A Case Study of Non-Industrial Private Forest Management: Effects of a Selective Harvest on the Regeneration of a Mesic Northern Forest in Baraga County, Michigan

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Forests and forest ecosystems are critically important to Native communities in the Upper Midwest of the United States. The management of these forests, whether on tribal lands or off, can have a great impact on the surrounding communities. In particular, human management decisions can affect successional pathways of forest ecosystems. In mesic northern forests of Michigan's Upper Peninsula, which are largely non-industrial private forests (NIPFs), selective harvesting creates canopy gaps that initiate the regeneration process. In this article, Andrew T. Kozich and Stephanie Cree Kozich have examined a mesic northern forest on contested lands near a tribal community in Michigan to compare regeneration of harvested plots to non-harvested reference plots. The medium-scale canopy gaps created by the harvest had mixed outcomes, significantly increasing mean stem density but not species composition. Findings add to the literature on forest gap dynamics and provide insight to forest owners to help predict how their decisions can impact long-term successional processes. In addition, the authors have articulated the connection between science and culture, and the mutually beneficial possibilities of considering both in human management decisions of forests and forest ecosystems.

Introduction

Private property owners can greatly influence ecological conditions of their forests through the management decisions they make. With approximately half of U.S. forest acreage in private ownership, the potential cumulative impacts of self-management are enormous (Birch, 1994; Butler, 2008; Butler & Leatherberry, 2004). Furthermore, impacts from disturbances such as harvesting can extend beyond each parcel's boundaries, as ecological processes are interconnected across the greater landscape. In instances where harvesting occurs near tribal communities, important cultural resources can be impacted as well. This paper summarized trends in U.S. private forest management and examined a case study involving effects of a recent harvest in northern Michigan. The objective of the study was to link management decisions to ecological outcomes, including those that could potentially impact a nearby tribal community.

Non-Industrial Private Forests

Over 400 million acres of U.S. forests are privately owned by individuals, families, or organizations that do not operate wood-processing facilities (Birch, 1994; Butler, 2008; Butler & Leatherberry, 2004). These forests are commonly known as non-industrial private forests (NIPFs), and they have over 10 million owners nationwide (Butler, 2008; Butler & Leatherberry, 2004). With such vast acreage of U.S. forestland in private hands, owners serve as de facto stewards of critical natural resources. The limited supply of timber available on public lands, combined with the public's general disfavor of large-scale harvesting on them, has generated increased interest in NIPFs as potential suppliers for timber markets (Bliss, 2000; Bliss, 2003; Brennan, Luloff, & Finley, 2005; Butler, 2008; Egan, 1997). Clearly there are good reasons to be concerned about the management decisions of NIPF owners.

In the U.S. scientific literature, studies of NIPF ownership characterizations reveal consistent trends of who owns forestland and why. Demographically, NIPF owners tend to be Caucasian males who are older, wealthier, and better educated than the general public and are likely to have owned their forestland for a longer period of time than the average property owner (Birch, 1994; Butler, 2008; Butler & Leatherberry, 2004; Creighton, Baumgartner, & Blatner, 2002; Johnson, Alig, Moore, & Moulton, 1997). Commercial timber harvesting is rarely the primary motivation for owning forestland; the most commonly cited reasons include recreation, viewing of nature scenery, wildlife protection, "peace and quiet," and privacy (Birch, 1994; Brunson, Yarrow, Roberts, Guynn, & Kuhns, 1996; Butler, 2008; Butler & Leatherberry, 2004; Creighton, Baumgartner, & Blatner, 2002; Erikson, Ryan, & DeYoung, 2002; Johnson, Alig, Moore, & Moulton, 1997; Koontz, 2001). Many NIPF owners report that they own forestland simply because it is part of their family heritage or is the location of their residence (Birch, 1994; Butler & Leatherberry, 2004). For many owners, trees comprise a minor part of a property that is owned for other primary purposes such as farming or grazing (Moser, Leatherberry, Hansen, & Butler, 2009). Considering that the U.S. Forest Service defines 'forestland' as any parcel one acre or greater that is at least 10 percent stocked with trees, many property owners may not even be aware that they are technically owners of forests (Butler, 2008).

Over half of NIPF owners cut trees from their forests for personal uses such as firewood, but only 3% engage in commercial harvesting for the purpose of financial gain (Birch, 1994; Butler, 2008). Owners typically harbor negative perceptions of commercial harvesting and believe that it results in an unattractive forest or is harmful to wildlife or other natural features of the property (Bliss, 2000; Young & Reichenbach, 1987). However, NIPF owners may feel increased pressure towards commercial harvesting in the future in regions such as Michigan that are developing markets for biomass energy production (Munsell & Germain, 2007).

While "personal harvesting" of firewood is very common among NIPF owners, few seek assistance from forestry professionals despite the fact that free or low-cost services are often available. Fewer than 5% of NIPF owners have a written management plan for their forestland (Birch, 1994; Butler & Leatherberry, 2004). Owners often appear confident in their abilities to self-manage their forests, believe that the limited amount of harvesting they do is not worthy of professional assistance, or distrust members of the forestry profession (Belin, Kittredge, Stevens, Dennis, Schweik, & Murzoch, 2005; Birch, 1994; Butler, 2008; Kilgore, Snyder, Taff, & Schertz, 2008).

The lack of interest in professional management advice among NIPF owners raises many concerns. At the broader landscape level, even small-scale personal harvesting can have wide-reaching impacts because ecological processes operate across property boundaries (Kimmins, 2004; Sharpe, Hendee, & Sharpe, 2003). Fragmentation of forests can result in an undesirable mosaic of landscape patches with increased edge effects that impact values to wildlife or cause behavioral changes (Kimmins, 2004; Schulte, Rickenbach, & Merrick, 2008; Sharpe, Hendee, & Sharpe, 2003). For example, many migrating species simply avoid recently-disturbed areas or are susceptible to increased predation there. Trans-boundary impacts can be further exacerbated when harvested forest areas include aquatic features. Streams and wetlands, even if seasonal or intermittent, are crucial for many organisms who migrate great distances to use them (Dutecher, Finley, Luloff, & Johnson, 2004; Schulte, Rickenbach, & Merrick, 2008; Sharpe, Hendee, & Sharpe, 2003). Furthermore, trends towards forest fragmentation and parcelization are increasing nationwide. While the total acreage of forestlands in the U.S. has remained steady in recent decades, the number of total owners is increasing and average parcel size is shrinking (Birch, 1994; Butler, 2008; Potter-Witter, 2005). Large forest tracts once managed by a single owner (or company) are frequently sold and subdivided into smaller parcels, with new owners exhibiting different motivations and management practices than previous ones. Some view smaller-parcel management as the most challenging aspect of ecosystem management objectives, because smaller-parcel owners are predictably the least likely to seek any kind of management advice (Best, 2004; Pan, Zhang, & Butler, 2007; Potter-

Witter, 2005). However, smaller-parcel NIPF owners collectively can have great influence over the continuity and integrity of vast forest ecosystems.

Forest management agencies have trended towards the concepts of “sustainability” and “ecosystem management” in recent decades, but ecosystem management objectives are difficult to attain across landscapes comprised of numerous private owners who manage their forest tracts independently from one another (Birch, 1994; Brunson, Yarrow, Roberts, Guynn, & Kuhns, 1996; Campbell & Kittredge, 1996; Finley, Kittredge, Stevens, Schweik, & Dennis, 2006; Schulte, Rickenbach, & Merrick, 2008). Collaborative management approaches are problematic when the desired participants have diverse ownership objectives or disdain towards outsiders in matters of their private property (Brunson, Yarrow, Roberts, Guynn, & Kuhns, 1996; Campbell & Kittredge, 1996; Egan, 1997; Janota & Broussard, 2008; Schulte, Rickenbach, & Merrick, 2008). In other words, getting all private forest owners “on the same page” in any given area is unlikely, despite the fact that the actions of each can affect all. The substantial body of literature examining agency outreach strategies such as education and promotion of cross-boundary collaboration consistently indicates that the receptivity of these efforts among NIPF owners is low (Brunson, Yarrow, Roberts, Guynn, & Kuhns, 1996; Butler, Tyrrell, Feinberg, VanManen, Wiseman, & Wallinger, 2007; Campbell & Kittredge, 1996; Egan, 1997; Finley, Kittredge, Stevens, Schweik, & Dennis, 2006; Janota & Broussard, 2008; Kilgore, Snyder, Taff, & Schertz, 2008; Kuhns, Brunson, & Roberts, 1998).

Importance of Forests to Ojibwa Culture

Forests are particularly sacred ecosystems for Ojibwa cultures such as the Keweenaw Bay Indian Community (KBIC) of northern Michigan. Historically, Ojibwa lifeways involved regular movement throughout the Tribe's home territory following the abundant resources that are associated with each season of the year. Forests provided materials for shelter and tools and food sources such as wild berries, maple syrup, and fish and game. As summarized by KBIC Forester Gerald Jondreau, "We've always been a woodlands people; almost all of our resources were gathered or collected from the woods, and our culture evolved with the landscape" (personal communication, March 25, 2013). The Ojibwa traditionally considered themselves an inter-connected component of the forests and recognized how their actions could affect the greater system (G. Jondreau, personal communication, January 24, 2015).

The important relationship with the region's forests continues today, as the KBIC relies on healthy and sustainable forest ecosystems for both its economic and cultural livelihood. The region surrounding the KBIC reservation was ceded by the Tribe in the Treaty of 1842, with Tribal members retaining rights to hunt, fish, and gather on these lands. These traditions remain very strong today and largely occur in off-reservation forests. The management of off-reservation forests, by whoever owns them, therefore takes on additional importance because decisions can impact cultural values and traditions in addition to ecological functions. Their fragmentation or conversion into other ecological communities as a result of harvesting is a substantial concern to KBIC natural resource personnel (G. Jondreau, personal communication, January 24, 2015). A KBIC elder summarized the critical role of the region's forests for maintaining the cultural identity of the community:

> Well, this is all we've got left. This is our home. This is where we live and this is what we have left. We've got to take care of the forests, to be able to fish and harvest our deer meat for feasts and support our families. The trees give them homes and give us

> oxygen, and what we breathe is what's being purified from all the trees out there, like a big filter. I really think that the earth is pretty delicate. I think a lot of people are taking it for granted that it's going to last forever (F. Dakota, personal communication, September 13, 2013).

While tribal natural resource personnel have limited influence over off-reservation activities, many tribes are increasing self-management of their own forest resources. This is particularly true of the KBIC, which recently established its own forestry department to oversee the abundant on-reservation forests. Compared to previous forest management arrangements, current objectives far exceed simple management of forests for timber sales to provide economic support for the community (G. Jondreau, personal communication, March 25, 2013). Long-term management objectives include increased attention to sacred species and the reduction of large-scale fragmentation that impacts valuable wildlife corridors (G. Jondreau, personal communication, March 25, 2013). Challenges to the management of tribal forests include the responsibility of deciding what gets taken and what does not – a responsibility that was not part of traditional Ojibwa roles in the environment – and the delicate integration of "modern" science and traditional knowledge (G. Jondreau, personal communication, January 24, 2015). Despite differences in Native and non-Native forest management, similarities certainly do exist. For instance, the KBIC's concern for long-term ecosystem stability follows the traditional "seventh generation" approach, which bears remarkable similarity to the recent emphasis among non-Native cultures known as "sustainability" (G. Jondreau, personal communication, March 25, 2013). The KBIC Forester summarized the strong cultural component to management that enhances "modern" forestry techniques:

> One aspect of forestry that I feel very strongly about is incorporating our culture into natural resource management. Up until now there's always been an aspect to forestry that I kind of feel is missing, and that's the cultural aspect. What I do is incorporate the cultural components. I want to look at individual tracts of land and think of what resources are here that are culturally significant, how can we still have a timber sale and create income, but how can we maintain our cultural identity in the landscape as well? When you walk into a KBIC forest, I am hoping it looks and feels different than a state forest. I want to have our cultural resources available to tribal members, or anyone else for that matter. If there's something that people need medicinally speaking, or materials for whatever they need, we need to have those intact on our reservation still. Forestry is a long term job, and if you screw something up, or if you make a bad decision, it takes a long time to rebound. It's something that is on my mind constantly (G. Jondreau, personal communication, March 25, 2013).

The preceding paragraphs are intended to emphasize the influence that individual NIPF owners can have across ecosystem expanses in terms of space and time, and how forest management and culture are intertwined. The cumulative effects of parcelization and the lack of interest in professional consultation among many NIPF owners are a cause for concern. It is critical to continue gaining insight that links private forest management behaviors to ecological outcomes. The remainder of this paper focuses on a case study in northern Michigan that typifies issues of NIPF ownership, and takes on additional cultural importance because the harvest occurred only five miles from KBIC reservation boundaries. We examined the owner's management decisions and the ecological outcomes of a harvest to draw conclusions about short-term and long-term effects of the harvest.

Context & Objectives

In Michigan's Upper Peninsula (U.P.), about 55,000 individual NIPF owners control 34% of the region's total forestland, or approximately 2.8 million acres (Cook, 1998). The remaining forestlands are primarily public lands or are owned by timber industry companies (Cook, 1998). The U.P. landscape is dominated by forests largely because the region's cold climate and short growing season limit agricultural productivity (Barnes & Wagner, 2011). The most common forest community across the region is known as a "mesic northern forest" (alternately referred to as "northern hardwood/conifer forest" or "hemlock-hardwood forest" by some sources). These mixed-species communities vary by location but in the western U.P. are broadly characterized by sugar maple (*Acer saccharum*) as the typical dominant. Significant co-dominants can include eastern hemlock (*Tsuga canadensis*), red maple (*Acer rubrum*), and yellow birch (*Betula alleghaniensis*), with white pine (*Pinus strobus*), northern white cedar (*Thuja occidentalis*), and others as important but smaller components (Cohen, 2000). The U.P.'s mesic northern forests were largely devastated during Michigan's logging era of the late 1800s but have since recovered to provide important ecological, economic, and cultural services.

The ecological processes occurring as forests recover from disturbances are known as "succession." Successional pathways follow predictable patterns in most forest ecosystems. Forests in a late-successional (mature) stage are typically characterized by a dense, multi-layer canopy and are dominated by long-lived, shade-tolerant species. Disturbances such as fire or clearcutting open the canopy and allow for the establishment of fast-growing, shade-intolerant species. After these early-successional species mature and create a new canopy, they are gradually replaced by the shade-tolerant species that were prevalent before the disturbance. Forests are dynamic ecosystems, always existing in some stage of this cycle, and their structure and species composition at any moment is essentially a reflection of the time that has passed since the last disturbance event (Kimmins, 2004; Sharpe, Hendee, & Sharpe, 2003).

Successional pathways are also influenced by the magnitude of disturbance events and the size of the canopy gap(s) created (Barnes & Wagner, 2011; Canham, 1985; Cohen, 2000; Crow, Buckley, Nauertz, & Zasada, 2002; Frelich & Lorimer, 1991; Hanson & Lorimer, 2007). Large-scale disturbance events such as fire are naturally rare in Michigan's mesic northern forests; the primary large-scale disturbance event is clearcutting (Cohen, 2000; Frelich & Lorimer, 1991). Following a clearcut, the maples and hemlock that previously dominated the forest are typically replaced by sun-loving early-successional *Populus* species such as aspen and poplar (Barnes & Wagner, 2011; Cohen, 2000). More common in these forests, however, are small-scale disturbance events such as wind-throw and selective harvesting that result in small canopy gaps from the removal of individual trees. Compared to large canopy gaps, smaller gaps often do not lead to the establishment of early-successional species; the gaps are instead filled by lateral growth from existing trees or by the growth of shade-tolerant seedlings that have been lingering in the understory, such as sugar maple (Canham, 1985; Crow, Buckley, Nauertz, & Zasada, 2002; Hanson & Lorimer, 2007; Hibbs, 1982; Woods, 2004).

Most disturbance research in mesic northern forests focuses on either very large-scale or very small-scale disturbance events. Intermediate-scale events, such as those that result in 30-60% canopy removal, are less-studied because they are less common (Frelich, Calcote, Davis, & Pastor, 1993; Hanson & Lorimer 2007; Woods, 2004). A key objective of our research was to examine successional outcomes involving "medium" canopy gaps in mesic northern forests, because the limited literature shows conflicting findings. In many instances, successional outcomes of medium gaps appear similar to those of large gaps, with rapid establishment of shade-intolerant species and increases in species diversity and stem density (Hanson & Lorimer, 2007; Kraft, Crow, Buckley, Nauertz, & Zasada, 2004; Metzger & Schultz, 1984). Others have found few such changes, however, with successional outcomes instead resembling those typical of small gaps (Crow, Buckley, Nauertz, & Zasada, 2002; Webb & Scanga, 2001). Clarity on this topic is important because in mesic northern forests today, human behaviors (i.e., harvesting) are the drivers of successional processes more often than natural events. Prediction of ecological outcomes from various-scale events should ideally guide forest management decisions. Furthermore, impacts from climate change are anticipated to include an increase in the intensity of wind events, which could result in canopy gaps from wind-throw that are larger than the historical norm (Woods, 2004).

Our study occurred in Section 23 of Arvon Township in Baraga County, Michigan (Figure 1). The land cover of this rural county is 85% forest, 67% of which is mesic northern forest (Michigan SAF, 2004). Over 25% of the county's forestlands are NIPFs (Michigan SAF, 2004). The owner of our study site fits the typical "profile" of NIPF owners – a college-educated, retired Caucasian male who until recently conducted frequent small-scale harvests for personal firewood use only. The parcel is 36 acres and has been in his family for over 70 years, with the last commercial harvest occurring during his youth. He estimates, therefore, that most upper canopy trees are at least 60 years old. The forest is in a mid- to late-successional stage and resembles a typical mesic northern forest dominated by sugar maple and red maple with eastern hemlock, northern white cedar, and others as sub-components. In early 2011, the owner oversaw a commercial harvest that resulted in canopy removal of approximately 50% in harvested areas, representing a "medium" scale disturbance for the purposes of our research. Other areas were left undisturbed. The owner has never had a professional management plan for the forest. Decisions about the harvest were made jointly with the contracted logging company, such as the decision to remove species relative to their pre-harvest proportions.

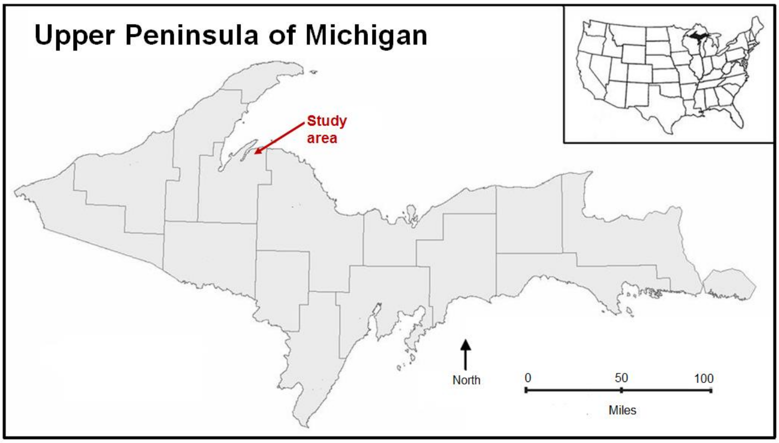

Figure 1: The Upper Peninsula of Michigan and location of our study.

Research Design

The broad objective of this research was to link NIPF management decisions to ecological outcomes. The creation of medium-size canopy gaps following the 2011 harvest offered a unique opportunity to examine successional processes under conditions not often studied. We compared successional processes in harvested forest plots to those in adjacent non-harvested (reference) plots, with the goal of adding to the literature on successional processes in mesic northern forests following a specific type of disturbance event. Based on a review of the literature, we formulated the following two hypotheses to guide our study:

• **Hypothesis 1:** Mean stem density of groundcover plants will be higher in harvested plots than in reference plots.

• **Hypothesis 2:** Diversity of groundcover plants will be higher in harvested plots than in reference plots.

Data were collected in early September 2013. In addition to cultural insight, the authors received training from the Tribal Forester in the field methodology used. Also, to be consistent with common forestry methods, we used standard U.S. units of measurement in all phases of our research. We used a systematic random sample to establish sampling plots in the forest to test the hypotheses. To sample in harvested conditions, we marked an east-west transect across the harvested segment of the parcel and sampled at 200-foot intervals (three sample sites), at a distance of 200 feet from the southern boundary of the forest (Figure 2). A second, parallel transect was used 200 feet to the north, repeating sampling intervals, and captured non-harvested reference conditions (three sample sites). Transects also captured the variety of site conditions that exist within a typical mesic northern forest community, although few differences in elevation or soil characteristics were found between sample sites.

At all six sample sites we used a multi-step protocol to characterize and quantify features from the ground surface to the upper canopy (Figure 2). Overstory characteristics were documented using a 1/10 acre sample circle (radius: 37.25' from plot centerpoint). In this circle, all trees with a DBH (diameter at breast height) greater than 4" were inventoried and measured. Midstory characteristics were similarly assessed for trees with a 1-4" DBH using a 1/100 acre sample. We also visually estimated percent canopy cover at each site and supported estimates with photographic evidence (Figures 3 and 4), which is appropriate for the scope of this project. Overstory and midstory data allowed us to infer general characteristics of each sample location and to make comparisons between canopy conditions of reference sites and harvested sites.

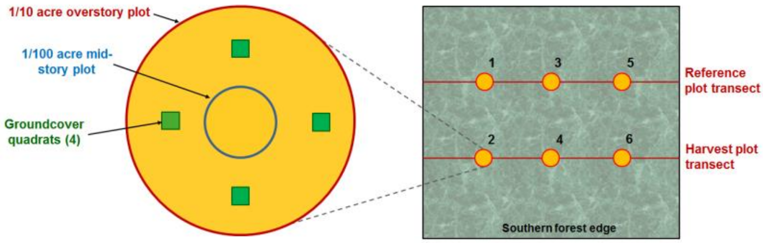

Figure 2: Schematic of sampling methodology (not to scale).

Groundcover characteristics were measured with four 36” x 36” sampling quadrats within each plot, with quadrats oriented 20’ from the plot centerpoint in each cardinal direction. All groundcover plant species in each quadrat (except grasses and sedges) were identified and counted. Percent cover of each species within each quadrat was visually estimated. Groundcover data was used to test the hypotheses, with the four groundcover quadrats at each plot resulting in a total of sample size of 24 (12 harvested, 12 reference).

Figure 3: Canopy of reference plot #5 (Photo: Kozich)

Figure 4: Canopy of harvested plot #4 (Photo: Kozich)

Results

Our initial assessments of canopy characteristics revealed key differences between reference and harvested plots. Reference plots had a mean density of 300 overstory trees/acre and 233 midstory trees/acre, while harvested plots averaged 177 overstory trees/acre and 100 midstory trees/acre. These findings support our visual estimates of 0-25% canopy openness in reference plots and 50-75% openness in harvested plots (Figures 3 and 4). The mean DBH of overstory trees was 9.5" in reference plots and 8.2" in harvested plots. The relative densities of overstory and midstory species, however, were similar across all plots. This finding was not unexpected, because the 2011 harvest removed species in proportion to their original composition.

Results of groundcover inventories in sample quadrats allowed us to test both hypotheses. Vegetation abundance, measured as stem density, provided the data necessary to test Hypothesis 1 and determine if the harvest likely affected succession of groundcover vegetation. We found a total of 178 individual groundcover plants in the 12 reference sample quadrats and 322 in the 12 harvested quadrats (Table 1). These findings translate to stem density results of 15 plants/yd^2 in reference plots (SD=12.5, N=12) and 27 plants/yd^2 in harvested plots (SD=12.6, N=12). A *t*-test analysis shows the difference between these groups to be significant at the 95% confidence interval (P=0.029), supporting Hypothesis 1. Stem density of groundcover plants was significantly higher in harvested plots than in reference plots.

Red maple and eastern hemlock were the most abundant species in reference plots, with 56 and 34 individuals respectively. Additional species indicative of shaded environments were common in reference plots, including balsam fir, shining clubmoss, spinulose woodfern, and yellow birch (Table 1). Red maple and eastern hemlock were also very abundant in harvested plots (111 and 31 respectively), along with shade-intolerant species exclusive to harvested sites such as wild raspberry, trembling aspen, and bigtooth aspen (Table 1). One quadrat in a harvested plot was almost completely covered by a dense growth of wild raspberry plants (with very few other species), which is a common occurrence in sunny, recently-disturbed areas.

Table 1: Results of groundcover samples.

Species	Reference plots	Harvested plots
Alternate-leaf dogwood (*Cornus alternifolia*)		1
Balsam fir (*Abies balsamea*)	4	3
Beaked hazel (*Corylus cornuta*)	2	4
Bigtooth aspen (*populus grandidentata*)		9
Black cherry (*Prunus serotina*)	2	
Blue-bead lily (*Clintonia borealis*)	7	7
Bracken fern (*Pteridium aquilinum*)	7	12
Canadian bunchberry (*Cornus canadensis*)	3	18
Eastern hemlock (*Tsuga canadensis*)	34	31
Ground pine (*Lycopodium obscurum*)		1
Northern red oak (*Quercus rubra*)	3	5
Northern white cedar (*Thuja occendatalis*)	2	
Red maple (*Acer rubrum*)	56	111
Sensitive fern (*Onoclea sensibilis*)	1	
Shining clubmoss (*lycopodium lucidulum*)	13	1
Spinulose woodfern (*Dryopteris spinulosa*)	18	3
Starflower (*Trientalis borealis*)	2	
Sugar maple (*Acer saccharum*)	3	6
Threeleaf goldthread (*Coptis trifolia*)		12
Trembling aspen (*Populus tremuloides*)		8
Wild ginger (*Asarum canadense*)	8	13
Wild raspberry (*Rubus sp.*)	2	70
Yellow birch (*Betula alleghaniensis*)	11	7
Total individuals:	**178**	**322**
Total species:	**18**	**19**

The species diversity of groundcover quadrats was very similar between reference and harvested plots. Reference plots contained a combined 18 species and harvested plots contained 19, with 14 species in common between the two groups. We used two well-established methods to conduct analyses of diversity, which both consider species' distribution as well as abundance. The Shannon Index (H) is a relative measure of diversity that is commonly used to compare multiple biological communities, and is explained by the formula:

$$p_i = \frac{n_i}{N} \quad \text{and} \quad H = \sum_{i=1}^{S} p_i\,[\ln(p_i)], \text{ where}$$

n_i = number of individuals of species *i*

N = total number of individuals of all species

p_i = relative abundance of species *i*

S = total number of species

H = Shannon diversity index value

According to this formula, the value of H would be 0 for a community with only one species. Diversity would increase with added individuals, additional species, or with a greater degree of evenness across samples. In our samples, the Shannon index value (H) was 2.24 for reference plots and 2.13 for harvested plots, indicating that reference plots were slightly more diverse than harvested plots.

We conducted a second analysis of groundcover data to check the validity of the Shannon Index results. The Simpson Index of Diversity (1 – D) measures the probability that two individuals randomly chosen from any sample will belong to the same species. A reduced likelihood to belong to the same species translates to a more diverse community. The Simpson Index equation is:

$$D = \frac{\Sigma\, n(n-1)}{N(N-1)}$$, where

n = total number of organisms of a particular species

N = the total number of organisms of all species

D = Simpson diversity index value

The results of any Simpson analysis will always yield a value between 0 and 1 but is counter-intuitive because higher diversity is reflected by a lower (D) value. To overcome this oddity, the value (1 – D) adds clarity to results by producing a higher numerical value for greater diversity. Analysis of our data using the Simpson Index (1 – D) method yielded results very similar to the Shannon Index; diversity of groundcover was slightly higher in reference plots (0.68) than in harvested plots (0.63). Because two well-established methods produced very similar findings, we confidently reject Hypothesis 2 and conclude that diversity of groundcover plants was not higher in harvested plots.

Discussion

For any forest owner or manager, the ability to predict outcomes of management decisions is very valuable. Different harvesting strategies can be applied to forests to produce different long-term results, with the common outcome that harvesting of any scale typically stimulates understory regeneration. In mesic northern forests, for example, clearcutting and shelterwood methods involve the removal of enough of the canopy that fast-growing, shade-intolerant species will typically be favored and an even-aged community will result. By contrast, individual-tree removal creates smaller canopy gaps and will typically retain shade-tolerant species (such as maple) as dominants and result in an uneven-aged community. Either strategy, however, is expected to result in changes to the structure or composition of the community that carry corresponding ecological and economic considerations. Therefore, owner/manager objectives should ideally be identified before a harvest takes place. A concern regarding NIPFs is that owners may make management decisions without a full awareness of the potential long-term and far-reaching impacts of their activities.

The decision to harvest by the owner of our study site was primarily financially-driven. He saw mature trees in his forest that had considerable market value and wanted to capture the opportunity to augment his limited retirement income before trees became over-mature and less valuable. The only other pre-harvest objective he stated was that he did not wish to drastically alter the species composition of the forest. Based on our findings, it appears as though he has met this objective so far. We did not find significant changes to the species composition of the forest – rejecting our second hypothesis – as regeneration of the harvested sites was not dominated by early-successional species that he considered less desirable (e.g., *Populus*). The similarities in composition between harvested and reference sites are somewhat surprising based on the literature (Kraft, Crow, Buckley, Nauertz, & Zasada, 2004; Metzger & Schultz 1984). We found mature *Populus* species abundant along the sunny edges of the southern boundary of the forest, only 200 feet from our sampled harvested plots. These species are prolific dispersers and reproducers, but had not (yet) managed to establish widely at the harvested plots we studied. Based on our findings, therefore, it seems that very large canopy openings are necessary for significant amounts of shade-intolerant species to establish in these communities. Because the sites we examined appear to be re-populating themselves predominantly with maples, eastern hemlock, and other shade-tolerant species, the 2011 harvest appears to be in the midst of outcomes resembling those from small-gap disturbances as far as species composition is concerned

(Canham, 1985; Crow, Buckley, Nauertz, & Zasada, 2002; Hanson & Lorimer, 2007; Hibbs, 1982; Woods, 2004).

The harvest did not significantly alter the forest's composition, but it did change the structure and significantly increase stem density as our first hypothesis predicted. While this finding is not a surprise, it nonetheless adds to the literature on successional process of mesic northern forests, agreeing with others (Crow, Buckley, Nauertz, & Zasada, 2002; Webb & Scanga, 2001). Canopy gaps of any size tend to initiate the rapid growth of seedlings (a process known as "release") as they take advantage of the sudden influx of sunlight. Changes in structure and stem density can certainly impact wildlife, but these considerations were beyond the scope of this project.

We earlier identified the need for better understanding of the ecological outcomes of "medium" scale disturbance events in these types of forest ecosystems. Perhaps the most valuable finding from our study is the determination that the successional processes we observed in medium canopy gaps closely resemble those expected to occur in small gaps. As few others have examined medium-gap outcomes in these forest communities, our findings help fill an important knowledge void (Hanson & Lorimer, 2007; Woods, 2004). Our findings are limited, however, by the fact that only three growing seasons occurred between the harvest and the time of our examination. Long-term outcomes on community composition can take quite some time to be realized, and therefore follow-up research is in order.

Concern for long-term outcomes could be particularly relevant regarding ongoing regeneration of eastern hemlock at our study site. We documented substantial early regeneration of hemlock in our sample quadrats but seedlings were small enough (typically 3" or less in height) to remain buried beneath snowpack for much of the winter for the time being. As they grow tall enough to emerge through the snow, however, they will likely suffer high mortality rates from herbivory by whitetail deer. Severely restricted hemlock and cedar regeneration has been widely documented across the U.P. due to excessive whitetail deer populations, thus rendering these species far-less significant components of mesic northern forests than historical norms (Cohen, 2000; Kraft, Crow, Buckley, Nauertz, & Zasada, 2004). In our study site, the removal of mature hemlock during the 2011 harvest may have long-term consequences that are currently unknown because they depend on future deer populations and snow conditions. If the owner had the objective of maintaining the previous relative density of hemlock, however, we suspect he will not succeed long-term, as hemlock seedlings are unlikely to eventually replace the mature individuals that were removed. A likely long-term outcome could be increased dominance of maple species, since we found limited establishment of others such as *Populus*. We suspected potential long-term impacts to hemlock would have been identified by a professional forester prior to the 2011 harvest, but none were consulted. We view this scenario as an example of a consequence of the disregard of professional forest management plans, which has been noted throughout the literature of NIPF ownership (Belin, Kittredge, Stevens, Dennis, Schweik, & Murzoch, 2005; Birch, 1994; Butler, 2008; Kilgore, Snyder, Taff, & Schertz, 2008). Species such as hemlock and cedar also hold important medicinal and ceremonial roles in Ojibwa culture, and their losses throughout the region are further examples of how natural resource management and culture are intertwined.

Researchers acknowledge the importance of ongoing monitoring of disturbance outcomes in mesic northern forests due to increased pressures to harvest, excessive deer populations, and possible impacts from climate change (Cohen, 2000; Crow, Buckley, Nauertz, & Zasada, 2002; Hanson & Lorimer, 2007; Kraft, Crow, Buckley, Nauertz, & Zasada, 2004; Woods, 2004). Our work contributes to the body of literature on these topics by increasing our understanding of successional outcomes following a specific type of disturbance. Findings also provide insight on issues related to NIPF management, which some regard as critical in this region (Potter-Witter, 2005). Tribal natural resource managers have numerous reasons to be concerned with harvesting activities and outcomes in this region, as discussed previously, since off-reservation management decisions can impact lifeways of tribal members. While our study was limited in scope, our findings effectively link management decisions to ecological outcomes, with results supported by statistical analyses using two well-established frameworks. Follow-up efforts could be enhanced by employing a larger sample size, more thoroughly examining soil characteristics at sample locations, and through replication in different regions where mesic northern forests exist.

Acknowledgements

The authors wish to thank the American Indian College Fund, the Andrew W. Mellon Foundation, and the All Nations Louis Stokes Alliance for Minority Participation for financial support for this research. We also thank Kathleen E. Halvorsen, Gerald Jondreau, Fred Dakota, Wesley Loosemore, and the anonymous reviewers whose insight helped improve the quality of this paper.

References

Barnes, B.V., & Wagner, W.H. (2011). *Michigan Trees.* Ann Arbor, MI: University of Michigan Press.

Belin, D.L., Kittredge, D.B., Stevens, T.H., Dennis, D.C., Schweik, C.M., & Murzoch, B.J. (2005). Assessing private forest owner attitudes toward ecosystem-based management. *Journal of Forestry 103* (1), 28-35.

Best, C. (2004). Non-governmental organizations: More owners and smaller parcels pose major stewardship challenges. A response to "America's family forest owners." *Journal of Forestry 102* (7), 10-11.

Birch, T.W. (1994). Private forest land owners of the United States. *USDA Forest Service Resource Bulletin NE-134*.

Bliss, J.C. (2000). Public perceptions of clearcutting. *Journal of Forestry 98* (12), 4-9.

Bliss, J.C. (2003). Sustaining family forests in rural landscapes: Rationale, challenges, and an illustration from Oregon, USA. *Small-scale Forest Economics, Management, and Policy 2*, 1-8.

Brennan, M.A., Luloff, A.E., & Finley, J.C. (2005). Building sustainable communities in forested regions. *Society and Natural Resources 18* (9), 779-789.

Brunson, M.W., Yarrow, D.T., Roberts, S.D., Guynn, D.C., & Kuhns, M.R. (1996). Nonindustrial private forest owners and ecosystem management: Can they work together? *Journal of Forestry 94* (6), 14-21.

Butler, B.J. (2008). Family forest owners of the United States, 2006: A technical document supporting the Forest Service 2010 RPA Assessment. *U.S. Forest Service Publication* June, 1-74.

Butler, B.J., & Leatherberry, E.C. (2004). America's family forest owners. *Journal of Forestry 102* (7), 4-14.

Butler, B.J., Tyrrell, M., Feinberg, G., VanManen, S., Wiseman, L. & Wallinger, S. (2007). Understanding and reaching family forest owners: Lessons from social marketing research. *Journal of Forestry 105* (7), 348-357.

Canham, C.D. (1985). Suppression and release during canopy recruitment in *Acer Saccharum. Bulletin of the Torrey Botanical Club 112* (2), 134-145.

Cohen, J.G. (2000). Natural community abstract for mesic northern forest. Michigan Natural Features Inventory, Lansing, MI.

Cook, B. (1998, July). Who are those guys? *Michigan Society of American Foresters.* Retrieved from http://michigansaf.org/ForestInfo/Newspaper/013-9807.htm.

Creighton, J.H., Baumgartner, D.M., & Blatner, K.A. (2002). Ecosystem management and nonindustrial private forest landowners in Washington State, USA. *Small-scale Forest Economics, Management, and Policy 1*, 55-69.

Crow, T.R., Buckley, D.S., Nauertz, E.A., & Zasada, J.C. (2002). Effects of management on the composition and structure of northern hardwood forests in Upper Michigan. *Forest Science 48* (1),129-145.

Egan, A.F. (1997). From timber to forests and people: A view of nonindustrial private forest research. *Northern Journal of Applied Forestry 14* (4), 189-193.

Erikson, D.L., Ryan, R.L., & De Young, R. (2002). Woodlots in the rural landscape: landowner motivations and management attitudes in a Michigan (USA) case study. *Landscape and Urban Planning 58*, 101-112.

Finley, A.O., Kittredge, D.B., Stevens, T.H., Schweik, C.M., & Dennis, D.C. (2006). Interest in cross-boundary cooperation: Identification of distinct types of private forest owners. *Forest Science 52* (1), 10-22.

Frelich, L.E., Calcote, R.R., Davis, M.B., & Pastor, J. (1993). Patch formation and maintenance in an old-growth hemlock-hardwood forest. *Ecology 74* (2), 513-527.

Frelich, L.E., & Lorimer, C.G. (1991). Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes region. *Ecological Monographs 61* (2), 145-164.

Hanson, J.J., & Lorimer, C.G. (2007). Forest structure and light regimes following moderate wind storms: Implications for multi-cohort management. *Ecological Applications 17* (5),1325-1340.

Hibbs, D.E. (1982). Gap dynamics in a hemlock-hardwood forest. *Canadian Journal of Forest Research 12* (3), 522-527.

Janota, J.J., & Broussard, S.R. (2008). Examining private forest policy preferences. *Forest Policy and Economics 10*, 89-97.

Johnson, R.L., Alig, R.J., Moore, E., & Moulton, R.J. (1997). NIPF landowners view of regulation. *Journal of Forestry* Jan., 23-28.

Kilgore, M.A., Snyder, S., Taff, S., & Schertz, J. (2008). Family forest stewardship: Do owners need a financial incentive? *Journal of Forestry* Oct., 357-362.

Kimmins, J.P. (2004). *Forest Ecology* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Koontz, T.M. (2001). Money talks - but to whom? Financial versus nonmonetary motivations in land use decisions. *Society and Natural Resources 14* (1), 51-65.

Kraft, L.S., Crow, T.R., Buckley, D.S., Nauertz, E.A., & Zasada, J.C. (2004). Effects of harvesting and deer browsing on attributes of understory plants in northern hardwood forests, Upper Michigan, USA. *Forest Ecology and Management 199*, 219–230.

Kuhns, M.R., Brunson, M.W., & Roberts, S.D. (1998). Landowners' educational needs and how foresters can respond. *Journal of Forestry 96* (8), 38-43.

Metzger, F., & Schultz, J. (1984). Understory response to 50 years of management of a northern hardwood forest in Upper Michigan. *American Midland Naturalist 112* (2), 209-223.

Michigan Society of American Foresters (SAF). (2004). *Baraga County Forest Resource Facts.* Retrieved from http://michigansaf.org/ForestInfo/MSUElibrary/BaragaFacts.PDF.

Moser, W.K., Leatherberry, E.C., Hansen, M.H., & Butler, B.J. (2009). Farmers' objectives toward their woodlands in the upper Midwest of the United States: Implications for woodland volumes and diversity. *Agroforestry Systems 75*, 49-60.

Munsell, J.F., & Germain, R.H. (2007). Woody biomass energy: An opportunity for silviculture on nonindustrial private forestlands in New York. *Journal of Forestry* Dec., 398-402.

Pan, Y., Zhang, Y., & Butler, B.J. (2007). Trends among family forest owners in Alabama, 1994-2004. *Southern Journal of Applied Forestry 31* (3), 117-123.

Potter-Witter, K. (2005). A cross-sectional analysis of Michigan nonindustrial private forest landowners. *Northern Journal of Applied Forestry 22* (2), 132-138.

Schulte, L.A., Rickenbach, M., & Merrick, L.C. (2008). Ecological and economic benefits of cross-boundary coordination among private forest landowners. *Landscape Ecology 23*, 481-496.

Sharpe, G.W., Hendee, J.C., & Sharpe, W.F. (2003). *Introduction to Forests and Renewable Resources* (7th ed.). Boston, MA: McGraw Hill.

Webb, S.L., & Scanga, S.E. (2001). Windstorm disturbance without patch dynamics: Twelve years of change in a Minnesota forest. *Ecology 82* (3), 893-897.

Woods, K.D. (2004). Intermediate disturbance in a late-successional hemlock-northern hardwood forest. *Journal of Ecology 92*, 464-476.

Young, R.A., & Reichenbach, M.R. (1987). Factors influencing the timber harvest of nonindustrial private forest owners. *Forest Science 33*(2), 381-393.