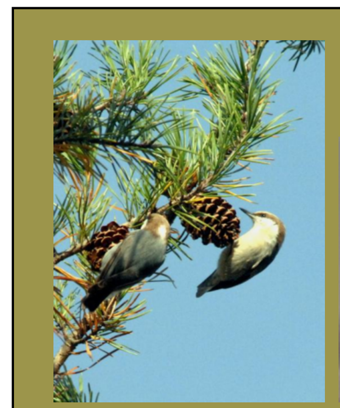
Fall 2013

A Multi-Scale Analysis of the Effects of Local- and Landscape-Level Variables on Nuthatch Occupancy and Distribution

Jesse Wood
Furman University




Brown-headed Nuthatch *(Sitta pusilla)*

A MULTI-SCALE ANALYSIS OF THE EFFECTS OF LOCAL- & LANDSCAPE-LEVEL VARIABLES ON NUTHATCH OCCUPANCY AND DISTRIBUTION

Jesse Wood, Dr. John Quinn

EES201 – Introduction to Geographic Information Systems – Fall 2013, Furman University, Greenville, SC

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I. Introduction / Lit Review

In the last four decades, the southeast has experienced a land-cover transformation trend of forest-cover loss, driven by urban development and land-use demands (Drummond and Loveland, 2010). The Piedmont conservation region (Figure 1), historically dominated by pine and mixed southern hardwoods, has experienced the greatest net change in forest cover of the eastern ecoregions (Drummond and Loveland, 2010). Increasing fragmentation of remaining habitat creates complications for wildlife populations as species occurrence is spatially determined by occupancy factors like movement/dispersal, resource availability, and the abiotic environment (Driscoll et al., 2013).

Avian cavity-nesting species are among the most threatened by recent forest-cover change—particularly those whose reproductive success is thought to depend on mature or old-growth stands (Cockle et al., 2011). The pine-specializing Brown-headed Nuthatch (*Sitta pusilla*) is one such species, whose population has been approximately cut in half over the last century (Figure 2; Sauer et al., 2011). South Carolina's Comprehensive Wildlife Conservation Strategy (2005) and the Open Pine Landbird Plan (2011) recognize this species as among the highest priority bird species for the state of South Carolina.

Given the trend of habitat loss and fragmentation, data are needed to evaluate conservation strategies for suitable remaining habitat, from both patch and matrix perspectives. A habitat "patch" designates the local, usable habitat of a species, distinguishable by clear boundaries (i.e. a stand of trees), and the "matrix" is the surrounding non-habitat area in the larger landscape. The discipline of landscape ecology has placed increasing importance on factors beyond patch size and isolation in determining habitat suitability for a species (Butcher et al., 2010; Fahrig, 2013). In addition to patch quality, which is determined by local microhabitat variables, matrix composition (Vandermeer and Perfecto, 2007) and ecological thresholds involving landscape structure have been shown to limit breeding success of sensitive birds (Butcher et al., 2010; Driscoll et al., 2013).

These data need to be collected for remaining scattered habitat patches and used to test the relative effect of patch- and landscape-scale drivers of species occupancy (Withgott and Smith, 1998; Yamaura et al., 2008; Chandler et al., 2009; Iglecia et al., 2010). Furthermore, these data need to be collected from areas not considered as part of traditional conservation efforts, including urban (Ramalho and Hobbs, 2011) and managed ecosystems (Quinn 2012).

The objectives of this study are to conduct a multi-scale analysis of the effects of habitat variables on Brown-headed Nuthatch *(S. pusilla)* occupancy and spatial distribution in the greater Greenville area of South Carolina. By understanding the local- and landscape-drivers of an ecologically sensitive species, we can build a predictive model of species occurrence and contribute to regional conservation efforts of both habitat and biodiversity.

Bird Conservation Regions

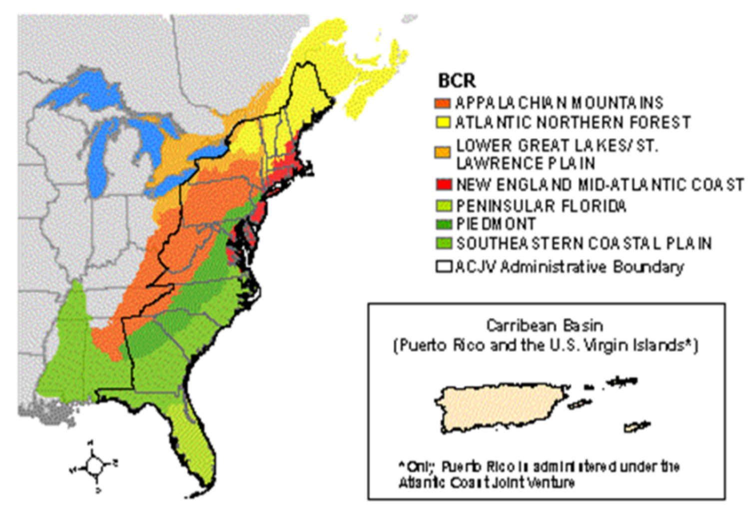


Figure 1. Bird Conservation Regions in the Atlantic Coast Joint Venture Initiative. The Piedmont region is dark green.

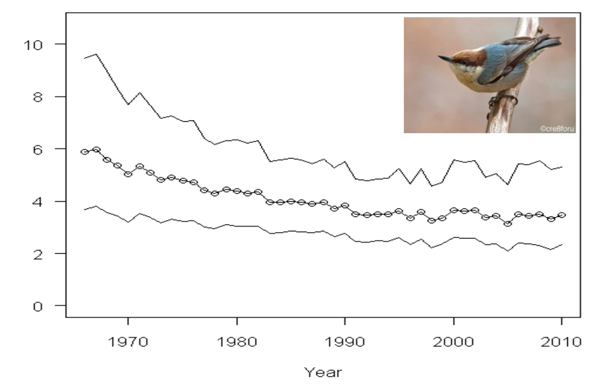


Figure 2. Regional Breeding Bird Survey trend of Brown-headed Nuthatch population (Index) in South Carolina (Sauer et al. 2011).

II. Methodology

Bird Surveys: We conducted point-count surveys in 53 pine stands in Greenville, Laurens, and Pickens counties (Figure 3). We surveyed each patch four times in the season (May– July 2013) using 10-minute point counts. Observers conducted surveys between dawn and 1045 hours (Figures 4-5). Detection is imperfect, so we included observation covariates (by recording wind speed on a Beaufort scale, percent sky cover, and volume of ambient noise on a 0-10 scale) and did not conduct surveys in persistent rain or wind.

Patch: We collected vegetation data on each study patch by replicating 5 surveys along a 100m transect: the point-count site at its center and sampling at 25m- and 50m-points in a randomized bearing from there. We used the point-center-quarter method (Mitchell, 2007) to estimate density of trees (all species and just pine species) and shrubs. We collected DBH information on surveyed trees in order to calculate basal area. In addition, at each point we measured canopy height and cover, and number of snags (dead but standing trees, which often have nesting cavities).

Landscape: Patches were embedded in either a protected, managed (agroecosystem), or suburban matrix. We used ArcGIS tools to conduct spatial analyses of the landscape: patch area, land cover type, and amount of pine habitat within 50m, 100m, 500m, and 1000m of the patch. Pine habitat was extracted from SC GAP vegetation data (SC DNR) and overlayed on ortho imagery files of each county, which were obtained from Geospatial Data Gateway (USDA). The spatial analyst toolset was used to calculate area and summarize data by study patch (Figure 6).

Data Analysis: We used binomial N-mixture models (Royle, 2004) to predict the relationship between estimated bird occupancy and relevant habitat variables, on a patch- and landscape-level. Detection is necessarily varied and imperfect, but N-mixture models use spatial and temporal replication to estimate occupancy while adjusting for survey-specific covariates affecting detectability (Chandler et al., 2009). We utilized "unmarked" package (Fisk and Chandler, 2011) in program R (2011)[A] for this occupancy analysis. We created 30 predictive models and compared their AIC values (Akaike Information Criteria) to rank models in order of best fit to the data in order to parse out the variables with the strongest effect on nuthatch occupancy.

Study Locations in the Upstate

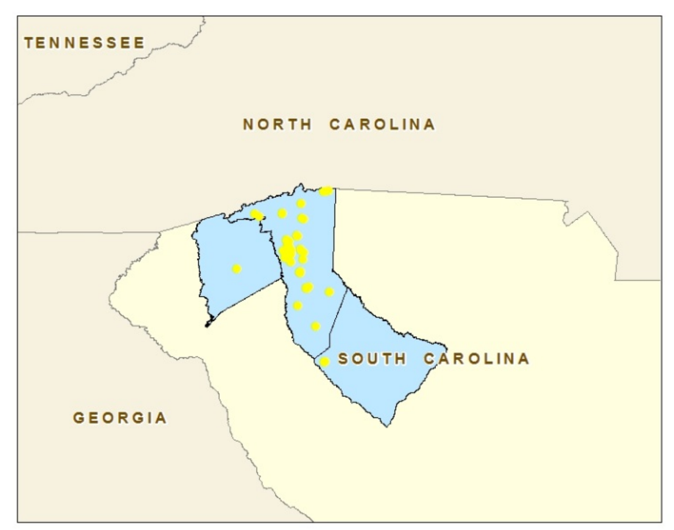
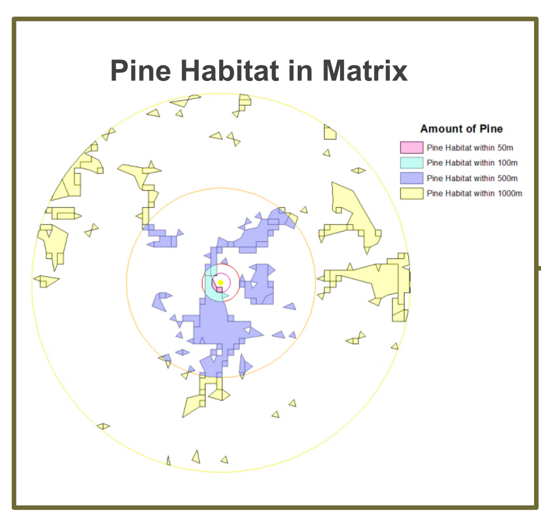
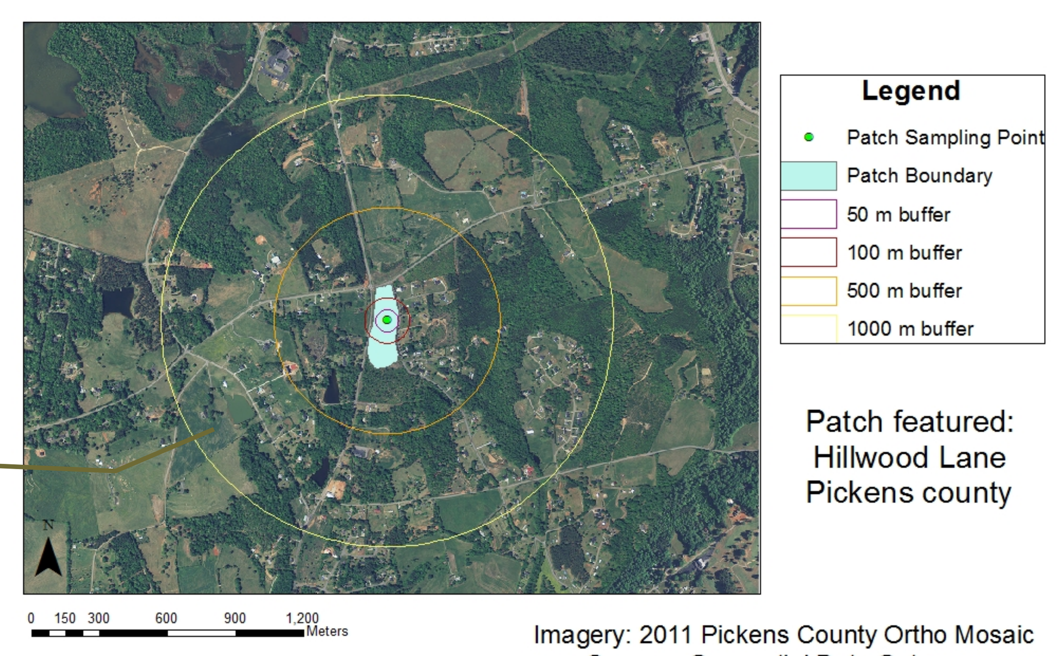


Figure 3. The 53 study sites for this study. Each point in Greenville, Pickens, and Laurens counties represents one pine patch where our data was collected.

Multi-scale Landscape Analysis





Patch featured: Hillwood Lane Pickens county

Imagery: 2011 Pickens County Ortho Mosaic
Source: Geospatial Data Gateway, Natural Resources Conservation Service

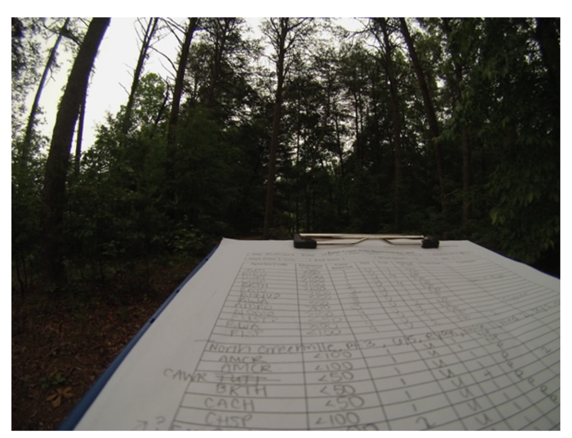



Figure 4 (left) and **Figure 5** (right): Images of data collection by Jesse Wood and Ryan Ernstes, captured by a GoPro camera. Point count-detection datasheet and conducting a survey.

Figure 6. An example of the spatial analysis of landscape conducted in ArcMap 10 (right image). The "Hillwood Lane" pine patch is digitized in blue, over the landscape imagery layer. A serious of buffers were created from the sampling point: at 50m, 100m, 500m, and 1000m. This step allows for a calculation of the amount of pine habitat in the matrix, within each of these distances of the point (left inset).

III. Results and Discussion

As expected, we did not detect Brown-headed Nuthatches *(Sitta pusilla)* in all of our 53 patches. Of the total 2623 detections (66 species), we detected our species of interest 65 times, at 23 sites. These sites, interestingly enough, were not all embedded within a protected matrix.

Our data show that the ecologically-sensitive Brown-headed Nuthatch *(S. pusilla)* is more abundant in urban and peri-urban landscapes (Figure 7). This spatial variation in species occupancy suggests many urban ecosystems are of unexpectedly higher quality and may provide important refuge for biodiversity. In Iglecia et al. (2010), nuthatches are described as "urban adaptors," meaning they may be quick to colonize new systems, and therefore could potentially serve as indicators of ecosystem health amidst urbanization.

In our N-mixture model analysis (Table 1), patch area was a strong predictor of nuthatch occupancy, with larger patches being more suited than small (Figure 8). This finding is consistent with papers that determine specific ecological thresholds of minimum patch size for songbirds (Butcher et al., 2010) and the basis for strategies of conservation of large contiguous habitat. Other patch-level variables that played a role in top models involved tree/pine density and, to a lesser extent, canopy structure. Denser pine stands with taller and denser canopies were better predictors of nuthatch occupancy (Figure 9-10). These results reinforce prior studies of nuthatch behavior, which suggest that they nest high in the canopy of dense, mature pine stands, but forage a little lower, in the open canopy of less dense pines (Withgott and Smith, 1998).

Most striking in our analysis was the significance of landscape-level factors. Of the top 8 models, system (matrix type of the patch) and amount of pine within 500m were each featured in half. Simply put, the more pine habitat available in the approximate home range of a nuthatch, the more likely they are to occupy a patch. A connection may exist between these landscape variables–for example, the development that results from converting forested to semi-urban or recreational systems causes fragmentation of the remaining trees, which means there are more numerous, although small, patches scattered across the landscape. This trend was certainly true at many of our sites and for dispersing birds it means more potential territory to claim.

The negative relationship of pine tree basal area (PineBA) to occupancy (Figure 11) was also noteworthy. We hypothesized PineBA (representative of tree volume) in each patch would be a strong positive predictor of occupancy because older, thus larger, pine trees are more likely to contain cavities ideal for nesting. Upon reflection, we realized that our patches with the largest pines are often composed of a few remnant pine trees surrounded by hardwoods and are therefore of lower-quality nesting habitat, but the stands of smaller pines are in stages of early-successional growth and less interspersed with other plant species, and therefore provide more potential foraging habitat. Clearly, even for seemingly straightforward patch-level characteristics, aspects of the matrix play an integral role in determining suitable habitat.

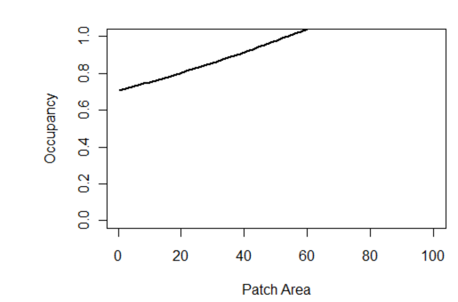


Figure 8. This plot shows the relationship between patch area (in square meters, adjusted by $x10^{-2}$) and nuthatch occupancy. The relationship is clearly positive, with nuthatch occupancy most likely to occur around or above 50 (5000 square meters).

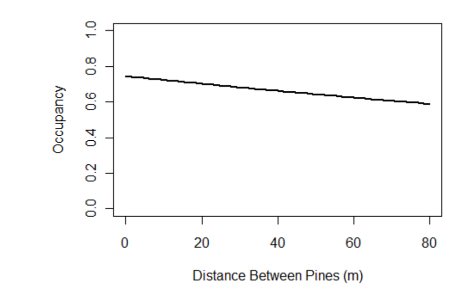


Figure 9. The relationship between pine density (measured in meters between pine trees) and nuthatch occupancy, with patch area included as a cofactor. Shows that denser stands are more predictive of occupancy.

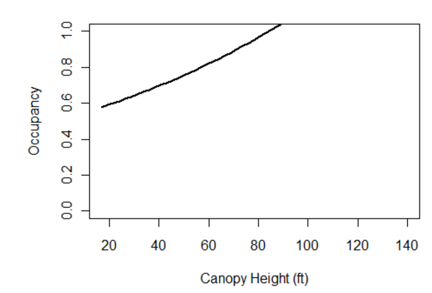


Figure 10. The relationship between the height of the canopy (in feet) and nuthatch occupancy. Shows that stands with a higher canopy (taller trees) are more predictive of occupancy.

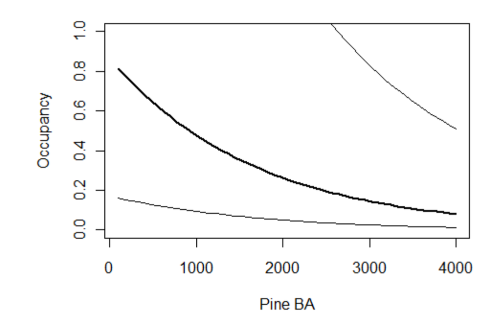


Figure 11. The relationship between basal area of pine trees (square centimeters) in a patch and nuthatch occupancy, with system type as a cofactor. The lighter grey lines are upper and lower limits of the confidence interval, while the dark line shows the inverse relationship between volume of pine and occupancy.

Total Nuthatch Detections by Matrix Type

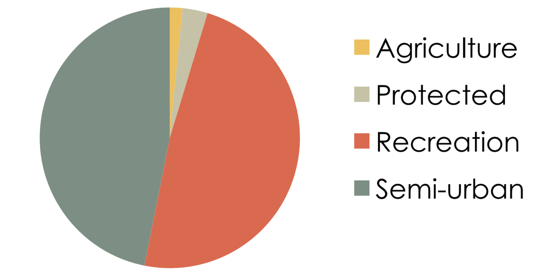


Figure 7. This pie chart shows the observers' detections of Brown-headed Nuthatches in pine patches across four matrix types in the Upstate, out of 65 total detections.

Table 1. Top Models by AIC Values

Model	k	AIC	ΔAIC	AICwt	cumltvWt
PatchArea *	6	193.34	0.00	0.23	0.23
TreeDensity + Pine500m + System	10	193.60	0.26	0.20	0.43
PatchArea + Pine500m + System	10	194.24	0.90	0.14	0.57
Pine500m + System	9	194.25	0.91	0.14	0.71
PineDensity + PatchArea *	7	195.32	1.98	0.08	0.80
PatchArea + Pine500m	7	196.05	2.70	0.06	0.86
PineBA + System *	9	196.76	3.42	0.04	0.90
PineBA + PatchArea	7	198.67	5.32	0.02	0.91
CanopyHeight *	6	199.03	5.68	0.01	0.93
PineDensity	6	199.71	6.37	0.01	0.94
TreeDensity	6	199.85	6.51	0.01	0.94
Pine100m	6	199.99	6.64	0.01	0.95
CanopyCover	6	200.20	6.85	0.01	0.96
Pine50m	6	200.20	6.86	0.01	0.97
CanopyCover + CanopyHeight	7	200.75	7.41	0.01	0.97
CanopyHeight + TreeDensity	7	200.79	7.45	0.01	0.98
TreeBA	6	201.39	8.05	0.00	0.98
CanopyHeight + CanopyCover + PineBA + Pat	9	201.44	8.10	0.00	0.99
Pine500m	6	201.64	8.30	0.00	0.99
CanopyCover + TreeDensity	7	201.69	8.35	0.00	0.99

This table shows the top models, sorted from most to least predictive of nuthatch occupancy. The ΔAIC value describes how close one model is to the best model (better models are <4.00), and the cumulative weight (cumltvWt) value is lower for more ecologically significant results. (Models marked * are graphed to the left).

IV. Conclusion

The results of our multi-model analysis make it overwhelming clear that variables at both the local- and landscape-level influence Brown-headed Nuthatch (*Sitta pusilla*) occupancy of habitat patches. Our findings confirm that Brown-headed Nuthatches *(S. pusilla)* are sensitive to patch quality in terms of size, stand density, and canopy structure. We revealed that the cumulative area of pine habitat outside a suitable patch is a powerful factor in determining the species' distribution. The pattern of spatial variation that we found, in terms of detections per matrix type, is encouraging for the future of nuthatch conservation in an increasingly human-dominated landscape.

Management for this high-priority species can be guided by land-owner decisions to retain and reestablish pine habitat and is feasible outside of protected systems. "Indicator" species—whose habitat requirements meet those of other species too—like the easily-detectable Brown-headed Nuthatch *(S. pusilla)* will be critical for research investigating the conservation value of novel ecosystems, like urban systems of parks and green space (Hobbs et al., 2009).

V. Future Research

A second field season of data collection is already planned for May-August 2014—this will expand our dataset and improve the accuracy of our models. An additional 20 sites may be added to create a larger sample size and broaden the variety of patch and matrix types. This field work will be continued by myself, Dr. Quinn, and new Furman Advantage students.

With the existing data, further analyses will be run. The same habitat variables will be analyzed for other pine-dwelling species, such as the Carolina Chickadee, Tufted Titmouse, and Red-Bellied Woodpecker. A comparative analysis of the species' top models would then be possible, and evaluations of the Brown-headed Nuthatch's status as a true indicator species could be evaluated. A wider array of variables, at both the patch- and landscape-level, could be incorporated in future analysis, including shrub density, vertical structure of the pine stands, and amount of urban area and protected area in 500m.

Results of our research will be reported to the respective owners of our study areas.

VI. Acknowledgements

Carolina Bird Club

This project was made possible by the efforts of many! Thanks to Ryan Ernstes for assistance with summer field work (point-count surveys and hours of driving). Thanks to Joshua Smith for assisting with vegetation surveys–both in the field and in data entry. Thanks to Furman Advantage for awarding me the research fellowship which provided funds for equipment and employment and to Carolina Bird Club for accepting my conservation grant which provided funds for travel costs. A big thank you to Mike Winiski, GIS instructor, for countless questions about spatial analyst tools. And finally, a huge thank you to Dr. John Quinn for the training, equipment, supervision, R coding, GIS layers, revision, frequent meetings and even more frequent emails. Thanks for agreeing to take me on as your first Furman Advantage Undergraduate Research advisee!

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[A]Data Analysis done with program R:
R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.
Figures created with Microsoft Office Excel (2010) or RStudio (2012).
Figure 1 map from Atlantic Coast Joint Venture Initiative, http://www.acjv.org/bird_conservation_regions.htm
All other maps created with ESRI ArcDesktop 10 (2012):
Figure 3 map Data Sources: 1) patch locations created from personally-collected UTM coordinates with a GPS device, in the field (North American Datum [NAD]83). 2) 3 counties of interest selected from a layer of data on several counties in SC, NC, and GA, originally downloaded from the USDA Natural Resources Conservation Service, hosted on the USDA's Geospatial Data Gateway website (http://datagateway.nrcs.usda.gov/). 3) background map of four states used data from Environmental Systems Research Institute (ESRI) Data & Maps Online (2012)
Figure 6 map Data Sources: 1) patch locations created from personally-collected UTM coordinates with a GPS device, in the field (NAD83). 2) patch boundary manually created in ArcMap 10 (2012) by creating polygon features. 3) 50m, 100m, 500m, 1000m buffers manually created from patch locations layer using buffer tool in ArcMap 10 (2012). 4) Ortho imagery layer of Pickens county comes from a downloadable Digital Ortho County Mosaic of 7.5' quads by APFO from the USDA Natural Resources Conservation Service, hosted on the USDA's Geospatial Data Gateway website (http://datagateway.nrcs.usda.gov/). 5. Land cover layers based on SC GAP vegetation data was obtained from the GIS download page of the SC Department of Natural Resources (DNR) website (http://www.dnr.sc.gov/GIS/gap/mapping.html). 6) A shapefile of pine habitat was created by selecting all pine-related land cover categories from the SC GAP vegetation layer (see above).