APPLICATION OF A GIS MODEL IN EVALUATING THE RED-COCKADED WOODPECKER HABITAT AT HOBCAW BARONY

Atul Kale
Department of Forestry and Natural Resources
Clemson University
261 Lehotsky Hall
Clemson, SC 29634
E-mail: atulk@clemson.edu

Thomas M. Williams
Clemson University
Belle W. Baruch Institute of Coastal Ecology and Forest Science
P.O. Box 596
Georgetown, SC 29442
E-mail: tmwllms@clemson.edu

Bo Song
Clemson University
Belle W. Baruch Institute of Coastal Ecology and Forest Science
P.O. Box 596
Georgetown, SC 29442
E-mail: bosong@clemson.edu

Donald Lipscomb
Department of Forestry and Natural Resources
Clemson University
261 Lehotsky Hall
Clemson, SC 29634
E-mail: dlpscmb@ clemson.edu

Ralph Costa
U.S. Fish and Wildlife Service
Clemson Field Office
Department of Forest Resources
261 Lehotsky Hall
Clemson, SC 29634
E-mail: rcwollc@gmail.com

Abstract

The red-cockaded woodpecker (*Picoides borealis*) (RCW) is a listed endangered species endemic in the southeastern United States. It is a cooperatively breeding species that prefers to live in an open, mature and old growth pine ecosystem. The restoration and management of red-cockaded woodpecker habitat is a difficult task within both public and private land. To analyze whether to delist the red-cockaded woodpecker from the endangered species list, the U.S. Fish and Wildlife Service developed the foraging matrix system in the recovery plan. The foraging

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index or score classifies habitat based on its condition. The foraging matrix standards contain twelve habitat criteria at the stand level and four habitat criteria at the partition level. These criteria are based on stand characteristics, canopy cover, stand age, and prescribed burning history. The RCW Foraging Analysis Program (RCWFAP) is the result of the automation of the foraging matrix within a geographic information system (GIS) and has become a valuable tool in evaluating the impact of various forest management practices on RCW habitat. In this study, the GIS foraging matrix was evaluated using data from a forest inventory that covered 18 years (1989-2007) at Hobcaw Barony. The partition and stand score obtained from the RCWFAP showed that the criteria of the scoring system and the GIS model both need critical improvement.

Keywords. Endangered species, foraging habitat, foraging matrix application, recovery plan

Introduction

The red-cockaded woodpecker (*Picoides borealis*, RCW), one of 22 species of woodpeckers native to North America (Jackson, 1971; 1994), is an endangered species endemic to fire-maintained southern pine forests. The RCW is monogamous and essentially single brooded, although rare instances of double brooding have been documented (Jackson, 1994; Schillaci and Smith, 1994). The breeding age for RCWs is approximately one year, and as the age increases the success of reproduction improves (Walters, 1990). It is a cooperative breeder living in groups consisting of a breeding pair with or without male helpers (Ligon, 1970; Lennartz et al., 1987; Walters et al., 1988) that forage and roost in living pines (Hooper and Lennartz, 1981). It is non-migratory and territorial bird; its territory ranges from 50 to 150 ha (Hooper et al., 1982; Porter and Labiskey, 1986; Walters, 1991).

It was observed that the RCW's foraging behavior is specialized and stereotyped (Skorupa, 1979). RCWs require an open pine ecosystem for foraging. The foraging area mainly consists of large pines rather than hardwoods (Ramey, 1980; Bradshaw, 1995).They forage primarily on arthropods especially ants and roaches, beetles, spiders, centipedes, crickets and moths (Harlow and Lennartz, 1977).

The RCW habitat is considered of good quality if it consists of open pines with little underbrush, and a basal area of 50-80 square feet with little or no hardwoods (Dickson, 2001). The loss of old pine habitat with the increase in midstory vegetation may be responsible for the decline of RCW population (Jackson, 1971) because it leads to the cluster abandonment. To ensure the protection of RCW habitat, a Recovery Plan and foraging habitat standards were developed for RCW populations on federal and private lands. A revision of RCW Recovery Plan that was approved by the U.S. Fish and Wildlife Service in 2003 includes two sets of foraging habitat guidelines: a recovery standard and a managed stability standard. These foraging habitat guidelines were also used to develop the matrix system.

After the establishment of RCW foraging guidelines in the 1990s, a matrix system was developed by the U.S. Fish and Wildlife Service to differentiate the quality of habitat based on the subsequent standard development. This matrix system evolved over the next decade, reflecting the increased number of standards.

Initially**,** the forests at Fort Bragg, North Carolina, were considered as ideal habitat for RCW. Its matrix was developed to maintain RCW habitat on both private and public lands. This first matrix system organized the foraging guidelines for implementation and evaluation of the habitat. However, it was not found to be inefficient in the management of habitat, because it was based on the natural habitat condition rather than the managed RCW habitat condition.

The partition concept was first introduced in this matrix system to help understand RCW foraging boundaries. There were a total of sixteen foraging habitat characteristics. For each characteristic scores were assigned from 1 to 5 on the basis of the occurrence of the characteristic, and then the total score was calculated by adding all the scores for the characteristics. RCW habitat was differentiated into five categories: 1) poor, 2) fair, 3) good, 4) very good, and 5) excellent, on the basis of total score of all characteristics.

Due to the lack of an auto-deployable format for GIS application, this matrix system was again modified based on the recommendations of the experts from Environmental Systems Research Institute, Fort Bragg, the U.S. Army Environmental Center, and the U.S. Fish and Wildlife Service, who ranked the habitat characteristics. The results were then used to establish a preliminary weighting system for a recovery standard matrix. In addition, it incorporated a deployable application using the geographic information system (GIS) to automate foraging habitat evaluation. In this matrix, the characteristics are clearly differentiated at the stand and partition levels, twelve characteristics being identified at the former and four at the later. This matrix system was more efficient because it included all requirements on RCW habitat, it classified the RCW habitat at both partition and stand levels, and more importantly, it ranked characteristics using weight factors. The disadvantage of this matrix system was that a score of 5 was too high, therefore it was almost impossible to meet all standards required by an ideal habitat.

The population of RCWs has been studied on the Hobcaw forest periodically since 1930's (Dennis, 1968). In 1977, Grimes studied specifically the relationship between vegetation characteristics and RCW clusters. The Hobcaw forest varied widely in terms of density, basal area, and understory characteristics; which primarily consisted of loblolly pine, longleaf pine, and pond pine (*Pinus serotina*) trees found in the RCW clusters. In addition, the cluster area varied considerably in terms of structure and species composition. As Grimes found in his study of 20 RCW clusters, the fledgling rate at Hobcaw was quite low, 1.44 per group.

It was observed that prescribed burning and different intensities of cutting, ranging from no cutting to seed tree harvests, were not been effective management strategies to improve the nestling productivity (Grimes, 1977). Wood conducted both early home range and the only manipulative study of RCW habitat needs (Wood et al., 1985), and found that clearcutting had no impact on the low fledgling rate, as 15 % of individual groups preferred this type of habitat. A second reproductive study conducted by Nalley (1998) found the fledging rate to be 1.0 per group. The basal area and stem requirements were used to predict the abandonment of individual clusters.

The partition approach that incorporates GIS into the foraging habitat standards evolves into a revised matrix system. It was used to define RCW territories using GIS. Using this tool, foraging

habitat was determined by creating a 0.5 mile radius foraging circle around the center of each cluster. The collected data about the stand characteristics was then applied to determine availability of foraging habitat within the newly created circular polygon. If the foraging circles outlining two clusters overlapped, equal portions of the foraging area were divided between the two (U.S. Fish and Wildlife Service, 2005).

The RCW habitat at Hobcaw forest was never before evaluated using the RCW Foraging Analysis Program or any other model. The RCW population is considered a small population in relation to its habitat at Hobcaw Barony. This study will focus on the relationship between the habitat quality and the RCW population given that the sufficient cavity trees are present. The quality of habitat reflects the nesting success as well as budding of clusters. It assumes that the nesting success in a specific cluster should have good habitat conditions and that each cluster fulfills most of the requirements of good RCW habitat. This study is important because it not only evaluates the RCW habitat, but also it tests whether the matrix standard is efficient or not to predict the RCW habitat change. Meeting the matrix standards for stand and partition characteristics in RCW foraging habitat also suggests the importance of those characteristics and how they affect habitat quality. In this study, the RCW habitat at Hobcaw forest is evaluated using the RCW Foraging Analysis Program (RCWFAP or RCW Foraging Matrix application) to predict the trends and successes of recovering clusters from 1989 to 2007, and the resulting partition scores were used to correlate the RCW habitat available and the RCW populations for three different years (1977, 1998, and 2007).

Specifically, this study will focus on the three areas: (a) the effectiveness of the partition score as an indicator of a good RCW habitat; (b) the relationships among stands, partition scores, and the number of nests over 14 year period, 1994-2007; and (c) the ability of the stand and partition scores to indicate a 'Wax and Wane' pattern in clusters. For example, according to quality and quantity of habitat, the partition and stand score should show same trend.

Methods

Study Area

The Hobcaw Barony is a 17,500 acre property, 7,600 of which are forest, 7,500 are salt marsh, and 2,400 are fresh water or brackish marshes and abandoned rice fields (Wood et al., 1985). The 7,600 acres of forest are comprised of 6,100 acres of pines, 800 acres of hardwood, and 300 acres of fields and marshes. The pine ecosystems of Hobcaw Barony mainly consist of longleaf pine, loblolly pine, and shortleaf pine, and the hardwood species are mainly oak (*Quercus spp*.) and sweetgum (*Liquidambar styraciflua*). The primary soils found on Hobcaw Barony are entisols and spodosols (Lipscomb and Williams, 1983).The Hobcaw Barony property is divided into six compartments: 1) Mud bay, 2) Hog pen, 3) Hobcaw, 4) Crabhaul, 5) Clambank, and 6) Bellefield. The Hobcaw is the largest, and the Crabhaul is the smallest.

Collection of Forest Inventory Data

The stand data collected for RCWFAP can be classified broadly into three periods: 1) the pre-Hurricane Hugo period; 2) the Hurricane Hugo period in which the data was collected on the

mortality and damage; and 3) and the post-Hurricane Hugo period. These data include the basal area and stems per acre for six classes: pines 4-10" in diameter, 10-14" in diameter, and 14"+ in diameter, and hardwoods 4-10" in diameter, 10-14" in diameter, and 14"+ in diameter. These data were generated from four sources: 1) a 5% inventory of the forest conducted in 1986; 2) growth data from 1979-1984 continuous forest inventories; 3) a 1% inventory of Hurricane Hugo wind damage; and 4) an aerial photo-based estimation of areas of salt mortality as a result of Hurricane Hugo.

Pre-Hurricane Hugo stand data were developed based on a stand inventory conducted in 1986 (Williams and Lipscomb, 2002). This inventory represented a 5% stratified sample of the forest. Point samples were allocated to 361 stands on the basis of their area. All included trees were measured for species group, diameter at breast height (DBH), and height. Since the Inventory Processor program was developed to classify forest products size classes, the original point data were reanalyzed to divide them into the six classes required by the matrix program. An Excel workbook was designed to organize the species and the DBH data based on stems per acre and basal area of pines and hardwoods in the three previously-described diameter classes. Each page of the workbook corresponded to a stand, and data from each page was then imported into an ArcGIS shapefile, which was used for forest management purposes (Lipscomb and Williams, 2005; 2006).

To ensure relevant data for each year, growth was estimated from the Continuous Forest Inventory system (Lipscomb and Williams, 1983). Since data collected from 1979-1984 represented a period of normal growth and mortality, they were used for periods of 1986-1989 and 1992-2007. The 1979-1984 data were used to calculate net growth up to 2007 in the three diameter classes for pines and hardwoods. This net growth estimation was then used to calculate annual changes in each class for the 1986-1989 and 1992-2007 periods.

Hurricane Hugo struck the Hobcaw Forest in September 1989, and had two primary impacts. First, winds caused significant mortality across species and diameter classes. Wind damage was assessed with a 1% inventory in 1989-1990. Line transects were used to determine damage and mortality by species and size class in each stand (Gresham et al., 1991). These data were used to determine the percentage loss of pines and hardwoods in each stand. Since the mortality increased with increasing DBH, the average stand mortality was halved for the 4-10" diameter class and doubled for the 14"+ diameter class. These wind mortality percentages became the basis for the mortality statistics from 1989 to 1990.

In addition to wind damage, approximately 1,000 acres of the forest were covered with salt water during the storm. Within this area, salt stress killed large number of trees. The mortality was mapped using aerial photographs to identify areas that had at least five or more dead trees (Gardner et al., 1991). The percentage of each stand mapped as dead was then calculated. Stand TPA and BA were reduced by the percentage of the stand area that was mapped as dead. These reductions were then applied to stand data for 1991. Data for 1992 -2007 were then calculated by applying the net growth that was estimated.

The stand data were categorized into the pine and non-pine data. The basal area and trees per acre of pine and hardwood were tabulated in the Excel workbook separately on the basis of the

three previously-described DBH classes. The pine and hardwood resources were categorized based on TPA was then calculated using the following formula:

Trees per acre = [Basal Area / (0.005454 (Avg. diameter of trees)^2]

These results, in addition to the basal area, were calculated in the Excel workbook, and then were into the attribute columns of the stand feature class of the RCWFAP geodatabase. Of the 59 attributes in the stand feature class, 23 represent the basal area, trees per acre, hardwood mid-story status, prescribed fire regime, stand age, herbaceous groundcover, site index, and stand type. The remaining 36 attribute columns were used to represent the recovery and management standards.

Cavity Tree Data, RCW Population, and Nest Count

From 1989 to 2007 all cavity trees were assessed in April and recorded as being active or inactive based on the condition of the cavity. Any new cavity trees located by GPS were assessed for cavity condition. All cavity trees were identified as possible nest sites if fresh resin flow was found on the bole of the tree. In May, the breeding season of the RCW, the boles were tapped to flush an adult RCW incubating eggs. This tapping method proved to be efficient for the identification of nest trees. However, when this method did not flush a bird, because an RCW might not be present, the tree was subsequently checked every other day until a nest was confirmed (Nalley, 1998). An adult RCW count was conducted during the nesting seasons of 1977, 1998 and 2007. The first two counts were conducted in April, and last one during from May and June. The existing database was used to verify the location of each cluster. It is easy to count the birds during the nesting season because the adults begin feeding the chicks in the morning and evening after 6 or 7 days of hatching. This activity makes it easy to count the number of adult birds in the clusters for two reasons, first they can be found near the nest tree while feeding the young ones, and second they can be found defending their territories. If a bird was not found in a cluster, then a second visit to that cluster was performed to verify the absence of the bird in that cluster.

Results

The stand scores indicate that model seems to be a good indicator of the RCW habitat condition (Figure 1). Stand scores ranged from 1.0 to 4.3, remaining relatively stable throughout the 18 year period. The impact of Hurricane Hugo is best indicated by the change of stand scores in the southeastern section of Hobcaw (clusters 22-28). The tree mortality in this area has a significant impact on the number of live large pines available, which are highly weighted in the stand scoring system. This same area showed a marked decline in RCW clusters from 1996 to 2006. Conversely, in the south central portion of the forest (clusters 12-20), continuously higher stand scores were associated with budding (budded clusters occur when a new RCW group forms and splits one cluster into two) during the 1991-1996 period and the survival of a high density of clusters.

The average partition score for Hobcaw Barony which didn't change significantly over the 18 year period, and ranged from the 1.0 to 2.2, with mean of 1.76. The average partition score did

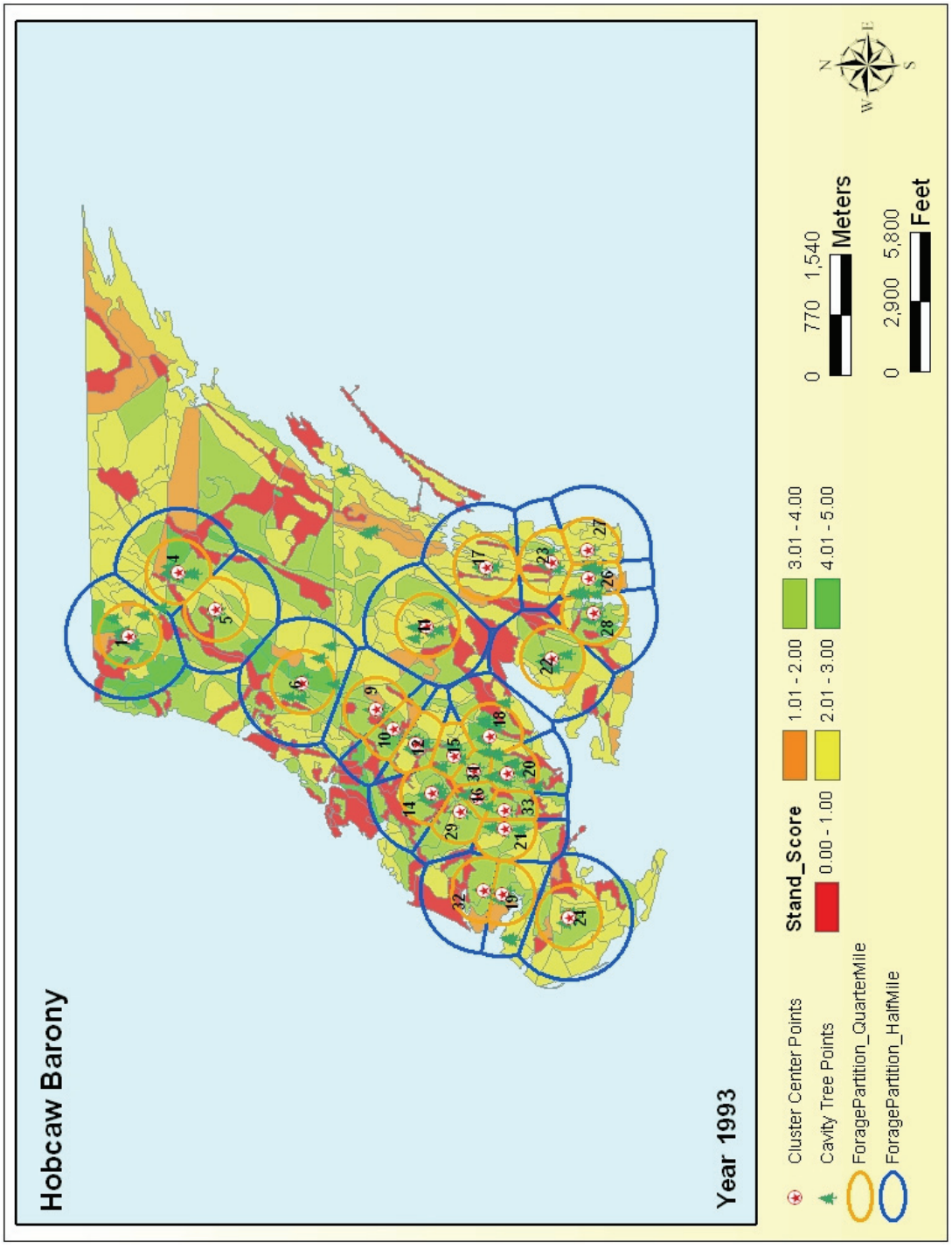

Figure 1. The stand score map in 1993.

not decrease much after the hurricane and in fact showed a detectable increase from 2000 to 2005. However, there was no strong correlation between the partition score and the presence of RCW groups. The number of actively-used trees increased sharply 1991 to 1996 then gradually decreased until 2006. Likewise, the number of clusters increased until 1995, then subsequently decreased quite sharply from 2000 to 2004. The number of nesting attempts declined most sharply during the increase in the partition scores from 2000 to 2005. While the number of clusters with nests peaked in 1995, and while nests and active trees peaked in 1996, the lowest average partition score of the period occurred in 1995, with 1996 being only slightly better.

Partition scores were not indicative of the overall success of a particular cluster. Abandoned clusters scored from 1.0 to 2.2, while budded clusters generally scored between 1.0 and 1.9, although cluster 39 was scored a 2.2 after 5 years. Partition scores of clusters that nested 13 or more years varied from 1.0 to 2.2. However, cluster 15 nested 13 years but never had a score above 1.2. Conversely, cluster 24, which never had a score below 2.1 except in 1991 (1.4), nested only nine years before being abandoned in 2005 when the score was 2.2. The foraging habitat may not be a significant limiting factor for the RCW population. As we observed on the Francis Marion National Forest after Hurricane Hugo, the installation of artificial cavity serves to recover the RCW. While these were not installed at Hobcaw, both cases indicate that the state of the active cavities is the prime important factor for the RCW population.

Discussion

Stand and Partition Scores of RCW Foraging Habitat at Hobcaw Barony

The partition and stand scores of the recovery standards were used to generates maps for Hobcaw Barony (Figures 1 and 2). RCWFAP provides scores for each stand in the partition as well as an overall score for the partition. Using RCWFAP, the stand scores of all 361 stands at Hobcaw Barony were calculated for the 18 year period, from 1989 to 2007.

Generally, the stand scores changed little over the 18 year period as shown in the five color scheme maps (Figure 1). The effect of the management activities, which primarily consisted of winter prescribed burns, can't be readily seen in stand score analysis for two reasons: a) the weighting factors for stand characteristics are weighted heavily towards the number of large trees and b) in those partitions in which Hurricane Hugo salt surge caused widespread mortality, the number of large trees decreased significantly. Except for the hurricane, the differences at Hobcaw seen in the map are related only to regular prescribed burn and the relative slow growth of large trees.

Group success in both persistence and the number of nests was related to stand scores, which varied from 1.00 to 4.38 across the Hobcaw forest. For example, partitions 1, 4, and 15 have stands score above 4.00 over the entire period. These three clusters persisted throughout the period, recording 40 nests total in the 14 years of nest observation. Conversely, of clusters 26 , 27, and 28, which were located in areas impacted by the Hurricane, only cluster 26 persisted until 2007, and these three clusters had only 21 nests in the 14 years of nest observation.

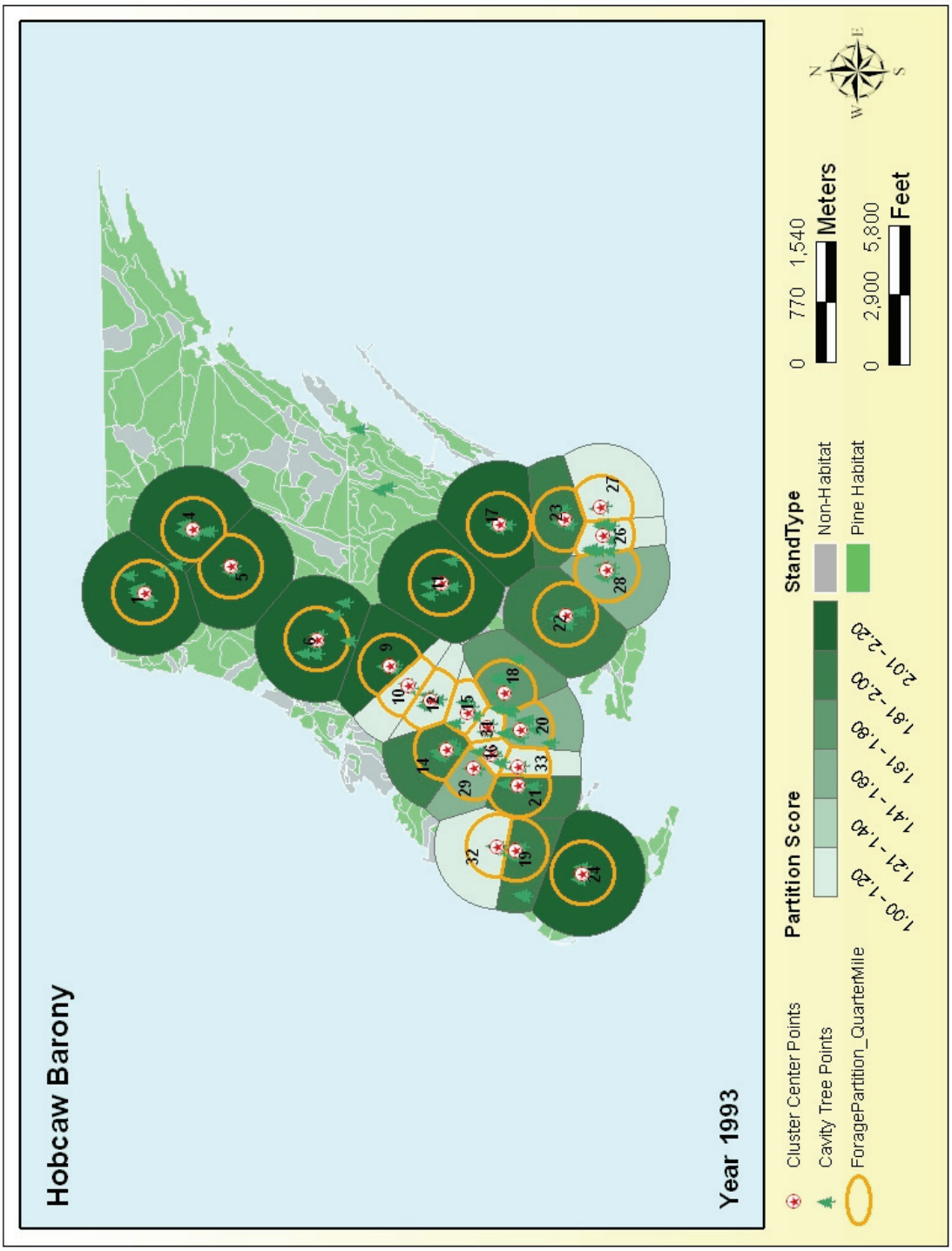

Figure 2. The partition map in 1993.

For the partition scoring system, four characteristics were also scored from 1 to 5 on the basis of occurrence of each. These four factors were then multiplied by a weighting factor and totaled to produce a partition score that should reflect the actual habitat conditions of the RCW. After running the RCWFAP for the 18 year period, the partition scores were low, although many important stand criteria met the standards. The scoring system in the matrix indicates the condition of RCW habitat in the field; a high score to a characteristic should produce both a high partition score and high stand scores. Although stand scores ranged as high as 4.38, no partitions scored above 2.2. The primary reason for the low partition scores was due to the lack of GQFH in the partitions The partition score primarily depends on GQFH area described in the following standards: 1) total area in GQFH, using a weighting factor of 0.4; 2) total area of GQFH within a ¼ mile, using a weighting factor of 0.3; 3) total area of pines in the partition, using a weighting factor of 0.2; and 4) the number of contiguous foraging areas, using a weighting factor of 0.1.

Factors involved in the GQFH account for 70% of the partition score. GQFH will be assigned to the stand only if all characteristics have a score of five. If the score is less than 5, even if it is 4.99, the stand will be not identified as a GQFH. In the partition scoring system, the RCWFAP checks the total area of GQFH, and any stand not meeting the GQFH standard will not contribute to the calculation of the partition score. For the Hobcaw Barony, the model computed stand scores ranging from 1.0 to 4.3, but none of these contributed to areas designated as GQFH. As a result, there is discrepancy between the stand and the partition levels in the evaluation of RCW habitat. This makes the partition scores dependent on total pine areas, and areas of contiguous foraging habitat, thus these scores could not exceed 2.2.

RCW Partition Scores and RCW Population at Hobcaw Barony

The increase in the RCW population depends on three parameters: the numbers of active clusters, the proportion of solitary males in the population, and the proportion of captured clusters. The RCW population in 1998 was 72 birds and 111 active cavities. Over the three observations in 1977, 1998, and 2007, the number of adults was 80% of the number of active cavity trees, indicating that active cavity trees can be used to observe trends in RCW population but that population changes are not as significant as the changes in active cavity trees. The number of active nest trees peaked in 1995 and active clusters peaked in 1996. The number of nests can be viewed as both an indicator of habitat quality and a predictor of the population trend. The number of nests peaked simultaneous to the peak in active clusters, yet declined before the decline in active clusters. These trends are not reflected in the average partition scores.

The minimum average score corresponds to the maximum active cavity trees, while the most significant increase in the score corresponds to the most significant decline in the active cavity trees. Individual cluster results followed the similar pattern, for example, the cluster consistently having a minimum score was nested all but one year during the observation period, yet a cluster with consistent scores of 2.2 was eventually abandoned. In a dense population, an increase in the number of clusters will reduce the size of each cluster, one of the reasons that the clusters in Hobcaw Barony are small, hence the foraging area of individual RCW groups decreases. Since the partition score depends on the total area of habitat, whether it is total pine or total GQFH, the overall area of foraging partition will decline as the density of clusters increases.

Recommendations for Matrix System

In Fort Bragg's sample data and in the Hobcaw stand data, largely 70-80% of pine stands (with score greater than 3.0, and a weighting factor of 0.1), the acreage does not affect the partition score as partition score solely depends on GQFH standards (weighting factors of 0.4 and 0.3 for the ½ and ¼ mile partition, respectively). An equivalent distribution of weighting factors in the partition standards may solve this problem, i.e., perhaps all partition standards should have a 0.25 weighting factor. The adjustment of the weighting factor also indirectly improves the weighting factor of the number of pine acres in the stand standards. It is important because this includes a number of cavity trees, which are a critical factor for the RCW.

The total area of GQFH in the ½ and ¼ mile partitions affects the evaluation of RCW habitat to a great extent. By studying 18 years of data, it was found that the RCWFAP can only judge the difference between ideal and non-ideal RCW habitat. Furthermore RCWFAP computes the habitat quality at stand level, and makes the decision between ideal and non-ideal RCW habitat at partition level. By considering the percentage of stands that scored greater than 3.0 in the partition will allow the model to judge the RCW partition more correctly. This may be calculated by dividing stand area (score greater than 3.0) by the total partition area, which will remove acreage factor to some extent in the partition.

Theoretically, these recommendations can be applicable without considering the acreage factor. The basic flaw in the matrix system was found to be an acreage factor present in the partition standards. It means that habitat quantity dominates the habitat quality. Imagine if all stands have a uniform GQFH score of 5.0, then the expected evaluation of RCW habitat should also be uniform. However, in reality, due to the acreage factor in the standards, a partition that has a large area will have a higher partition score, as compared to partitions that have smaller areas.

Budding of clusters frequently occurs. As RCW clusters bud, the partition score will decrease. This can be also seen by observing the partition score for the years 1994 -1995. Here, cluster number 32 budded and formed two new clusters 35 and 36, and cluster number 24 also budded to form new cluster 37. The splitting of clusters indicated that RCW groups, which were formed in those clusters and partitions, found more favorable foraging habitats in those partitions, yet this led to a decrease in the partition score. The formation of RCW groups also suggests an increase in RCW populations, but in the RCWFAP model, a decreasing partition score is considered a degradation of habitat quality.

In the evaluation of RCW foraging habitat, each stand characteristic should contribute to the partition score. In RCWFAP, the partition score is determined mostly on the basis of the number of large pine trees (>14" and 10"), and the rest of stand standards contribute collectively rather than individually to the partition score. For example, the hardwood midstory, percent canopy in hardwoods, and fire characteristics have significantly affected the RCW habitat in the field, but within RCWFAP all of these characteristics contribute to the partition score as part of an overall stand score. Assume a stand has greater number of pines trees >14" and 10" than an adjacent stand. Thus, assume it also has more basal area per acre than the adjacent stand. But if in the adjacent stand, other habitat characteristics are better than the first stand, such as the low mid-story, the use of a growing season burn, and low herbaceous ground cover, then the partition

score will be affected in such a way that the number of pines in the partition have more of a weighting factor than the other characteristics. Although both stands will contribute to the partition scores, RCWFAP will assign a higher stand score to the stand containing a greater number of large pines.

If the GQFH criteria are not assigned a score of 5.0, stand standards and GQFH criteria can be excluded from the partition characteristics. As a result, the scoring system will be more effective because all scores from 1.0 to 5.0 will contribute to the RCWFAP and foraging evaluation. It will also give a fair score to partitions even if the acreage factor is included in the matrix standards. And, it also allows the partition score to be more closely correlated with the stand score.

It is a difficult task to judge the foraging habitat on the basis of sparse and dense RCW population, because matrix standards exclude numbers of active cavity trees in quantifying habitat structure. It was due to the inability to establish a relationship between the total number and total basal area of pines greater than or equal to 25.4 cm (10") DBH within a group's foraging area and group fitness, such as total group size, on the foraging area or reproduction success. From the previous research it was found that sparse populations were more affected by habitat removal and fragmentation compared to dense populations. Previous guidelines stressed quantity of foraging habitat, as defined by number of medium and large trees. The habitat selection by RCW, and the group fitness are both influenced by the structure of foraging habitat, which includes: 1) healthy groundcover of bunchgrasses and forbs; 2) minimal hardwood mid-story; 3) minimal pine mid-story; 4) minimal or absent of hardwood overstory; 5) low to intermediate density of small- and medium-sized pines; and 6) substantial presence of mature or old pines.

The requirements for a habitat can be maintained through management practices such as prescribed burning and thinning of the foraging area. Doing so is important because RCWs require foraging habitat suitable in both quantity and quality. In addition, the quality of foraging habitat affects the size of home range: as the quality improves, the area of foraging habitat used is reduced.

For GQFH, a minimum of 75 acres is required in a single partition to earn a score 1.0 and more than 120 acres is considered as ideal habitat. This does not mean that GQFH in a partition of less than 75 acres is of poor quality. It was also found that the presence of RCW groups in the partition does not indicate that it has met all the standards of matrix. It only indicates the future potential of an area to act as RCW habitat.

In a good quality habitat the home range size is almost always found to be smaller than the size of average quality of a habitat. A possible reason for this difference is that usually the RCW clusters tend to bud rather than form new clusters away from the existing clusters. At Hobcaw, the partition maps indicate that the budding of clusters occurs almost in the same areas over an 18 year period. The number of clusters range from 18 in 2006 to 30 in 1995, with the average number of being 24.16 over 18 year period. RCW habitat, where population data is available, indicates that the incremental increase in the RCW population occurs in a specific area over a given period of time. The density in budded clusters is greater than in other clusters. These

budded clusters can help categorize the standards of GQFH to the total foraging area. On the basis of this, the other foraging area and partitions can be categorized poor to ideal. Doing so will reduce the habitat requirements mentioned in matrix standards as well as help establish the relationship between RCW population density and the quality of foraging habitat. By doing this we can also begin to understand the relationship between the foraging habitat characteristics and RCW group fitness.

By considering the other good RCW habitat, like the Francis Marion National Forest, Fort Bragg, etc., and analyzing the GQFH area (where RCW population is dense or area of budded clusters) in the foraging habitat over a specific time period, we can estimate the requirement both RCW and habitat quality. The RCW response to habitat quality can vary from region to region, and is influenced by bird behavior, demography, and other factors, but still it may be helpful to set the GQFH standards and understand the relationship between it and RCW population density (personal communication with Dr. Costa).

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