**Site suitability analysis of endangered species habitat areas for pesticide risk assessment: A case study of the red-cockaded woodpecker in the coastal plain counties of North Carolina**

By

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**Abstract**

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The Environmental Protection Agency conducts ecological risk assessments in order to determine potential risk to endangered species from pesticides. Currently, species range maps generated by the Fish and Wildlife Service are used to determine where an endangered species could be found, and thereby, the potential for exposure to pesticide applications within that same area. However, these range maps cover broad areas that may not provide a completely accurate representation of where a species might actually be found.

Alternative approaches could provide a more realistic estimate of exposure by refining the areas where a species would likely be found. This case study uses site suitability analysis with weighted overlay in GIS software in order to more accurately determine where the endangered red-cockaded woodpecker could be found in the coastal plain counties of North Carolina. Red-cockaded woodpeckers have very specific habitat requirements. They excavate and nest in living mature, longleaf pine trees that are greater than 80 years old. Data on vegetative land cover and forest age were obtained from the Southeast Gap Analysis Project and Oak Ridge National Laboratory, respectively. These data were processed in ArcMap 10.4.1 using weighted overlay to develop a rasterized map of the areas where the red-cockaded woodpecker could most likely be found.

ArcMap area calculations found that the Fish and Wildlife species range map defines 13,377,518 acres of the coastal plain counties of North Carolina as suitable for red-cockaded woodpecker habitat. The weighted overlay approach used in this paper refined that area to 534,736 acres of suitable habitat. This significant change in area provides a more accurate estimate of where the red-cockaded woodpecker would likely be found. This information could be incorporated into pesticide risk assessments to improve exposure assessments. If biological data are available on a given species' habitat preferences, weighted overlay and site suitability analysis could be used to refine habitat areas, and therefore, improve the accuracy of risk assessments for endangered species.

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## Introduction

The conservation and protection of endangered species has been an area of national interest since the US environmental movement of the 1970s. The Endangered Species Act (ESA) of 1973 states that endangered and threatened species of wildlife and plants are of “aesthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people” (ESA, 1973). Although extinctions occur naturally, there is mounting evidence that anthropogenic influences such as habitat destruction, the over-exploitation of wildlife for commercial purposes, the introduction of harmful nonnative organisms, environmental pollution, and the spread of disease exacerbate the threat to at-risk species (Chapin et al., 2000). Pesticide application is a unique situation where both man-made and naturally occurring chemicals are intentionally introduced into the environment to control a target pest. Due to the inherent nature of pesticides to inhibit biological processes and to repel and/or kill organisms, it is important to assess potential ecological effects on non-target organisms (EPA, 1998). The US Environmental Protection Agency (EPA) is responsible for regulating pesticide use under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and assessing pesticide risk to endangered species in compliance with the ESA. When conducting ecological risk assessments to evaluate risk to threatened and endangered species, EPA uses a tiered approach (EPA, 2018). If the initial screening-level assessment indicates there is potential risk of adverse effects to a species, a more specific species-level assessment may be conducted. As a part of this process, EPA examines pesticide use patterns, generally extracted from product labels, and relates that information to location information for a particular species to determine the potential for exposure. Currently, this location information is generated in one of two ways, using an elemental occurrence (EO) map, or using a species range map (Smyth, 2016). The EO map depicts locations where a species has been observed. However, this results in an under-prediction of the actual occupied area and an over-prediction of the unoccupied area. Conversely, range maps are the opposite, generally over-predicting occupied area and under-predicting unoccupied area (Amos, Kearns, & Kay, 2017). This current approach can result in an inaccurate estimate of endangered species' exposure to pesticides.

This paper proposes a new alternative approach to mapping endangered species for pesticide risk assessments: using weighted site suitability analysis in Geographic Information System (GIS) software to determine suitable and unsuitable locations for a species within a given area of interest. Weighted site suitability is an analytical geospatial technique that simultaneously assesses multiple physical parameters to locate areas of significant overlap. The analysis can be weighted towards parameters of greatest significance, and will produce a visual representation of site suitability (ESRI, n.d.). Suitable spatially-associated habitat characteristics for a given species (e.g. elevation, proximity to water, soil type, etc.) can be overlain to determine the areas where they have the most and least overlap and, therefore, are the most and least suitable.

While data are available on habitat preferences of various endangered species, more accurate, species-specific maps for use in pesticide risk assessments are not generally available at this time for the majority of endangered species. A specific case study can be used to demonstrate the utility of site suitability analysis of endangered species habitat areas for use in pesticide risk assessments. This paper will focus on the Red-cockaded Woodpecker (RCW, *Picoides borealis*) and its habitat areas in the coastal plain counties of North Carolina. The RCW is an endangered woodpecker native to the southeastern United States. This woodpecker is the only species known to excavate nest and roost sites in living trees. Specifically, the red cockaded woodpecker seeks out mature longleaf pine trees that are greater than 80 years old (FWS, 1985). Longleaf pines may have historically covered anywhere from 60 to 92 million acres in the Southeastern US, but today fewer than 3 million remain (Oswalt et al., 2012). Stemming from this habitat loss, RCW populations significantly declined and the species has been listed as endangered since 1970. A species range distribution map has been generated by the US Fish and Wildlife Service (FWS), however this range map does not indicate 'hotspots', i.e. the areas where the RCW is most likely to be found (FWS, 2001). Additionally, a critical habitat has not been assigned for the RCW. The objective of this paper is to utilize site suitability analysis with weighted overlay in ArcMap to develop a map of suitable habitat locations for the Red-cockaded Woodpecker for use in pesticide risk assessments.

**Methods**

In order to determine which portions of the North Carolina Coastal Plain counties are most suitable for RCW habitat, a stepwise approach for site suitability analysis was used in ArcMap 10.4.1. First, land cover data obtained from the Southeast Gap Analysis Project (SEGAP) were added to ArcMap (SEGAP, 2008). The SEGAP used multi-season satellite imagery (LandSat ETM+) from 1999-2001 in conjunction with digital elevation model (DEM) derived datasets to model natural and semi-natural vegetation. From this process and a comparison to the 2001 National Land Cover Dataset, the SEGAP mapped 214 land cover classes in the Southeast region of the United States. Only data from the NC Coastal Plain were included in the current analysis, which resulted in a total of 83 land cover classes in that area. Each of the coastal plain's 83 land cover classes were classified as most suitable, potentially suitable, and least suitable for RCW habitat. Suitability was determined by the vegetation of each class, as identified by SEGAP. The most suitable classes were the five that were dominated by longleaf pine trees. The potentially suitable classes were the four covering areas that contained some pines, but were predominated by hardwood species. All seventy four remaining classes were deemed the least suitable. These included urbanized areas, barren areas, agricultural lands, and open water.

In addition to the SEGAP data, forest age data from the Oak Ridge National Laboratory (ORNL) were added into ArcMap and clipped to the study area. The ORNL dataset provides the age in years of North American forest stands. These maps were compiled from forest inventory data, historical fire data, optical satellite data, and images from NASA's Landsat Ecosystem Disturbance Adaptive Processing System project (Pan et al, 2012).

Once the SEGAP and ORNL data were added and clipped to the study area, data were reclassified into three classes for comparison. For the SEGAP data, the land cover classes that were most suitable were assigned a value of three, potentially suitable a two, and the least suitable classes were assigned a value of one. For the ORNL forest age data, the most suitable tree stand ages (80 years and older) were assigned a value of three, potentially suitable tree stands between 40 and 80 years old were assigned a two, and tree stands less than 40 years old were assigned a one. The reclassified values were then used to perform a weighted overlay of the data. Because RCW species data indicate that tree species appears to be a more critical factor in habitat suitability than tree age, the land cover data were assigned 70% of the weighted analysis and the forest stand age data were assigned 30%. Finally, area calculations were performed on the resulting map from the weighted overlay analysis and compared to habitat area calculations of the FWS species range map covering the same area in order to quantify how effectively the weighted overlay approach refined the FWS range map.

**Results**

The coastal plain counties of North Carolina have 534,643 acres of land that are the most suitable habitat for the red-cockaded woodpecker, 2,356,891 acres of land where the woodpecker could potentially be found, and 7,933,318 acres of land that are unsuitable habitat (Figure 1). Of note, no ORNL data existed for 5,616,870 acres of the study area. Those areas are displayed as No Data and could not be included in the analysis. Calculated from the FWS species range map, the habitat range in the coastal plain counties is 13,377,518 acres (Figure 2). This accounts for 81% of the total land area of the coastal plain counties (16,441,722 acres). Using the weighted overlay approach, the woodpecker's most suitable habitat accounts for 3.25% of the total land area, a 96% reduction of the FWS range (Table 1).

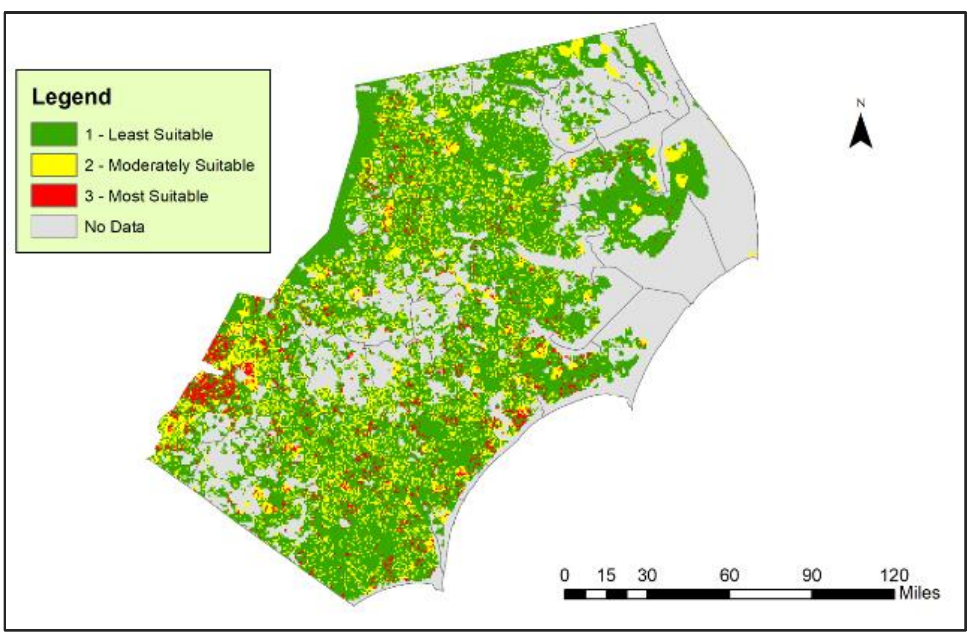

Figure 1. Red-cockaded Woodpecker Habitat Suitability – Weighted Overlay Approach

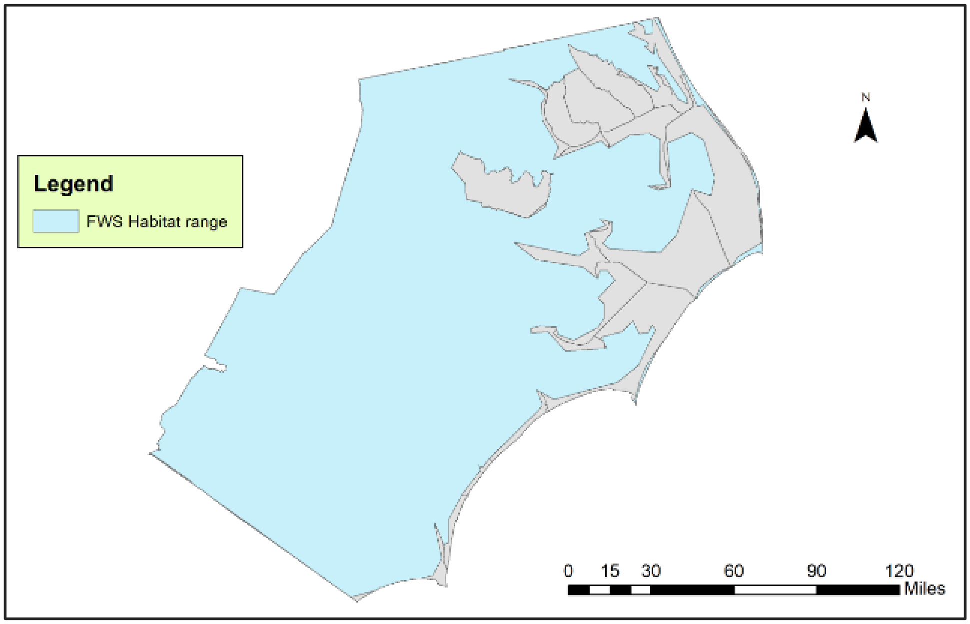


Figure 2. Red-cockaded Woodpecker Habitat Suitability – FWS Range Map

Table 1. FWS Range Map and Weighted Overlay Suitable Habitat Area Summary

| Approach | Most Suitable Habitat Area (acres) | Total Area (acres) | Coverage (%) |
|---|---|---|---|
| FWS Range Map | 13,377,518 | 16,441,722 | 81.36% |
| Weighted overlay | 534,736 | 16,441,722 | 3.25% |

**Discussion**

Using weighted site suitability analysis to define areas of suitable habitat greatly refined the species range predictions for the RCW in the coastal plain counties of North Carolina. A reduction in the range from over 13 million acres using the FWS range map to roughly half a million acres using the weighted suitability approach produces a much more precise basis for determining where the red-cockaded woodpecker would likely be found. The newly defined most suitable areas would likely be more useful in predicting pesticide exposure if the RCW was a species of concern. If the EPA were seeking to mitigate RCW exposure to a specific pesticide active ingredient, the FWS range map might suggest the need for certain pesticide use practices within that entire range area. However, there would likely be signficantly varying areas of expsosure within that range, depending on the pesticide product use pattern. Alternatively, the weighted suitabilty approach would provide the EPA with a means to refine endangered species mitigations to more specific areas.

There are a few limitations to the data presented with this case study. The SEGAP land classification data is nearly twenty years old and the ORNL forest stand age data is thirteen years old. While these data do demonstrate general trends in the study area that are likely still true today, land use and land cover are constantly changing and more contemporary data would provide more accurate results. Additionally, a significant portion of the study area did not have forest stand age data available. For this reason, a habitat suitability assessment could not be completed for those areas. Ideally, up-to-date aerial imagery, combined with a land cover analysis and modern estimates of stand age would provide the best fit for defining current habitat suitability. While these data were beyond the scope of this paper, the objective of this paper is to demonstrate the utility of the weighted overlay site suitability approach in developing habitat suitability maps. Even though the data presented in this paper are over ten years old, they effectively show how the weighted overlay tool in GIS software can be used to refine FWS range map habitat areas.

**Conclusion**

This paper demonstrated the utility of site suitability analysis using weighted overlay in ArcMap in developing a suitability map of habitat locations for the Red-cockaded Woodpecker for use in pesticide risk assessments. A 96% reduction from the FWS range map area to the suitable locations from the weighted overlay approach effectively corroborates the value of using GIS spatial analysis techniques to define more precise habitat range maps. If the EPA adopts this, or a similar approach, during their pesticide registration and review procedures, their exposure estimates for endangered, or other non-target species, would be significantly refined.

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