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forest ecology

Mapping and Modeling Ecological Conditions of Longleaf Pine Habitats in the Apalachicola National Forest

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We developed a historical natural community map and a spatially explicit ecological condition model (ECM) to evaluate conditions of the Apalachicola National Forest's longleaf pine habitats. We identified and mapped historical vegetation patterns across the forest and then compared current vegetation structure derived from LiDAR and field surveys to desired conditions for the respective habitat types. In the first example of how these tools may be applied, we show how the natural communities map improved our understanding of wet savanna distribution and how the ECM then revealed opportunities and challenges for managing this unique habitat. In the second example, we show that the ECM scores were closely aligned with red-cockaded woodpecker habitat selection at three nested spatial scales relevant for that species' ecology. Both of these analyses demonstrate how historical data and ecological condition assessments improve our understanding of resource patterns and may inform possible management actions.

Keywords: longleaf pine, ecological condition model, LiDAR, wet savanna, red-cockaded woodpecker

Restoring ecosystem integrity has been identified as an overarching goal for the United States Forest Service's (USFS) management of National Forest System lands. The increasing emphasis on restoration culminated in several national initiatives and policies, including establishing the Collaborative Forest Landscape Restoration program (in Title IV of the Omnibus Public Land Management Act of 2009) and revising regulations for forest planning under the National Forest Management Act that recognize "restoration of natural resources to make our NFS lands more resilient to climate change, protect water resources, and improve forest health" as a primary purpose of Forest Service work (77 FR 68, p. 21164). However, when developing and implementing land management projects in national forests, it is not always clear how to identify the desired structural, functional, or compositional characteristics of managed landscapes that are necessary for defining restoration objectives.

Assessing landscapes for restoration potential requires comparing the focal area with some range of reference conditions thought to characterize high-quality habitat. In many cases, parameters for desired conditions of a specific area may be based on historical conditions at the same site or current conditions at a less degraded site with a similar ecological history (White and Walker 1997; Keane et al. 2009; Landres, Morgan, and Swanson 1999). This approach is particularly informative when landscapes have been substantially altered due to past land management activities or disruption of processes that maintained conditions within a natural range of variation (Swetnam, Allen, and Betancourt 1999; Bolliger et al. 2004). The differences between current conditions and reference conditions may then be used to identify management priorities and develop activities that could be implemented to promote desired structure and function of ecosystems (Gärtner et al. 2008; Hessburg et al. 2007). In the context of Forest Service management, rigorously evaluating the departure of current landscapes from reference conditions may provide a quantitative and defensible basis for restoration planning at multiple spatial scales, from project areas covering a few hundred or a few thousand acres to long-term planning for entire forests or regions (Bollenbacher, Graham, and Reynolds 2014).

This paper briefly describes the development of a historical natural community map and a landscape-level ecological condition model from the Apalachicola National Forest in Florida, USA. Additional technical description of the ecological condition model is provided in the online supplementary material, but here we focus on two examples demonstrating the potential application and value of these tools for understanding landscape patterns and informing management.

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Study Area and Historical Natural Communities Map

The Apalachicola National Forest (ANF) encompasses approximately 570,000 ac of public land in the Florida panhandle, USA. The forest is managed in accordance with a Land and Resource Management Plan (i.e., the Forest Plan) that established objectives and guidelines for Forest Service activities (USDA Forest Service 1999). The ANF is one of the few remaining large and contiguous areas of longleaf pine (*Pinus palustris*) habitats, which are among the most diverse and imperiled communities in the United States (Brockway et al. 2005). The entire Florida panhandle is considered a biodiversity hotspot (Blaustein 2008), and dozens of rare endemic species occur in the ANF.

Relatively recent historical conditions may be interpreted from a variety of sources, including written accounts, land survey records, long-term monitoring, or interpretation of aerial photographs. For landscapes that have experienced recent change, aerial photograph analysis is particularly useful for quantifying land development or vegetation dynamics (Hellesen and Levin 2014; Morgan and Gergel 2013). In 2010 the National Forests in Florida initiated a project with the state natural history survey, Florida Natural Areas Inventory (FNAI), to identify and delineate historical natural communities of the Apalachicola National Forest. In 2011–2012, FNAI biologists generated a natural community map based on multiple years of georeferenced aerial photography (1930s–present), soil types, LiDAR digital elevation models, several hundred vegetation plots, element occurrences of habitat-specific taxa, and ground-truthed GPS points (Florida Natural Areas Inventory 2012). The resulting GIS database and map (Figure 1) classified all federally managed land within the boundaries of the ANF into five major vegetation types following FNAI's guide to natural communities of Florida (Florida Natural Areas Inventory 2010).

We field-validated and refined the natural communities map with over 400 plots throughout the forest, where we collected data on vegetation structure and composition. Although the map was based on a specific time frame (conditions during the first half of the twentieth century) rather than a dynamic range of conditions that certainly characterized the area (Keane et al. 2009), we are confident that the historical natural community map is nevertheless a better representation of historical conditions than the current distribution and condition of habitats.

Development of an Ecological Condition Model (ECM)

The spatial delineation of historical natural communities in the Apalachicola National Forest provided a basis for assessing the ecological conditions of the four major longleaf pine associations in the forest: flatwoods, sandhills, wet savannas, and upland pine communities. Forested cypress or hardwood wetlands were not considered in this model because they are not actively managed and one of the primary objectives for our ECM was to assess baseline conditions and then track the effects of management activities on the landscape.

Desired conditions for longleaf pine habitat types were defined from descriptions in the Forest Plan or FNAI's Guide to Natural Communities of Florida (Florida Natural Areas Inventory 2010, available at http://fnai.org/naturalcommguide.cfm). Important variables and indicators of condition were further refined based on reference sites and expert opinion of land managers and scientists familiar with the area. Current conditions were estimated for 0.52 ac cells (150 x 150 ft) from vegetation structure derived primarily from airborne LiDAR data, namely relative density for shrubs, midstory, and canopy layers and estimated basal area of canopy trees (summed trunk cross-section area per unit of area, usually ft^2/ac). Additional information such as stand age, dominant species, and time since most recent fire were added to the model from Forest Service databases and records of management history. Recent (1995–2010) fire frequency and severity was estimated from satellite imagery following the methods of Picotte and Robertson (2011). Habitat variables from these sources were used to calculate subscores for canopy, midstory, and groundcover layers based on the difference between the current and desired conditions of each natural community. These scores were then weighted, summed, and binned to produce an overall ecological condition score ranging from the integers 1 (= excellent condition) to 5 (= very poor condition) for each map cell. A more technical description of data collection, score calculation, and background information is provided in the online supplemental material. Table 1 summarizes the ECM scores across the entire ANF. Multiple methods of validation (described in the online supplement) showed that the model has high predictive ability of habitat structure and overall condition, but it is not based on nor does it predict current vegetation composition.

In the examples below, we used simple statistical analyses to illustrate patterns related to ecological conditions across the landscape. Most results in the two case studies include mean ECM scores and results of χ^2 tests based on frequency of scores (integers 1–5) of the categories being compared. These tests compared the observed distribution of condition scores among categories to expected frequency if ecological condition scores were distributed randomly across the forest. For the χ^2 tests we present the test statistic as an indication of overall difference and then discuss comparisons of scores between the categories to show directional differences. We considered a cell-level standardized residual

Management and policy implications

The USDA Forest Service and many other public land managers work under a multiple-use mandate that includes maintaining or restoring high-quality habitats. However, agencies often lack reliable, large-scale data on both the historical distribution of ecological communities and their current conditions. Technological advances in satellite imagery, LiDAR, and remote sensing analysis techniques have increased the reliability and reduced the cost of these tools for assessing forest conditions. We show here how aerial photography, remote sensed data, agency records, and field surveys were integrated into a map of historical natural communities and a data-rich ecological condition model. These products allow users to efficiently identify high-quality habitats for conservation and better understand the condition and spatial distribution of potential restoration sites. We suggest that developing similar products could greatly improve understanding of landscape patterns by agency decision-makers and resource specialists, provide a basis for evaluating restoration opportunities and objectively reporting management accomplishments, and facilitate interactions and collaboration with the public.

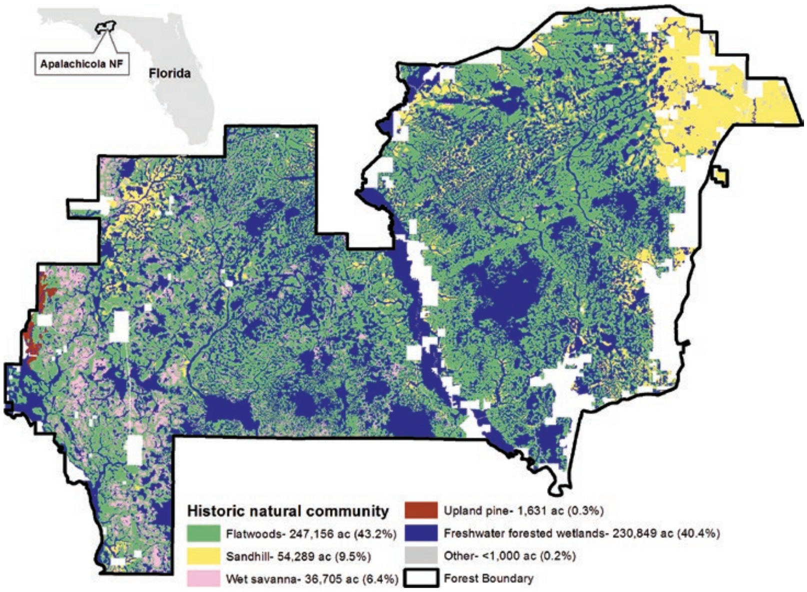

Figure 1. Distribution of historical natural communities in the Apalachicola National Forest.

>2 as a significant deviation from random distribution between categories for the post hoc interpretation of scores.

Case Study 1: Wet Savanna Management

Background. Wet savannas (often referred to as wet prairies) are one of Florida's major freshwater marsh associations (Kushlan 1990) and were historically widespread throughout the state (Stephenson 2011). These habitats are notable for high plant species diversity that is similar at the genus level among sites, but species vary depending on hydrology, soils, and geography (Walker and Peet 1984; Clewell et al. 2009; Carr, Robertson, and Peet 2010). Wet savannas in the Florida panhandle are characterized by a sparse or absent canopy and midstory with a dense groundcover of wiregrass and diverse herbaceous vegetation (Florida Natural Areas Inventory 2010). Development, agriculture, hydrological alteration, and plantation forestry have all contributed to loss and degradation of wet savanna habitat (Myers and Ewel 1990; Stephenson 2011). Even in otherwise protected areas, alteration of fire regimes (generally reduced frequency and more winter as opposed to summer burning) has also led to loss of wet savannas through encroachment of woody shrubs and trees (Florida Natural Areas Inventory 2010; Clewell et al. 2009; Hess 2014).

When this study was initiated in fall 2014, 160 stands totaling 6617 ac of the Apalachicola National Forest were classified as "undrained flatwoods," the US Forest Service vegetation type most frequently used to identify wet savanna habitats. Examination of aerial imagery and field visits verified that most of these stands were correctly classified based on current conditions, although many were degraded. Almost all of the stands (140 stands totaling 6360 ac) were in the Apalachicola District on the western side of the forest, and most of that area (4168 ac) was within Management Areas (MAs) designated for wet savanna conservation (i.e., MA 2.1–Savanna Research Natural Area and MA 3.1–Apalachicola Savannas Special Interest Area). However, due to past degradation and conversion to other vegetation communities (e.g., slash pine plantations), extant wet savannas represent only a fraction of the historical distribution of this habitat type in the region (Kindell 1997; Stephenson 2011, Hess 2014).

Historical Distribution and Ecological Condition. The historical natural communities map included 2244 polygons totaling 36,705 ac of historical wet savanna—over five times the area currently recognized in USFS databases. Many of these polygons (shown in pink in Figure 1) were relatively small linear areas between forested swamps and slightly higher-elevation flatwoods. However, there are also relatively large and connected patches of historical wet savanna habitat on the western side of the Apalachicola National Forest.

Because many wet savannas on the historical natural community map were narrow ecotonal areas between other habitats, only 34,734 ac of the estimated 36,705 ac of historical wet savannas were captured in the 0.52 ac square cells used in the ECM. Analysis of ECM scores showed that the current conditions of wet savannas are closely linked to Forest Plan direction for different Management Areas (MAs) in the forest. Approximately 10% of historical wet savannas (~3500 of 35,000 ac) is within the two Management Areas (MA 3.1–Apalachicola Savannas Special Interest Area and MA 2.1–Savanna Research Natural Area) that recognize the ecological value of these habitats and provide guidance for their protection and management. The average condition scores in these wet savanna MAs is 2.1, compared to an average score of 3.9 for historical wet savanna in other MAs, and the wet savanna MAs contained a disproportional frequency of excellent and good ECM scores (χ^2 = 19784, d.f. = 4, P < .0001). The continued presence of high-quality wet savannas in these areas

Table 1. Area (acres) and percent of total for each ECM score within the four longleaf pine habitats considered in the model and for the entire ANF.

Condition	Flatwoods	Sandhill	Wet savanna	Upland pine	All longleaf habitats
Excellent	110 (<1)	18 (<1)	1823 (5)	3 (<1)	1954 (<1)
Good	57709 (23)	14262 (26)	4871 (14)	341 (20)	77183 (23)
Fair	69623 (28)	19699 (36)	7461 (22)	357 (21)	97140 (28)
Poor	52734 (21)	12386 (22)	8123 (24)	328 (20)	73571 (23)
Very poor	69499 (28)	8860 (16)	12222 (35)	651 (39)	91232 (26)

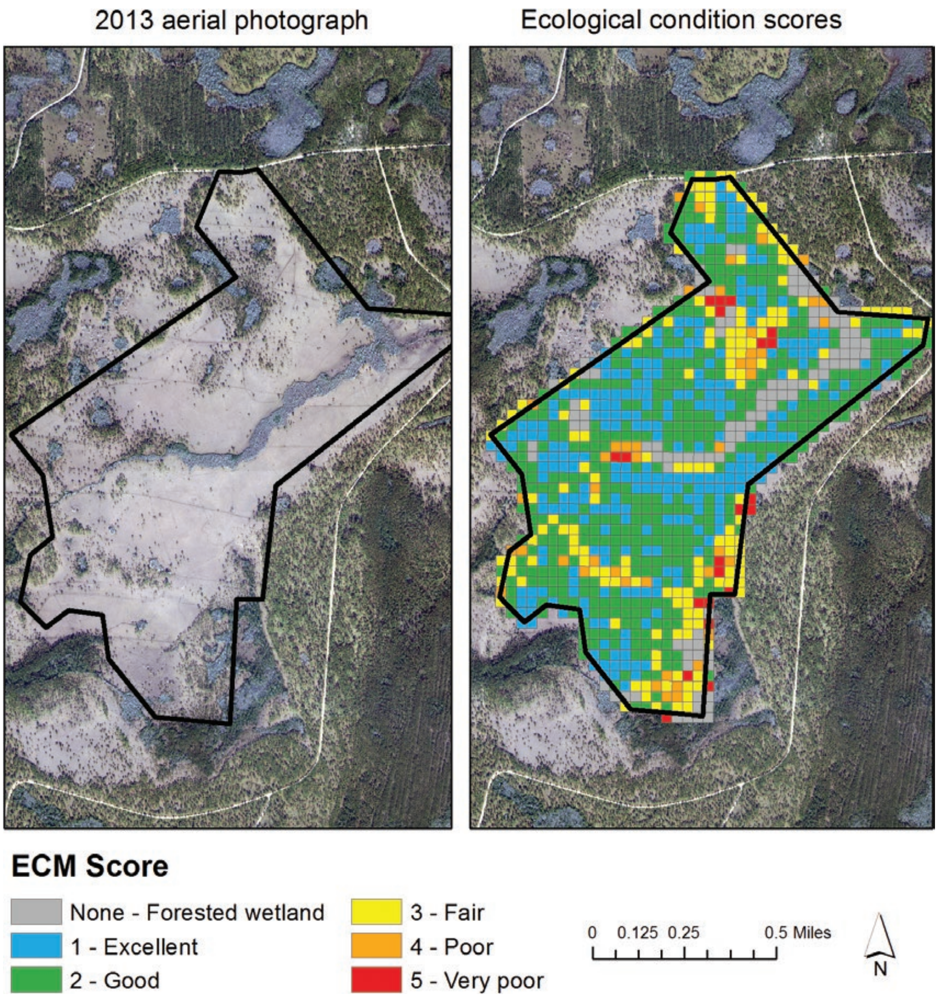

Figure 2. Aerial imagery and ECM scores for mapping units identified as historical wet savanna within the Savannah Research Natural Area (MA 2.1). For ease of interpretation, panel B includes only the 0.52ac ECM cells that had their center located within MA 2.1 and were classified by the historical natural communities map as wet savanna.

indicates that the USFS has generally met their management objectives as described in the Forest Plan, as exemplified by the Savanna Research Natural Area (Figure 2).

By contrast, historical wet savannas outside MAs 2.1 and 3.1 are in relatively poor condition, with only 2% (~590 ac) of historical wet savannas in excellent condition and only an additional 11% (~3500 ac) in good condition. Historical aerial photographs clearly show how plantation silviculture or shrub and tree encroachment due to lack of fire have influenced wet savannas in Management Areas that did not provide guidance for managing these habitats. For example, Figure 3 shows a striking example of the divergence in ecological condition of adjacent wet savanna sites within the past 80 years. The wet savannas east of CR 379 (the line running NW to SE in the images) were maintained and then designated as MA 3.1 in the Forest Plan and currently have good to excellent ECM scores. Most of the wet savannas west of CR 379 were mostly managed for timber production, were not recognized as savannas during Forest Plan revision, and are currently dense slash pine plantations with poor or very poor ECM scores.

Importance of Wet Savannas for Rare Plant Species. Of the 25 rare plant species that occur in panhandle wet savannas, most are habitat specialists and 12 are endemic to the region (Florida Natural Areas Inventory 2010). Four plant species listed as threatened or endangered under the Endangered Species Act of 1973 are known to currently occur in Apalachicola National Forest: Harper's beauty (*Harperocallis flava*), white birds-in-a-nest (*Macbridea alba*), Godfrey's butterwort (*Pinguicula ionantha*), and Florida skullcap (*Scutellaria floridana*). All of these species can occur within wet savannas or on the ecotone between wet savannas and adjacent swamps or flatwoods (US Fish and Wildlife Service 1983, 1994). Of the 744 recently confirmed occurrences of these species in the Apalachicola National Forest, 426 (~57%) are within 269 ECM cells classified as historical wet savanna (some cells contained multiple occurrences). The average ECM score of wet savanna sites where federally listed plants have been found was 2.9, compared to 3.7 in cells where these species have not been found. There was a significantly higher proportion of excellent and good habitat scores and a lower proportion of very poor habitat scores in map cells containing these rare plants ($\chi^2 = 113$, d.f. = 4, $P < .0001$). It is likely that higher-quality areas have been more intensively sampled for these species, which may account for the apparent habitat selection, but the extent of surveys in lower-quality sites strongly suggests that these species have simply not persisted in degraded wet savannas. This relationship suggests that maintenance and restoration of wet savanna habitats may be particularly important to protection and recovery of listed plant species in the Apalachicola National Forest.

Management and Restoration. Development of the historical natural communities map and an ecological condition model provided a greater understanding of the spatial extent of wet savanna habitats and the level of degradation across the forest, both of which can be used in project planning and monitoring management success. The wet savannas recognized by the Forest Plan and assigned to Management Areas 2.1 and 3.1 are generally in good condition and are maintained by frequent prescribed fire. Other than continued prescribed fire and periodic thinning of encroaching trees or shrubs, these sites likely require little active management. Where fire has been excluded from wetland ecotones, maintaining wet savannas may require mechanical or chemical reduction of shrubs such as titi (*Cliftonia monophylla* and *Cyrilla racemiflora*) that have isolated wet savannas from the rest of the burn unit. ECM scores, rare plant occurrences, and the spatial distribution of wet savanna patches across the landscape can help prioritize these efforts.

Most historical wet savannas outside MAs 2.1 and 3.1 are in fair, poor, or very poor condition. It is important to recognize that these ECM scores encompass a range of vegetation structure and site histories, so appropriate restoration activities vary

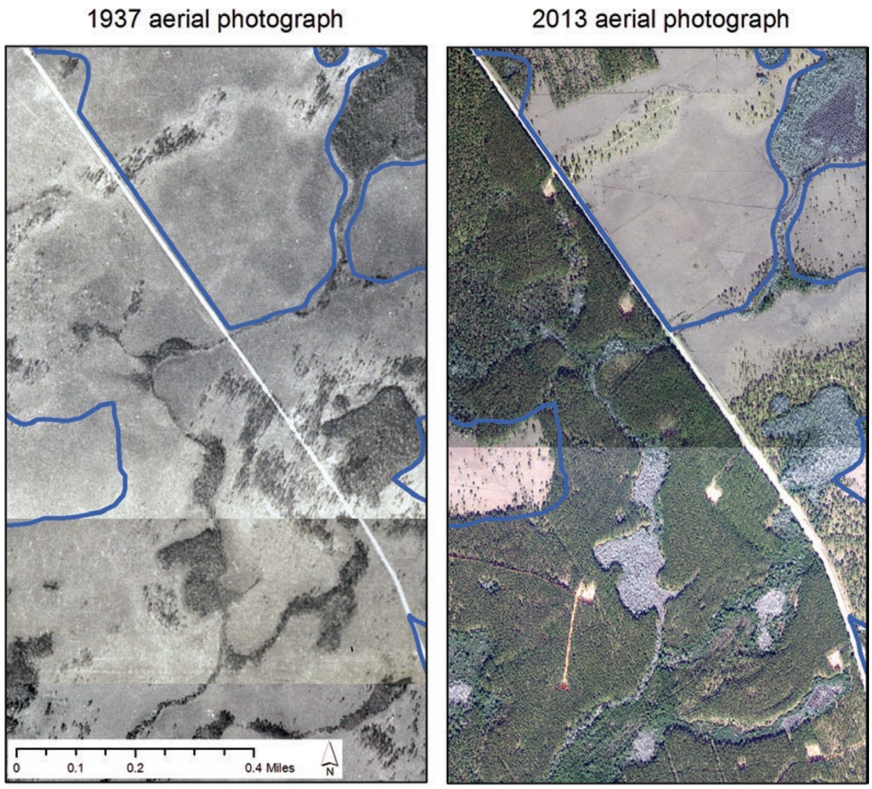

Figure 3. Comparison of historical and current vegetation of an area of historically contiguous wet savanna bisected by County Road 379 (Liberty County, Florida). Blue outlined polygons represent the current MA 3.1 Savanna Special Interest Areas. These are shown in the 1937 photograph for comparison only.

substantially among these conditions. The sites in fair condition (i.e., ECM score of 3) usually have some intact groundcover, but shrub and tree density is higher than desired for wet savannas. Thinning trees through harvest combined with a greater emphasis on short fire return intervals and early growing season fire (March to June) will likely restore many desired elements of structure, function, and composition for these wet savanna sites (Kindell 1997). Because prescribed fire and thinning trees have potentially substantial benefits with relatively low cost, particularly if the trees are marketable, the over 7000 ac of historical wet savannas with a condition score of 3 are reasonable areas for investing resources in restoration. By contrast, sites in poor or very poor condition (i.e., ECM condition 4 and 5) often have few recognizable elements of wet savanna vegetation. In many cases these sites have been either bedded and planted with slash pines or covered by dense titi; occasionally wiregrass, pitcher plants, or sundews may be found at the end of beds along roads or in small gaps in the dense shrubs. For sites planted with slash pine, thinning the canopy and continued efforts to burn the stand are reasonable and low-risk steps toward restoration (Hess and Tschinkel 2017; Van Lear et al. 2005; Walker and Silletti 2006). Historical wet savanna sites that have been dramatically altered may require more intensive restoration efforts (e.g., flattening beds, removing slash pine, cutting and herbiciding shrubs, restoring groundcover) to restore structure and function. However, because such activities are expensive and could disrupt important processes such as hydrological function and fire, it may be reasonable to manage the stands more like wet flatwoods than like high-quality wet savannas, with timber thinning and fire gradually enhancing wet savanna characteristics.

Case Study 2: Habitat Selection by Red-Cockaded Woodpeckers

Background. Red-cockaded woodpeckers (RCWs; *Picoides borealis*) are an iconic species of southeastern pine forests that have been protected under the Endangered Species Act since its passage in 1973. This species breeds cooperatively, and family groups establish and defend territories surrounding one or more cavity trees that are used for roosting and nesting. Although the relative importance of specific habitat elements varies among studies and populations (Garabedian, Moorman, et al. 2014; McKellar et al. 2014), RCWs prefer areas with widely spaced mature pine trees, little or no midstory, and a fire-maintained grassy and herbaceous groundcover (Conner, Rudolph, and Walters 2001; US Fish and Wildlife Service 2003).

There are approximately 750 active red-cockaded woodpecker groups in the Apalachicola National Forest. Management activities in pine flatwoods and sandhills have been conducted largely to maintain and improve RCW habitat, and the Forest Plan directs all timber harvest projects to follow management guidelines described in the RCW recovery plan (US Fish and Wildlife Service 2003). Past studies of RCWs in the Apalachicola National Forest have found preferential occupancy and higher group performance in areas that meet recovery plan criteria for good-quality foraging habitat (James, Hess, and Kufrin 1997; James et al. 2001). Even within occupied areas, one study found evidence for hierarchical habitat selection in which cavity trees were older and larger than surrounding trees and the area surrounding cavity trees (<200m) was more open with larger trees and less midstory than area farther (200–400m) from the cavity trees (Hovis and Labisky 1985).

Ecological Condition of RCW Habitat. The vegetation structure scores in the ECM align closely with the criteria for good-quality foraging habitat described in the RCW recovery plan (US Fish and Wildlife Service 2003, pp. 188–189), with higher-quality flatwoods and sandhills generally falling into scores 1 and 2 in the model. Because RCW respond strongly to structural elements of their habitat and have high fidelity to cavity trees, comparing the distribution of ECM scores in relation to RCW habitat occupancy was a reasonable validation for the modeling methods and an exploration of a potentially powerful habitat assessment tool.

To evaluate this potential application of the model for RCW presence, we compared the proportional distribution of ECM scores at three successively smaller scales of habitat selection relevant for RCW ecology: 1) Forest-wide: map cells within ¼-mile radius of cluster centers partitioned using Theissen polygons (i.e., ¼ mi. foraging partitions) compared to map cells in the rest of the forest, 2) Within partitions: map cells within 200 ft of cavity trees (i.e., the cluster) compared to map cells in the ¼ mi. foraging partition but farther than 200 ft from active cavities, and 3) Within clusters: map cells containing active cavity trees compared to map cells within the cluster but not containing active cavity trees. The spatial relationships for these three analyses are shown in Figure 4. Although most RCW clusters were located in flatwoods or sandhills, the ECM scores for all cells falling within the areas described above were used for these analyses, with no distinction among historical natural communities.

We found different proportions of good-quality habitat, as measured by ECM scores, at all three levels of habitat selection. The average score of map cells within ¼ mi. foraging partitions was 2.8, whereas the average score of the rest of the forest was 3.6. The proportional distribution of scores differed between these areas ($\chi^2 = 34619$, df = 4, $P < .0001$), and examination of the residuals showed that scores 1–3 were over-represented in ¼ mi. foraging partitions and scores 4 and 5 were over-represented in the areas outside partitions (Figure 5A). The within-partition comparison of map cells in clusters to those farther than 200 ft from active trees showed a similar pattern (Figure 5B; $\chi^2 = 3458$, df = 4, $P < .0001$). The average score of map cells within clusters was 2.5, whereas the average score of the rest of the partition was 2.9. Examination of the residuals showed that map cells with an ECM score of 2 were very over-represented within clusters and scores 1 and 3 were slightly over-represented in clusters, whereas scores 4 and 5 were over-represented in the areas outside clusters. The within-cluster analysis found more subtle differences (Figure 5C), but map cells containing active cavity trees (average score = 2.3) still had proportionally more scores of 1 or 2 compared to map cells within the cluster but not containing active cavity trees (average score = 2.5; $\chi^2 = 225$, df = 4, $P < .0001$). These results demonstrate that the ECM incorporated relevant variables at a spatial resolution that is appropriate for evaluating red-cockaded woodpecker habitat attributes in a heterogeneous landscape.

Habitat and Population Management. Two recent reviews have found substantial geographic variation in the relative importance of specific habitat variables for RCW populations (Garabedian, Moorman, et al. 2014; McKellar et al. 2014). However, the general description of good-quality habitat as areas with "some large old pines, low densities of small and medium pines, sparse or no hardwood midstory, and a bunchgrass and forb groundcover" (US Fish and Wildlife Service 2003, p. 188), remains well supported. We have shown above that the ECM scores on the ANF align well with these habitat features and correspond with RCW presence. As such, our ECM provides a landscape-level tool that can help determine where actions such as timber harvest could adversely affect RCW foraging habitat or where management actions may be most beneficial for RCW.

The recommended process for analyzing the effects of proposed management activities (e.g., timber harvest) on RCW foraging habitat requires extensive field surveys to estimate vegetation structure parameters of all forest stands in RCW foraging partitions (US Fish and Wildlife Service 2003). Quantifying specific habitat characteristics on a stand level is simple, but doing so on large spatial scales is time consuming and expensive. As such, developing tools based on remote sensing to estimate habitat quality could result in substantial cost savings and increased efficiency. In a recent study, Garabedian and colleagues (Garabedian, McGaughey, et al. 2014) used LiDAR to separately estimate multiple variables related to RCW foraging habitat. Their analysis of habitat quality within ½ mi. foraging partitions was based on evaluation of each variable against their respective thresholds as described in the RCW recovery plan's description of good foraging habitat. Our approach, by contrast, showed that a composite ecological condition score based on multiple elements of vegetation structure and fire frequency was strongly related to RCW habitat selection at three nested spatial scales.

The ECM scores may also be helpful for informing more direct population management activities. Two important techniques used in the ANF are establishing recruitment clusters (artificial cavities placed in apparently suitable habitat) for colonization within the forest and translocation of fledglings to clusters of artificial cavities in other locations across the southeast. Because the ECM scores clearly corresponded with RCW habitat preferences, spatial analysis of unoccupied areas both on the ANF and at recipient sites for translocation could help managers understand where recruitment clusters are most likely to be successful based on quality of the surrounding habitat. Additionally, components of the overall score such as

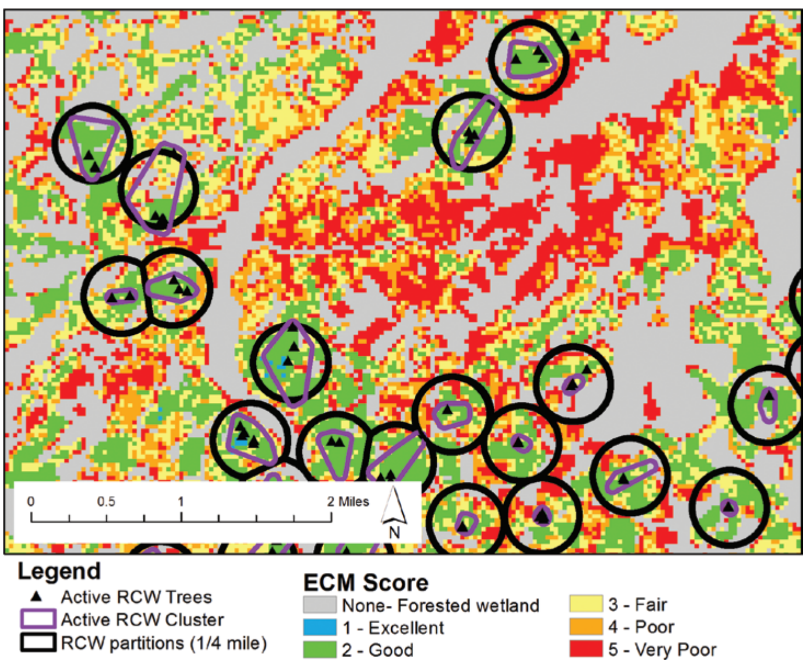

Figure 4. Example of RCW foraging partitions, clusters, and active cavity trees overlaid on ECM scores from the western Apalachicola National Forest.

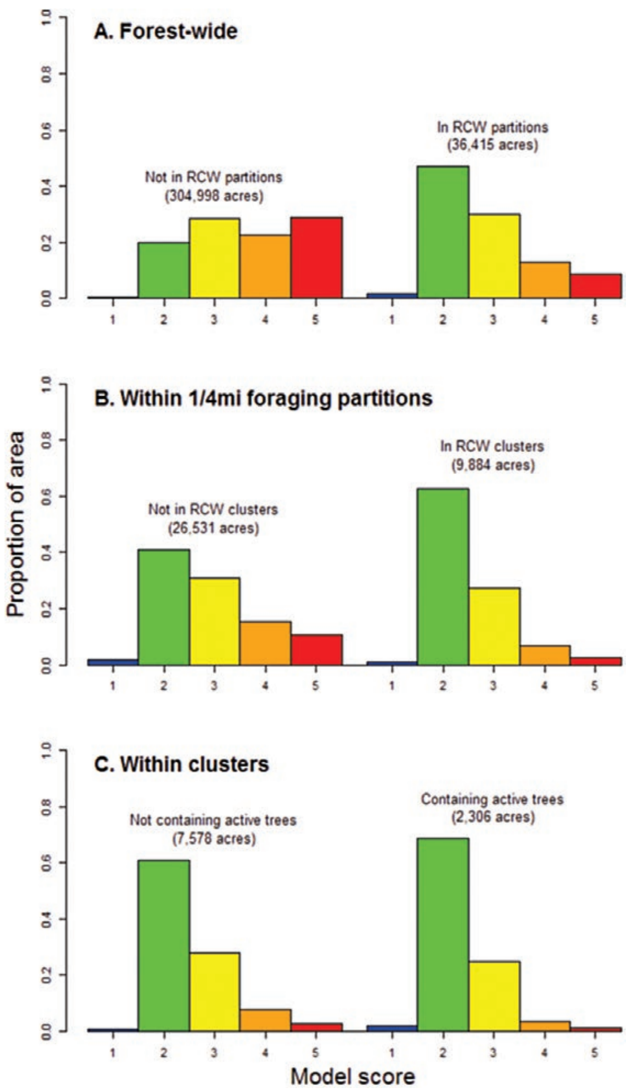

Figure 5. Distribution of ECM scores for RCW habitat selection at three nested spatial scales—A. forest-wide, B. within foraging partitions, and C. within clusters of cavity trees. The colors of the bars match the colors in the ECM results in Figure 4 above.

midstory and canopy density can be displayed individually in GIS to identify areas with appropriate canopy structure but degraded conditions that could be improved by midstory reduction and fire to improve success of recruitment or translocation. Since RCW population health generally increases with density due to the importance of inter-cluster movements (Conner, Rudolph, and Walters 2001; US Fish and Wildlife Service 2003), creating large contiguous areas of suitable habitat should facilitate population growth. We have not explored the relationship between ECM scores of habitat and RCW group variables such as reproductive performance or the presence of helpers, but such an analysis could reveal further applications of remote sensing for RCW management.

Summary and Future Work

Public lands such as national forests face increasing demands to provide a wide variety of resources, including timber and biomass products, habitat for rare species, and recreation opportunities for the public. Given limited or declining budgets, there is a clear need for tools that can help forest managers make more informed decisions and to develop a more deliberate and efficient program of work. Understanding historical conditions of altered landscapes and assessing the current conditions of natural communities are key elements of ecological restoration and should be part of conversations related to balancing restoration goals with other management objectives. Additionally, repeated measurement of ecological condition can indicate restoration success or provide feedback to improve land management activities. In this paper (with greater technical detail provided in the online supplement), we have described the development of a historical natural communities map, a spatially explicit ecological condition model, and the application of these tools to two complex management issues in the Apalachicola National Forest.

As we further develop and update the ECM, it may be used to answer a wide range of questions relevant to restoring longleaf pine habitats within and beyond the Apalachicola National Forest. For example, the composite ECM score or variables from which it was calculated could be used to prioritize ongoing activities such as prescribed fire, timber harvest, or midstory removal. Additionally, although the LiDAR-based approach was very productive, we are also exploring the use of frequently updated National Agricultural Imagery Program or other similar products processed with new techniques to estimate forest structural parameters from satellite imagery (Hogland et al. 2014). If successful, this refinement would reduce the time and expense of generating and updating the ECM, which in turn could decrease the barriers to widespread adoption of such rigorous and objective decision support tools.

Supplementary Materials

Supplement 1. Description of methods used to develop the Ecological Condition Model.

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