INTEGRATING FOREST STAND PROJECTIONS WITH WILDLIFE OCCUPANCY MODELS TO DEVELOP A DECISION SUPPORT TOOL.

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ABSTRACT

Natural resource managers must often balance multiple objectives on a single property. When these objectives are seemingly conflicting, the manager's job can be extremely difficult and complex. This paper presents a decision support tool, designed to aid land managers in optimizing wildlife habitat needs while accomplishing additional objectives such as ecosystem restoration or timber production. A growth and yield model, the Forest Vegetation Simulator, is used to project future stand structure based on three management scenarios: no management, active manipulation of species composition through harvesting and underplanting, and single tree selection based on the Proportional-B method. At five-year time steps, predicted forest structure is input into species specific wildlife occupancy models to estimate probability of occurrence. This allows quantification of these species response to the silvicultural prescription. By integrating these two models a unique tool is available for land managers to both gauge the efficacy of their management plans before their implementation and to develop a predicted timeline of forest structure that can be used for comparison in adaptive management.

INTRODUCTION

With consumptive trends of wood products on the rise (Bowyer 2007), the need for more comprehensive management grows (Bowyer and others 2007). The Multiple-Use Sustained-Yield Act of 1960 required by law that national forests broaden their focus to include the production of other commodities such as recreation, wildlife and water. However, some argue that the practice has fallen short of the ideal set up by the act (McQuillian 1990 and Shepard 1990). Shands (1988) argued that "multiple use has become a pejorative term that many people believe is synonymous with management that emphasizes timber production to the detriment of other forest resources" (p. 14). In recent years there has been a push for more "Ecosystem Management" (Bengstion 1994), or a process that aims to conserve major ecological services and restore natural resources while meeting the socioeconomic, political and cultural needs of current and future generations (Bengstion 1994, Brussard and others 1998, Grubine 1994, and Szaro and others 1998).

With the greater push for ecosystem management and more efficient natural resource management, the forests that provide timber also need to incorporate other uses, such as wildlife habitats. Therefore, it is increasingly common that natural resource managers are asked to balance multiple objectives on a single property. Management of these multiuse areas can be exceedingly complex, but extremely important for all the parties involved (Keeney and Raiffa 1993). However, bringing multiple fields together, with perceived competing objectives, is never easy.

The fields of wildlife biology and forest management have supposed opposing objectives for the use and management of forests. Wildlife biologists tend to focus on the organism of interest, while forest managers tend to look at the available timber in the forest. The common area is in forests where both wood products and wildlife habitat are provided. From my experience, disagreements on the best way to manage the forests often occur because of differences in the way management is applied and implemented. Although the management perspectives from each field vary, the results are not necessarily mutually exclusive.

Tools exist in both fields to model forest growth and response of wildlife to changes in habitat. However, they are seldom used together. Forest growth and yield models use current forest inventory to predict forest growth and potential outputs in the future by using a set of tree based measures that include tree species, sizes, and densities. Occupancy models provide an estimate of species occurrence based on a variety of factors, including habitat characteristics like tree species and size, density, and available cover. Being that habitat characteristics, or structure is a big predictor of a species occurrence, and growth and yield models are able to produce structure based outputs it may be possible to integrate these tools to determine the effects of forest management on a species before implementation.

METHODS

FIELD METHODS

A forest inventory was designed to quantify vegetative structure, focusing on characteristics that are most important for wildlife habitat suitability (Van Horne and Weins

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1991). Fixed area circular plots, 0.20 hectares (25m radius) were established during July and August 2008. Starting at plot center, a grid of 49 points spread 6.25m apart, was established along the cardinal directions (Figure 1). At each point on the grid the presence or absence of cover was recorded for the canopy, mid-story, reproductive/shrub, and herbaceous/ground cover layers using a "moose horn" densitometer. The canopy layer was defined as the dominant tree cover above the point on the grid. The mid-story layer was defined as trees that were two thirds the height of the dominant canopy, but not extending into the dominant canopy. The reproductive/shrub layer was defined as vegetation not exceeding 3.5 meters in height. The herbaceous/ground layer was defined as any herbaceous ground cover. Within the plot the presence of snags and their DBH was recorded. The height of three of the tallest trees was recorded to establish canopy height. A variable radius plot using a 10-factor angle gauge was established using the center of the grid to determine the basal area of the stand. These trees were tallied by species and DBH.

Point count surveys for birds were conducted at each plot center during the breeding season (May-July) no later than four hours after sunrise. Each survey consisted of three, four minute counts during which each bird that was seen or heard was tallied along with the estimated direction and distance (0-25m, 25-50m, greater than 50m) (Hamel and others 1996). At the beginning of each survey, the temperature was recorded (°C) along with the date and time.

STAND PROJECTIONS

The Southern variant of FVS (SN) was used for stand projection. Three different management scenarios were produced for each stand; (a) No Management, (b) Even-aged, and (c) single-tree selection using Proportional-B Method. All projections with FVS started in 2008 and were for run 100 years at five-year intervals. For the purposes of this project the hardwood sprouting module (SPROUTING) was turned off in the FVS program and all regeneration was simulated manually.

For the No Management simulations no management treatments were simulated in FVS. The stands were allowed to progress for 100 years with no anthropogenic interference, as well as no natural disturbance. In the even aged simulation run for each stand, the current exsisting trees were clearcut in 2008 and replanted with 121 trees per hectare, with 90 percent survival, in 2009. Alternating summer and winter burns were simulated every 5 years starting in 2013. Each stand was grown for a 60-year period, during which time a thin from below was applied when BA exceeded $7.4 m^2 ha^{-1}$ or when growth was being impeded, on average 2 times during the rotation . A final harvest took place in 2068. In 2069, the stand was replanted at the same initial planting density. The same management parameters were applied throughout the second rotation until the end of the projection in 2108.

For the single-tree selection using the Proportional-B Method, each stand was prescribed a unique treatment based on the initial stand structure in 2008. The Pro-B method uses three broad size classes as a surrogate for age classes. For this project size classes were always set to 5 to 15cm DBH, 20 to 30 cm DBH, and greater than or equal to 35cm DBH.

If the current structure fit the parameters for an uneven-aged stand Pro-B was implemented immediately. The largest tree existing in the stand was used to set the LDT. Residual basal area (RBA) was set to $5.6 m^2$, and Q always equaled 1.3. Harvest of trees was applied using a set amount of BA for each size class, with proportionally more in the largest classes. Subsequent harvests were applied when the stand accrued $1.4 m^2$ to $2.8 m^2$ BA or roughly 10 or 15 year cutting cycles. Because FVS-sn works in 5-year cycles, cutting cycles for the Pro-B method were simplified to fall on an existing cycle boundary; cutting cycles tend to fall between 7 to 15 years.

If loblolly pine (*Pinus taeda*) was present it was kept as a main component of stand structure. One management objectives is to restore the Longleaf pine ecosystem (open pine woodland); however it is not currently present on the property. Loblolly pine can also form an open pine woodland, therefore if loblolly pine was present it was kept as a main component of the stand to surrogate for longleaf until it can be established. All cuts were made by using the "thin throughout a diameter range" option. The "thin throughout a diameter range" option allows for the user to define diameter classes and cut those classes to a defined amount of BA. All reproduction was simulated manually to adequate levels for structure to be maintained, meaning enough regeneration was simulated to maintain levels of BA needed in the smallest diameter class. Composition of the simulated regeneration was decided by the dominate species within the initial stand structure, and were attempted to be kept proportional to the dominate canopy.

Using the "Compute Stand Variables with SpMcDBH" function canopy cover was calculated for every cycle in the simulation. Midstory cover was calculated with "Compute Stand Variables in Editor". A code that defined our definition of midstory cover was written (Personal communication. Chad Keyser. 2010. FVS Staff, Remote Location: Bent Creek Experimental Forest, 200 W.T. Weaver Blvd. Asheville, NC 28804) and calculated for each cycle. All other structural characteristics needed for calculation of probability of use through the Occupancy models were pulled from the main FVS output.

VEGETATIVE COVER PROJECTIONS

Regression models (R ver. 2.12.0) were created to project the amount of reproductive cover and ground cover at each time step. FVS does not provide an estimate of these two cover layers, both of which are known to influence occupancy by certain wildlife species. A multi-model inference was run on collected inventory data. Multi-model inference is a statistical technique where alternative plausible models are assessed given the data presented and ranked based on relative likelihoods (Burnham and Anderson 2002). A global model was created to include all potentially influential variables for each layer of cover. Model coefficients were averaged and relative variable importance greater than 0.5 was used to determine which variables would be used in the regression model.

OCCUPANCY MODELS

Occupancy models were created by the Alabama Corporative Fish and Wildlife Research Unit using vegetation inventory data of vegetation structure combined with bird point count data. For purposes of this project the top or best model was used to determine probability of use. The best model is the most applicable or has the highest likelihood of being correct from the list of generated models. Other studies use an averaged model where coefficients are averaged; however averaged models were not available for use in this study. Probability of use was calculated for each time step interval using stand projections from FVS and the occupancy models for each species. The Yellow-breasted Chat model included a landscape component, edge, which could not be simulated in FVS. Edge is defined as a border of one area to another, like forest to field or forest to road. The amount of edge is give as a value between -1 and 1. One represents no edge being present, while -1 represents edge being present. Edge was held constant at three levels (-1, 0, 1) to represent various amounts of edge that could be present.

RESULTS

VEGETATIVE COVER PROJECTIONS

FVS does not provide an estimate of reproductive cover or ground cover, which are needed to estimate probability of use of the focal species. The global model parameters for reproductive cover consisted of the variables canopy cover, midstory cover, basal area, and trees per acre. The global model parameters for Ground Cover consisted of canopy cover, midstory cover, reproductive cover, percent basal area hardwood, basal area, and trees per acre. All of the models generated by the multi-model inference were average. The parameters were averaged and relative importance values were obtained for each parameter. The linear regression models generated and used for were:

Reproductive Cover = 36.7 + 0.397Midstory Cover – 0.0945 Basal Area

Ground Cover = 69.3 + 0.171 Reproductive Cover – 0.292 Midstory Cover – 0.0213 Trees per Acre

STAND STRUCTURE

Diameter distributions were similar for all stands in each scenario. In the no management simulation diameters are normally distributed throughout time. Over the projection cycle the average stand diameter increases as the range of diameters increase, but the number of trees in each diameter class decreases, flattening the normal curve over time. In the Pro-B simulations a reverse j-shaped or negative exponential curve was achieved and maintained by 40-years into the simulation. The even-aged scenarios maintain normally distributed diameters throughout the projection.

Basal area increases to a stable point in the no management projections (Figure 2). In the Pro-B projections basal area oscillates with each cut, staying between 5.6m^2ha^{-1} to 7.0 m^2ha^{-1} at the lowest for each Pro-B cut. When even-aged management is implemented stands follow the pattern seen in Figure 2.

Canopy cover follows similar trends seen in basal area for all scenarios (Figure 3). Midstory cover has an initial decrease in the no management projection, then a short period of increase from 2013 to 2048, when it declines to about 6% at the end of the projection (Figure 4). The even-aged projection has no midstory cover after the initial clearcut. In the Pro-B projection the amount of midstory cover varies throughout (Figure 4). It steadily increases from 2038 to 2073, and then oscillates between 30 to 40% as it steadily decreases for the remainder of the projection. Reproductive cover does not change much between the projection scenarios (Figure 5), staying within 10 to 20 percentage points of each other. Ground cover has similar trends between the scenarios (Figure 6); amounts of ground cover stay within 15 to 20 percentage points between scenarios. Ground cover always trended to increase throughout the projection, but only slightly.

PROBABILITY OF USE

The pine warbler is predicted to use stands under both the no management and Pro-B scenarios 100 percent of the time for 100 percent of the projection cycles. Under the even-aged management scenarios pine warbler has a probability of use for the stands between 80 and 100 percent throughout the projection cycle (Figure 7). The yellow-breasted chat's probability of use varies between management scenarios and with what the edge value was held constant at. When there is no edge (edge=1) the yellow-breasted chat is more likely to use even-aged stands over time (Figure 8a). With more edge the difference in probability of use becomes less between management scenarios. The yellow-breasted chat is more likely to use any management scenario, the difference in probability of use becomes significantly less between scenarios (Figure 8b and 8c).

DISSCUSSION

PROBABILITY OF USE MODEL RESPONSES

Each species' occupancy model responds differently to the simulated management scenario. The pine warbler's probability of use is 100 percent for the entire projection cycle for no management and Pro-B scenarios, and 80 to 100 percent for even-aged scenarios. The occupancy model created for pine warbler is responding to a multitude of parameters. It responds positively to canopy height and canopy cover, but negatively to midstory cover, reproductive cover, and ground cover. In many of the simulations canopy height and cover remain high over time, while midstory and reproductive cover decline. In the even-aged scenarios the probability of use for pine warbler decreases to 80 percent because canopy height and cover are not present in sufficient amounts. In most of its range it is associated with a dense canopy layer and a sparse understory or a low density shrub layer (Rodewald and others 1999). While species composition was not taken into account, pine warbler is mostly associated with the North American pine forests. There is anecdotal evidence that it prefers tall dense canopies of pines (Rodewald and others 1999).

The yellow-breasted chat's probability of use varies with the amount of edge represented in the model. The occupancy model for yellow-breasted chat is negatively correlates to edge, there for the more edge available the more yellow-breasted chat is likely to use that stand. When edge is equal to -1, there is no difference between uses of the scenarios. Yellow-breasted chat is often found in low dense vegetation, like power-line corridors, fence rows, and forest edges (Eckerle and Thompson 2001). Its occupancy model also responds negatively to canopy, midstory, and reproductive cover, while it has a positive response to ground cover. When there is no edge present (edge=1) it has preference for the even-aged scenario, especially in its early development. Early stages of plantations are similar to edges or opening. This species is considered a generalist, with preferences to edges (Eckerle and Thompson 2001), which might explain its preference to the even-aged scenario.

Advantages of Integrating FVS with Probability of Use
FVS is a growth and yield model, which uses empirical growth. Therefore, assumptions are held constant for all forest growth simulations, allowing management alternatives to be compared without bias. Using a forest inventory allows the user to update stand information to current conditions after pervious simulations have been made. FVS provides a set of raw outputs tables that need further summarization to obtain the required information for the probability of use estimates. This allows the user to pull what is important from that information, and use it in any model available.

The most important advantage of automating these calculations in FVS is the ability to develop and analyze many alternatives quickly. Stand level simulations can be made to assess and communicate the effects of proposed management regimes. The rapid analysis is especially important when some parties involved in planning have backgrounds other than forestry, and so do not understand standard forestry metrics such as volume, tree sizes and stands structures. Information can be easily explained in terms that any planner can understand. Several alternative silvicultural pathways can be compared to assess their potential benefits. A hypothesis-testing framework can be used before they are applied in a stand or at the whole landscape level.

There are many other analyses available to the user of FVS. Tables which summarize the current and projected future inventories in different ways are available for users. Data created in FVS have been developed to answer questions related to other forestry measures such as inventory tables and stand summary tables. FVS can answer questions about carbon sequestration, as well as stand structures. Visualizations produced by the Stand Visualization System also allow the user to communicate changes in to forest caused by forest management activities.

Limitations of Integrating FVS with Probability of Use
There are several limitations with using this approach. FVS is unable to produce information about reproductive or ground cover. Therefore, regression models were created from inventory data. These models were produced from the best information available. The parameters included within these models (i.e. canopy cover, midstory cover, basal area, trees per acre) were used because they may influence the amount of light that reaches the forest floor. Therefore, changing how much is present or absent within the forest stand. Ellsworth and Reich (1993) found that light attenuation occurs in the upper and middle portions of the canopy; furthermore, light may affect how vegetative structure forms throughout all canopy layers.

However, development of cover layers may relate more to site productivity than to light availability (Liira and others 2007). Liira and others (2007) found a correlation between canopy closure and productivity, and an increase in abundance of shrubs with higher productivity. There has been little study of understory relationships with light in the Southeastern U.S. However, in other regions, like the Pacific Northwest, understory relationships have been studied at length. Studies have focused on developing relationships between overstory and understory structure and composition in a variety of forest types (Halpern and Spies 1995 , VanPelt and Franklin 2000). The vegetation cover models could be improved if these other factors like light availability and productivity are included in future modeling efforts, therefore improving the efficacy of the overall decision model.

Spatial arrangement and size of habitat patches is important for some species. The integration of FVS and occupancy models does not take into account how big and where stands are located on the property. Birds can occupy larger areas with a matrix of suitable and unsuitable habitat because they are capable of flight but other taxa may have size and spatial requirements that cannot be accounted for in this model. Yellow-breasted chat had a landscape scale parameter within its model that was easily modeled. However, edge should also be considered within the matrix of the spatial landscape, and how it could change probability of use over time.

MANAGEMENT IMPLICATIONS

The integration of stand projection models and occupancy models creates a powerful tool for land managers to gauge the efficacy of their management decisions before implementation. Land managers often do not consider the long term effects of the management they are implementing; often short term goals are achieved without any consideration for what the long term challenges might include. This decision support tool will allow for long term planning, not only for wildlife but also for other concerns such as timber or carbon sequestration. Optimistically, it will change the way management is preformed over the long term, and allow for careful planning for future natural resource use.

LITERATURE CITED

Bengston, D.N. 1994. Changing forest values and ecosystem management. Society and Natural Resources. 7: 515-533.

Bowyer, J.L. 2007. Consumption and Wood Products Substitution: Environmental Concerns. Forests and Forestry in the Americas: An Encyclopedia. Society of American Foresters. http://www.encyclopediaofforestry.org

Bowyer, J.L., Shmulsky, R., and Haygreen J.G. 2007. Forest Products and Wood Science: An Introduction. Blackwell Publishing: Ames, Iowa.

Burnham, K.P and Anderson, D.R. 2002. Model Selection and Multimodel Inference: a Practical Information-theoretic Approach, second ed. Springer-Verlag, NewYork.

Brussard P.F., Reed M.J. and Tracy C. R. 1998 Ecosystem Management: What is it really? Landscape and Urban Planning 40: 9-20.

Ellsworth, D.S. and Reich, P.B. 1993. Canopy structure and vertical patterns of photosynthesis and related leaf traits in a deciduous forest. Oecologia 96: 169-178.

Eckerle, K. P., and Thompson, C. F. 2001. Yellow-breasted Chat (*Icteria virens*). In The Birds of North America, No. 575 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Grumbine, R.E. 1994. What is Ecosystem Management? Conservation Biology 8: 27-38.

Halpern, C. B. and Spies, T.A. 1995. Plant species diversity in natural and managed forest of the Pacific Northwest. Ecological Applications 5: 913-934.

Hamel, P.B., Smith, W.P., Twedt, D.J, Woehr, J.R., Morris, E., Hamilton, R.B. and Cooper, R.J. 1996. A land manager's guide to point counts of birds in the southeast. United States Department of Agriculture Forest Service General Technical Report SO-I 20.

Keeney, R.L. and Raiffa, H. 1993. Decisions with multiple objectives: preferences and value tradeoffs. Cambridge University Press, Cambridge, United Kingdom.

Liira, J., Sepp, T., and Parrest, O. 2007. The forest structure and ecosystem quality in conditions of anthropogenic disturbance alond productivity gradient. Forest Ecology and Management 250: 34-46

McQuillan, A. G. 1990. Is national forest planning incompatible with a land ethic? Western Wildlands 15(4):7- 11.

Rodewald, P. G., J. H. Withgott, and K. G. Smith. 1999. Pine Warbler (*Dendroica pinus*). In The Birds of North America, No. 438 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Shands, W. E. 1988. Beyond multiple use: Managing national forests for distinctive values. American Forests 94(3/4): 14-1 5,56-57.

Shepard, W. B. 1990. Seeing the forest for the trees: "New perspectives" in the Forest Service. Renewable Resources Journal 8(2):8-11.

Szaro, R., Sexton, W.T., and Malone C.R. 1998. The emergence of ecosystem management as a tool for meeting people's needs and sustaining ecosystems. Landscape and Urban Planning 40: 1-7

Van Horne, B. and Wiens, J.A. 1991. Forest Bird Habitat Suitability Models and the Development of General Habitat Models. U.S. Department of Interior Fish and Wildlife Service Research Report 8:1-31.

Van Pelt, R. and Franklin, J.F. 2000. Influences of canopy structure on the understory environment in tall, old-growth, conifer forests."Canadian Journal of Forestry Research 30: 1231-1245.

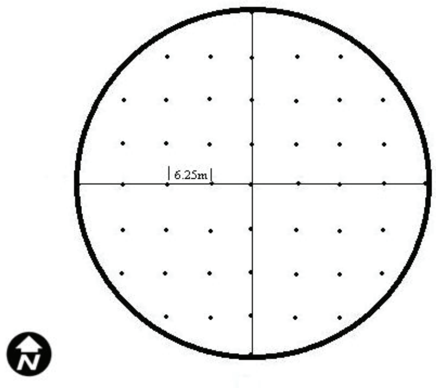

Figure 1—Grid layout used for measuring cover at each of the four layers. At each point on the grid the presence or absence of cover was recorded with a "moose horn" densitometer for the canopy, mid-story, reproductive/shrub, and herbaceous/ground cover layers. The radius is 25m and the distance between points is 6.25m.

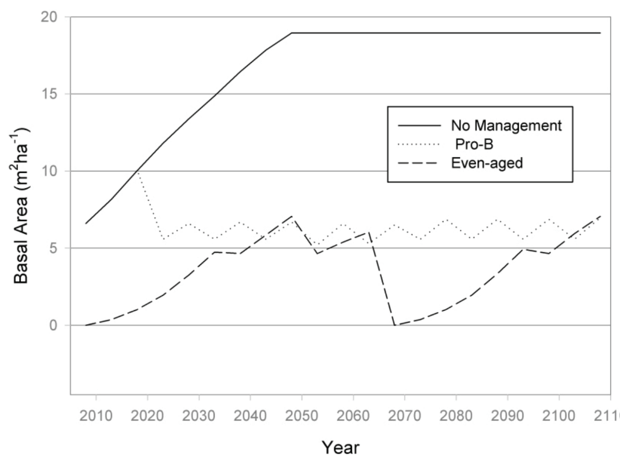

Figure 2—Basal Area in a stand for all three management scenarios after harvesting took place. Basal area increases to a stable point in the no management projections. In the Pro-B projections basal area oscillates with each cut, staying between 5.6m^2ha^{-1} to 7.0 m^2ha^{-1}. Even-aged management follows the pattern seen below.

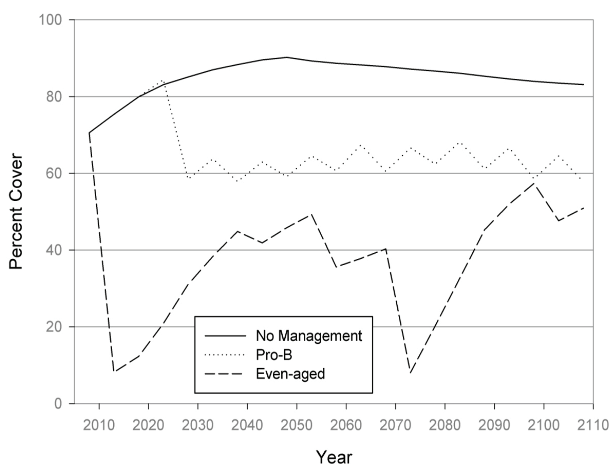

Figure 3—Canopy cover found in a stand for all three management scenarios over the projection cycle. Canopy cover follows similar trends seen in basal area for all scenarios. Canopy cover increases to a stable point in the no management projections. In the Pro-B projections canopy cover oscillates with each cut, staying between 60 to 70% covered. Even-aged management follows the pattern seen below.

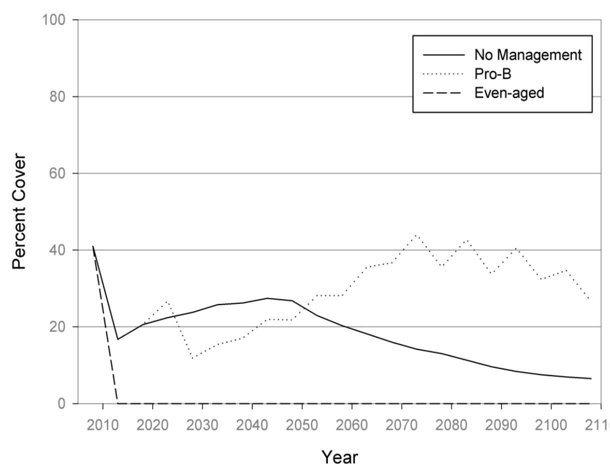

Figure 4—Midstory cover found in all three scenarios for the projection cycle. Midstory cover has an initial decrease in the no management projection, then a short period of increase from 2013 to 2048, when it declines to about 6% at the end of the projection. The even-aged projection has no midstory cover after the initial clearcut. In the Pro-B projection the amount of midstory cover varies throughout but generally steadily increases from 2038 to 2073, and then oscillates between 30 to 40% as it steadily decreases for the remainder of the projection.

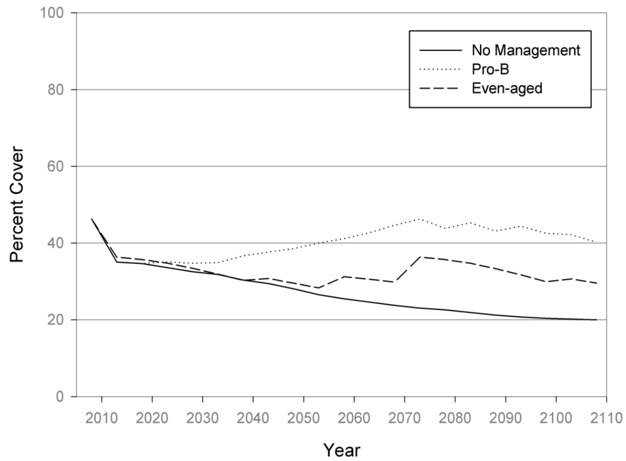

Figure 5—Reproductive cover found in a stand for all three management scenarios over the projection cycle. Little variation can be found in the amount of reproductive cover between scenarios, at the most only a 20 percentage points of difference between the most in the Pro-B scenario and the least in the No Management scenario.

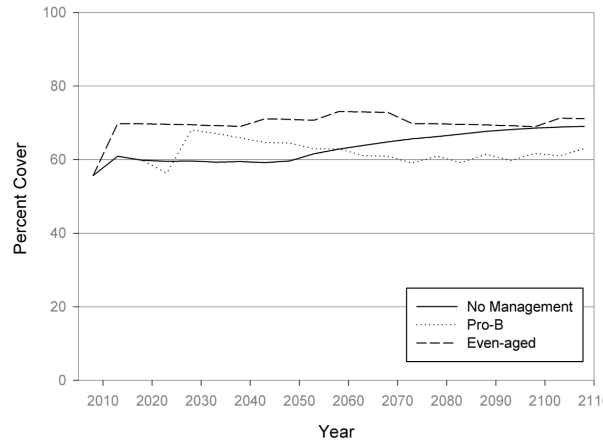

Figure 6—Ground cover found in a stand for all three management scenarios over the projection cycle. Ground cover has similar trends between the scenarios. The amounts of ground cover stay within 15 to 20 percentage points between scenarios.

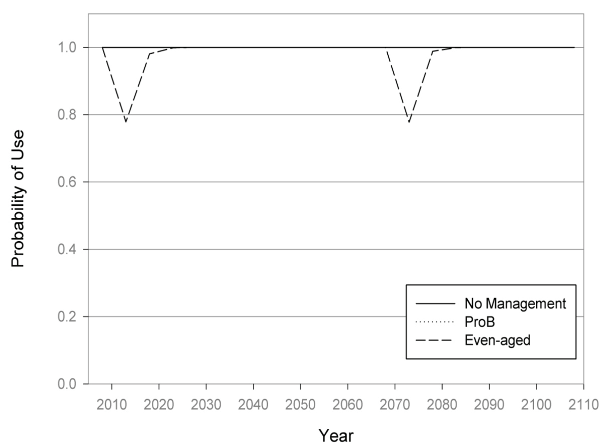

Figure 7—Probability of use of pine warbler over the 100 year projection cycle for all three management scenarios. The pine warbler is predicted to use stands under both the no management and Pro-B scenarios 100% of the time for 100% of the projection cycles. Under the even-aged management scenarios pine warbler has a probability of use for the stands between 80 and 100% throughout the projection cycle.

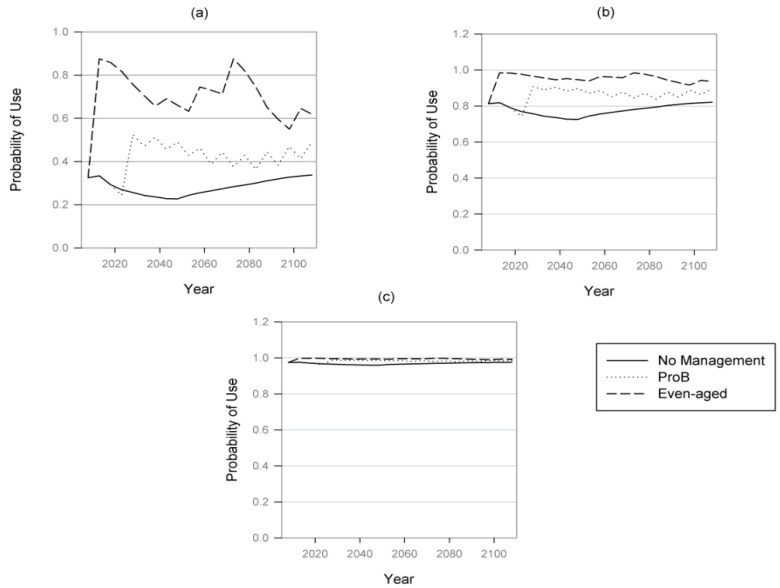

Figure 8—Probability of use of yellow-breasted chat over the 100 year projection cycle for all three management scenarios with (a) edge held constant at 1, (b) edge held constant at 0, and (c) edge held constant at -1. With increased edge there is less of a difference in probability of use between the scenarios.