Disturbance in Wisconsin Pine Barrens: Implications for Management

Abstract We compared cover, structure, and diversity of woody vegetation in three types of early successional habitat patches in the pine barrens of northwestern Wisconsin. Patch disturbance types included repeated prescribed burning, crown fire, and clearcutting. All three disturbances set back succession, but with distinct differences in vegetation structure and composition. Vegetation in patches created by crown fire had greatest tree density, diversity of structure and composition, and cover by jack pine and large woody debris. Differences in woody vegetation among disturbance types may influence the success of savanna restoration and landscape management projects at providing habitat for savanna wildlife species in the pine barrens.

Timber harvest is frequently alluded to as a surrogate disturbance for fire in forested ecosystems because both reduce vegetative structure and/or create habitat harboring similar animal communities (e.g., Urban et al. 1987, Hansen et al. 1991, Hunter 1992, Sharitz et al. 1992, Vora 1993). Yet the relative effects of timber harvest on plant and animal communities are rarely quantified (but see Hansen et al. 1991, Fitzgerald and Tanner 1992, Greenberg et al. 1995).

In Wisconsin pine barrens, large-block timber harvest has been proposed as a landscape-level management tool that would create large habitat patches for area-sensitive grassland and shrubland bird species (Niemuth 1995, Parker 1995, Strand and Epperly 1995). Many grassland and shrubland bird species readily accept early successional habitat created by clearcutting in pine barrens (Niemuth 1995), although the relative effects of fire and clearcutting on pine barrens vegetation structure and composition are largely unknown.
Fire is the primary natural disturbance in the region (Curtis 1959), although pine barrens are also subject to catastrophic windthrow (Canham and Loucks 1984), ice storms (Vora 1993), and infestations of jack pine budworm (*Choristoneura pinus*; Volney and McCullough 1994). Before fire control began in the 1920s, recurrent fires swept the pine barrens, creating extensive openings largely devoid of trees (Norwood 1852, Murphy 1931, Curtis 1959, Vogl 1970). Because of fire control and tree planting, most of the region is currently forested, and timber production is the primary land use. Timber harvest is the dominant vegetation-removing disturbance in the pine barrens, as most wildfires are quickly extinguished and are limited in extent. However, early successional habitat is maintained in the region at four savanna reserves larger than 1,000 ha, along with several smaller reserves and fuelbreaks. Reserves are managed primarily to provide habitat for sharp-tailed grouse (*Tympanuchus phasianellus*). Early successional vegetation is maintained at these reserves through frequent prescribed burning, which, over time, creates a vegetation community that may differ considerably from pre-settlement conditions (Mossman et al. 1991, Parker 1995).

We compared characteristics of woody vegetation in 40 patches created by crown fire, clearcutting, and repeated prescribed burning in northwestern Wisconsin pine barrens. We focused on structure of woody vegetation because woody vegetation is an important nesting and foraging substrate for wildlife (Niemuth 1995). In addition, structure of woody vegetation will be determined largely by management practices and disturbance type rather than by plant species’ range and response to site characteristics. Our goal was to show how woody vegetation structure differed among disturbance types, as well as provide direction for future experimental analysis of vegetation response to disturbance in the pine barrens.

**Materials and Methods**

**Study Area**

Sampling took place during July of 1993 and 1994 in Burnett, Douglas, and Bayfield counties in northwestern Wisconsin (Figure 1). Pine barrens in the region are delimited by xeric, outwash sand soils; predominant tree species included jack pine (*Pinus banksiana*), red pine (*P. resinosa*), quaking aspen (*Populus tremuloides*), big-toothed aspen (*P. grandidentata*) and red, Hill’s, and burr oak (*Quercus rubra*, *Q. ellipsoidalis*, and *Q. macrocarpa*). Oak, hazel (*Corylus spp.*), and cherry (*Prunus spp.*) shrubs were common in the openings we sampled. Typical ground cover included blueberry (*Vaccinium spp.*), sweet fern (*Myrica asplenifolia*), bluestem (*Andropogon spp.*), and sedge (*Carex spp.*). The surrounding landscape primarily was forested, with timber production and recreation being the primary land uses.

**Study Sites**

Selection criteria included (1) location on outwash sand soils; (2) mean vegetation height visually estimated to be < 1.2 m; (3) creation or maintenance of opening by fire or clearcutting, rather than other management practices, frost, or edaphic conditions; (4) > 1 year since site was clearcut or burned; and (5) well-defined patch with forest > 5 m tall surrounding 90% of site. All known crown fire sites (*n* = 4) and savanna reserves (*n* = 11) within the region.
Figure 1. Location of sample sites. Squares represent savanna reserves; triangles represent openings created by wildfire; circles represent clearcuts. (Inset) Distribution of historic Wisconsin pine barrens, after Curtis (1959). Study took place within region bounded by square.
that fit these criteria were sampled. Known clearcut sites within the study region meeting selection criteria were stratified by size, and 25 were randomly selected (Figure 1). All sample sites were > 1 km apart.

**Sampling Methods**

Woody vegetation was sampled using the line intercept method (McDonald 1980). Intercept lines were 250 m long, although shortened intercept lines were used in seven patches that were too small to contain a 250-m sample line. Sampling of sites was proportional to patch size \( n = 2 \times \log \text{estimated patch area in ha} \), with the number of lines per patch ranging from one to eight. In patches containing multiple lines, sample lines were randomly placed off a systematically divided baseline with a random starting point. Height and intercept length were recorded for eight variables: percent cover by oak, pine, cherry, hazel, willow (Salix spp.), aspen, large woody debris, and dead standing trees of any species. Only woody vegetation > 0.5 m in height, length, or width was recorded. In addition, all live and dead trees > 12 cm diameter at breast height and within 10 m of the transect line were counted. Diversity of woody vegetation was calculated for each site using the Shannon-Wiener diversity index:

\[
H' = -\sum_{i=1}^{k} p_i \ln p_i
\]

where \( k \) is eight and \( p_i \) is the proportion of line intercept coverage found in each of the eight woody vegetation cover categories. Horizontal patchiness was calculated as the number of times woody vegetation cover types were encountered along a 250-m transect.

**Statistical Analysis**

We used direct discriminant analysis (SPSS Inc. 1990) to maximally differentiate line intercept data for the three patch types. We treat the discriminant analysis as descriptive, rather than a test of null hypotheses concerning differences among treatments because of inequality of the discriminant function variance-covariance matrices, lack of experimental control, and unknown management history (e.g., agricultural use, fire interval, pre-settlement vegetation, logging history). Descriptive statistics are presented to aid in understanding differences in woody vegetation among management types.

**Results**

The discriminant function created a two-dimensional ordination showing relative scores for the three patch types. The first discriminant function (Figure 2) accounted for 56.9% of the total variation in the data set and showed that greatest tree density, woody debris cover, and jack pine cover occurred at crown fire sites (means and standard deviations in Table 1). Savanna reserves scored lowest for these variables, and clearcuts were intermediate. The second discriminant function accounted for 34.2% of the total variation in the data set and showed that greatest height variation and Shannon-Wiener diversity were found in crown fire patches. Clearcuts scored lowest for these variables; savanna reserves were intermediate (Figure 2). Horizontal patchiness was greatest at savanna reserves and lowest in clearcuts. Greatest correlation between variables included in the discriminant analysis was 0.42. Category classification success in the discriminant analysis ranged from 75% to 92%, with an overall correct classification rate of 87.5% (Table 2).
Figure 2. Woody vegetation discriminant function scores for 15 clearcut patches, 11 savanna reserves, and 4 wildfire-created savanna patches in northwestern Wisconsin pine barrens. Solid symbols represent centroids for each group. Triangle with * represents the Loon Lake wildfire, which burned twice in 11 years.

Discussion

Relative Effects of Disturbance Type on Vegetation Structure and Pine Barrens Wildlife

The most obvious difference among the three patch types was greater density of trees at crown fire sites than managed or clearcut sites. Trees, whether dead or alive, are an important habitat component in the pine barrens. For example, tree density is a significant predictor of Eastern bluebird (Sialia sialis) and tree swallow (Tachycineta bicolor) presence in Wisconsin pine barrens savanna; conversely, other savanna species such as the horned lark (Eremophila alpestris) and vesper sparrow (Pooecetes gramineus) prefer areas of lower vegetation (Niemuth 1995). Differences in tree quality for nesting and foraging may also exist among the three disturbance types. The few trees that remain at savanna reserves are generally oaks and red pine that are sufficiently large to survive...
Table 1. Mean (± standard error) of vegetation and structure variables at three patch types in Wisconsin pine barrens.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Disturbance Type</th>
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<tbody>
<tr>
<td></td>
<td>Wildfire</td>
</tr>
<tr>
<td>Trees/0.5 ha</td>
<td>20.36 ± 3.9</td>
</tr>
<tr>
<td>Large woody debris (%)</td>
<td>7.69 ± 1.7</td>
</tr>
<tr>
<td>Shannon-Wiener diversity</td>
<td>1.32 ± 0.16</td>
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<tr>
<td>Height coefficient of variation</td>
<td>0.82 ± 0.11</td>
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<tr>
<td>Jack pine cover (%)</td>
<td>7.94 ± 4.2</td>
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<tr>
<td>Patchiness (intercepts/transect)</td>
<td>117 ± 41</td>
</tr>
</tbody>
</table>

Table 2. Classification results for predicted group membership of three patch types based on discriminant analysis. Percent correct for each group in parentheses; 35 (87.5%) of 40 cases were correctly classified.

<table>
<thead>
<tr>
<th>Actual Group</th>
<th>Number of Cases</th>
<th>Predicted Group Membership</th>
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<tbody>
<tr>
<td></td>
<td>Clearcut</td>
<td>Savanna Reserve</td>
</tr>
<tr>
<td>Clearcut</td>
<td>23</td>
<td>2 (92)</td>
</tr>
<tr>
<td>Savanna</td>
<td>11</td>
<td>9 (18.2)</td>
</tr>
<tr>
<td>Wildfire</td>
<td>4</td>
<td>0 (25)</td>
</tr>
</tbody>
</table>

repeated prescribed burns (pers. obs.). But crown fire patches were dominated by injured and dead trees, which typically have different physical attributes than live trees. Sloughing bark on dead trees provides cover for invertebrates and foraging sites for bark-gleaning birds, and rotting wood hosts invertebrates and simplifies excavation by primary cavity nesters (Evans and Conner 1979, Cline et al. 1980, Mannan et al. 1980).

Woody debris is also an important component of pine barrens vegetation structure. Woody debris provides escape cover, foraging habitat, and perch sites for many bird species (Mossman et al. 1991). Nests of Brewer's blackbirds (Euphagus cyanocephalus) and brown thrashers (Toxostoma rufum) are frequently associated with woody debris in pine barrens, and black bears (Ursus americanus) regularly turn over and tear apart large woody debris in search of food (pers. obs.). Woody debris is also an important substrate for fungi and provides cover for invertebrates and small vertebrates (Zappalorti and Burger 1985, Gillis 1990, Hansen et al. 1991, Haim and Izhaki 1994). In addition to providing cover for wildlife, woody biomass is an important nutrient reservoir in pine ecosystems (Boerner 1982). The relative scarcity of woody debris at managed sites is apparently caused by repeated prescribed burns with relatively little time for regeneration of woody vegetation between burns.

Density of jack pine varied greatly among the three patch types. Jack pine density was greatest at crown fire sites, where serotinous cones opened in response to fire. Some jack pine cones in the region open in response to high ground temperatures (D. Epperly, pers. comm.), allowing jack pine regeneration in many clearcut patches. Repeated
burns eliminate age cohorts of jack pine before regeneration can occur (Anonymous 1931, Vogl 1970), explaining extremely low jack pine densities at managed savanna reserves. Curtis (1959) described the jack pine as the most usual tree on the pine barrens, yet management practices intended to perpetuate savanna have virtually eliminated jack pine from savanna reserves. Fire frequency strongly influences structure and composition of vegetation at a site. For example, the Five-Mile Fire burned approximately 5,400 ha of jack pine-dominated forest in northwestern Wisconsin in 1977 (Gregg 1987). Jack pine quickly regenerated following the fire, and most of the area was soon covered with dense growth of jack pine saplings. Without further disturbance, jack pine at the site would have grown to maturity. But in June 1988, the Loon Lake Fire burned a portion of the Five-Mile Fire. Jack pines were eliminated from that patch, and the Loon Lake Fire became a brush prairie, with characteristics similar to clearcuts in the area (Figure 2). Fire frequency also affects densities of blueberries, which provide food for wildlife and humans. Blueberry cover was greatest at crownfire sites and lowest at managed savanna reserves (Niemuth 1995). Burning stimulates blueberry growth (Murphy 1931, Vogl 1970), but Buell and Cantlon (1953) found that blueberry cover decreased at their New Jersey study site when burns became more frequent than every three years.

Clearcuts had reduced Shannon-Wiener diversity and height range of woody vegetation, which may negatively impact many savanna wildlife species. For example, species richness and density of savanna birds along transects are positively correlated with Shannon-Wiener diversity of woody vegetation in early successional habitat in the pine barrens (Niemuth 1995).

Management Implications

Altering management practices can address some of the differences in which clearcuts and savanna reserves differed from crown fire patches. For example, tree density can easily be increased in clearcuts by leaving dead and live trees during timber harvest. Diversity of woody vegetation in clearcut patches could be increased by discontinuing management practices that reduce diversity such as release of young pines by removal of deciduous shrubs. Lengthening the return interval for prescribed fires at savanna reserves will allow added growth of woody vegetation and, over time, potential for more woody debris. With a longer fire return interval, trees can (1) grow larger and develop thicker bark, better enabling them to survive fire (see Vogl 1970) or (2) survive long enough to produce seed, permitting seedlings to regenerate even if parent trees are lost to fire.

Landscape-level management could add a dimension of spatial and temporal variability that is largely absent from present disturbance in the pine barrens. Presently, most clearcuts are small relative to proposed management (Parker 1995, Strand and Epperly 1995), leading to habitat fragmentation. Also, savanna reserves in Wisconsin pine barrens are spatially static, and vegetation is burned approximately every five years.

Temporal variation in disturbance was noted by Vogl (1964), who observed that “brush prairie savanna undoubtedly reverted back and forth from brush to forest and forest to brush again, depending on the absence or presence of fire.” Depending on the time of observation, a site might accurately have been described as brush prairie, pine savanna, or forest. Indeed, such variation would have influenced the pre-fire vegetation at crown fire sites we sampled,
influencing post-fire characteristics to which we compared vegetation at prescribed burn and clearcut sites.

Of course, fire is not the only factor shaping the pine barrens. Vogl (1970:200) noted that “all factors including soil type, soil fertility, topography, climate, drought, and fire are inseparably linked. . . . Fire is one of the essential ingredients. . . . but the critical factor. . . . is not so much fire, but the presence of sandy plains; sites with low fertility that lend themselves to droughts and fires of the proper intensities and frequencies to produce a vegetational structure and composition called barrens.” The myriad forces that shape pine barrens vegetation are too complex and variable for managers to duplicate, illustrating a key problem experienced at many nature reserves: trying to preserve that which changes (White and Bratton 1980).

The influence of disturbance on other processes and taxa in the pine barrens must also be considered. Our analysis demonstrated that disturbance type can influence the structure and composition of woody vegetation persisting after disturbance occurs. But disturbance size and intensity can also alter the trajectory of succession, influencing composition and growth form of vegetation established following disturbance (Canham and Marks 1985).

Duplicating pre-settlement conditions will be difficult, if not impossible, when the “natural” disturbance regime is unknown, but through active adaptive management and simulation modelling, habitat quality on managed landscapes can be improved (see Walters and Holling 1990, Boyce 1993, Hansen et al. 1993). An understanding of the range of vegetation types and disturbances in a dynamic ecosystem can guide management (Sprugel 1991). Management of the pine barrens, whether through timber harvest or prescribed burns at dedicated reserves, must reflect the dynamic nature of the ecosystem.

Acknowledgments

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