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Mapping critical areas for migratory songbirds using a fusion of remote sensing and distributional modeling techniques

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ABSTRACT

Of the 338 species identified as Nearctic-Neotropical migrants occurring in North America, 98.5% have been recorded in Texas. The seasonal migration of these birds is a well-studied natural phenomenon – individuals weighing < 15 g will cross in the Gulf of Mexico approximately 965 km non-stop, completing a total distance of 1900–3200 km over the course of 26–80 h. The physiologically demanding nature of this feat makes the Texas coastline crucial to the success of these species. We used a fusion of multi-spectral remote sensing data and distributional modeling techniques to generate and evaluate predictive maps identifying critical areas for migratory passerines on the Texas coast. Imagery acquired from Landsat 8 OLI, maps provided by United States Geological Survey and the Texas Department of Transportation, and migratory bird occurrence records from the eBird citizen-contributed database were used to build predictive distribution models using three algorithms. Using the AUC to compare model performance, the Random Forest produced the most accurate distribution model, followed by MaxEnt, and Support Vector Machine (0.98, 0.81, and 0.79, respectively). We interpreted, from Boosted Regression Tree analysis, that elevation is the single most influential factor in determining migrant occupancy, with vegetative biomass the least influential predictor. Our approach here allows conservation biologists a more sophisticated approach to identifying critical areas for migratory passerines across large spatial extents in a short amount of time.

1. Rationale

Located in the heart of the central flyway (a major migratory pathway for new world birds, crossing the Gulf of Mexico), Texas offers crucial stop-over points for migratory birds, the majority of which is made up of Nearctic-Neotropical migrants. This group is comprised of species that breed in temperate latitudes, but leave for the winter for tropical latitudes (i.e. Central and South America). Of the 338 species identified as Nearctic-Neotropical migrants occurring in North America, 98.5% have been recorded in Texas (Shackelford et al., 2005). These birds – individuals weighing < 15 g (0.53 oz) – will cross in the Gulf of Mexico (approximately 600 miles) non-stop, completing a total distance of 1200–2000 miles over the course of 26–80 h (Shackelford et al., 2005; Moore and Kerlinger, 1987). The physiologically demanding nature of this feat makes the Texas coastline crucial to the success of these species since it offers the first opportunity to rest and refuel.

Additionally, avian field technicians are limited in the amount of space and time they can survey across the 39,960-km^2, 14 counties, that comprise the Texas coastline. The recent growth of new remote sensing data and techniques have enabled successful distributional mapping of migratory birds along a small area of the East coast of the United States, but has yet to be applied to other areas with heavier migratory traffic and higher landscape heterogeneity (Swatantran et al., 2012). Remotely sensed products have been shown to increase species distribution model accuracy when included as input variables, specifically leaf area index (LAI) and enhanced vegetation index (EVI) (Buermann et al., 2008). Remote sensing data are particularly useful for identifying patterns and large-scale constraints on distribution across areas difficult to access as well as those where animal presence is poorly documented (Bradley and Fleishman, 2008). Despite migration being responsible for the majority of adult mortality, habitat requirements and stopover concentration of migratory birds remains poorly understood (Bonter et al., 2009; Sillett and Holmes, 2002). Here, we used a fusion of multispectral remote sensing data and distributional modeling techniques to generate and evaluate predictive maps identifying critical areas, sites with the appropriate vegetation or structure conducive for rest and refueling, for migratory passerines on the Texas coast.

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Fig. 1. Diagram of 14-county shape study area. Each county is labeled individually but data across the study area extent was considered collectively.

2. Methods

2.1. Study area

The 39,960-km^2 that comprise the Texas coast is considered critical migratory area for songbirds (Hunter et al., 1993) (Fig. 1). The landscape is heterogenous, amosaic of sandy tidal flats and salt marsh, variable-sized patches of deciduous vegetation, with well-defined, dense urban centers (e.g. Beaumont, Galveston, Corpus Christi) (Fig. 1). Pockets of freshwater and several rivers dot the landscape and are often the first available water to the migrating birds.

2.2. Data

We acquired bird presence data for all 14 coastal Texas counties from the eBird citizen-contributed database for 1 March 2016 through 30 April 2016 (eBird Basic Dataset, 2017). This date range coincides with peak migration activity in this region (Shackelford et al., 2005). Occurrence records for resident, winter-resident, or summer-resident species were omitted to focus the analysis solely on migratory species habitat.

We acquired Six Landsat 8 OLI Level-1 tiles (courtesy of U.S. Geological Survey) containing the full extent of the study area and processed the imagery in ENVI® 5.1 (NASA Landsat Program, 2016a–f). Image acquisition dates coincided with the bird occurrence data range. The tiles were seamlessly mosaicked into one raster and then resized to the rectangular extent of the poly-outline of the coastal counties. The resulting GeoTIFF was then exported to ArcMap in the ArcGIS® 10.3 suite where the counties shape mask extracted the spatial data.

2.3. Processing approach

Vegetation index values, urban areas, proximity to water, and elevation were considered environmental predictors in these models since it is well-documented that these shape the distribution of migratory birds with the greatest influence (Degraaf, 1998). Fig. 2 outlines the processing workflow for this study. An Enhanced Vegetation Index (EVI) analysis was performed in ENVI® 5.1, exported as a GeoTIFF and read into the R statistical language (a free, and free-standing program) as a raster (R Core Team, 2013). EVI and Normalized Difference Vegetation Index (NDVI) are similarly driven by variation in the red and near-infrared wavelengths (Running, 1990). However, the EVI function is optimized by de-coupling the canopy background and reducing atmospheric influences (Huete et al., 2010). The EVI is more sensitive to canopy structural variations (e.g. LAI, canopy type, canopy structure) whereas the NDVI is mainly chlorophyll sensitive (Huete et al., 2010). The EVI was appropriate for this study since canopy structure and LAI have been shown to be significant constraints on bird distributions