.2
  Build number: 41833
  Product license: ArcInfo
  Spatial Analyst status: Available

  MODEL INPUTS

Parameter	Value
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PROJ_DIR	C:\LM1
CORE_LYR	C:\LM1\Ha_VIPR_LM_Input.gdb\Hubs
CORE_FLD	UID
RESIS_LYR	C:\LM1\Ha_VIPR_LM_Input.gdb\VIPRResistance
STEP1	true
STEP2	true
S2_ADJ_METHOD	Cost-Weighted & Euclidean
S2_EUCDIST_FILE	#
STEP3	true
S3_DROP_LCCS	true
STEP4	true
S4_MAX_NN	4
S4_NN_UNIT	Cost-Weighted
S4_CONNECT	true
STEP5	true
S5_TRUNC_RAST	true

S5_CWD_THRESH	200000
CUS_BUF_DIST	200000
CUS_MAX_CWD	#
CUS_MAX_EUCDIST	#
CUS_OUTPUT_MB	#
CUS_SET_FILE	#

Custom Settings

CALCNONNORMLCCS	False
MINCOSTDIST	None
MINEUCDIST	None
SAVENORMLCCS	True
SIMPLIFY_CORES	True

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Make Final Caribbean Corridors

This step extracts the final corridors for Caribbean area from the continuous corridors surface. It creates the corridor raster used in the Caribbean portion of the Southeast Blueprint 2023 area.

Input Data

- 2023 combined Zonation results
- Caribbean hubs (created above)
- Full Caribbean corridor continuous surface (created above)

Mapping Steps

- The above steps produce a corridor raster with a continuous surface covering the entire Caribbean Southeast Blueprint 2023 area.
- To turn the continuous corridor output into corridors, we have to find a cutoff value in the output. We do this by combining it with the Zonation results, with the goal of making the corridor class cover 5% of the Caribbean portion of the Southeast Blueprint.
- We tested different cutoffs and found that keeping all pixels <27,500 created corridors that cover approximately 5% of the Caribbean region of the Southeast Blueprint (that were not already covered by highest, high, and medium).
- This result is the full Caribbean corridor layer for Southeast Blueprint 2023. Caribbean corridor pixels not already identified as highest, high or medium priority were incorporated into the priority connections class of the Southeast Blueprint. We chose the 27,500 cutoff because it resulted in a priority connections area of approximately 5% of the Caribbean region (not already covered by highest, high, or medium priority pixels).

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Known Issues

- There is a mismatch in the cutoffs used to identify the inland continental hubs and the Caribbean hubs, compared to the highest priority class of the Southeast Blueprint, where ideally, they would match. This results in hubs that are more restrictive than the highest priority class of the Blueprint in the Caribbean and inland continental areas. When creating the Caribbean and inland continental hubs, we identified the top 10% of the Zonation results using values >90. Later, when creating the final Blueprint, we realized that using >89 did a better job of getting at the top 10%. If we had used >89 to identify these hubs, it would have influenced the resulting corridors and priority connections class of the Blueprint in the Caribbean and inland continental areas.

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Creating Southeast Blueprint 2023

The Southeast Conservation Blueprint is a living, spatial plan to achieve the SECAS vision of a connected network of lands and waters across the Southeast and Caribbean. It identifies priority areas based on a suite of natural and cultural resource indicators representing terrestrial, freshwater, and marine ecosystems. A connectivity analysis identifies corridors that link coastal and inland areas and span climate gradients. So far, more than 2,000 people from over 500 organizations have actively participated in developing the Blueprint.

Priority Categories

The Southeast Blueprint covers 50% of the SECAS geography, as described below.

Priorities for a connected network of lands and waters

Highest priority: Areas where conservation action would make the biggest impact, based on a suite of natural and cultural resource indicators. This class covers roughly 10% of the Southeast Blueprint geography.

High priority: Areas where conservation action would make a big impact, based on a suite of natural and cultural resource indicators. This class covers roughly 15% of the Southeast Blueprint geography.

Medium priority: Areas where conservation action would make an above-average impact, based on a suite of natural and cultural resource indicators. This class covers roughly 20% of the Southeast Blueprint geography.

Priority connections: Connections between priority areas that cover the shortest distance possible while routing through as much Blueprint priority as possible. This class covers roughly 5% of the Southeast Blueprint geography.

Combining Zonation Results with Corridors to Create the Southeast Blueprint

Input Data

- 2023 combined Zonation results
- Southeast Blueprint 2023 hubs and corridors

Mapping Steps

Creating the Inland Continental Blueprint

- Start with the mosaiced, rebalanced Zonation scores for all inland continental subregions. Clip to the inland continental corridor extent created in the Blueprint 2023 hubs and corridors analysis. In this layer, each pixel in the inland continental Southeast Blueprint geography has a continuous value ranging from 0 to 100 according to its rank by Zonation prioritization, rebalanced by linear rescale.
- Pixels with values >89 are in the highest tier of indicator value. Select all pixels with values >89 and classify them as “highest priority for a connected network of lands and waters”.
- Pixels with values >74 that aren’t already classified as highest priority are in the second-highest tier of indicator value. Select all pixels >74 and ≤89 and classify them as “high priority for a connected network of lands and waters”.
- Pixels with values >55 that aren’t already classified as highest or high priority are in the third-highest tier of indicator values. Select all pixels >55 and ≤74 and classify them as “medium priority for a connected network of lands and waters”. This makes up the first portion of the medium priority class.
- Add to the medium priority class any inland hubs used in the connectivity analysis that that were not already classified as highest, high, or medium priority in the steps above. This ensures that the large patches of protected lands used as hubs in the connectivity analysis can score no lower than medium priority in the Blueprint. This adds an additional 1.3% of total area to the medium priority class.
- Use the inland continental corridors to fill in the priority connections class. Classify as “priority connections” any pixel identified as a corridor in the inland corridor analysis that is not already assigned to the highest, high or medium priority categories in the steps above. This contributes an additional 5% to the total Blueprint area, ensuring the final Blueprint ultimately covers 50% of the Southeast Blueprint landscape.

Creating the Marine/Estuarine Continental Blueprint

- Start with the mosaiced, rebalanced Zonation results for all continental subregions. Clip to the marine/estuarine corridor extent created in the Blueprint 2023 hubs and corridors analysis. In this layer, each pixel in the marine/estuarine continental Southeast Blueprint geography has a continuous value ranging from 0 to 100 according to its rank in the Zonation output, rebalanced by linear rescale.
- Pixels with values >90 are in the highest tier of indicator values. Select all pixels with values >90 and classify them as “highest priority for a connected network of lands and waters”.
- Pixels with values >75 that aren’t already classified as highest priority are in the second-highest tier of indicator value. Select all pixels >75 and ≤90 and classify them as “high priority for a connected network of lands and waters”.

- Pixels with values > 57 that aren't already classified as highest or high priority are in the third-highest tier of indicator value. Select all pixels >57 and ≤75 and classify them as "medium priority for a connected network of lands and waters".
- Use the marine/estuarine corridors to fill in the priority connections class. Classify as "priority connections" any pixel identified as a corridor in the marine/estuarine corridor analysis that was not already assigned to the highest, high or medium priority categories in the steps above. This step ensures that the final Blueprint ultimately covers 50% of the Southeast Blueprint landscape.

Creating the Caribbean Blueprint

- Start with the mosaiced, rebalanced Zonation scores for the Caribbean subregion. In this layer, each pixel in the Caribbean Blueprint geography has a continuous value ranging from 0 to 100 according to its rank by Zonation prioritization, rebalanced by linear rescale.
- Pixels with values >89 are in the highest tier of indicator value. Select all pixels with values >89 and classify them as "highest priority for a connected network of lands and waters".
- Pixels with values >74 that aren't already classified as highest priority are in the second-highest tier of indicator value. Select all pixels >74 and ≤89 and classify them as "high priority for a connected network of lands and waters".
- Pixels with values >54 that aren't already classified as highest or high priority are in the third-highest tier of indicator value. Select all pixels >54 and ≤74 and classify them as "medium priority for a connected network of lands and waters". This makes up the first portion of the medium priority class.
- Add to the medium priority class any hubs used in the Caribbean connectivity analysis that that were not already classified as highest, high, or medium priority in the steps above. This ensures that the large patches of protected lands used as hubs in the connectivity analysis can score no lower than medium priority in the Blueprint. This adds an additional 1% of total area to the medium priority class.
- Use the Caribbean corridors to fill in the priority connections class. Classify as "priority connections" any pixel identified as a corridor in the corridor analysis that is not already assigned to the highest, high or medium priority categories in the steps above. This contributes an additional 5% to the total Blueprint area, ensuring the final Blueprint ultimately covers 50% of the Southeast Blueprint landscape.

Combining the Inland Continental, Marine/Estuarine Continental, and Caribbean Components into Southeast Blueprint 2023

- As a final step, combine the inland continental, marine/estuarine continental, and Caribbean results into a single raster representing final Southeast Blueprint 2023. Do this using the ArcGIS-Cell Statistics "MAXIMUM" function.

Note: For more details on the mapping steps, code used to create this layer is available in the Southeast Blueprint 2023 Data Download or Caribbean-only Southeast Blueprint 2023 Data Download under > 6_Code.

Known Issues

Continental

Terrestrial

Uplands

- Some managed grasslands are underprioritized. Examples include Prairie Wildlife grasslands west of Vinton, MS; Balcones Canyonlands National Wildlife Refuge in TX; Caddo National Grassland in TX; Lyndon B. Johnson National Grassland in TX; Black Kettle National Grassland in OK; restored glades on the eastern and northern edge of Ozark National Forest in AR; areas along Pretty Ridge Rd. east of Cove Lake in KY; May Prairie State Natural Area in TN; Bark Camp Barrens Wildlife Management Area in TN; DuPont State Forest and some surrounding areas in NC; and the Voice of America site east of Chicod, NC. Improvements to the fire frequency and grassland indicators could fix this in the future.
- Some important riverscour grasslands downstream of major dams are underprioritized (e.g., part of the Rockcastle River in Daniel Boone National Forest in KY). Improvements to the reservoir mask, which currently removes these areas from the prioritization, could fix this in the future.
- Some pastures are overprioritized in TX and OK. Examples include an area of small-parcel improved pastures southeast of Austin, TX; an area of non-native pasture east of Cherokee, OK; an area of non-native pasture east of Salt Plains National Wildlife Refuge in OK; and non-native pastures east of Cashion, OK. This could be fixed in the future with improvements to the Great Plains perennial grasslands indicator.
- Parts of some important ecological corridors are underprioritized. Examples include parts of the corridor between Ocmulgee Mounds National Historic Park and Bond Swamp National Wildlife Refuge in GA; parts of the corridor between Fort Campbell, Land Between the Lakes, and Clarks River National Wildlife Refuge in KY and TN; some of the areas from Alligator River National Wildlife Refuge to Pocosin Lakes National Wildlife Refuge in NC; multiple corridors coming out of Okefenokee Swamp in GA; and the Osceola to Ocala corridor in FL. Improvements to prioritization methods and indicators will likely fix these in the future.
- Some upland areas in large habitat patches that are fragmented by dirt roads are underprioritized. This issue impacts parts of some national forests and military bases. Improvements to the intact habitat cores indicator and/or new prioritization methods currently under investigation will likely fix this in the future.

- Some patches of open pine with good local conditions are underprioritized. Examples include parts of Yellow River Marsh Preserve State Park in FL; important gopher tortoise habitat in an area just east of Mauk, GA; Fort Rucker in AL; an area east of Bexley, MS; and Daniel Boone National Forest in KY. Ongoing updates to the fire frequency indicator could continue to improve this issue in future updates.
- Some parts of small, low-elevation islands are underprioritized. The exact boundaries of these highly dynamic islands can be hard to predict. The boundaries used in the islands indicator and areas used for critical habitat of key island species don't always align perfectly—especially in the most dynamic parts of the island. A potential improvement to address this is under investigation. Examples include Tybee Bar in GA, Lanark Reef in FL, and the Chandeleur Islands off of LA.
- Within the Interior Plateau subregion, planted pine areas are being overprioritized when they are part of intact habitat cores. Potential indicator improvements to fix this are under investigation.
- Some recently developed areas are overprioritized (e.g., a solar field near Wedgefield, FL and the Moncure Megasite in NC). Updated landcover and indicator updates based on newer landcover should fix this issue.
- Some new conservation areas where restoration has only started recently are underprioritized. Examples include Wolfe Creek Forest in FL, an airfield north of Tarkiln Bayou Preserve State Park in FL, and the Wolf River corridor in MS. Updated landcover and indicator updates based on newer landcover should fix this issue.
- Some important urban natural areas are underprioritized. For example, an area east of Puryear Park in St. Petersburg, FL; Kapok Park in Clearwater, FL; the West Atlanta Watershed Alliance education hub in Atlanta, GA; Lost Corner Preserve in Sandy Springs, GA; part of Chattahoochee River National Recreation area in GA; and part of Simpsonwood Park in Peachtree Corners, GA. Improvements in indicators related to urban natural areas could fix this in the future.
- Culturally important historic areas are underprioritized through the Blueprint. This is particularly true in areas outside of the Piedmont, Atlantic Coastal Plain, and East Gulf Coastal Plain subregions. Even within these subregions, where there is an indicator for these areas, there are significant gaps. Some low-urban historic areas in these subregions are underprioritized because 1) they are not yet part of the National Register of Historic Places (e.g., Lost Island Farm on Roanoke Island, the likely landing site for the Lost Colony at the mouth of the Chowan River, and Native American sites on the Dan River near the NC/VA border), 2) because their location isn't publicly shared (e.g., sensitive archeological sites), or because 3) the GIS depiction of their spatial boundaries has significant errors (e.g., sites in GA and AL).
- Some areas with important ecological communities are underprioritized in TX and OK (e.g., shinnery oak scrub).
- Some upland areas in the Upper Coastal Plain of GA are overprioritized. Improvements in prioritization methods could improve this in the future.

- The Trail Ridge area east of Okefenokee Swamp in GA, which has significant longleaf restoration potential and is an important movement corridor for longleaf-associated species, is underprioritized. Improvements in prioritization methods could improve this in the future.
- Some small patches of pine rocklands habitat in South FL are underprioritized.
- Some small or newer quarries are overprioritized (e.g., American Stone Quarry near Chapel Hill, NC). While most quarries are classified correctly as developed, smaller or newer ones don't have large enough areas of barren landcover in the 2019 National Land Cover Database to be filtered out in the resilient terrestrial sites indicator. If not identified as non-natural, quarries tend to score very highly on landscape diversity given all the elevation change that happens within them. This issue could be fixed in a future update to the resilient terrestrial sites indicator.

Wetlands

- Some important wetlands are underpriorized. Examples include the east and west sides of Felsenthal National Wildlife Refuge in AR; Ten Mile Pond Conservation Area in MO; the southeast part of Big Oak Tree State Park in MO; xerohydric flatwoods in Clarks River National Wildlife Refuge in KY; white fringeless orchid habitat in Daniel Boone National Forest in KY; wetlands just east of Macedonia, TN; depressional wetlands southeast of Raeford, NC; the Stony Run wetlands in Northeast Dunn, NC; the Tar River wetlands in Northeast Greenville, NC; and a section of the Waccamaw River floodplain between Edward E Burroughs Hwy and SC 31 in SC. Improvements to indicators and prioritization methods could fix these in the future.
- Some ephemeral wetlands are underprioritized. New prioritization methods under investigation for next year could address this.
- A small set of bottomland forest areas in areas flooded by dams are underprioritized (e.g., the area between Summerfield and Faircloth, LA and the Little River wetlands in Millwood Recreation Area in AR). These areas are misidentified as open water reservoirs in the current reservoir mask. Improvements to that mask for future Blueprints are under investigation.
- Some inland areas that play particularly important buffering roles for key offshore habitats are underprioritized (e.g., St. Joseph Bay State Buffer Preserve in FL). New prioritization methods under investigation for next year could address this.
- Sections of the Everglades on either side of US Hwy 41 are underprioritized. Indicator improvements under investigation could fix this in the future.
- Important Carolina bays are often included in large patches of medium priority, but the bays and nearby areas should be higher priority. Different methods for resolving this issue are under investigation.
- Some important areas of tidal freshwater marsh are underprioritized (e.g., Mackay National Wildlife Refuge). Indicators that better represent waterfowl habitat needs could improve this in the future.
- The salt marshes on the west side of Swanquarter National Wildlife Refuge seem to be underprioritized. Improved indicator and priority methods could fix this in the future.

Species-Specific

- Some important caves for Ozark big-eared bat, Northern long-eared bat, and Indiana bat are underprioritized. A potential indicator to address this is under investigation.
- Some important upland habitat for range-restricted species is underprioritized (e.g., Texas kangaroo rat). Indicator improvements under development could fix that in next year's update.
- Some coastal marsh areas important for diamondback terrapin are underprioritized (e.g., Cedar Point marsh north of Dauphin Island, AL).
- Some important areas for salamanders in the Appalachians are underprioritized (e.g., the Little River headwaters south of Masseyville, GA).
- Some islands particularly important for species that don't yet have critical habitat spatially mapped (e.g., red knot) or are not federally listed species (e.g., seabirds, heron rookeries) are underprioritized (e.g., Ogeechee Bar in GA and Walker and Robinson Islands in AL).
- Some Florida panther habitat that is important for breeding and movement in South FL is underprioritized.
- Some parts of Cape Sable seaside sparrow critical habitat are being underprioritized. All critical habitat for this species is prioritized in the Blueprint, but it is currently a mix of high and medium priority. Multiple indicator improvements under investigation could fix this in the future.
- Important areas for beach birds that are not on islands are underprioritized in the FL Peninsula and all other Gulf coast subregions.
- Some areas that are important for mottled duck nesting in the edge of the Texas Blackland Prairie and West Gulf Coastal Plain subregions are underprioritized.

Freshwater

- Some river sections important for aquatic diversity are underprioritized. This is especially true in WV where the data used are older than in other states. Underprioritized areas include some sections of Shoe Heel Creek in NC that are important for broadtail madtoms and other endemics; Neuse River waterdog habitat in the Trent River near Croatan National Forest in NC; the VA section of the Nottoway River; the lower section of the Little River in NC; some parts of the lower Neuse River in NC; Buck darter streams near Shopville, KY; some sections of the Edisto River in SC; parts of Ashley River northwest of Charleston, SC; an area near the confluence of Black Mingo Creek and the Black River in SC; the headwaters of the Flint River; and sections of the Flint River north and south of the Atlanta airport. Ongoing improvements in the imperiled aquatic species indicators and prioritization methods should improve these issues.
- Some aquatic areas, particularly smaller rivers and streams, are overprioritized. The imperiled aquatic species indicator is at a subwatershed (HUC12) scale while the species hotspots it seeks to depict are often only a part of that subwatershed.

- Some important areas for migratory fish in Gulf of Mexico drainages are underprioritized. The source data for the Gulf migratory fish connectivity indicator didn't include migratory fish species that are important for the Mississippi Alluvial Valley and all Gulf coast watersheds west of that subregion.
- Some important areas for migratory fish in Atlantic drainages (e.g., a section of the St. Mary's River west of I-95) are underprioritized. Updated prioritization methods will likely fix this issue next year.
- Some open water areas of artificial waterbodies are underprioritized. In some cases, parts of these waterbodies can provide important species habitat (e.g., American crocodile habitat in cooling canals in South FL and waterfowl habitat in parts of some reservoirs).
- Some river areas are underprioritized in South FL (e.g., the north fork of the St. Lucie River and Ten Mile Creek). Potential aquatic indicator improvements under investigation could fix this in the future.
- Some canals are overprioritized in South FL. Potential aquatic indicator improvements under investigation could fix this in the future.
- While the Blueprint tries to not prioritize the open water parts of reservoirs, a small number of small reservoirs were missed in the layer that estimates reservoir locations (e.g., Tired Creek Lake in GA).

Marine

- Mouths of many priority rivers are underprioritized where they transition into the estuarine ecosystem. Improved estuarine indicators should improve this issue in the future.
- Some marine Blueprint priorities are at a coarser resolution due to the marine birds, sea turtles, and marine mammals indicators. The coarser data results in what looks like parts of large squares or hexagons and unnatural edges in priority. Improvements in indicator resolution should fix this in the future.
- Some marine areas in the far eastern part of the Blueprint, particularly beyond the Blake Plateau, may be underprioritized due a lack of survey data for marine birds and mammals in that region.
- Some important black-capped petrel feeding areas far offshore in the Atlantic are underprioritized. Future improvements in the marine birds indicator should fix this.
- Some areas along the Atlantic shelf break are overprioritized due to overprediction in deep-sea coral richness models (e.g., select areas east of GA). While the models predict high coral richness in these areas, surveys show that they are almost entirely sand. Improvements in the models could fix this in the future.
- Some important areas of the Charleston Gyre upwelling are underprioritized. While the exact location of the upwelling and its high concentration of nutrients and fish larvae isn't fixed, there are some areas where it commonly occurs that are underprioritized.
- Some parts of the deeper waters off Onslow Bay, NC, which are important for reef fish and many tropical/subtropical species, are likely underprioritized.

- Some areas important for corals in the Gulf are underprioritized (e.g., an area east of the West Florida Escarpment that's being considered for a Coral Habitat Area of Particular Concern). Future coral indicator improvements will likely fix this.
- Some important areas for Rice's whale may be underprioritized. The Blueprint currently covers habitat predicted by the GoMMAPPS model for Rice's whale, but NOAA core distribution polygons cover a much larger area.
- DeSoto Canyon—an important area for corals, fish and nutrient upwellings south of Pensacola, FL—is underprioritized. Future improvements in coral, fish, or marine bird models could improve this in the future.
- Parts of important species movement corridors are underprioritized (e.g., a marine mammal corridor southeast of LA, a Kemp's ridley sea turtle corridor near the TX border). Improved corridor methods could fix this in the future.

Caribbean

Terrestrial

Uplands

- Parts of some protected areas in the east part of St. Croix in USVI (e.g, Point Udall, Jack and Issac Bay) are underprioritized. Indicator and/or method improvements could fix this in the future.
- Some relatively undeveloped areas that are important for maintaining water quality in nearby high priority marine areas are underprioritized (e.g., some areas east of the St. Croix cruise terminal in USVI). Improvements to indicators and/or corridor methods could fix this in the future.
- Some important areas related to Taíno history are underprioritized (e.g., sections of Salt River Bay National Historical Park and Ecological Preserve in St. Croix, USVI). Work to better integrate this information into cultural indicators is ongoing.
- Inland corridors are underrepresented in St. Croix, USVI. Due to the patterns of priority, the estimated corridors are all coastal and marine. Improvements to corridor methods could fix this in the future.
- Parts of the coastal hills in eastern PR, important for their unique vegetation composition, are underprioritized.

Wetlands

- The Altona Lagoon area of St. Croix, USVI—an important area for birds, sportfish, and the potential reintroduction of the St. Croix ground lizard—is underprioritized.

Species-Specific

- Some areas important for future Puerto Rican parrot habitat are underprioritized (e.g., northeast of El Yunque in PR; east of Lares, PR). Improvements to species-specific indicators could fix this in the future.

- Some areas important for rare plants are underprioritized (e.g., east of Lares, PR).
- Some areas that are important for coquí species in PR may be underprioritized (e.g., Puerto Rican rock frog *[Eleutherodcactylus cooki]* habitat southwest of El Yunque). Work on a coquí-specific indicator is ongoing.

Marine

- Some important areas for coral reef restoration are underprioritized (e.g., north of Teague Bay in St. Croix, USVI; north of Christiansted in St. Croix, USVI). Better incorporation of restoration in coral indicators could fix this in the future.
- Some marine areas strongly impacted by point source pollution may be overprioritized (e.g., area of south St. Croix, USVI impacted by Cruzan rum distillery discharge).
- Some marine corridor routes do not sufficiently account for variation in habitat quality between hubs (e.g., corridors south of Culebra, PR; corridors southwest of the big island of PR).

Appendix A

Additional information on SARP aquatic animal SGCN HUC12 summaries used in imperiled aquatic species indicator

Species Summaries by HUC12 Methodology*

All species data was obtained by contacting the appropriate representatives from State Natural Heritage Programs. The request made was:

Data Request: I am the GIS coordinator for the Southeast Aquatic Resources Partnership, and I am contacting you to obtain GIS (lat/long) data for occurrences of rare aquatic species: **fishes, mussels, snails, crayfishes, amphibians and reptiles.** If this is not possible, the ultimate product that we will be creating are species genus and species names by HUC 12, so we can calculate the number of T&E, State Listed, and SGCN species in a HUC 12 where particular dams are located. Please see below for project description.

What is SARP: The Southeast Aquatic Resources Partnership (SARP) is a regional collaboration of natural resource and science agencies, conservation organizations and private interests developed to strengthen the management and conservation of aquatic resources in the southeastern United States. SARP is a joint party committee created by the SEAFWA Directors to complete the mission of conserving aquatic habitats across political boundaries (more under SEAFWA https://www.seafwa.org/committees/southeast_aquatic_resources_partnership/) We are state governed by a steering Committee with representatives from every state with advisory roles for our federal, corporate, and NGO partners. You can learn more at www.southeastaquatics.net. The representatives that serve on the SARP Steering Committee for Kentucky are Ron Brooks and Mike Hardin under the appointment of Commissioner Storm.

How will the data be used: SARP has an Aquatic Connectivity Program where we are working to inventory and prioritize dams and road related barriers for removal based on ecological metrics. One additional piece of information that we have and we will use your data for, is to determine the number of threatened and endangered species, number of state listed species, and number of species of greatest conservation need within a HUC12. You can see our tool here: https://connectivity.sarpdata.com

Who will view the data: This is a public facing tool, so the HUC12 summaries will be viewed by whoever frequents the tool, mostly aquatic resource managers that we work with, but also anyone who happens upon it. For the public facing tool, it DOES NOT show species names, only number of TE, state listed, and SGCN in a HUC12.

Internally, we use lat/long information to work with partners to look at how far upstream or downstream a species of concern is from potential projects. So if raw lat/long information is provided, only I will see this information.

Methodology:

1) Project all species data feature classes into one geodatabase and then add to map.
2) Select out only aquatic occurrences if necessary.
3) Merge blank schema containing fields for scientific name, common name, federal status, state status, SGCN Listing, historic status.
4) Remove all occurrences listed as extirpated, and calculate an ‘H’ in the historic status for those older than 1970, or listed as historical. Note: for those with no historical status, separate out the year of the date last observed using this code in field calculator: DatePart(“yyyy”, [DATEFIELD]).
5) Remove historical records.
6) Calculate scientific, common, and historic fields using scripts.
7) Delete unwanted fields.
8) Join on SGCN species look up table for each state and calculate SGCN List field, calculate yes or no based on field.
9) Merge all polygon occurrences together.
10) Intersect polygon occurrences by HUC 12 so that features split by HUC12 and contain only one HUC12 ID.
11) Merge all point occurrences together.
12) Iterate feature classes to spatial join HUC12 ID to each feature class.
13) Export to geodatabase tables.
14) Merge into one geodatabase table that contains species names and status and HUC12ID for each.
15) Send to Astute Spruce to calculate numbers of TE, State, SGCN, and Regional SGCN species by HUC12 and join to dams/crossings. Astute Spruce cleans up any spelling errors.

State Status

State	Data in tool
TN	Nov 2022
SC	Nov 2022
MO	Jan 2023
AR	Nov 2022
VA	Dec 2023
LA	Dec 2022
KY	Jan 2023
FL	Nov 2022
NC	Oct 2022
AL	Nov 2022
GA	Nov 2022
MS	Dec 2022
OK	Dec 2022
TX	Feb 2023

*Information provided by Kat Hoenke with the Southeast Aquatic Resources Partnership (SARP) in April 2023 accompanying the aquatic animal SGCN HUC12 summary data. Please direct any questions to kat@southeastaquatics.net.