POST-FIRE REVEGETATION OF JACK PINE SITES IN MICHIGAN: AN EXAMPLE OF SUCCESSIONAL COMPLEXITIES

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ABSTRACT

This study investigated early plant succession following clearcutting and burning and age structure of jack pine in northern lower Michigan. Thirty-nine species surveyed on burned sites were not found on unburned clearcuts or in mature stands. Within 3-6 years following clearcutting, all unburned sites became dominated (45-78% cover) by *Carex*; these sites had low species richness. Several burned sites also developed *Carex* meadows, but other sites were dominated by shrub and early successional hardwood species or had enough jack pine vegetation to insure a future overstory of that species. Thus, multiple pathways during early succession were evident following clearcutting and burning. The rapid increase in hardwood species following burning on certain sites may be considered an example of disturbance-mediated accelerated succession. About two-thirds of the stands surveyed were uneven-aged, which suggests that recruitment of jack pine can occur fairly long after partial stocking has developed. Only a small percentage of the sites surveyed had a significant amount of jack pine regeneration. Unless forest managers devise a workable silvicultural system for natural regeneration (e.g., partial cutting followed by prescribed burning) or are prepared to plant vast acreage of jack pine, many clearcut and burned areas in Michigan will convert to *Carex* meadows or early successional hardwoods.

INTRODUCTION

The distribution of jack pine (*Pinus banksiana* Lamb.) in the Lake States is closely tied to the history of frequent fire and intensive logging in the region. Jack pine, with its serotinous cones, is one of the classical fire adapted species in North America, and it has dominated frequently burned, dry, sandy outwash plains (barrens) in the Lake States for hundreds or thousands of years (Heinselman 1973, Voss and Crow 1976). Seeds of this species remain viable within the cones and may accumulate to several million or more per acre in mature stands (Fowells 1965). During early logging (1840-1900), the vast majority of white and red pine stands were cut for timber, while much of the jack pine was left standing (Ahlgren 1974). Following logging extensive slash fires occurred throughout the region, facilitating the conversion of many presettlement white and red pine stands to jack pine. It seems likely that the

present day distribution of jack pine in the Lake States exceeds that in the original forests.

Jack pine represents a very important species in the Lake States for its timber and wildlife habitat values, and much attention has been paid to devising a workable silvicultural system for its perpetuation. However, obtaining adequate natural regeneration for this species continues to be a major management problem and most forest managers rely on planting for regeneration. The focus of this study was to describe early revegetation following clearcutting and burning and age structure of jack pine stands in northern lower Michigan to gain insight on successional processes following regeneration failure and possible factors causing this failure.

STUDY AREA

The work was conducted in Roscommon, Crawford, Oscoda, and Ogemaw counties in northeast lower Michigan. These counties are generally between 275 and 365 m above sea level with little surface relief. The topography derives from the Wisconsin glaciation, with level areas consisting of outwash and till plains or ground moraines (Veatch et al. 1924). Before the near-complete logging in the middle to late 1800s, these areas were largely occupied by dense coniferous and hardwood forests interspersed with small areas of bog, marsh, and grasslands. The presettlement forests of this area comprised a good deal of the prime white and red pine stands found in Michigan (Maybee 1960). Today these counties are a patchwork of small woodlots, second- and third-growth hardwood and coniferous forests, farmlands, bracken grasslands, and swamp forests.

The Grayling sand soil series (a mixed, frigid, Typic Udipsamment) covers large areas in these counties and is characterized by its loose consistence, incoherent structure, and low water-holding capacity. Average moisture content during the growing season is very low to a depth of 1 m or more, and fertility is also low. Soil reaction varies from medium to strongly acid (pH 6.5-4.5) to a depth of 1 m or more (Veatch et al. 1924).

This area is characterized by cold winters, short, mild summers, a large number of cloudy days, low evaporation, and moderately high humidity. Average yearly temperature generally is 6°-7° C, with mean monthly temperatures ranging from -8° to 19° C. Precipitation is fairly well distributed throughout the year, with a mean annual rainfall and snowfall of 77 and 180 cm, respectively (Anonymous 1971).

Twenty-four jack pine sites were used for detailed study during the summers of 1979, 1980, and 1981; included were eight unburned clearcuts, ten summer-burned areas, two 35-year-old stands, and four mature stands (55-68 years, but showing little or no signs of being decadent). The ten burned areas included three prescribed burns in 35-year-old jack pine stands, four prescribed burns in clearcut jack pine, two wildfires in mature jack pine stands, and one

wildfire through a clearcut area of mixed jack pine and oak (*Quercus* spp.—northern red oak group). All burned and unburned 35-year-old jack pine areas were part of a larger area burned by wildfire in 1946, and from which a few commercially mature jack pine, red pine, and oak which survived the 1946 fire were harvested in 1975 and 1976.

All burns occurred during the months of July, August, and September (summer burns), except for one site which was burned in October. All areas were left unplanted following treatment. Sites used in this study were located on the Grayling sand series, and were chosen to encompass as little variation in topography and other environmental gradients as possible.

METHODS

Frequency and cover were estimated for all vascular plants. In mature and 35-year-old stands only the understory vegetation (plants $\leq$ 1.5 m) was surveyed. Frequency was determined using 1 m^2 circular plots randomized along transects. Transects were oriented to best include the entire area to be surveyed. Cover determinations were made by summing the distance intersected by each species along randomly placed 20-m transects. In general, 30 frequency plots and three cover transects (60 m) were used to characterize each site.

To estimate the year of stand establishment, ages were determined for 20 trees on each of 20 sites described above that supported, or had recently supported, mature jack pine (trees $\geq$ 50 years old). Ages of standing trees (of the largest diameters) were determined by taking increment cores at breast height and adding five years to the ring count. Where trees had been clearcut, rings were counted on the largest stumps. Ages were also recorded for all diameter classes in two stands that came in after a wildfire in 1946 (35-year-old stands).

RESULTS AND DISCUSSION

Eighty-nine different species were recorded on burned sites compared with 51 species on unburned sites. Thirty-nine species were exclusive to burned clearcut sites compared with four species exclusive to unburned clearcuts or mature jack pine stands. The establishment, following fire, of a large number of species not present on unburned sites has been well documented in a variety of ecosystems (Ahlgren and Ahlgren 1960, Christensen and Muller 1975, Purdie and Slatyer 1976). Many of these species are temporary fire followers, whose dominance wanes within a few years after fire. The best example of a temporary fire follower in this study involved *Geranium bicknellii* Britt., whose cover was as high as 24% one year after fire but was reduced to scattered individuals two to six years after fire. The importance of *G. bicknellii* only on 1-year-old burned sites seems to be related to heat stimulated

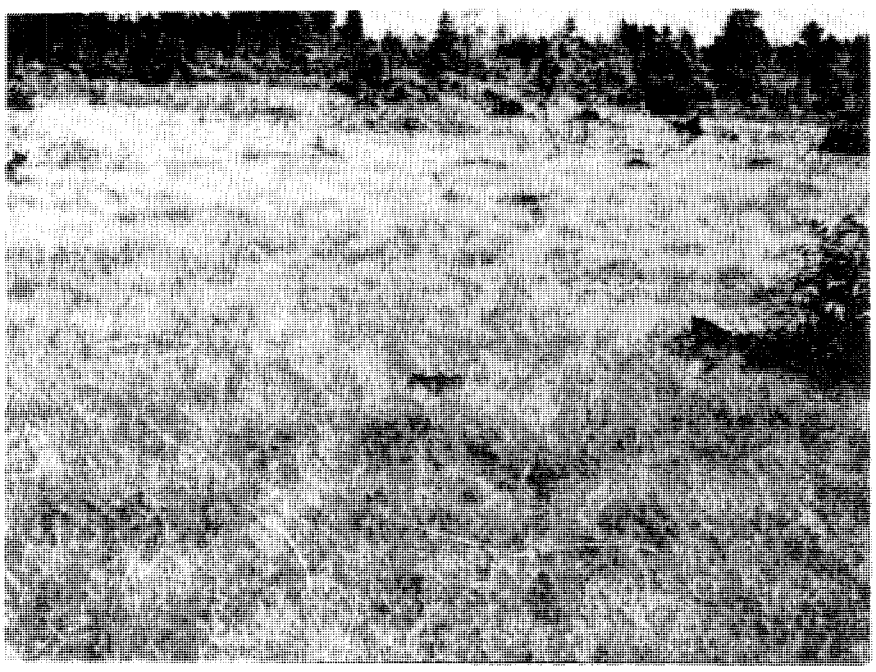

Figure 1. Sedge meadow on a 5-year-old unburned clearcut site.

germination of buried seeds (Abrams and Dickmann 1984).

A consistent pattern exhibited by unburned clearcut sites was the near-complete domination of *Carex pensylvanica* Lam., forming sedge meadows (Fig. 1). *Carex pensylvanica* represented 45-78% cover on unburned sites 3-6 years after clearcutting. This greatly contrasts with mature jack pine understories where *Vaccinium* species averaged 61% cover and *C. pensylvanica* only 10% cover. The pattern is clearly illustrated in a study of a mature jack pine understory and an adjacent site surveyed 3-5 years after clearcutting (Table 1). The decrease in *Vaccinium* cover on unburned clearcut sites was correlated with the increased *Carex* cover. It is interesting to note the relatively high frequency but low cover of *C. pensylvanica* in the mature understory. Also correlated with the increase in *Carex* on unburned clearcut sites was a decrease in species richness from years 0 to 6 after clearcutting (Fig. 2). An increase in sedges following fire in the Lake States has been previously documented (Ahlgren 1960, Vogl 1970), but the overwhelming dominance of *C. pensylvanica* observed in this study seems to be unique to jack pine sites in northern lower Michigan (Abrams and Dickmann 1982).

Early successional patterns on burned areas were much more complex than that described for unburned clearcuts, but did include the formation of sedge meadows on certain sites. Four burned sites, including two burned by wildfire, had cover values exceeding 50% for *C. pensylvanica.* In contrast, two clear-

Table 1. Relative cover and frequency of dominant species and species groups in a mature jack pine understory and an adjacent unburned site surveyed 3, 4 and 5 years after clearcutting.

Species	Mature jack pine		Unburned clearcut					
			Year 3		Year 4		Year 5	
	cover	freq.	cover	freq.	cover	freq.	cover	freq.
Graminoids								
Carex pensylvanica	3.2	20.7	65.3	30.0	70.3	29.0	76.7	30.4
Total	3.6	25.7	65.5	32.5	70.9	35.9	77.1	39.7
Forbs								
Pteridium aquilinum	0.0	0.8	3.3	10.6	0.3	6.2	0.0	5.7
Total	2.4	23.1	3.8	17.7	0.4	13.5	0.0	9.4
Woody plants								
Vaccinium spp.	90.7	24.8	22.7	28.3	23.8	28.4	18.3	29.2
Total	94.0	51.2	30.9	50.0	28.5	50.7	23.0	51.0

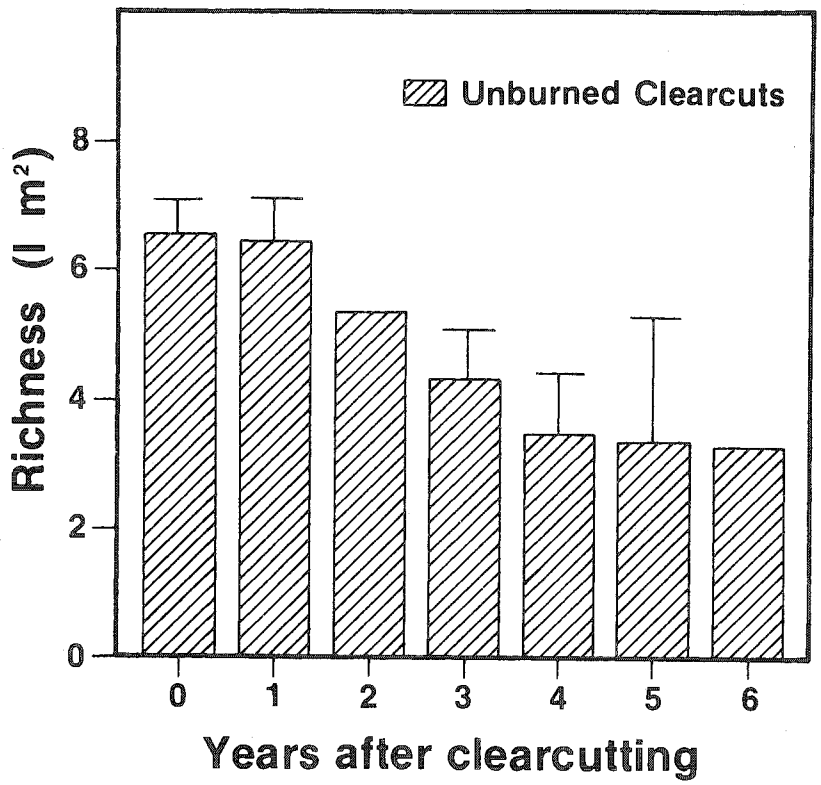

Figure 2. Changes in species richness (per 1 m² plots) with years following clearcutting on unburned jack pine sites in northern lower Michigan. Bars equal one standard deviation. Year 0 indicates that sites were surveyed during the summer following a winter or spring clearcut and did not have a full year to develop.

cut sites surveyed 4-6 years after prescribed burning had relatively high cover of tree species (e.g., *Populus tremuloides* or *Prunus serotina*) compared to mature jack pine understories or other burned sites (Table 2, Figures 3 and 4). Prescribed burn 2 (Table 2) contained scattered areas of aspen prior to logging and burning. Finally, two mature stands burned by wildfire had greater than 2000 jack pine seedlings per hectare, which should represent adequate stocking to insure a future overstory of that species.

In 65% of the stands surveyed in this study, tree ages for the largest individuals varied from 10-23 years. Moreover, the two 35-year-old stands had an emergent class with individuals 40- 45 years old (that survived the wildfire), a dominant intermediate class from 22-35 years old and many smaller individuals 4-20 years old. Thus, many jack pine stands in northern lower Michigan are uneven-aged, based on Smith's (1962) definition in which the difference in age between the youngest and oldest individuals must exceed 20% of the rotation length (Abrams 1984). The typical jack pine rotation in the region is 40-50 years. Larson (1982) also studied age structure of jack pine in Michigan and reported that tree ages varied by 25-35 years in three stands which had mean ages of 37, 52 and 75 years.

The major findings of this research are that multiple pathways exist during early successional development following clearcutting and burning (Fig. 5), and that many jack pine stands in the study area are uneven-aged. The latter point indicates that establishment and growth of jack pine into the canopy can occur fairly long after partial stocking has developed. This contrasts with the traditional idea that jack pine grows almost exclusively in even-aged stands. Following clearcutting without burning all the sites studied developed a *Carex* meadow within 3-5 years. Certain burned sites also formed *Carex* meadows, but others exhibited a fairly substantial canopy of early suc-

Table 2. Cover (%) of understory tree species (≤ 1.5 m tall or < 2.5 cm dbh) in four mature (> 55 years) jack pine stands ($\bar{x}$ ± s.e.) and in two jack pine clearcuts surveyed at years 4-6 after prescribe burning in northern lower Michigan (after Abrams and Scott 1989).

Tree Species	Mature stands	Prescribe burns	
		1	2
Crataegus sp.	0.2 ± 0.2	2.1	0.2
Pinus banksiana	0.3 ± 0.2	2.6	0.3
Populus tremuloides	—	2.6	17.7
Prunus serotina	0.6 ± 0.3	12.8	2.9
Quercus spp.	0.8 ± 0.5	1.0	2.5
Salix glaucophylloides	—	—	3.0
Total	1.9 ± 0.6	21.1	26.6

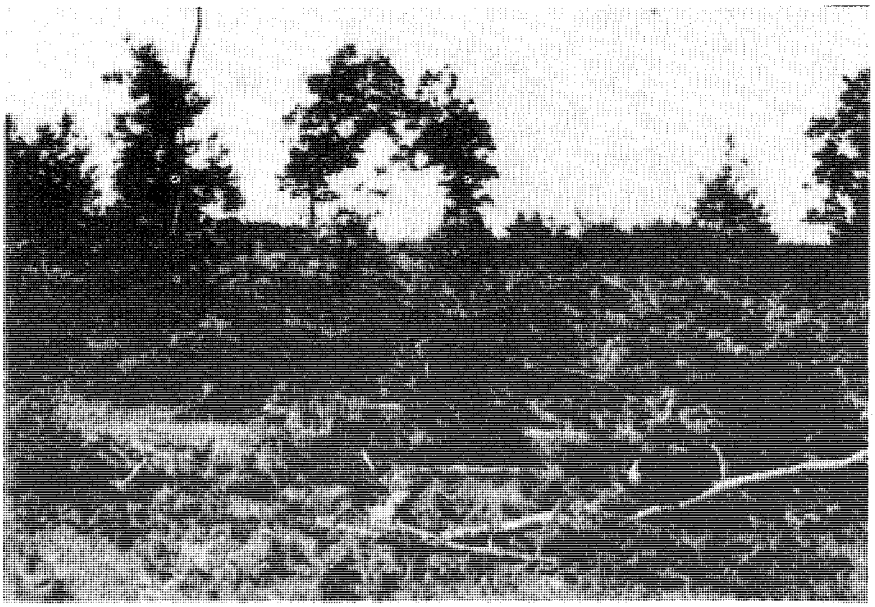

Figure 3. Stratified canopy of shrubs and early successional hardwood species on a 5-year-old prescribe burned clearcut site.

Figure 4. Understory of a mature jack pine stand dominated by blueberry and bracken fern, with little advance regeneration of tree species.

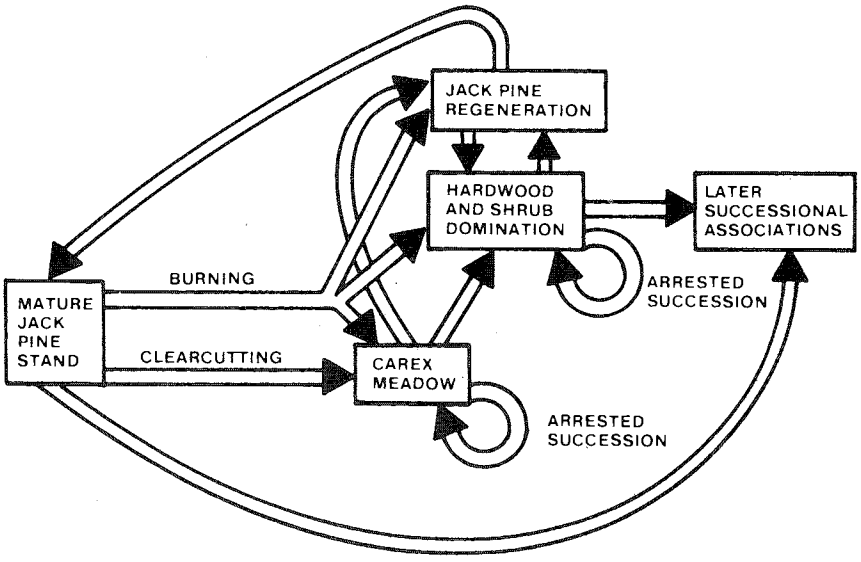

Figure 5. Possible successional pathways following disturbance to jack pine stands on sandy soils in northern lower Michigan (after Abrams et al. 1985).

cessional hardwood and shrub species, while others had enough jack pine regeneration to probably establish a future overstory of that species. It is important to note that *Carex pensylvanica* dominated sites may experience arrested, or greatly inhibited, rates of succession due to the ability of that species to monopolize nutrients, and probably other resources, relative to other community members (Abrams and Dickmann 1983, Abrams et al. 1985). On the other hand, *Carex* meadows remain highly exposed to sunlight at the herb layer, which may allow jack pine establishment over a fairly long period and result in an uneven-aged stand. Marshall (1980), working on similar sites in northern lower Michigan, found newly germinated seedlings on a 15-year-old burn. This would be facilitated by the relatively high proportion of non-serotinous jack pine trees in the Lake States region and by the fact that young jack pine can produce and disseminate seed that may reinforce their own stocking (cf. Ahlgren 1960, Schoenike 1976).

Another important aspect of the successional complexities on disturbed jack pine sites involves the invasion or reestablishment of early successional hardwood species after burning. Conversion of older clearcut and burned jack pine sites to hardwood species has been observed in some area forests (Don Grant, Michigan Department of Natural Resources, pers. comm.). This phenomenon seems to occur more often on better quality sites that are less prone to early frost, including less depauperate phases of the Grayling sand series (Jerry Nilsson, U. S. Forest Service, pers. comm.). It is unlikely that jack pine, because of its extremely low shade tolerance, will become established under the hardwood canopy developing on those sites. A more likely predic-

tion would be a progression to later successional species such as black oak, red maple, black cherry, white pine, or red pine. Later associations developing on these sites will be limited, however, by the Grayling sand series, which represents the poorest of the sandy soil types in Michigan.

It has also been observed that, despite initially poor jack pine regeneration and early dominance by hardwood species, jack pine seedling density can, over time, approach full stocking on poor Grayling sites (Jerry Nilsson, pers. comm.). This suggests that resources made available directly following clearcutting and burning can temporarily support certain hardwood species during early succession, but that further hardwood development may be limited by normal edaphic constraints, giving jack pine an opportunity to reestablish itself. This supports the idea that jack pine represents an edaphic climax on very dry sands (Fowells 1965).

I believe that the conversion of clearcut and burned jack pine sites to early successional hardwoods and then later successional species represents an example of disturbance-mediated accelerated succession (cf. Abrams and Scott 1989). A schematic diagram of this process for the jack pine example is shown in Figure 6. Following an initial disturbance (e.g., fire) jack pine seedlings become established and dominate the area. As these individuals mature they exclude the development of younger stems (advance regeneration). A temporary stem exclusion stage seems to occur in many forest-types of North America (cf. Oliver 1981). However, as seen in this study, stem exclusion in the understory may exist even in mature stands. The duration of the stem exclusion stage may be a function of resource availability in the understory and the migration rate of species to the site (cf. Oliver 1981, Abrams and Scott 1989). Following logging of mature jack pine and subsequent burning, early successional hardwood species invade and eventually dominate in the overstory. As succession proceeds, later successional tree species become established

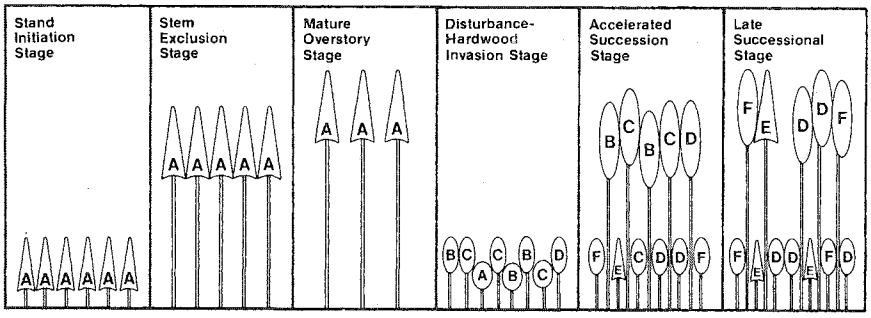

Figure 6. Schematic diagram of disturbance-mediated accelerated succession in a jack pine forest. Species A is jack pine, species B and C are early successional trees, and species D, E, and F are later successional trees.

under the early hardwoods and given adequate resources and disturbance-free conditions they may dominate the canopy.

Later successional species often dominate over-mature jack pine stands in the long-term absence of disturbance (Eyre and LeBarron 1944, Heinselman 1973). Thus, the main feature of this model is that a successional sequence, that may ultimately occur in the absence of exogenous disturbance during the demise of an over-mature jack pine stand, occurs at an accelerated rate after disturbance. This process may be even more apparent in other jack pine stands on better quality sites in which hardwood species invade the understory prior to disturbance (cf. Abrams and Scott 1989). Disturbance-mediated accelerated succession contrasts with the traditional idea that disturbance sets back succession to an earlier stage.

MANAGEMENT IMPLICATIONS

Because of jack pine's importance in the pulpwood industry and as the nesting habitat for the endangered Kirtland's warbler (*Dendroica kirtlandii*), there is much concern about the regeneration of this species. Jack pine is a light-demanding species with obvious adaptations to fire, and traditionally clearcutting and burning were prescribed in its management. This system, however, almost invariably fails to stimulate good regeneration because the cones in the logging slash ignite during fire killing the seeds inside. Prescribed burning after clearcutting is presently used for site preparation prior to planting, and little hope is given for adequate natural regeneration.

It is not surprising that the only sites in this study that had sufficient jack pine regeneration were mature stands burned by wildfire. During this "natural" situation (i.e., a rapidly moving crown fire) the cones are just scorched by fire, which melts the waxes and resins and allows the cone scales to open and release an abundance of seed. This result was apparent on a much larger scale, when following the Mack Lake fire (May 5, 1980; 25,000 acres burned) abundant regeneration became established under crown fire areas in mature jack pine (Jerry Nilsson, pers. comm.)

In addition to an adequate seed source it appears that on dry, nutrient poor sites (such as the Grayling sand) sufficient mineral soil needs to be exposed. The performance of germinating jack pine on an organic layer or in close proximity to competing vegetation on xeric sites is generally very poor (Fowells 1965, Chrosciewicz 1974). Consistent with this idea, I often observed abundant jack pine regeneration in old fire lines (even in the understory of closed stands) and around burned snags where higher fuel accumulations resulted in the exposure of mineral soil.

It would be unacceptable to most forest managers to burn mature jack pine on a large scale for regeneration purposes because the charred wood will not be used for pulp and because of the potential wildfire hazard created by this situation. However, the present value of jack pine timber may be less than the cost of artificially regenerating sites. A promising compromise may

be to conduct partial cuts in mature jack pine using seed tree, shelterwood, or strip clearcutting, followed by prescribed burning. Thus, a high percentage of the wood will be harvested, yet an adequate seed source in the canopy will be retained to hopefully reproduce the next generation. Fire managers should encourage a certain degree of crowning because a low to moderate intensity surface fire would probably not be effective in opening serotinous cones, unless tree height is quite low. Efforts in this direction were taking place in northern lower Michigan the late-1970s, but were temporarily curtailed following the escape of a prescribed-burn that resulted in the Mack Lake fire, and remain to date not adequately tested.

This study of early revegetation on clearcut and burned jack pine in Michigan indicates the potential complexity of succession. Multiple pathways to *Carex* meadows or hardwood forests represents a short-term or, possibly, long-term loss of jack pine from the site. The eradication of persistent hardwoods from these areas may represent an even greater challenge to forest managers than reproducing jack pine via artificial or natural techniques. A third successional pathway identified in this study involved the establishment of adequate jack pine regeneration following wildfire in mature stands. Widespread occurrence of this pathway can not be expected, due to wildfire suppression policy in the area. However, wildfires occur frequently in northern lower Michigan, and if not suppressed they would burn vast acreage each year (e.g., the Mack Lake fire). Much of our present day jack pine forests were a result of intensive logging and burning of the original white and red pine stands. The distribution of any species or forest-type is highly dynamic and affected by a suite of biotic and abiotic processes. Unless forest managers devise a workable silvicultural system for natural regeneration or are prepared to plant vast acreage of jack pine, many clearcut or burned areas in northern lower Michigan will convert to *Carex* meadows or early successional hardwoods.

ACKNOWLEDGEMENTS

An earlier draft of this paper was critically reviewed by E. Menges and J. Nilsson. This research was supported by USDA Forest Service under Cooperative Research Agreement 13-635. I also wish to thank the Michigan Department of Natural Resources for their support throughout the study.

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