

GIS CONTRIBUTION TO RED-COCKADED WOODPECKER HABITAT MANAGEMENT: BENEFITS AND REMAINING PROBLEMS

Donald J. Lipscomb
Department of Forestry and Natural Resources
Clemson University
Clemson, SC 29634
E-mail: dlpcomb@clemson.edu

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

Thomas M. Williams
Baruch Institute of Coastal Ecology and Forest Science
Clemson University
P.O. Box 596
Georgetown, SC 29442
Email: tmwillms@clemson.edu

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

Abstract

The Red-Cockaded Woodpecker (RCW) is the most notable endangered species of the southern pine forest. Habitat destruction and fragmentation are the primary cause of declining populations. In the 1990s, GIS was applied to mapping habitat in relation to plans for RCW recovery formulated in the 1980s. The program RCW Forage Analysis Tool mapped foraging habitat and calculated tabular data that could be used to evaluate habitat by criteria of the recovery plan. However, computed habitat criteria showed little correlation to indices of woodpecker fitness. In 2003, a new recovery plan was developed and expanded the criteria of good quality foraging habitat. The habitat Matrix program has been developed to evaluate habitat in relation to the new criteria. Yearly average partition scores do not correspond to population trends and actually are negatively correlated ($r^2 = 0.63$). Scores of habitat for individual RCW partitions (the habitat within ½ mile of the cluster center not used by another group) also do not correlate well with nest data. The cause of this poor correlation is found to be the logical idea that more area of good quality habitat is better. The partition score increases with larger area of good habitat. Unfortunately RCW are attracted to good habitat and the area used by each group declines as the

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habitat improves. In this paper we propose a simple index of RCW habitat quality: habitat area / active cavity tree. We suggest that nesting is highest with a value of 30-60 acres per active tree, decreases above 60 acres per active tree, and groups tend to disappear above 150 acres per active cavity tree.

Keywords. Endangered species, cavity trees, Matrix program

Introduction

Since being listed as an endangered species in 1972, the habitat characteristics of red-cockaded woodpeckers (RCW) have been studied extensively. Early attempts to evaluate RCW habitat were published in the 1980's (Hooper et al., 1982; Costa and Escano, 1989; Wood, 1983). Foraging characteristics described in guidelines printed near the end of this period (Henry, 1989; Costa, 1992) were a subset of what was published for recovery in the 2003 plan. They required contiguous pine stands within ½ mile of the centers of clusters of cavity trees that contained 8,490 ft² of basal area or 6,350 stems of pines 10 inches DBH or larger on a minimum of 60 acres. These pines, growing in stands of open character (60 to 90 ft² per acre), were required to be over 30 years old. In the late 1990's we developed a GIS based program to evaluate RCW habitat under these earlier guidelines and to promote uniformity of the geometry operations that accompanied such evaluations (Lipscomb and Williams, 1998).

RCWFAT is an ArcInfo (workstation) AML program that assigns cavity trees to clusters based on their location or an integer in the point attribute table (users choice) (Lipscomb and Williams, 1995, 1996, 1998). Using these assignments, it then mapped the cluster areas with the required 200 foot buffer (nesting habitat), and mapped the foraging areas available to each cluster by partitioning circle overlaps. The foraging partitions can be mapped using either ½ mile or ¼ mile distances from the cluster centers. Cluster centers were calculated by the program from the cavity tree positions. With the exception of cluster maps, these operations became the basic process for future RCW foraging habitat analysis. Additional AML programming performed overlay analysis using the foraging partition boundaries along with a stand layer containing appropriate stand attributes to estimate the quantity of foraging habitat available to the birds using each cluster of cavity trees. Reports from this program simply showed the amount of foraging habitat available to the birds using each cluster without any scores or evaluation of the quality of that habitat. This part of the program was subject to change as new information caused reform of parameters used to evaluate RCW habitat quality.

The 2003 recovery plan (U.S. Fish and Wildlife Service, 2003) described characteristics for good quality foraging habitat (GQFH) that include most of those in previously published guidelines and added new parameters to be evaluated for each stand in a foraging partition. It also defined a separate set of parameters to evaluate RCW foraging habitat at the partition (available foraging area) level. There were eleven stand parameters enumerated in the recovery guidelines with defined standards for meeting the criteria of GQFH. All of these parameters pertained to vegetative characteristics using standards of quality, size, quantity, and density. There were also four criteria described for the evaluation of partitions to meet recovery standards and all pertained to or were determined by quantity (acres) of foraging habitat types. Stand areas that

qualified as GQFH contributed to several of the partition parameters, but stands that did not achieve the needed perfect score contributed very little to partition evaluations.

Shortly after the official publication of the 2003 recovery guidelines, efforts began to implement that plan. It was recognized early that a computer program would be necessary to evaluate all of the parameters and interactions for habitat evaluation in the foraging partitions (Lipscomb and Williams, 2004). During 2004, 2005, and 2006, programmers associated with Fort Bragg, ESRI, and others worked on a scoring matrix to evaluate RCW habitat under the 2003 guidelines. The matrix eventually contained thirteen stand parameters and four partition parameters with standards to meet the recovery guidelines.

In 2003 we modified the habitat analysis portion of the RCWFAT program to include the criteria established in the Recovery Plan (pages 188-189). It was modified to score stands and partitions using parameters and the scoring scheme being developed by the U.S. Fish and Wildlife Service in the summer of 2003. This modified version was used in several projects and revealed potential problems with implementation of the guidelines and with the proposed scoring system. Our evaluations using only 10 of the stand parameters in the matrix, showed a very low percent of existing habitat could meet the criterion to be GQFH (less than 5% on forest wide data sets evaluated) (Lipscomb and Williams, 2005). While stand scores were fairly consistent and might be used to judge relative quality between them, 95% still failed to meet GQFH standards. Partition scores were not consistent and appeared insensitive to change in habitat, and did not reveal any difference between known poor quality habitat and good quality habitat (Lipscomb and Williams, 2005).

The U.S. Fish and Wildlife Service began development of a GIS based program to use a scoring matrix to evaluate stand data and to score partitions near the beginning of 2004. The RCW Matrix program was released in the Spring of 2006 and is currently in use for project evaluation. It develops weighted scores for all eleven parameters stated in the 2003 recovery guidelines plus two prescribed burning parameters involving season of burn and recent fire return interval for each stand in RCW cluster foraging partitions. This matrix program was applied to an 18 year history of RCW activity on Hobcaw Barony (Williams et al., 2004; Kale et al., 2008). This application revealed inconsistencies between partitions scores and population trends. In this paper we will discuss a simple index that might be used to evaluate and revise the matrix scoring system.

Methods

Hobcaw Barony is a 7,600 acre experimental forest located on the Atlantic coast near Georgetown, South Carolina. It is on a peninsula between Winyah Bay and the Atlantic Ocean which probably limits movement of birds to and from other populations. RCW on Hobcaw have been documented since the late 1960's by a number of authors (Dennis, 1968; Grimes, 1977; Wood, 1983; Lipscomb and Williams, 1995; Lipscomb and Williams, 1998; Nalley, 1998; Williams et al., 2004). RCW cavity tree density on Hobcaw has been documented to exceed one per 32 acres (13 hectares) at times. Early studies by Wood (1983) and Grimes (1977) were used along with other publications (e.g., Henry, 1989) as background for the 1989 guidelines.

Hobcaw's RCW population was managed and monitored directly under the supervision of a wildlife biologist until the late 1980's, and the various publications documented the numbers woodpeckers and cavity trees. In 1988 and the early part of 1989 all known RCW cavity trees were visited and evaluated. These cavity trees were located by conventional surveying techniques and the data (including coordinate positions) were put in a GIS system established in 1986 (Lipscomb and Williams, 1991). This GIS system has been maintained since 1989.

Two GIS data sets are needed for input to the U.S. Fish and Wildlife Service's RCW matrix program: 1) cavity tree data with cluster assignments in the attribute table and 2) stand data with the eleven required attributes in the table. Cavity tree data was developed by evaluating each cavity tree for a number of parameters including a cavity activity code, tree species, tree DBH, number of cavity holes, cavity tree status, and basal area around the cavity trees. This database was established before the advent of Hurricane Hugo in late 1989 that caused catastrophic destruction to the habitat on Hobcaw (Gardner et al. 1992). From that time on every cavity tree on Hobcaw was revisited and reevaluated each year to the present. Also every cluster area was searched and new starts and cavity trees added to the database along with data about tree status and cavity activity status. Starting in 1994 nest trees were recorded annually in the GIS database as well. Records from three separate graduate student or research projects show a count of total adult birds sighted during the annual cavity tree survey at widely separated points in time, 1977, 1998, and 2007. As a result of these activities, there is currently a 19 year GIS data set containing RCW cavity trees on Hobcaw Barony.

Stand data was derived from a periodic inventories conducted in 1986. For the 18 year evaluation of RCW habitat in the RCW Matrix program it was necessary to use the original field data and redistribute the diameter classes before adjusting for annual growth and losses. These data were grown for the three years prior to Hurricane Hugo. The data were then reduced based on a combination of a forest wide sampling in the winter of 1990 (to determine wind losses) and remote sensing surveys of trees killed as a result of salt water intrusion into the forest. Resulting inventory summaries for each stand were then grown using normal growth and mortality parameters derived from the previous inventories to get best estimates of matrix parameters for each year in the analysis. Prescribed burn records were kept from 1975 to 2007 during which most burning was done in the dormant season. Once these adjustments were made, data in diameter classes could be used to estimate some of the missing parameters. For example, percent hardwood in the overstory could be estimated from the ratio of hardwood to pine basal areas for DBHs greater than 10 inches. Mid-story vegetation was estimated from diameter distributions and aerial photo interpretation. Percent herbaceous ground cover could not be obtained from the historical data, therefore it was not used. Burn season and burn return interval were added to the stand attribute data from burning records for the appropriate year.

Results

The Hobcaw RCW data set does not directly track the population of RCW. While using cavity trees as an indicator of population size results in a systematic overestimate, cavity trees are more easily found and tracked through time. The first question in evaluation of habitat from this data set is: Are active cavity trees an accurate reflection of the number of RCW in a population? The status of the RCW population has been studied three times in the last 30 years. Grimes (1977)

monitored 21 selected RCW groups, Nalley (1998) monitored 23 groups and Kale et al. (2008) monitored 21 groups. Results of these studies are summarized in Table 1, and show a rather stable ratio of roughly 0.7 bird per active cavity tree. Active cavity trees account for 93% of the variation in bird population over a thirty year period as found by these three independent studies (number of birds = $-1.9 + 0.687 \text{ cavities } r^2 = 0.933$).

Data has been collected on the number of active cavity trees since 1989. The Harlow technique (Harlow et al., 1983) has been used to place these trees into clusters and the location of nests have been determined since 1994. Of 36 active clusters identified after 1994, 31 also contained a nest in at least one year. The Harlow method of estimating clusters works very well on Hobcaw Forest and can be used to estimate the number of clusters. Table 2 lists the yearly values for active cavity trees, number of clusters, and number of nests.

The number of active cavity trees, clusters, and nests all show a consistent trend. Numbers declined after the Hurricane until 1991, followed by a rapid recovery and a peak in 1995 for clusters and 1996 in cavity trees and nests. This peak was followed by a decline and minimum in cavity trees in 2004 and 2006, clusters in 2006, and nests in 2004. All three show a slight increase in 2007.

The standard method to express RCW populations is the number of potential breeding groups. The number of potential breeding groups will be less than the number of clusters, due to clusters of solitary males, and greater than the number of nests, due to unsuccessful nesting. From 1994 through 2007, both the number of clusters and the number of nests were recorded. The proportion of nests to clusters varied from 0.52 in 2002 to 0.85 in 1997. A reasonable estimate of potential breeding groups is the mean of the number of clusters and the number of nests. For 1994 to 2007, the average number of potential breeding groups is 0.834 of the number of clusters (Table 2). When determined that the population declined until 1992 (19), rose to a peak in 1996 (28), and then declined to a minimum in 2004 and 2006 (16). This technique predicted 22 breeding groups in Hobcaw in 1998, which corresponded to the 22 breeding groups actually found by Nalley (1998).

Table 1. Relationship between the number of cavity trees found in three studies of RCW status on Hobcaw Forest during the last thirty years.

Year	Active cavity trees	Number of birds
1977	71	42
1998 ^a	111	75
2007	65	47

^a There were 111 active cavity trees in 1998, although there were only 95 in the 23 clusters studied by Nalley (1998).

Table 2. Yearly values of the number of active cavity trees, number of active clusters, number of nests, and the average partition score of all clusters active in that year. The estimated potential breeding groups are the average of clusters and nests. Over the years 1989-1994, potential breeding groups were estimated by the average proportion of clusters to breeding groups for 1994-2007.

Year	Active cavity trees	Number of clusters	Number of nests	Estimated potential breeding groups	Partition score
1989	82	26		22	1.74
1991	77	23		19	1.60
1992	92	23		19	1.68
1993	91	26		22	1.64
1994	99	27	16	22	1.66
1995	118	31	21	26	1.56
1996	135	30	25	28	1.64
1997	116	26	22	24	1.76
1998	111	25	19	22	1.70
1999	92	26	20	23	1.64
2000	85	26	19	23	1.69
2001	83	27	15	21	1.70
2002	74	24	13	19	1.80
2003	60	21	13	17	1.96
2004	51	21	11	16	1.99
2005	62	22	12	17	2.01
2006	51	20	12	16	2.04
2007	60	22	17	20	2.01

The Matrix program was developed to provide an index of RCW foraging habitat for both individual stands and RCW (U.S. Fish and Wildlife Service, 2003). It is to be used to evaluate habitat manipulations to minimize and mitigate damage done by human activities. The score is to be used to determine if such manipulation degrades potential RCW forage. Table 2 reveals a devastating problem with the score as it is now calculated at the partition level. The score declines as the population increases and increases as the population declines. This negative relationship explains 63% of the variation of number of nests and 58% of the variation in number of potential breeding groups.

There are a number of sensible relationships between the easily measured number of active cavity trees and other aspects of RCW population dynamics. Active cavity trees account for most of the variation in clusters (75%), potential breeding groups (86%), and nests (87%) (Figure 1). It is interesting that the number of nests is most closely correlated to the number of active trees and

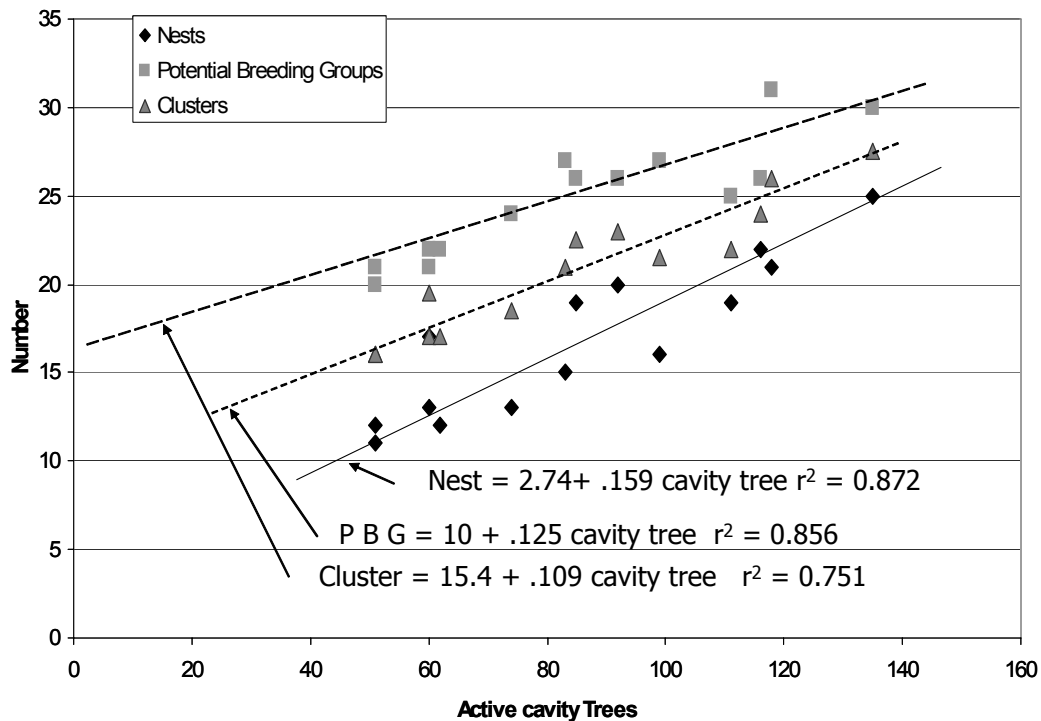


Figure 1. Relationship between the number of active cavity trees and clusters, potential breeding groups, and nests. Data is based on 14 years of nesting data on Hobcaw Forest. Note, there may be less than 14 data points since some years had identical values.

the y intercept is closest to 0. The slope of this line can be used to suggest that each nest is associated with 6.28 active cavity trees.

The relationship between active cavity trees and nests can also be examined on an individual cluster basis. Over the 14 year nest data collection period, 37 individual clusters existed from 3 to 14 years. For each cluster the probability the group nested can be calculated as the number of nests per number of years the cluster was active. The average number of active trees in the cluster predicts 79% of the variation in the probability a group will nest (Figure 2). An interesting aspect is that this relationship predicts 100% nesting at 6.26 cavity trees, similar to the annual whole forest data above.

Discussion

RCW data from Hobcaw Forest presented one of the first opportunities to examine the connection of the Matrix score with woodpecker productivity data. The effort revealed a flaw in the calculation of the Matrix partition score. The partition score in its present form is determined by the number of acres of Good Quality Foraging Habitat, pine habitat, and contiguous forage. All of these measures increase as the size of a partition increases. However, it has been known

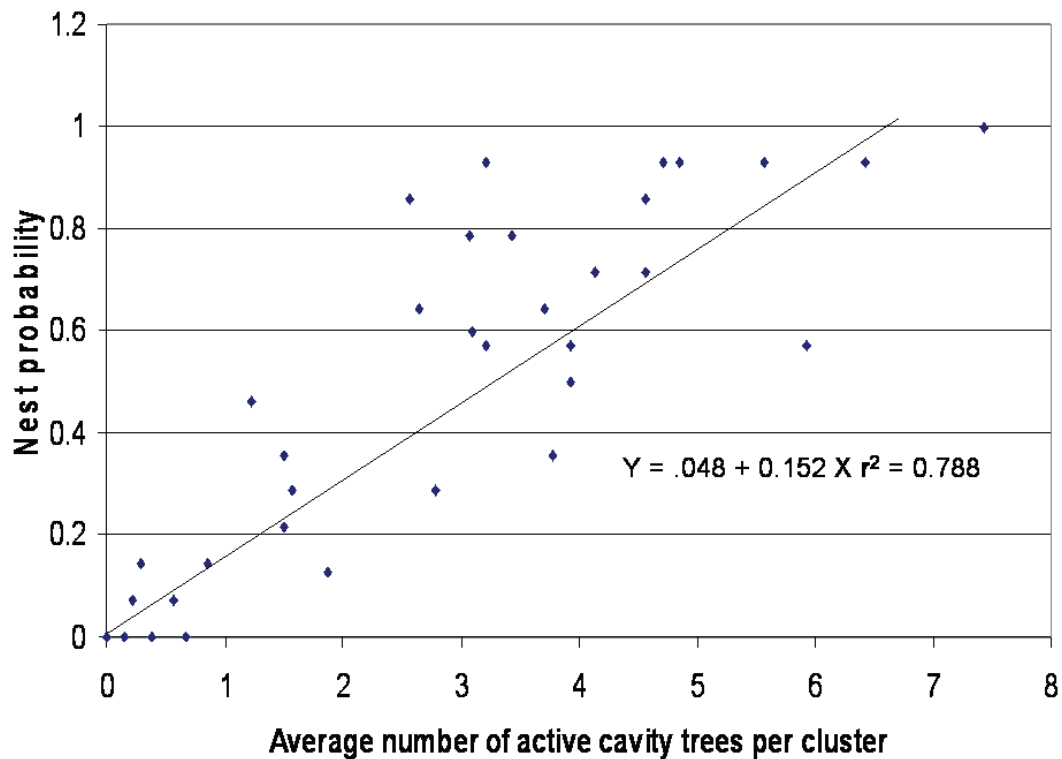


Figure 2. Probability a group will nest with different average number of active cavity trees within the cluster.

for at least 20 years that the size of group home ranges declines with better habitat quality (Wood et al., 1985). The partition score must allow for partition size to be reduced in good habitat.

In lieu of a valid method to estimate foraging habitat quality, the relationship we have found with active cavity trees may provide a simple index of quality. We have noted a clear relationship of increasing clusters, potential breeding groups, and nests with the number of active cavity trees and a clear increase in the likelihood of nesting with more active cavity trees in a cluster. We propose that a simple index of habitat quality may be the number of acres of habitat supporting each active cavity tree (inverse of cavity tree density). This value is easily obtained from the GIS by calculating the ½ mile foraging partitions, and dividing the area of the partition by the number of active cavity trees in that partition.

Figures 3-5 may demonstrate the utility of such a simple index. Figure 3 examines whole forest values of cavity tree density (acres per active cavity tree considering all habitat within partitions) to show that density is also closely related to clusters, potential breeding groups, and nests. Figure 4 examines the cavity tree density (average acres per active cavity in each cluster) for nesting clusters. Figure 5 shows the index value for clusters the year before that cluster became inactive for five years or more.

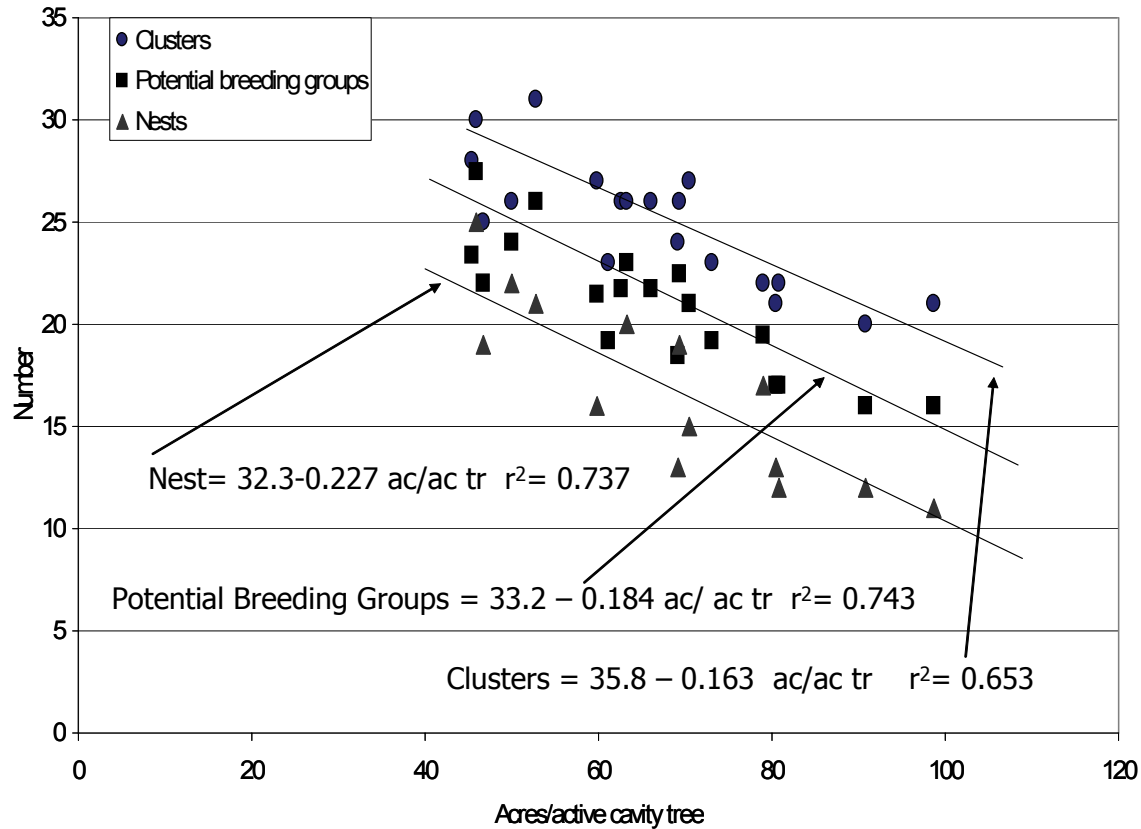


Figure 3. Relationship between clusters, potential breeding groups and nests with acres of habitat per active cavity trees based on the whole forest estimate of each year.

Since the area encompassed by all partitions on Hobcaw forest was relatively stable (average = 5,447 acres; standard deviation = 477 acres; range = 4,633 acres to 6,226 acres) the density of active cavity trees varies primarily with the number of trees. This would suggest that all of the available habitat is being used and the number of cavity trees varies with the quality of that habitat. The relationships in Figure 3 are nearly as strong as the regressions with the number of cavity trees. The average density in all clusters varied from 40 to slightly over 100 acres per active tree. All indicators of RCW population health decline as the density decreases, with nesting having the steepest rate of decline. If we look at only the clusters with nests the rate of decline is slightly greater than with all clusters (Figure 4). The RCW population on Hobcaw appears to nest primarily with values from 40 – 100 acres per active tree. In the upper part of that range the number of nests declines quite sharply. This decline can be seen more subtly in the whole forest data of Figure 3. The slope of each regression in Figure 3 is consistent with a scenario of declining habitat quality. As habitat declines one might expect reproduction to decline, followed by breeding pairs, and finally even solitary males will disappear and the cluster will become inactive.

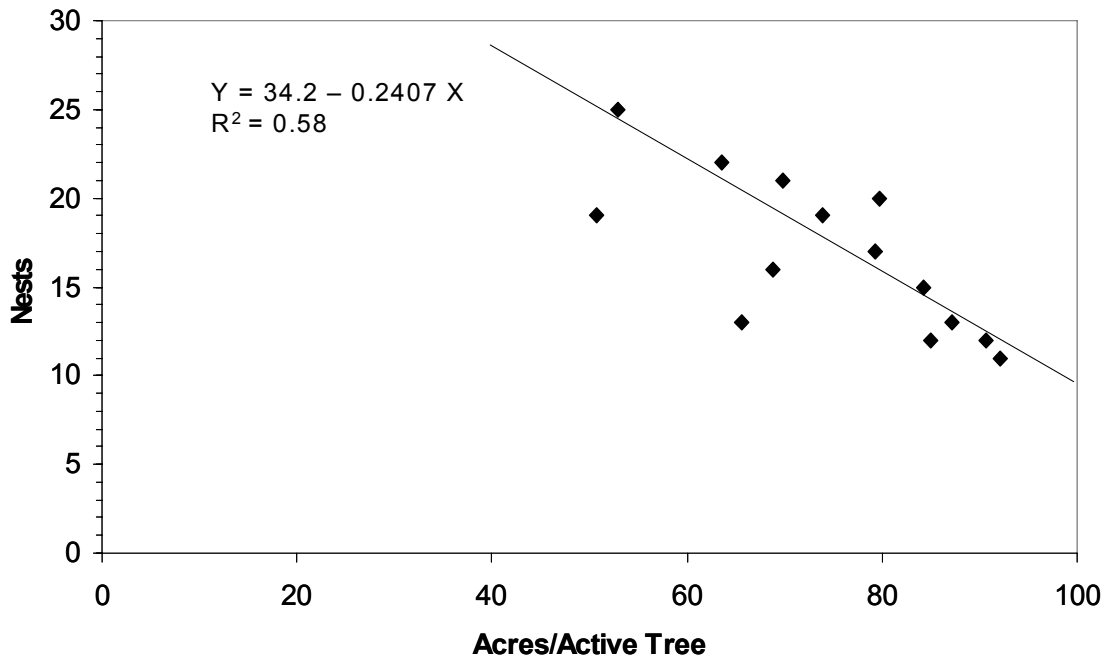


Figure 4. Relationship of active cavity tree density within nesting clusters to number of nests produced. Acres per active tree were calculated for each nesting cluster each year and those averages are regressed against the number of nests in that year.

Figure 5 lists the density of cavity trees in the clusters that became inactive and remained that way for at least five years. Cavity trees on Hobcaw have a very high rate of mortality (Williams et al., 2004) compared to other populations where cavity tree mortality was measured (Conner and Rudolph, 1995). With this high cavity tree mortality, it is not uncommon for a RCW group to move into a cluster of inactive trees. Therefore a cluster is only truly abandoned after all the cavity trees die. This has occurred only in clusters 3, 8, and 13. Figure 5 shows two different type of cluster loss. The more common is for the density of cavity trees to decline to values over 100 acres per cavity tree. The number of cavity trees continues to decline until there is a single solitary male and the cluster goes inactive at his death.

Alternatively clusters became inactive at densities less than 30 acres per active cavity tree, as happened for clusters 16, 25, and 31. All three of these clusters were in areas where multiple partitions overlapped. For cluster 16 there were up to 10 clusters within 1 mile during some years. One might speculate that in very good habitat the number of cavity trees increases until clusters are so close that there is insufficient habitat for the pair to successfully defend that territory. Clusters 16 and 29 coexisted from 1991 – 2001 but never nested simultaneously. However, after 16 became inactive cluster 29 nested 4 of 6 years. These data would suggest that less than 30 acres per active cavity tree will result in capture of a cluster by another group.

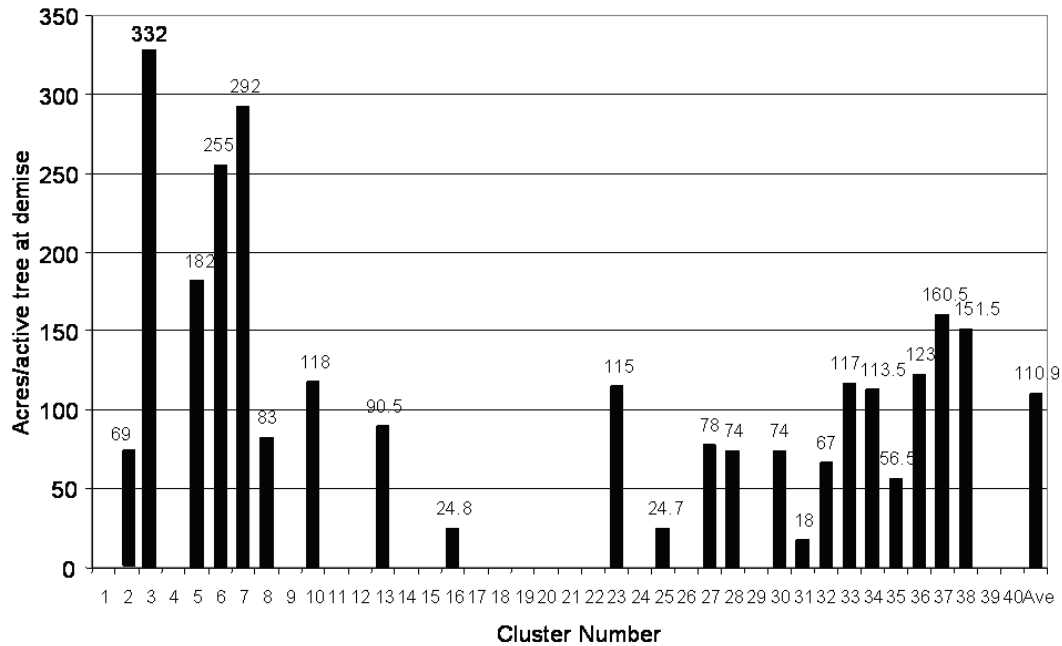


Figure 5. Index value at time a cluster went inactive for a period of over five years. Following stress, RCW on Hobcaw often moved into trees that have been inactive for several years and clusters have not been considered abandoned until all inactive trees have died.

Conclusions

RCW cavity trees were monitored on Hobcaw Forest from 1989 through 2007. Active cavity trees varied from a low of 51 to high of 135 during the period. These trees were distributed in 19 to 31 clusters, with 40 different clusters being identified over the 19 year period. Nesting was observed from 1994 through 2007 and varied from a high of 25 nests in 1995 to a low of 11 in 2004. The number of active cavity trees predicted the variability in the number of birds (93%), nests (87%), potential breeding pairs (86%) and clusters (75%) quite well.

Historic forest vegetation data was reconstructed in order to examine the latest Matrix habitat evaluation program in relation to population trends on Hobcaw Forest. The calculated partition scores were negatively correlated to the number of nests or potential breeding groups. This revealed a flaw in the calculation of the partition score. All factors considered in the score increased with larger area of the cluster. However, RCW groups tend to concentrate in good habitat resulting in small home ranges or foraging partitions.

This relationship suggested that habitat could be evaluated by simply determining the density of active cavity trees within the ½ mile partition. By expressing the density as a reciprocal (acres per active cavity tree), a range of easily understood numbers is obtained. Examining forest averages indicated that nesting increased with increased density ($r^2 = 0.75$) and that values below

about 60 acres per active cavity tree resulted in more nesting. Nesting decreased with decreasing density and was not very common at values above 80 acres per active cavity tree. Examining inactive clusters suggested that clusters may be captured by surrounding groups if values fall below 30 acres per active cavity tree. Also, values over about 150 acres per active cavity tree are associated with clusters about to go inactive. Since a complete ½ mile circle is 502 acres any value over 250 acres per active cavity tree indicates a cluster with only one active cavity tree which is obviously bound for demise.

We propose that this simple index be used to test revisions of the Matrix program to assure that high scores are associated with higher RCW productivity.

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