National Park Service
Indiana Dunes National Lakeshore
Fire Monitoring Plan

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1. PURPOSE

The purpose of this Fire Effects Monitoring Plan (FEMP) is to update the Indiana Dunes National Lakeshore 1994 Prescribed Fire Monitoring Plan and to meet the requirements of RM-18, Chapter 11 (USDI NPS 2005) and the Fire Management Plan by describing the extent of the monitoring program, the type of plots and protocols being used and schedules for monitoring.

Prescribed fire will be used to maintain and restore fire-adapted ecosystems at Indiana Dunes National Lakeshore (INDU or the Lakeshore). National Park Service Reference Manual 18 states: "Fire monitoring plans are required for all units using prescribed fire or wildland fire use in order to ensure that treatments are effective and that management goals and objectives are met… The fire monitoring plan describes in detail how fire monitoring will be conducted." Monitoring of prescribed fires is also mandated in Director's Order #18: Wildland Fire Management (2005). Section 5.2 states that Fire Management Plans will; "Include procedures for short- and long-term monitoring to document that overall programmatic objectives are being met and undesired effects are not occurring." Section 5.8 directly addresses *Prescribed Fire Monitoring*:

a) Fire effects monitoring must be done to evaluate the degree to which objectives are accomplished.
b) Long-term monitoring is required to document that overall programmatic objectives are being met and undesired effects are not occurring.
c) Evaluation of fire effects data is the joint responsibility of fire management and natural resource management personnel.

2. INTRODUCTION

2.1 SITE DESCRIPTION

Indiana Dunes National Lakeshore is located in northwestern Indiana along the southern tip of Lake Michigan. Composed of active and stabile sand dunes, interspersed with wetlands, the Lakeshore contains significant natural resources within a mixed urban and rural setting. The dunes area serves as a meeting place for species of the southern boreal forest, tallgrass prairie and eastern deciduous forest. With more than 1134 native plants, the Lakeshore ranks third in floristic diversity within the National Park Service. Additionally, over a quarter of Indiana's state listed Threatened, Endangered, Rare, and Watch List plants can be found here. There are also over 250 exotic plant species in the park, the bulk of which are forbs (64 species).

2.2 FIRE HISTORY

Fire has played a significant role in shaping the vegetation communities within Indiana Dunes National Lakeshore. Wildland fires, ignited by lightning or Native Americans, frequently burned through the Lakeshore in pre-settlement times (before 1845). Early residents and historical records indicate extensive prairies, pine forests, sedge meadows, and other fire-dependent plant communities which are now very rare within the Lakeshore. Although current Lakeshore policy is to suppress all wildfires, excellent examples still remain of fire-dependent plant communities such as oak savanna, sedge meadow and tallgrass prairie. Fire suppression, continued ecosystem fragmentation, encroaching fire-sensitive hardwoods and invasion by exotic species all threaten these remnant communities.

2.3 Fire Management

Prior to 1992, the use of prescribed fire at the Lakeshore was limited to research burns, which were initiated in 1982 (on a small scale) and in1986. Research results clearly demonstrated the benefits of fire re-introduction and identified a need for a broad-based, long-term prescribed fire program. The 1992 Fire Management Plan approved the use of prescribed fire as a routine management tool. The 2005 Fire Management Plan approved of a more extensive use of prescribed fire and called for monitoring of long-term fire effects.

2.4 Fire Monitoring Program

The Lakeshore's fire effects monitoring program was initiated with the approval the 1994, Prescribed Fire Monitoring Plan and was run by the park botanist. Monitoring protocols follow the NPS Fire Monitoring Handbook (FMH), (USDI NPS 2003). Currently there are 40 permanent full-sized forest FMH monitoring plots, 28 permanent grassland FMH plots, and numerous non-FMH plots installed in 7 monitoring units at the Lakeshore.

The first official fire effects crew was hired at the Lakeshore in 1998. This staff began maintaining and updating a document describing changes to monitoring protocols (Coon et. al 2002). These reports are available in the Fire Effects office at Lakeshore headquarters. Future changes and updates to protocols will be documented each year in the Fire Effects Monitoring Annual Report and/or the FEMP. Specific information in this update regarding ecological descriptions and management goals were based in part on the Developing Landscape Strategies Workshop held in 2002 (Gorman 2002).

3. DESCRIPTION OF THE ECOLOGICAL MODEL

The Lakeshore's vegetation varies dramatically from east to west. The eastern most sections contain mesophytic forest communities dominated by American beech (*Fagus grandifolia*), black oak forest (*Quercus velutina*), and wetland and marsh complexes. As one progresses west, communities grade toward xerophytic types, such as black oak savanna and tallgrass prairie. This gradient is thought to be caused by the spatial distribution of fire, juxtaposition of Lake Michigan, and dune orientation and relief. Fires entered the area from the west and south-west due to the prevailing winds. The lake and dune orientation (N/S) and steep relief present physical barriers effectively eliminated fires from eastern portions of the Lakeshore (Henderson 1987, Poulson 1999).

Park resource management staff selected five plant communities for short- and long-term monitoring during the Developing Landscape Strategies Workshop held at the Lakeshore in November, 2002. These five vegetation communities are tallgrass prairie, mesic sand prairie, black oak savanna-woodland-forest complex, mesic dune forest, and graminoid-dominated (peat-based) wetlands communities (see Appendix A for vegetation maps). The black oak savanna-woodland-forest complex is composed of three distinct communities, black oak savanna, black oak woodland, and black oak forest. These differ significantly in their disturbance regime and species composition and are therefore treated as separate communities for monitoring purposes, creating a total of seven. Of these types, oak savanna and woodland are transitional between prairies and forests. They grade into one another and represent different stages of succession from prairie to forest. Excepting the forests, all types were chosen since prescribed fire is being used to maintain and/or restore these native fire-dependent communities. The forests are being monitored for their protection because some are considered fire sensitive communities and prescribed fire is being used within the complex in which they occur. There are several community types that are not being monitored by the fire effect staff including jack pine, cottonwood, marram grass, deep water wetlands and some highly degraded communities.

Information pertaining to each type's natural and current condition is presented below as well as an ecological model. Following in Section 4, the goals and objectives for each community are discussed.

3.1 RESTORED TALLGRASS PRAIRIE

In its natural state tallgrass (siltloam) prairie is highly diverse and dominated by big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium* formerly *Andropogon scoparium*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and a wide variety of herbaceous plants (Risser 1990). It is nearly absent of woody vegetation.

Mnoké prairie (previously called Indian Boundary Prairie) is currently the only siltloam tallgrass prairie being restored at the Lakeshore. It is 197 ac (80 ha) in size, including 118 ac (48 ha) of abandoned agricultural land, and 78 ac (31.5 ha) of wooded ravine bordering the Little Calumet River. Soils are glacial moraine of the clay-loam series (INDU, no date). Currently, it is dominated by numerous exotic and/or invasive species in particular, bluegrass (*Poa* spp.), brome

(*Bromus* spp.), clover (*Trifolium* spp.), fescue (*Festuca* spp.), timothy (*Phleum pratense*), wild carrot (*Daucus carota*), goldenrod (*Solidago* spp.*)*, black locust (*Robinia pseudoacacia*) and autumn olive (*Elaeagnus umbellata*)), but patches of big bluestem, little bluestem, and prairie dropseed (*Sporobolis heterolepis*) persist.

3.1.1 Ecosystem Processes and Management

Tallgrass prairies depend on fire every 3-4 years (Knapp et al. 1998) to prevent invasion by woody species and to favor native herbaceous vegetation (Anderson 1990, Bragg and Hulbert 1976, Murphy and Grant 2005) (Fig. 1). However, prairie restoration treatments often require more frequent fire, every one to two years, in combination with mechanical, chemical and cultural treatments (Bragg 2001). After restoration the more natural 3-4 year fire return interval is sufficient to maintain it. Less frequent fire, every five to ten years, may allow encroachment of woody species, and once established even high frequency burning will not extirpate them (Briggs et al. 2005). With this in mind, periodic drought may be the only way to revert this successional progression (Faber-Langendoen and Tester 1993). Long–term regional climate and associated weather extremes regulate ecosystem changes and distribution (Transeau 1935, Brown and Wu 2005, Overpeck et al. 1990), and likely to what extent prairies and other fire dependant ecosystems can be restored. The climate, by regulating drought occurrence, alters fire frequencies and thus influences community structure.

Fire, grazing and small scale disturbances greatly influence species diversity and abundance (Fig. 2), (Hartnett and Fay 1998). The high diversity in tallgrass prairies is attributed to a large group of forb species, while overall dominance resides within a small group of core species, mainly C_4 grasses. Prolonged high frequency (annual) fires decreases forb richness and overall diversity by increasing competition and dominance of native C_4 grasses (Collins and Gibson 1990, Bowles et al. 2003), while grazing tends to have the opposite effect (Knapp et al. 1998, Collins and Wallace 1990). The greatest diversity is found 6-7 years post fire as grass dominance fades and forbs become more abundant (Gibson and Hulbert 1987). Large grazers, preferring grasses over forbs, reduce competition to forb species thus promoting their abundance and propagation. Small scale disturbances, such as badger dens and gopher mounds, create micro-sites for plant colonization. Plants that colonize these sites come from assemblages that are different from those in the surrounding undisturbed area (Hartnett and Fay 1998).

Fire seasonality is widely recognized as having a significant impact on the species composition of a prairie (Fig. 2). Howe (1994 and 1995) points out that depending on its flowering guild a plant will be favored or disfavored by the season of fire. C_4 grasses and warm season plants, flowering in late summer, are favored by spring burns, while C_3 and cool season plants that flower in early summer are favored by mid-summer burns (Hover and Bragg 1981, Engel and Bidwell 2001, Ewing and Engle 1988). Spring or dormant season burns create warmer, shade free and nutrient rich soil conditions prior to C_4 spring emergence, giving them an earlier start than normal, conversely, C_3 plants that have already sprouted are set back. This early start leads to an increase in C_4 biomass (Kucera and Ehrenreich 1962) thus increased competition for C_3 plants (Knapp et al. 1998). Mid-summer burns hit C_4 plants while their reproductive parts are still developing and meristems are exposed, thus causing die-back (Copeland et al. 2002). C_3 plants which have already finished reproduction are thus favored. Mid-summer burning regimes that suppress C_4 grasses often increase plant diversity (Howe 1994, Copeland et al. 2002). Most researchers agree that mid to late-summer prairie fires were the norm since lightning is most frequent at that time and fuel conditions are favorable (Howe 1994, Higgins 1984 & 1986, Bragg 1982, Knapp et al. 1998). West (1996) supports the above findings but warns against frequent late summer burns in restored or severely degraded prairies. This may encourage non-native C_3 grasses while suppressing native C_4 grasses that may not be overabundant.

There is growing literature concerning fire and insect populations. Despite known impacts of fire on vegetation, care must be taken to burn in accordance to protecting insect populations, especially prairie specialists. This should be taken into consideration when determining fire frequencies (N. Pavlovic pers. comm.).

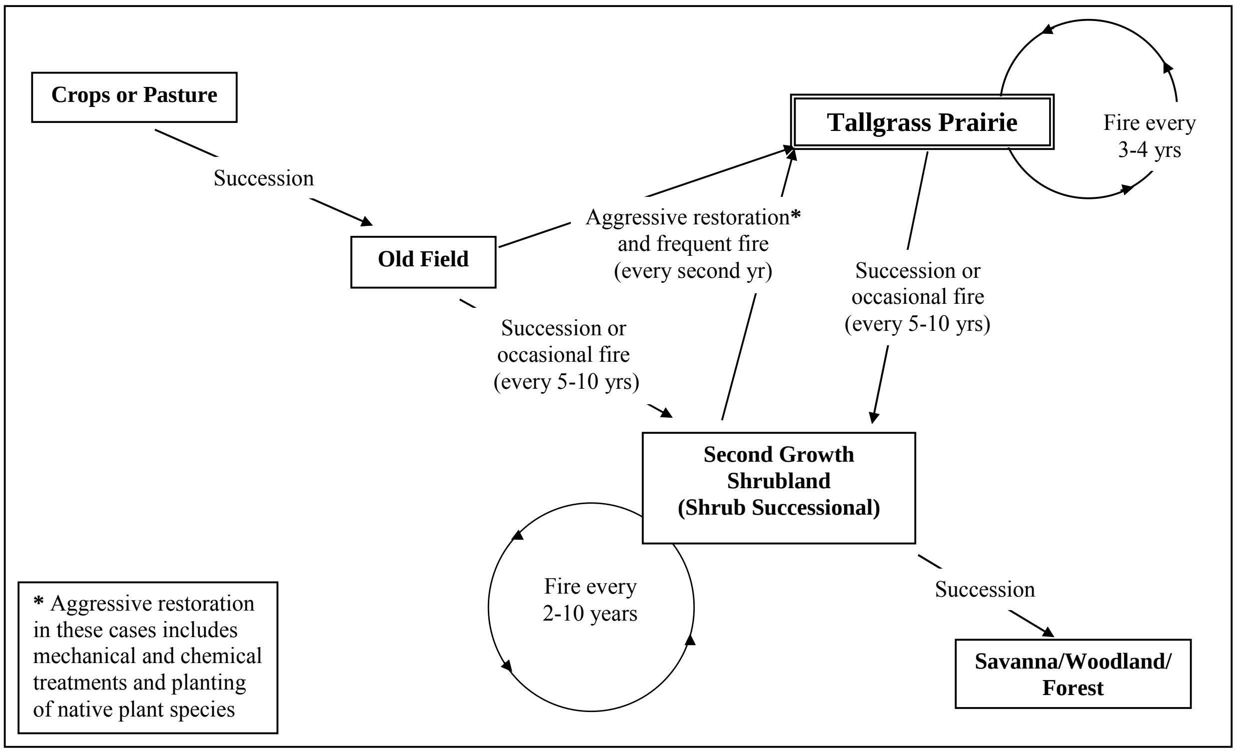

Figure 1. Ecological model for tallgrass prairie.

3.1.2 Successional Pathways (Fig.1)

After abandonment of agricultural fields and pastures, an area will succeed to an old field condition composed of a limited variety of grasses and forbs. Old fields are typically dominated by smooth brome (*Bromus inermus*) and Kentucky bluegrass (*Poa pratensis*). Continued succession, even in the presence of periodic fire, will result in a shrubland. A tallgrass prairie community can be re-established from the two aforementioned conditions with aggressive restoration efforts, though it becomes increasingly more difficult with succession. The shrubland condition may remain even in the presence of a frequent fire regime (Briggs et al. 2005). Eventually, a woodland or forest condition will result depending on the recurrent fire regime.

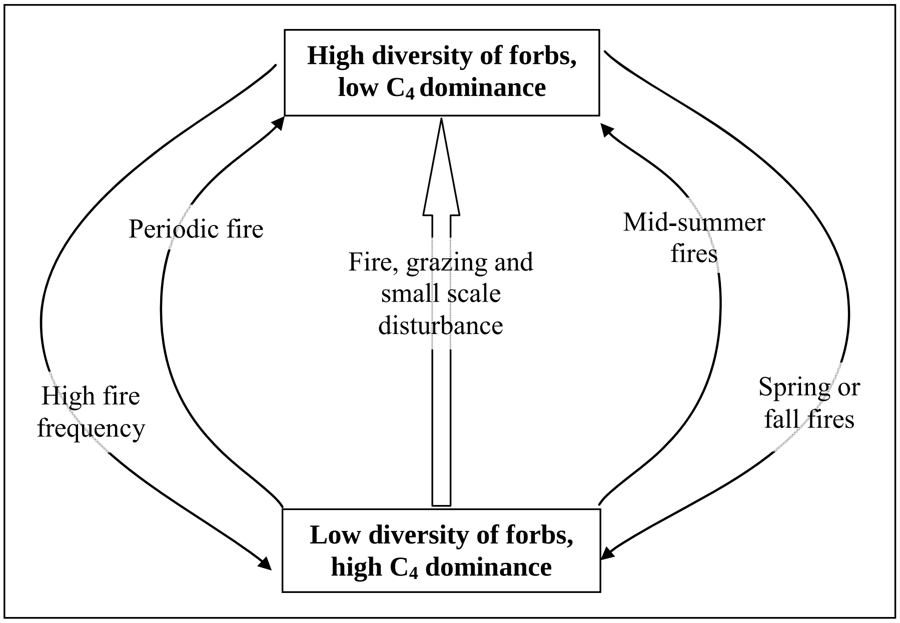

Figure 2. Effects of disturbance on tallgrass prairie diversity

3.2 MESIC SAND PRAIRIE

Mesic sand prairie is a diverse community, which occurs in open, moist swales or just above pond edges in the savanna-woodland-forest complex (INDU, no date). Soils are sands, usually dune sands. The majority of this type is found at Howes Prairie and Inland Marsh, with lesser areas in Miller Woods, Tolleston Dunes and The Dunes State Park. Howes Prairie contains the most intact remnant of this community. Frequently occurring species include little blue-stem, big-blue stem, Indian grass, blazing-star (*Liatris* spp.), rattlesnake-master (*Eryngium yuccifolium*), western sunflower (*Helianthus occidentalis*) and tall coreopsis (*Coreopsis tripteris*). It is also home the following less common species: colic root (*Aletris farinosa*), marsh bluehearts (*Buchnera americana*), clubmoss (*Lycopodium inundatum & L. tristachyum*), false indigo (*Baptisia* spp.), spike-rush (*Eleocharis* spp.), spotted wintergreen (*Chimaphila maculata*), trailing arbutus (*Epigaea repens*) and state-listed Hall's bulrush (*Scirpus hallii*) (Cole and Pavlovic 1988).

3.2.1 Ecosystem Processes and Management

Mesic sand prairies respond to fire in much the same way tallgrass prairies do, as described in the previous section. While fire controls the invasion of woody and exotic species, flood levels, in the context of dunescape physiognomy, control the spatial extent of the mesic prairie (Fig. 3). Mesic prairies are found at slightly higher elevations than the wet prairie system and remain dry except during high flood levels (Cole and Pavlovic 1988). Mesic sand prairies are often found at the east end of wetland complexes at the base of the dune, where sand flats occur. This type is fairly isolated at the Lakeshore and historically fires were less frequent than in the tallgrass prairie. Fire likely occurred at frequencies similar to those found in the surrounding savannas and as such, the two communities should be managed collectively. Taylor (1990) reports fire intervals at Howes Prairie and Inland Marsh of 2 to 24 years with an average of 5 years.

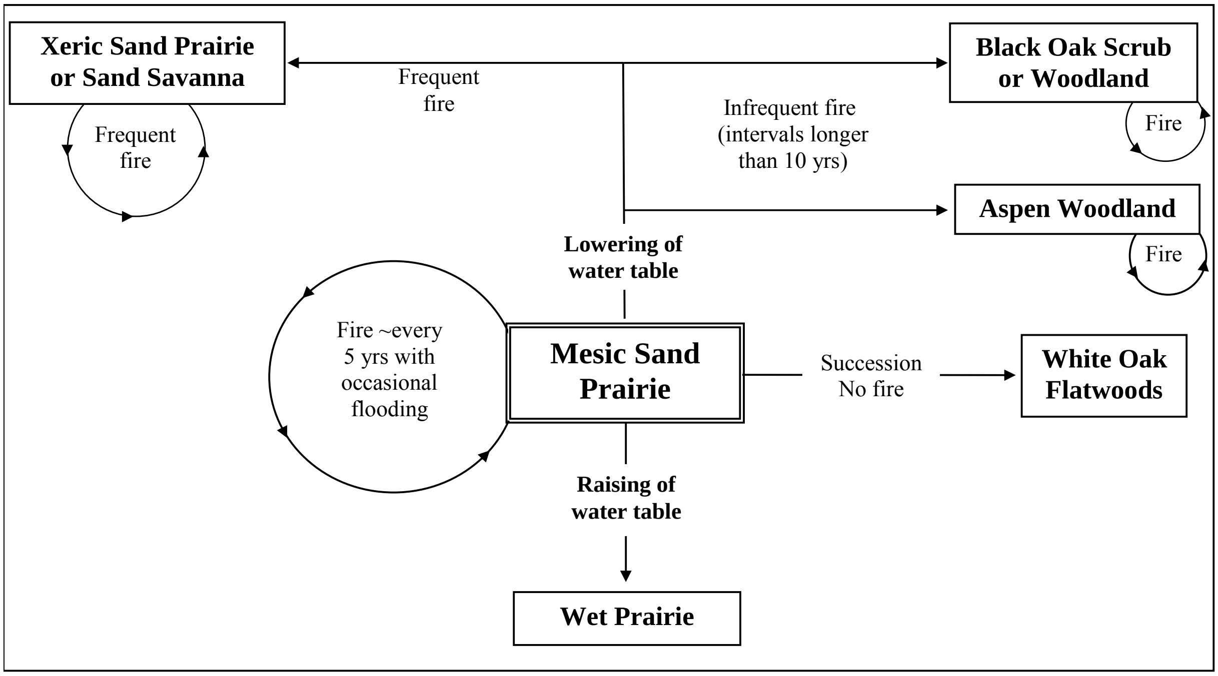

Figure 3. Ecological model for mesic sand prairie.

3.2.2 Successional Pathways (Fig. 3)

Mesic sand prairie is maintained with periodic fire and occasional flooding. Changes in the fire regime and/or hydrologic regime will cause mesic sand prairies to follow various successional pathways. Without fire the area will succeed to white oak flatwoods. Changes in the water table without a change in the fire regime throughout the prairie-savanna-woodland-forest complex will lead to wet or dry prairie. A long term lowering of the water table associated with less frequent fire will convert the system to aspen or oak scrub/woodland. The resultant community will depend on how much the water table lowers and whether aspen are present. This interaction between flooding and fire frequency creates a very complex and diverse ecosystem. Other disturbances can also change the successional pathway of this community. Heavy foot traffic will promote invasion by exotic species and lower species richness and wind events or dune movement will result in a blowout community.

3.3 BLACK OAK SAVANNA

The once widespread oak savannas of the Midwest are now considered imperiled ecosystems (McPherson 1997). The variation in light found in savannas supports a highly diverse understory community of shade tolerant and intolerant grasses and forbs. Though specifics on canopy cover vary, savanna is generally defined as having a single discontinuous and patchy tree or shrub canopy layer of between 15 and 50% closure and a continuous herbaceous layer dominated by grasses (McPherson 1997, Taft 1997, Will-Wolf and Stearns 1999). The precise amount of woody vegetation is not as important an indicator of savannas as is the existence of the two distinct vegetation layers. Treed communities with an understory dominated by low growing shrubs are not considered savannas (McPherson 1997). Savannas can, however, include patches of oak scrub instead of the herbaceous layer.

Currently, degraded black oak savannas at the Lakeshore have an overstory of black oak with white oak (*Q. alba*), sassafras (*Sassafras albidum*) and cottonwood (*Populus deltoides*) also present. The understory is dominated by several common species, Pennsylvania sedge (*Carex pensylvanica*), bracken fern (*Pteridium aquilinum*), woodland sunflower (*Heianthus divaricatus*), blueberry (*Vaccinium* spp.) and blackberry (*Rubus* spp.). Over 100 fire dependent and fire sensitive species are present. Grass cover is not dominant, averaging less than 10% cover (INDU monitoring data), but includes important species such as little bluestem, bluejoint (*Calamagrotis canadensis*), Indian grass and June grass (*Koeleria macrantha* previously *K. cristata*).

3.3.1 Karner Blue Butterfly

Oak savanna is regionally rare and declining and is habitat for the federally endangered Karner blue butterfly (KBB) (*Lycaeides melissa samuelis*). It prefers sandy barrens and oak savannas as these areas contain its larval host plant, wild lupine (*Lupinus perennis*) (Coffin and Pfannmuller 1988). Adults are known to feed on at least 70 different nectar producing species across its range (Haak 1993). This list includes plants that flower in the shade and those that flower in the sun, hence its preference toward habitats that contain a mixture of sun and shade (Knutson et al. 1999). Frequent and patchy fires seem to be most effective in providing habitat for KBB (Anderson et al. 1999). Haney (2006) found that 20 years of low intensity fires failed to produce any lupine while one intense fire resulted in lupine reproduction. At the Necedah NWR in central Wisconsin, King (2006) found the best lupine reproduction using soil scarification. King (2006) also found no reduction in KBB populations immediately after burning during the flight of the second brood. Incomplete burns were likely a large factor in this effect. Clearly adaptive management is needed to discover how KBB and its habitat are best maintained.

3.3.2 Ecosystem Processes and Management

Fire history studies show fire as an historical disturbance agent in savannas (Taylor 1990, Henderson and Long 1984) and is essential to a savannas' continued persistence (McPherson 1997). Frequent fire prevents invasion of woody species, and maintains an open canopy with a grassy/herbaceous understory. Taylor's 1990 dendro-chronological study estimated the average fire interval for Howes Prairie and Inland Marsh at 5 years with a minimum of 1-2 years and a maximum of up to 24 years. Sites with deep fertile soils will require a higher fire frequency to maintain savannas than infertile sites (McPherson 1997).

When considered in a 100 year time frame, continued short interval fire (<3 years) will convert the system to oak grub or brush prairie (Fig. 4). Frequencies which continually allow ingrowth (>10 years) will convert the system to woodland and possibly forest. Such a transformation can be permanent due to changes in fuel type, shading and subsequently the fire regime (McPherson 1997). Cottam (1949) and Briggs et al. (2005) both found persistence of woody species even with high fire frequencies. Long-term and winter droughts, which stress and/or kill trees by preventing deep recharge of soil moisture, are important in maintaining or restoring prairie and savanna conditions (Britton and Messenger 1969, Anderson et al. 1999). These droughts may be key opportunities where fire can kill significant amounts of persistent woody vegetation (Anderson 1990).

Fire frequency is only part of the equation. Fire intensity and behavior, soil type, nutrient cycling, topography, climate and their interactions are all important factors that must be considered when managing this system (Anderson 1990, Peterson and Reich 2001). Reich et al. (2001) provides an in depth evaluation of the interactions between fire and vegetation type, and resulting positive feedback loops, which can perpetuate a conversion from grass-dominated systems to tree-dominated systems. Intrinsic differences in fine root turnover rates, leaf and litter chemistry and nitrogen (N) mineralization rates between grasslands and forests facilitate further differences over time causing the systems to diverge. Frequent fires limit woody species invasion and volatilize N leading to N deficiencies, which are perpetuated by the graminoid communities favored by fire. In contrast, fire intervals that allow invasion of woody species will lead to increases in N mineralization and eventually canopy cover, shading out of grasses and promotion of more woody species. Even with similar fire frequencies N mineralization rates in woodlands are substantially higher than those of grasslands.

The overstory cover regulates light, moisture and nutrient regimes, which in turn have controlling effects on the understory. McPherson (1997) states the relationship between the understory and overstory cover is logarithmic. With little canopy cover, small increases will result in large decreases in grass and forb cover. As the canopy approaches closure, increases in tree cover will have little effect on the already diminished herb layer.

Recent long term studies at the Cedar Creek Natural History Area (CCNHA) offer some insight on savanna management. Restoration of bur oak/pin oak savannas at CCNHA indicate that fire intervals of <3 years successfully eliminated most fire sensitive species and oak trees ≤4" (10 cm) dbh (Faber-Langendoen and Davis 1995). Therefore, prescribed fire will have a limited effect on reducing the density of overstory trees and associated canopy cover. Peterson and Reich (2001) found little difference among fire frequencies of 1-3 years, while frequencies less than 20% (2 in 10 years) resulted in thickets. Conclusions of these studies suggest that perpetual high frequency fire will stop ingrowth but will not restore the natural structure. Periodic high intensity fires or mechanical treatments are needed to reduce the cover of large trees and achieve savanna conditions. Additionally, long term, constant, frequent fire will result in unsustainable tree populations in which case the community may revert to oak scrub and, given enough time, a prairie. The minimum fire frequency necessary to halt degradation by in-growth can be based on the length of time it takes for trees to become resistant to top-kill. Unfortunately, Lakeshore monitoring data shows that under normal burning conditions trees as small as 2" (5 cm) in diameter are rarely killed by prescribed fire (Weyenberg 2006). However, much larger trees are killed on occasion e.g. Inland Marsh, 2001 and Dune Ridge, 2006 prescribed fires.

It is recommended that management of fire frequency and intensity should be scheduled on decadal scales (Peterson and Reich 2001) to provide more flexibility in treatments and allow managers to address concurrent resource objectives. Irregular fire frequencies that burn only parts of an area have been the most effective management for multiple resource concerns (Anderson et al. 1999).

3.4 Black Oak Woodland

Oak woodland is defined as having an overstory canopy closure between 40 to 80%, a mid-story shrub layer and an herbaceous layer (Taft 1997). These systems are a later successional stage of oak savannas resulting from extended periods without fire (Fig. 4), (Fralish et al. 1999). The herbaceous layer is patchy and includes some prairie grasses, forbs and woody plants (Taft 1997). Pavlovic et al (2006) demonstrated that the C4 grass component of the understory varies with size of canopy gaps in black oak woodlands, while forb diversity remains constant and forbs shift in composition with gap area and canopy cover. However, little bluestem persists further into the understory. This pattern conforms with Leach and Givnish's (1999) continuum from savanna grasslands to savanna/woodland forblands with both types having high diversity of forbs.

Woodlands at the Lakeshore have an overstory of black and white oak with a sassafras and witchhazel (*Hamamelis virginiana*) mid-story. Fire-sensitive woodland species are present and include bearberry (*Arctostaphylos uva-ursi*), lettuce (*Lactuca hirsuta*), Pennsylvania sedge (*Carex pensylvanica*), shinleaf (*Pyrola elliptica*), Solomon's seal (*Polygonatum* spp.), trailing arbutus (*Epigaea repens*), and wintergreen (*Gaultheria procumbens*). They occur on older dunes that have been stable for a significant period of time (INDU, no date). Species composition differs on a gradient from drier dune uplands to mesic low swales; however blueberries (*Vaccinium* spp.), Pennsylvania sedge, and sumac (*Rhus* spp.) are common throughout.

3.4.1 Ecosystem Processes and Management

Henderson and Long (1984) examined the effects of differing fire frequencies on stand structure of black oak woodlands at INDU. They found fire can be as frequent as 5 years. Though this interval is characteristic of a savanna, the systems relatively dense overstory and shrubby understory characterize it as woodland, but without many fire-sensitive species. Longer intervals of 10-20 years will also maintain woodland but the resulting stand structure may be much different due to the increased severity of the fires. This fire regime can create an open canopy of slow growing, short stature oaks with a dense shrub mid-story (Fralish et al. 1999) (Fig. 4). However, similar fire regimes may produce different stand structures, depending on site soil properties and associated moisture availability. With long term absence of fire, woodland succeeds to black oak forest and eventually to mesic dune forest. Drought and/or severe fire can result in black oak savanna or oak scrub. Additionally, researchers have concluded that oak wilt (*Ceratocystis fagacearum*) may play an important role in maintaining openings and preserving prairie species within this community (Haney 2006).

3.5 Black Oak Forest

Forest is defined as having a canopy closure of greater than 80% (McPherson 1997, Taft 1997), and more than two layers of understory. The average litter depth is greater than what is found in woodlands, which, with the dense canopy, leads to a limited herb/grass layer. Black oak forest serves as a refuge for some fire-sensitive species within the prairie-savanna-woodland-forest mosaic and thus increases overall diversity of the complex. As the forest tends toward xeric, numbers of summer and fall flowering plants increase while spring ephemerals decrease (Curtis 1959). Curtis (1959) described Wisconsin dry forests as having a dense shrub layer dominated by blackberries (*Rubus* spp.), gooseberries (*Ribes* spp.), grey dogwood (*Cornus racemosa*), hazelnut (*Corylus americana*) and prickly ash (*Zanthoxylum* sp.).

Black oak forests at the Lakeshore have a canopy dominated by black oak with white oak and sassafras also common. In highly disturbed areas black locust, tree of heaven (*Ailanthus altissima*) and Siberian elm (*Ulmus pumila*) may also appear in the canopy. The mid-story shrub layer can be dense and is dominated by witchhazel, sassafras, chokecherry (*Prunus virginiana*) and downy arrowwood (*Viburnum refinesquianum*). The understory is generally sparse and of low diversity. It includes Pennsylvania sedge, wild sarsaparilla, woodland sunflower, fire sensitive species such as clubmoss and witch-hazel, as well as some exotic herbs and grasses. The forest is generally found on dry sandy soils of older stable dunes (INDU, no date). It may develop from black oak woodland as a result of fire exclusion or it may occur in mesic soil pockets of the prairie-savanna-woodland mosaic (Fig. 4).

3.5.1 Ecosystem Processes and Management

Oak forest is promoted by some intermediate fire interval, depending on the site and region. In the eastern United States the interval is thought to be within the range of 50-100 years (Abrams 1992), however, given the proximity of oak forests at the Lakeshore to high fire frequency ecosystems, an interval as high as 10-20 years may have been likely. With fire intervals approaching 100 years, oak forest will be replaced by fire sensitive forest species and succeed to mesic hardwood forest. A significant conversion of the herb layer can take place even without conversion of the overstory. Curtis (1959) states that a solid layer of shrubs, in particular witchhazel, occasionally cause a conversion of dry forest understory species to a suite more common to mesic forests. On the most xeric sites succession is subtended and oak forest will persist indefinitely due to harsh conditions (Abrams 1992). Severe fire or drought may convert the system to an earlier successional stage (Fig. 4). Disturbances such as windthrow and oak wilt not coupled with fire will create pockets or stands of mesic forest as the tolerant understory is released (Curtis 1959). If fire is associated with these events the stand will revert to an earlier successional stage (Fig. 4).

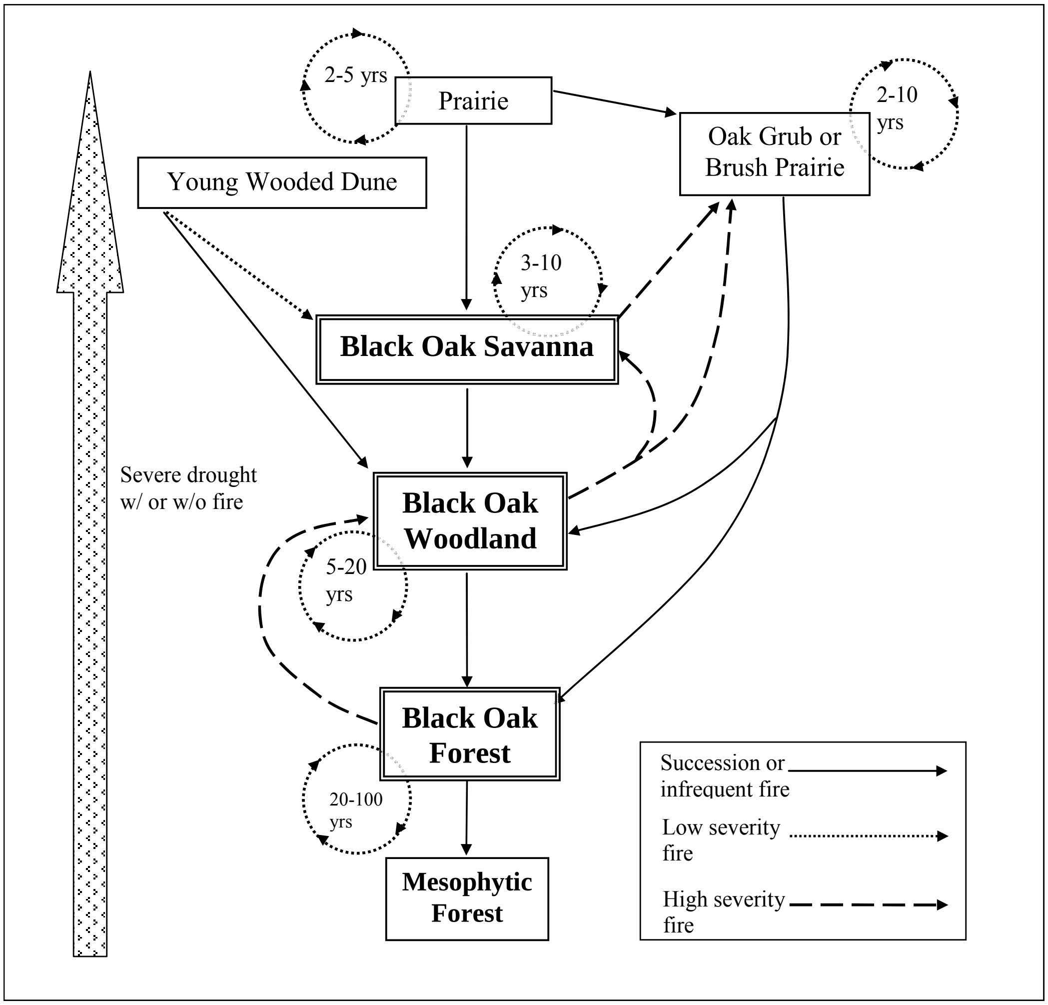

Figure 4. Ecological model for black oak savanna, woodland and forest. In this figure and those that follow, fire severity, low and high, generally refers to plant mortality caused by fire. High severity implies high mortality and other associated fire effects on soils, fuels, etc. Fire severity is not meant to imply a fire type, e.g. surface or crown fire, since surface fires can be low, medium or high severity.

3.6 SUCCESSIONAL PATHWAYS FOR BLACK OAK SAVANNA, WOODLAND AND FOREST (Fig. 4)

The prairie/savanna/woodland/forest complex is a result of the interaction of fire with numerous environmental factors. In general, systems will succeed without fire or with infrequent fire from a prairie toward a mesophytic forest. Depending on the frequency of fire, succession may be halted at any point along the way. Within each community type there is variability in stand structure which allows gradation from one type to another. Low severity surface fires within the range given will maintain a system once it is established. There is overlap in fire frequencies among systems since low severity fires will not destabilizes these systems. Severe fires or drought will destabilize systems and set them back to an earlier or alternate successional stage depending on the severity and type of the disturbance. Severe fires in woodlands and savannas tend to create oak grub or brush prairie shrublands since the roots of the former trees re-sprout vigorously. This stage may also be produced from prairie given the right soils and a long enough lapse between fires. Shrublands left unburned will succeed to oak thickets and woodland or forest. Savannas and woodlands may originate from young wooded dunes. More frequent fires will produce savannas while less frequent fires lead to woodlands. Black oak forest will increasingly grade toward mesophytic forest as the time since fire increases. Windthrow and oak wilt will speed up this process by releasing pockets of mesophytic species. Mesophytic forests rarely experience fire; return intervals are in the range of once every several hundred years for low severity surface fire. High severity fires are as rare as once every 2000-3000 years (Frelich 2002).

3.7 Mesic Dune Forest

Mesic dune forest is a transitional community between secondary, unforested dunes and near-shore white and jack pine stands. It occurs on north-northeast facing slopes and in deep moist depressions. On steep dunes the transition between the savanna complex and mesic dune forest can be abrupt across the crest of the dune proceeding from the southwest slope to the northeast lakeside exposure. The canopy is characterized by a mix of fire-tolerant and intolerant species where no one species dominates. Black and white oak, sassafras and white pine (*Pinus strobus*) comprise the fire tolerant species. Fire-sensitive mesophytic species include basswood (*Tilia americana*), red oak (*Quercus rubra*), black cherry (*Prunus serotina*), flowering dogwood (*Cornus florida*) and tuliptree (*Liriodendron tulipifera*). Common understory species are bellwort (*Uvularia* spp.), big white trillium (*Trillium grandiflorum*), hepatica (*Hepatica* sp.), witch-hazel and ricegrasses (*Oryzopsis asperifolia, O. racemosa*). The litter layer is deep, greater than two inches except where winter winds have scoured it away. Variants of mesic dune forest occur below the lee slope of the dunes on the north side of Great Marsh; others occur north of the Calumet Dune ridge and in disturbed lands between the Glenwood and Calumet dune ridges. Typical species include the addition of red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), slippery elm (*Ulmus rubra*) and swamp white oak (*Quercus bicolor*) without the presence of red oak and basswood (N. Pavlovic, pers. comm.). Garlic mustard (*Alliara petiolata*), an invasive exotic herb, may also be common.

Mesic dune forests are protected from fire during normal fire years due to the surrounding topography and their position on the landscape. However, low-severity fires may occur as often as every 20-40 years, and though tolerant of this frequency, fire is not necessary for it stability. As fire becomes more severe or more frequent, it will revert to black oak forest, woodland, or savanna (Fig. 5).

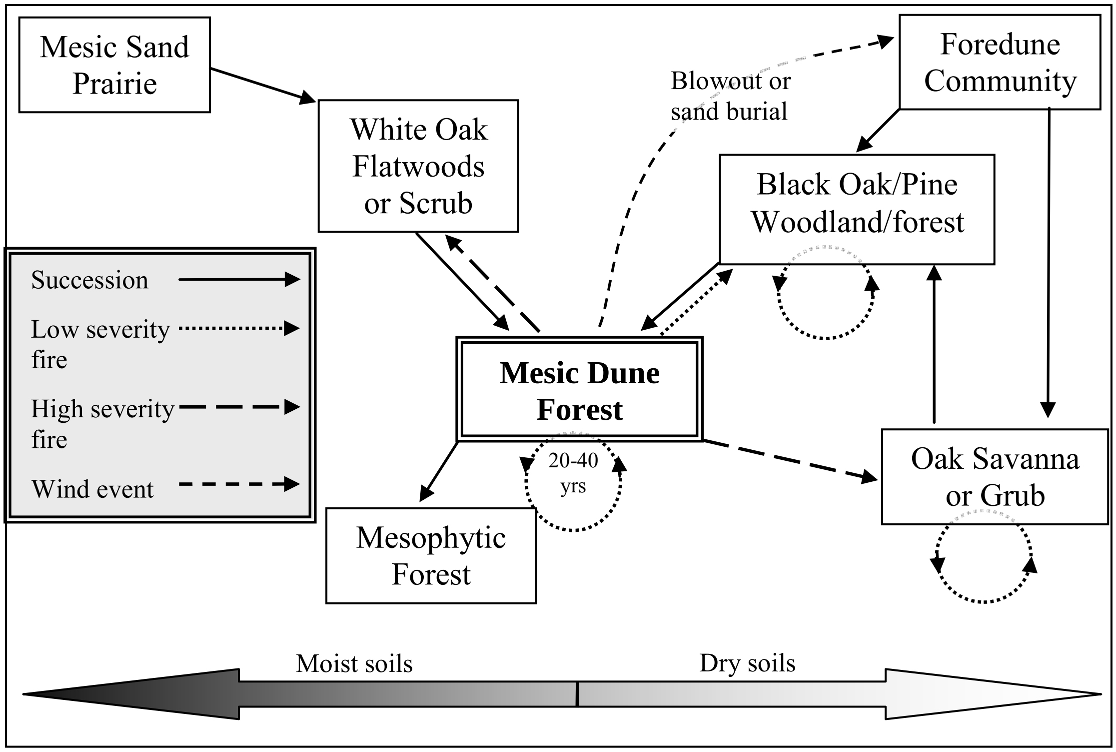

Figure 5. Ecological model for mesic dune forest.

3.7.1 Successional Pathways (Fig. 5)

Depending on the soil type, mesic dune forest may develop through succession from several different systems. On moist soils, found in swales, mesic prairie and white oak flatwood types will succeed without fire to mesic dune forest and eventually to mesophytic forest. On dry soils, starting with a foredune community, succession will lead to a black oak and pine woodland or forest, or depending on the chain of events, a black oak savanna or grub type. These community types can be maintained with periodic fire (see appropriate sections above). Little or no fire will lead to development of a mesophytic dune forest. Once established low severity fires every 20-40 years will prevent succession to mesic forest but will not destabilize the system. High severity fire, usually following a stand destroying wind event, will likely lead to oak savanna, white oak flatwoods or scrub community depending on soils and species present. Dune blowout wind or sand burial events will convert the stand to a foredune community.

3.8 GRAMINOID-DOMINATED (PEAT-BASED) WETLAND

Graminoid peat-based wetland is a generic term which identifies the various wetland types contained within the Great Marsh. The Great Marsh, now about 10 miles long by 0.5 miles wide, was once a floristically rich wetland, dominated by graminoid species. Wetland community types once abundant in the Great Marsh include bog, vegetated floating mat, graminoid fen, calcareous seeps, shallow-marsh, sedge meadow, wet-prairie and hydromesophytic swamp forest. These communities are increasingly rare due to anthropogenic disturbance including changes in the hydrology of these systems. A century of anthropogenic stressors including ditching, peat fires, fire suppression, landscape alterations, biological pollutants, lumbering, hydrological alterations and haying of the graminoid resource, have left these communities highly degraded or entirely eliminated them. These stressors produced a species poor upland/wetland complex dominated by wind dispersed tree species such as green ash, eastern cottonwood and silver maple (*Acer saccharinum*), exotic shrubs such as honeysuckle (*Lonicera* spp.) and multiflora rose (*Rosa multiflora*), and invasive herbaceous species such as reed canary grass (*Phalaris arundinaceae*), common reed (*Phagmities australis*), hybrid cattail or white cattail (*Typha X glauca*) and garlic mustard (Mason 2005 & 2006). As of 1990, this area at the Lakeshore contained 15 state listed species including northern white-cedar (*Thuja occidentalis*) and white lady's slipper (*Cypripedium candidum*).

Of the wetland types mentioned above only wet or sedge meadows will be discussed further as they are the primary fire-dependent system in the complex. These meadows occur within a continuum of community types that differ with water table depth (Fig. 6). They occur on mineral or muck soils or on peat deposits as deep as 20 feet where substrate and water table heights are near equal (Curtis 1959, Aaseng et al. 2003). Species composition is highly variable depending on the depth and persistence of standing water. High-quality sites are peat-based with highly diverse floral assemblages dominated by graminoids. Bluejoint grass (*Calamagrostis canadensis*), tussuck sedge (*Carex stricta*) and water sedge (*C. aquatilis*) are the most common graminoids present.

Through the use of fire and other treatments, wet meadows type can be maintained and re-establish from cattail types. Maintenance prescribed fires, every five to ten years, will thwart woody invasion, and also reduce litter and organic debris remaining after chemical and mechanical treatments (Fig. 6). Without fire these types may succeed to shrub types and eventually to hardwood swamp, particularly when accompanied by a lowering of the water table.

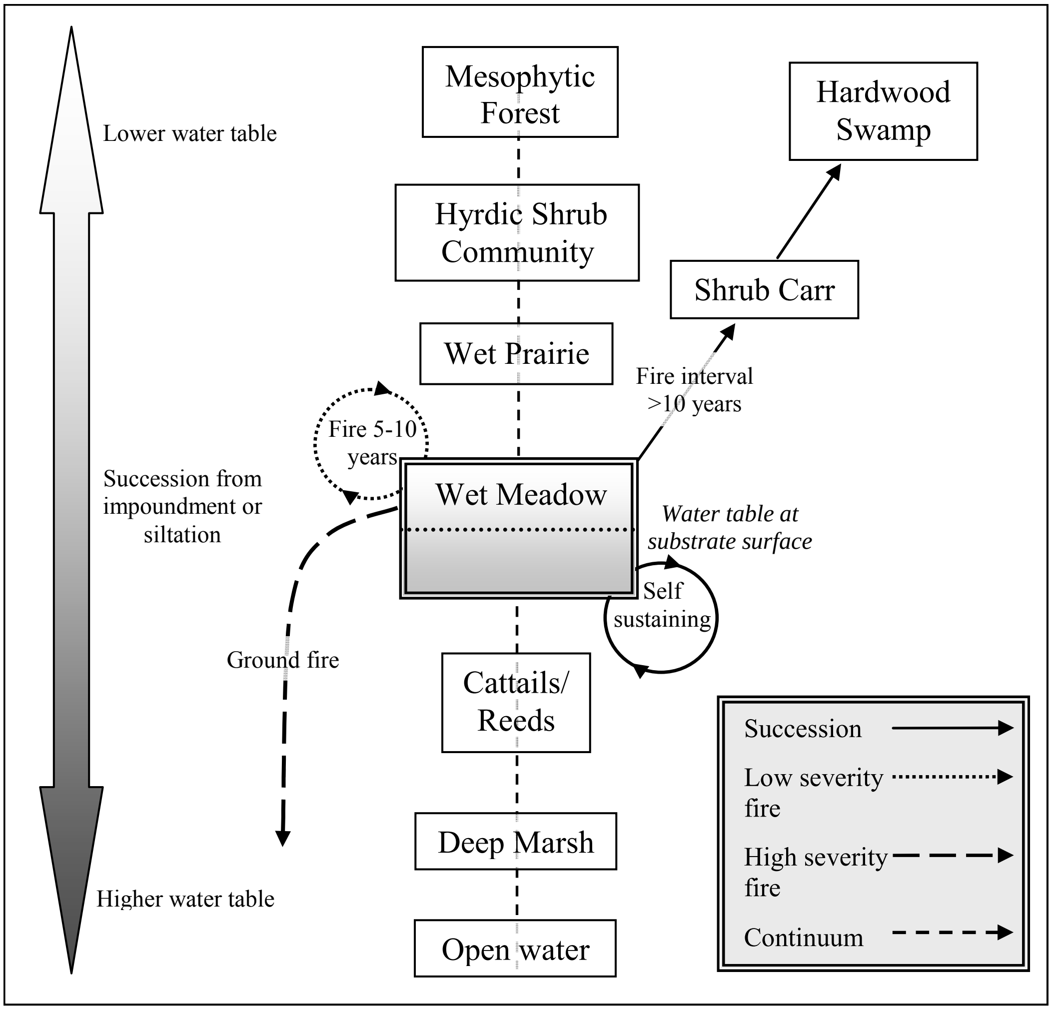

Figure 6. Ecological model for graminoid dominated (peat based) wetlands.

3.8.1 Successional Pathways (Fig. 6)

Two main mechanisms cause shifts in community types in wetland systems, water table fluctuation and fire. Siltation, ditching, dam removal and development of sedimentary peat or floating mats all effectively lower the water table. This will cause a shift toward drier systems depending on the resulting water table depth (Aaseng 2003). Conversely, impoundment of water flow, e. g. beavers, will cause a shift toward wetter communities (Curtis 1959). Wet meadows dominate when the water table is at or near the substrate surface. When this community is at the wettest end of its range the water depth can sustain the system (Curtis 1959). However, at the drier end, periodic fire is necessary to prevent invasion and conversion to shrubs and eventually hardwood swamp. A fire interval of 5-10 years will maintain wet meadows. An interval of greater than10 or 20 years without fire will result in conversion to shrub carr (Curtis 1959). During severe droughts ground fires can occur, which partially remove the peat base below the normal water level. This can effectively raise the water table and may result in conversion to more hydric communities and possibly domination of invasive species (Curtis 1959).

4. GOALS/OBJECTIVES FOR RESOURCE MANAGEMENT & FIRE

4.1 GENERAL GOALS/TARGET CONDITIONS

Lakeshore management desires to maintain the prairie-savanna-woodland-forest mosaic in its current spatial configuration and extent. The restoration, maintenance and preservation of fire and non-fire dependent species and community assemblages within this mosaic are the general goals. More explicit target conditions for each monitoring type are defined below.

4.2 OBJECTIVES

4.2.1 Restored Tallgrass Prairie

The target condition is to produce a dry to mesic tallgrass clay prairie remnant uninterrupted by fencerows. This implies a community dominated by native grasses such as big bluestem and switchgrass with a mixture of numerous native forbs. To achieve this it is necessary to reduce or eliminate exotic herbaceous species, namely bluegrass, brome, clover, fescue, timothy, and wild carrot and reduce the frequency of aggressive native goldenrods such as giant goldenrod (*Solidago gigantea*), flat-top goldenrod (*S. graminifolia*), early goldenrod (*S. juncea*) and Canada goldenrod (*S. canadensis var. scabra* formerly *S. altissima*). Additionally, extirpation and prevention of future invasion of woody species, especially exotic black locust and autumn olive is needed. Given the state of the prairie and the combination of fire and cultural treatments only long term goals were set.

The following management and prescribed fire objectives will be met through the use of prescribed fire, as well as mechanical and chemical treatments.

a) Treat the area with prescribed fire at least twice every five years, allowing at least 10% but no more than 30% of the area to be unburned during any given burn year.

The following (b-e) are benchmarks to be met by 2017; this is not the final desired condition.

b) Increase combined cover of desirables (*Andropogon gerardii, Schizachyrium scoparium, Sorghastrum nutans, Panicum virgatum* and *Sporobolis heterolepis*) to >30% (2005 coverage, 12%).

Reduce the following:

c) Turf grass *(Poa pratensis)* **cover** to less than 10% (2005, 31%).
d) Undesirable species *(Poa* spp., *Festuca* spp., *Bromus inermus*, *Trifolium* spp., *Phleum pretense)* **cover** to less than 30% (2005, 62%).
e) Woody species cover to less than 10% (2005, 30%).

Maintain or achieve the following:

f) Species richness of at least 100 non-woody species.
g) Coefficient of Conservation of 3.5 or greater.

4.2.2 Mesic Sand Prairie

The target condition for mesic sand prairie is to maintain or increase the current area and quality of mesic sand prairie. High-quality sites are characterized by high floral and faunal species richness, absence of woody plants and scarcity or absence of invasive species. Key species which characterize mesic sand prairie are big and little bluestem, Indian grass, colic root, marsh blazing-star and rattlesnake master. Higher quality sites contain blue-hearts, clubmoss, false indigo, spike-rush, spotted wintergreen, trailing arbutus and Hall’s bulrush. Control of invasive species such as Canada thistle (*Cirsium arvense*) is imperative to the maintenance of the system.

Management and prescribed fire objectives.

a) Treat the area with prescribed fire at least twice in 10 years, allowing at least 10% but no more than 30% of the area to be unburned during any given burn year.
b) Top-kill >75% of woody stems < 2” (5 cm) dbh by two years post-burn.
c) Increase or maintain a species richness of at least 100 native species per acre within five years post-burn.
d) Maintain or increase mesic sand prairie coverage.
e) Control or eliminate invasive Canada thistle.

4.2.3 Black Oak Savanna

Management desires to restore current and former oak savannas to natural conditions. Quantifiable target characteristics include a single layer canopy dominated by black oak, canopy closure between 15 and 50% and a single understory layer dominated by grass (cover) excluding Pennsylvania sedge. Restoration efforts will also include improving KBB habitat by increasing the presence of wild lupine. Understory species which identify savanna include all those common to prairies plus corydalis (*Corydalis sempervirens*), fame flower (*Talinum* spp.), Bicknell’s geranium (*Geranium bicknellii*), bristly sarsaparilla (*Aralia hispida*) and silky aster (*Aster sericeus*). Fire-sensitive herbs and sedges also occur and include lettuce, Pennsylvania sedge, shinleaf (*Pyrola* spp.), Solomon’s seal, and wintergreen.

The following management and prescribed fire objectives will be met through the use of prescribed fire, as well as mechanical and/or chemical treatments.

a) Treat individual sites with fire every 3-8 years, allowing at least 10% but no more than 30% of the area to remain unburned during any given burn year.
b) Maintain and/or increase the cover of wild lupine.

Achieve and maintain:

c) Canopy closure between 15 and 50%.
d) Percent cover of native grasses between 30 and 60%.
e) Coefficient of Conservatism of 3.5 or more.
f) Average litter depth less than 2” (5 cm).

Within a year post-burn:

g) Reduce by 50% the percent cover of fire-sensitive herbs.
h) Top-kill at least 50% of woody stems less than 2” (5 cm) dbh.

4.2.4 Black Oak Woodland

Management desires to restore current and former oak woodlands to natural conditions. Quantifiable target characteristics include a single black oak dominated overstory of between 40 and 80% canopy closure and two distinct, but usually patchy, understory canopy layers consisting of an herbaceous and a shrub layer. The understory contains some prairie grasses and forbs and all of the fire-sensitive species found in savannas and many that are found in oaks forests. Target conditions include maintaining populations of fire-sensitive species and the elimination or reduction in frequency of exotic honeysuckles (*Lonicera tatarica*, *L.* spp.), Japanese bareberry and winged euonymus.

The following management and prescribed fire objectives will be met through the use of prescribed fire, as well as mechanical and/or chemical treatments.

a) Treat individual sites with fire once every 5 to 20 years, allowing at least 10% but no more than 30% of the area to remain unburned during any given burn year (frequency is site dependant).

Achieve and/or maintain:

b) Maintain between 25 and 50% of the total cover as fire-sensitive species (site dependent).
c) Percent cover of exotic *Lonicera spp*. below 2% on any given site.
d) Canopy closure between 40 and 80%.
e) Two understory layers, shrub and herbaceous.
f) Average litter depth greater than 2” (5 cm) during non-fire years.

Within two years post-burn.

g) Top-kill at least 25% of woody stems < 2” (5 cm) dbh.

4.2.5 Black Oak Forest

The target condition for black oak forest is an upper canopy dominated by black oak with greater than 80% closure and 3 or more canopy layers, mid-story tree, shrub and herb layers. The herb layer can be described as sparse and contains mainly fire sensitive species. Similar to woodlands, the target conditions include maintaining populations of fire-sensitive species and eliminating or reducing the cover of exotic honeysuckles (*Lonicera tatarica*, *L.* spp.*)* and garlic mustard.

Management objectives for black oak forest.

a) Treat individual sites with fire every 10 - 20 years, allowing at least 10% but no more than 30% of the area to remain unburned during any given burn year.
b) Maintain the percent cover of exotic *Lonicera spp*. and garlic mustard below 2% on any given site.
c) Ensure >75% of the canopy gaps are being filled with black oak seedlings and saplings.
d) Maintain >50% of the total understory cover as fire-sensitive species.
e) Maintain the average litter depth to 2” (5 cm) or more during non-fire years.

4.2.6 Mesic Dune Forest

This type is not as far askew as the more fire dependent systems. As such the target condition for Mesic Dune Forest is nearly the current condition. The structural characteristics described above for black oak forest apply here as well. The overstory however is not dominated by any one species but is a mixture of fire-sensitive and fire-adapted species. These species are listed in the ecological model above (Section 3). The target condition requires the elimination or control of garlic mustard and Asiatic bush honeysuckles, exotic and undesirable species that are found occasionally in this type.

Management objectives for mesic dune forest:

a) Identify and map forest locations.
b) Maintain the current coverage and quality.
c) Treat no more than 1 ac (0.4 ha) or 25% of mesic dune forest, whichever is more, with fire during any single burn.
d) Achieve less than 10% mortality in fire-sensitive tree species greater than two inches dbh, two years post-burn.
e) Maintain greater than 60% of the total herbaceous cover as fire sensitive species.

4.2.7 Graminoid-dominated (peat-based) Wetlands

The target condition for graminoid-dominated (peat-based) wetlands is a diverse floral community dominated by wide-leaved sedges (especially *Carex stricta, C. aquatilis*) that is absent of monotypic stands of cattail, common reed, reed canary grass and shrubs. Desirable species include the fire-sensitive northern white-cedar and pitcher plant and the early successional, fire-adapted lady's slippers. Restoration toward the target condition must include the elimination or control of undesirable species such as the exotic/invasive Canada thistle, purple loosestrife, reed canary-grass, hybrid cattail and common reed.

The following management and prescribed fire objectives will be met through the use of prescribed fire, as well as mechanical and/or chemical treatments.

a) Maintain current area and quality of sedge meadow/wet prairie communities.
b) Reduce percent cover of invasive species to less than 30% (note: this is a benchmark not the final desired condition).
c) Reduce by 80% litter resulting from mechanical treatments.
d) Top-kill 50% of shrubs within two years post-burn.

5. MONITORING OBJECTIVES

The monitoring objectives build upon the management objectives listed above by adding quantitative measures of precision (how narrow of a confidence interval around the sample statistic is acceptable), power (the ability to detect a change of a particular size (1-β)) and false and change error rate (alpha level, a measure of how willing we are to say a change has occurred when in fact it has not). The monitoring objectives follow the same lettering as the management objectives above.

For the sake of brevity, time frames and other specifics per variable are not included as they are stated previously under management objectives. All implied changes regard pre- vs. post-burn levels and/or year to year variation and we are willing to accept a 10% chance of falsely detecting a change ($\alpha = 0.1$)

5.1 RESTORED TALLGRASS PRAIRIE

a) Confirm that individual sites are burned at least twice every 5 years and that between 10 and 30% of the site is left unburned during any given burn year.
b-e) Detect with 80% certainty cover changes (minimum detectable change) in native and nonnative, grasses, forbs and live woody species groups (Table 1).No statistics are available for FQI at the site level.
f) Be 80% confident that the true mean Coefficient of Conservatism is within 20% of the true mean of 3.5 or greater.
g) Be 80% certain that the herbaceous species diversity is within 20% of the true herbaceous diversity.

Table 1. 2005, Mnoké Prairie minimum detectable change.

$\alpha = 0.1$, $\beta = 0.2$	Native		Invasive	Non-Native		All
	Forbs	Grasses	Forbs	Forbs	Grasses	Woody
2005 Mean Percent Cover* (n=20)	42	12	55	18	62	30
Desired MDC**	10 (24%)	5 (42%)	15 (27%)	10 (56%)	15 (24%)	10 (33%)
2005 MDC	7 (16%)	6 (47%)	6 (11%)	9 (47%)	11 (18%)	6 (21%)
Min. Sample Size	9	26	4	15	11	8

* Total percent cover can be greater than 100% due to overlapping of plants.
** MDC minimum detectable change. Actual change in percent cover & (percent of the mean).

The 2005 minimum detectable changes in Table 1 were determined using the following equation:

$$MDC = \sqrt{(sd)^2 (Z_\alpha + Z_\beta)^2 / n}$$

where sd is the standard deviation of the difference, Z_α and Z_β are the Z-coefficients for the false- and missed-change error rates respectively and n is the sample size. The standard deviation of the difference was determined by averaging this term calculated from all years of data.

5.2 MESIC SAND PRAIRIE

a) Confirm that individual sites are burned at least twice every 10 years and that between 10 and 30% of the site is left unburned during any given burn year.
b) Detect with 80% certainty that a change has occurred in the density of live woody stems.
c) Be 80% confident that the estimated mean total species richness is within 20% of a true mean of 50 or more species per acre (100+ spp/ha).
d) Mapping spatial boundaries of mesic sand prairie is done externally from the fire effects monitoring program.
e) Detect with 80% certainty changes in the percent cover of Canada thistle.

5.3 BLACK OAK SAVANNA

a) Confirm that individual sites are burned every 3 to 8 years and that between 10 and 30% of the site is left unburned during any given burn year.
b) Detect with 80% certainty changes in wild lupine cover.
c) Be 80% certain that the mean canopy closure is within 25% of a true canopy closure of 15 to 50%.
d) Be 80% certain that the mean percent cover of native grass is between 30 and 60%.
e) Be 80% confident that the true mean Coefficient of Conservatism is within 20% of the true mean of 3.5 or greater.
f) Be 80% certain that the mean litter depth is within 20% of a true mean litter depth of less than 2”.
g) Detect with 80% certainty changes in the cover of fire sensitive herbs.
h) Detect with 80% certainty changes in the mean density of woody stems less than 2” (5 cm) dbh.

5.4 BLACK OAK WOODLAND

a) Confirm that individual sites are treated with fire at least once every 5 to 20 years and that between 10 and 30% of the site is left unburned during any given burn year.
b) Be 80% certain that the mean total cover of fire sensitive species is within 25% of a true mean cover of between 25 and 50% of the total cover.
c) Be 50% certain that the mean cover of exotic *Lonicera spp.* is within 100% of a true mean cover that is <2%.
d) Be 80% certain that the mean canopy closure is within 25% of a true canopy closure of 40 to 80%.
e) Document with plot photos the presence of two understory layers.
f) Be 80% certain that the mean litter depth is within 20% of a true mean litter depth of greater than 2”.
g) Detect with 80% certainty that a change has occurred in the mean shrub, tree seedling, and pole-size tree densities.

5.5 BLACK OAK FOREST

a) Confirm that individual sites are treated with fire at least once every 10 to 20 years and that between 10 and 30% of the site is left unburned during any given burn year.
b) Be 50% certain that the mean covers of exotic *Lonicera spp*. and garlic mustard are within 100% of the true mean covers that are <2%.
c) Be 80% certain that the mean seedling and sapling densities are greater than the combined densities of the other trees species in >75% of the canopy gaps. Precision is 25% of the mean.
d) Be 80% certain that the mean total cover of fire sensitive species is within 25% of a true mean cover of >50% of the total cover.
e) Be 80% certain that the mean litter depth is within 20% of a true mean litter depth of greater than 2".

5.6 MESIC DUNE FOREST

(Not currently being monitored by the fire effects monitoring program)

a) Ensure that pockets of mesic dune forest are mapped or noted on a project map or in the burn plan.
b) Detect with 80% certainty changes in the mean cover of understory species.
c) Be 98% confident that no more than 1 ac (0.4 ha), or 25% of the forest type is treated with prescribed fire each year.
d) Detect with 80% certainty changes in mean overstory and pole-sized tree density.
e) Be 80% certain that the mean total cover of fire sensitive species is within 25% of a true mean cover of greater than 60%.

5.7 GRAMINOID-DOMINATED (PEAT BASED) WETLANDS

(Not currently being monitored by the fire effects monitoring program)

a) Mapping of sedge meadows is done externally from the fire effects monitoring program. And detect with 80% certainty changes in the mean cover and/or frequency of native understory species (Assesses floristic quality in part a).
b) Detect with 80% certainty changes in invasive species cover.
c) Detect with 80% certainty changes in the mean litter depth.
d) Detect with 80% certainty changes in the mean woody shrub.

6. MONITORING LEVELS

Different monitoring levels are employed to assess fire effects. Levels 1 and 2, environmental, reconnaissance and fire observation provide background information needed for decision making and assessing fire behavior. This knowledge is critical for implementing prescribed fire and when analyzing the after effects on vegetation. Level 3, surveying short-term post-fire effects, and Level 4, evaluating long-term change, address whether the management objectives are being met and whether any negative impacts are being produced. Data gathered per monitoring level are listed below.

6.1 Level 1

6.1.1 Environmental:

Weather, fire danger rating, fuel conditions, resource availability, concerns and values to be protected and other biological, geographical and sociological data.

The above elements are fulfilled by the fire management staff as a whole. Weather is monitored hourly via a permanent RAWS station located at park headquarters. From this data, fire danger ratings, drought indices and fuel moistures are computed. Additionally, 10 hour fuel sticks are occasionally placed at perspective prescribed fire units prior to burning. Fuel loading is determined via fire effects plots and with a rough fuel model map. The fire effects staff collects and maintains these data. Fuel model maps are also held by regional GIS staff. Resource (people) needs and availability are determined by fire management and are based on fire hazard and current activities. Distribution of resources for the Lakeshore is administered through the Indiana Interagency Coordination Center. Concerns and values to be protected, as outlined in FMH (2003, page 8) are included in all burn plans. Various resource managers are consulted prior to burning to address natural resource concerns. Research projects and fire effects plots are also considered in prescribed fire planning.

6.2 Level 2

6.2.1 Reconnaissance:

Fire cause/origin, location, size, fuel type, vegetation, fire activity, potential for spread, current and forecasted weather, resource or safety threats and constraints, and smoke volume and movement.

The origins, locations and sizes of all fires greater than 0.1 acres are mapped in GIS. Depending on the situation the IC, fire monitors or other qualified personnel document fuel and vegetation type(s), fire activity, spread potential, weather, smoke characteristics and threats to safety and cultural and natural resources. These data are maintained at the fire management office. A fire report is produced by the fire incident commander including all the above information plus logistical information.

For prescribed fires, reconnaissance information is detailed in the burn plan. It includes a prescription describing acceptable weather conditions such as temperature, relative humidity, wind direction, mixing height and transport winds for smoke dispersal.

6.2.2 Fire Observation:

Fire monitoring period, ambient conditions, duff moisture, fuel models, and fire and smoke conditions.

On the day of the prescribed fire, weather observations are taken on site just before the test burn and hourly thereafter for at least one hour after ignition is complete. Spot weather forecasts are requested from the National Weather Service as needed. Weather observations include: location, dry and wet bulb temperatures, relative humidity, wind speed and direction and cloud cover.

Fire behavior and smoke dispersal data are collected during the burn. Data include flame length and depth, rate of spread, ignition pattern, fuel characteristics, smoke dispersal and visibility on nearby roads. Pictures are taken of ignition, holding, and fire behavior. The ignition pattern and method, and anything unusual occurrences are documented i.e. media on scene, smoke complaints, etc.

Post-burn and fire reports are filed in the fire effects and fire management offices respectively. The post-burn report includes: prints or a CD of pictures taken, a map, the incident action plan, the spot weather forecast, and weather observations from the RAWS station at headquarters (Appendix D-6).

6.3 Levels 3 and 4 Monitoring

6.3.1 Immediate Post-burn & Long-term Trends:

Attributes collected to identify trends are selected based on the goals and objectives for the burn and the vegetation community. These attributes are listed below.

- *Tree Layer* – Density, diameter & height by species, canopy closure.
- *Dead and Downed Fuel Loads* - Loading by size class, duff & litter depth, ladder fuels.
- *Brush and Herbaceous Layer* – Frequency, cover &/or density by species, diversity.
- *Post-burn Conditions* - Average scorch & char heights, burn severity based on substrate and vegetation mortality.

7 SAMPLING PROTOCOLS

7.1 INTRODUCTION

There are several different protocols in use at the Lakeshore for a variety of reasons. Most plots conform to protocols found in the NPS Fire Monitoring Handbook (FMH) (NPS 2003). Procedural changes, modifications and additions to these methods continue to take place. A detailed account of past changes can be found in the report titled Indiana Dunes National Lakeshore Fire Effects Monitoring Protocols 1998-2002 (Coon et al. 2002) and a summary is provided below. Several changes took place in 2004 and 2005. During this time Project Level monitoring plots were installed, Mnoké prairie plots were treated and used to monitor the success of various restoration treatments and plots previously installed by Noel Pavlovic (and Kenneth Cole at the latter two sites) at Hobart Prairie Grove, Lupine Lane and Howes Prairie were absorbed by the monitoring crew. Each of these items is described below. The protocols regarding what level 3 and 4 variables are measured per monitoring type are summarized in appendix C, tables 4-8.

As of 2006 there were 46 FMH forest plots, 28 FMH grass plots, 112 project level and 31 Howes Prairie/Lupine Lane monitoring plots in 18 prescribed fire units (Appendix B, Figs. 14 & 15).

7.2 NEW PLOT ESTABLISHMENT

Plot installations will be based on prescribed burn priorities and minimum plot analyses for each monitoring type. New plots should be installed the growing season prior to burning. All plot poles are labeled with aluminum tags. Additional information is included with each protocol description. A map of all FMH plots is provided in appendix B, figures 14 and 15.

7.3 TIMING OF MONITORING

An attempt is made to read all plots during the peak growing season, preferably between mid May and late July, while the herbs and grasses are flowering and setting seed. However given the number of plots, sampling often takes till mid-September.

Burned plots are read within 4 weeks post burn, and at year 2, 5, 10, and at 5 year intervals thereafter. The year 2 read for all plots is the second growing season following burning. The year one read was eliminated due to the overwhelming number of plots that would have to be read each year. Each time a plot is burned, whether by a scheduled prescribed burn or due to wildfire, the schedule is re-set. Unburned plots are read every five years and at one year prior to burning.

7.4 MONITORING TYPES

Protocols are described below per monitoring type.

7.4.1 Mesic Dune Forest

No sampling is currently being done in this monitoring type. This type will be monitored if it is scheduled to be burned.

7.4.2 Black Oak Forest

7.4.2.1 FMH plots

Six ¼ sized (25 X 10 m) FMH forest plots exist in this monitoring type (Fig. 7). Plots were established in 1997 and measured again in 1998 for the year 1 post-burn reread. The plots have not been measured since then. All plots are marked with steel rebar each approximately 1' (0.3 m) tall and have an aluminum tag indicating the plot number and the position of the stake relative to the plot map (see NPS FMH, 2003). Future plot installments will follow the protocols listed for black oak woodland.

7.4.2.1.2 Trees

All live and dead trees >15.0 cm in diameter within 4 – 12.5 X 5 m plots were measured. The species, status (live or dead), diameter at breast height (DBH) in centimeters, crown position and damage were recorded (see FMH 2003). Trees were mapped but not tagged.

7.4.2.1.2 Poles

All live and dead trees ≥2.5 and ≤15.0 cm DBH within one 12.5 X 5 m plot were measured. The species, status, DBH and height class were recorded (see FMH 2003). Trees were mapped but not tagged. Height classes are as follows, 1: 0-15cm, 2: 15.1-30cm, 3: 30.1cm-60, 4: 60.1-100cm, 5: 100.1-200, 6: 200.1-300cm, etcetera to height class 13: 900.1cm+.

7.4.2.1.3 Seedlings

All live and dead trees <2.5 cm DBH were tallied by species, status (live/dead) and height class (m) within a 5 X 2.5 m plot. Height classes are the same as those for pole trees.

7.4.2.1.4 Shrubs

Within 2 - 2 X 25 m belt transects, all live and dead shrub stems rooted in the plots were tallied per species, status and maturity class (mature or immature-seedling). To facilitate counting, tallies were conducted in 10 - 2 X 5 m sub-belts per belt.

7.4.2.1.5 Herbaceous

The point intercept method was used to assess plant cover below 2 m in height. Intercepts of all species, not just herbaceous, occurring below 2 m were recorded every 0.3 m (166 total points), along 2 - 25 m point intercept transects per plot. All annuals live or dead and all live perennials were recorded. Intercepted dead portions of live plants were ignored. Only one intercept is recorded per species per point. The height of the first intercepted species is recorded as well as the species, order and status of all other plants intercepted at that point. Foliage or branches of trees >2 m tall were not recorded.

7.4.2.1.6 Plot Photos

In 1997 and 1998 photos were taken from Q4 to Q1, Q1 to Q4, Q3 to Q2, Q2 to Q3, 0P to Origin, and 25P to the Origin. Photos from P1and P2 to the Origin were not taken.

7.4.2.1.7 Fuels

Fuels were not measured.

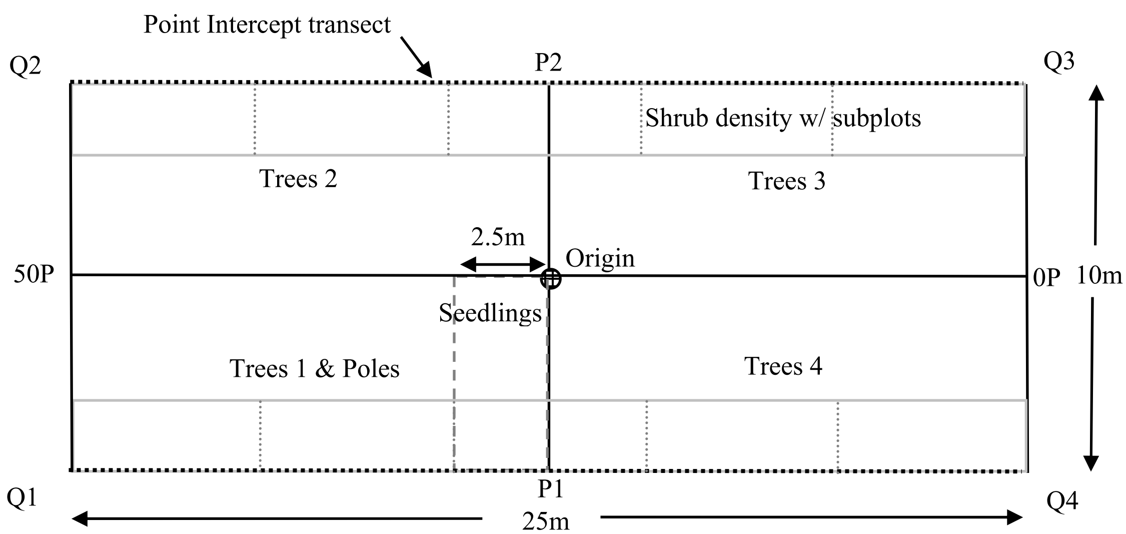

Figure 7. One-quarter sized FMH forest plot.

7.4.2.1.8 Canopy Gaps

In the future canopy gaps will be monitored with temporary seedling plots to determine which species are filling these gaps. Gaps will be determined subjectively but should be at least 3 crown widths across. Depending on the gap size one or more plots will be installed. Protocols are as follows; all live tree species less than DBH are tallied by species within a 3.5 m (11.5') radius plot. Estimates should be done for tallies >25 stems.

7.4.3 Black Oak Woodland

7.4.3.1 FMH Plots

Twenty-three standard FMH forest plots are installed in oak woodlands throughout the Lakeshore. See FMH (2003) Chapter 5 for specific details on sampling methods and categorical codes. The general and most pertinent methods are described below.

7.4.3.1.1 Plot Selection

Plots locations are selected randomly within a particular monitoring type, however given the patchiness of the vegetation communities at Lakeshore, plots tend to be chosen somewhat subjectively near a random point. All plots are marked with steel rebar each approximately 1' (0.3 m) tall and have an aluminum tag indicating the plot number and the position of the stake relative to the plot map (see NPS FMH, 2003). All plot origin locations are geo-referenced using the Global Positioning System.

7.4.3.1.2 Trees

All live and dead trees >15.0 cm in diameter are tagged and mapped within 4 - 25 X 10 m plots (Fig. 8). The species, status (live or dead), diameter at breast height (DBH) in centimeters, crown position and damage codes are recorded. The damage codes for lichen and moss have not been used since 2002 since they appear on most trees. In 2005, VINE (live vine growing in canopy of tree) was added as a damage code. Prior to this it was entered as a comment. Current protocols follow those established in FMH (2003)

In 1994 the lower diameter limit was set at 9.0 cm. This was increased to 15.0 cm in 1998. See Coon et al. for comments regarding species identification and data entry of snags.

7.4.3.1.3 Poles

The species, status, DBH and height in meters of all live and dead trees ≥2.5 and ≤15.0 cm DBH are recorded within one 25 X 10 m plot (Q1) (Fig. 8). Heights were not recorded in 2004.

Trees > 2.5 cm and ≤ 9.0 cm were considered poles, in 1994. In 1998, the diameter limit was increased to 15.0 cm. All trees were mapped and numbered but not physically tagged. As of 2005, individual trees are no longer tracked due to the large number of witch hazel stems. All other protocols follow FMH (2003).

7.4.3.1.4 Seedlings

All live trees <2.5 cm DBH were tallied by species, status and height class in a 2.5 X 10 m subplot within Q1 and along P1 (Fig. 8). Prior to 2003, dead seedlings were also recorded.

The seedling plot history is similar to the story of the three bears. The original 5 X 10 m plot was **too** large so in 1999, the plot was reduced to 2.5 X 5 m. Now this was **too** small, so in 2005 it was increased to 2.5 X 10 m. Hopefully, this will be **just right**. The plot size was not changed in FMH since the program would not accept decimals. This was not a problem since the data was never analyzed using FMH.

7.4.3.1.5 Vines

All live vines greater than 4.5 feet tall are recorded per species throughout the 20 X 50 m FMH plot. This protocol began in 2005. Prior to this, vines were sometimes recorded as a comment when growing on a tree.

7.4.3.1.6 Shrubs

The method for collecting shrubs changes as frequently as the weather. Hence, there is an entire page of details regarding these changes in Coon et al. (2002) that cannot be covered here, however the highlights are discussed. As of 2005, shrub cover and density are recorded using two methods. In Q1 the percent cover, to the nearest 5%, is recorded for those shrubs that regularly attain 2 m or taller. A list of those shrubs that fit that description was made (Appendix D-2). The cover estimate includes all shrubs of that species even if they are currently less than 2 m tall. Shrubs not on the list, as well as those that are, are assessed in 10 – 1 X 1 m squares. The squares are placed along the inside of the point intercept transect at 4-5, 9-10, 14-15, …, 49-50 m from points Q4 and Q3 (Fig. 8). Stem density and percent cover, to the nearest 5%, per species are both recorded. Plants must be rooted in the plot to be recorded.

Shrub stems were originally tallied within 2 - 2 X 50 m belts placed along the inside of the herbaceous transects. Starting in 1999, shrub stems were tallied by species within the current 1 X 1 m squares that are placed every 5 m along the transect. *Vaccinium* was sampled separately at times due to its growth form and *Vitis spp.* were recorded as "*VITISS*" to accommodate FMH (see Coon et al. (2002) for details). From 1999 to 2003 only stem density was collected. This however, was not thought to be as useful a measure as cover. Therefore in 2004 ocular cover was recorded in cover classes (0.1 = present, 0.5 = <1%, 1 = 1-5%, 2 = 5-10%, 3 = 10-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-95%, 7 = 95-100%). To create a crosswalk between the two methods, both ocular cover and density were collected in 2005. Live and dead stems were sampled from 1999 to 2002; dead were not sampled in 1998 and from 2003 to 2005. Beginning in 2004, *Vitis* spp. was no longer counted as a shrub. Mature, immature, and resprout were only sporadically recorded.

7.4.3.1.7 Herbaceous

Two 50 m point intercept transect are used to assess plant cover below 2 m in height. Plant and substrate intercepts are recorded every 0.3 m for vegetation ≤2 m high (166 total points). All annuals live or dead and all live perennials were recorded. Intercepted dead portions of live plants are ignored. Only one intercept is recorded per species per point. The height of the first intercepted species is recorded as well as the species, order and status of all other plants intercepted at that point. Foliage or branches of trees >2 m tall are not recorded.

Starting in 2004, ocular percent cover was estimated for herbaceous species within the 1 X 1 m squares described in the shrub section above. Cover was estimated per species using the following cover categories; 0.1 = present, 0.5 = <1%, 1 = 1-5%, 2 = 5-10%, 3 = 10-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-95%, 7 = 95-100%. In 2005, cover was estimated to the nearest 5% as per shrubs.

Beginning in 1998, all species observed within 2 m either side of each transect, and not previously "hit", are recorded.

7.4.3.1.8 Fuels

Fuels are recorded using four - 50 foot planar intercept transects (Brown 1974). General methods follow those outlined in FMH (2003) and Brown (1974). The starting points for the four lines are located on the 0P – 50P plot segment at 10, 20, 30 and 40 m. A random azimuth is chosen and a stake is placed at the end of each 50' transect. One hour and ten hour fuels are tallied from 0 - 6' and 1000's for the entire 50'. One-hundred hour fuels were measured from 0 - 12' until 2006 when the transect for this type was increased to 25'. Litter depths (in inches) are measured at 6, 12, 25, 35 and 45 feet. Duff depth is not recorded.

Prior to 2006 litter depths were taken at ten locations per line (1, 5, 10, 15, 20, 25, 30, 35, 40, 45'). Duff depths were taken at these same locations but were discontinued in 2004 since these data were deemed unnecessary.

7.4.3.1.9 Canopy Cover

Canopy openness is determined via five canopy photos taken with a fisheye lens at the Origin, Q1, Q2, Q3 and Q4. Each photo is analyzed using the Gap Light Analyzer (GLA) program to obtain canopy openness not canopy cover (Frazer et al. 1999). However the two measurements should be strongly correlated barring any topographic shading. The output is very similar to Leaf Area Index since the program essentially computes the percent light available rather than simply counting the openings in the canopy as is done with a densiometer.

Beginning in 1999 a densiometer was used to measure canopy cover. In 2000, canopy photos were taken with a fisheye lens in addition to densiometer readings. Densiometer readings were discontinued in 2001 after which all canopy monitoring was done solely with photography and the GLA.

7.4.3.1.10 Plot Photos

Eight plot photos are taken, one from each corner toward the adjacent stakes (Q1-Q4, Q4-Q1, Q2-Q3 & Q3-Q2) and one from each of the line midpoint stakes (0P, 50P, P1 and P2) toward the origin (Fig. 8). A dry erase board labeled with the date, burn unit, plot code, burn status and line segment (i.e. Q1-Q4) is used to identify each photo. A range pole is not used in the photo.

7.4.3.1.11 Burn Severity and Fuel Consumption

Burn severity data is collected within a month of burning. Prior to 1999 it was done anywhere from 2 weeks to 2 months post burn. Severity assessments of vegetation and substrate are conducted on the fuel lines every 5 feet at the former litter/duff measurement locations. FMH protocols are used except that the definitions (scorched, moderately burned, etc.) were made more specific to the vegetation community. These definitions are attached in appendix D-2, FMH-21. Char and scorch heights are measured on overstory trees only. Char height is measured to the highest point of continuous black and scorch height to the highest black fleck. Fuel lines are re-measured as well.

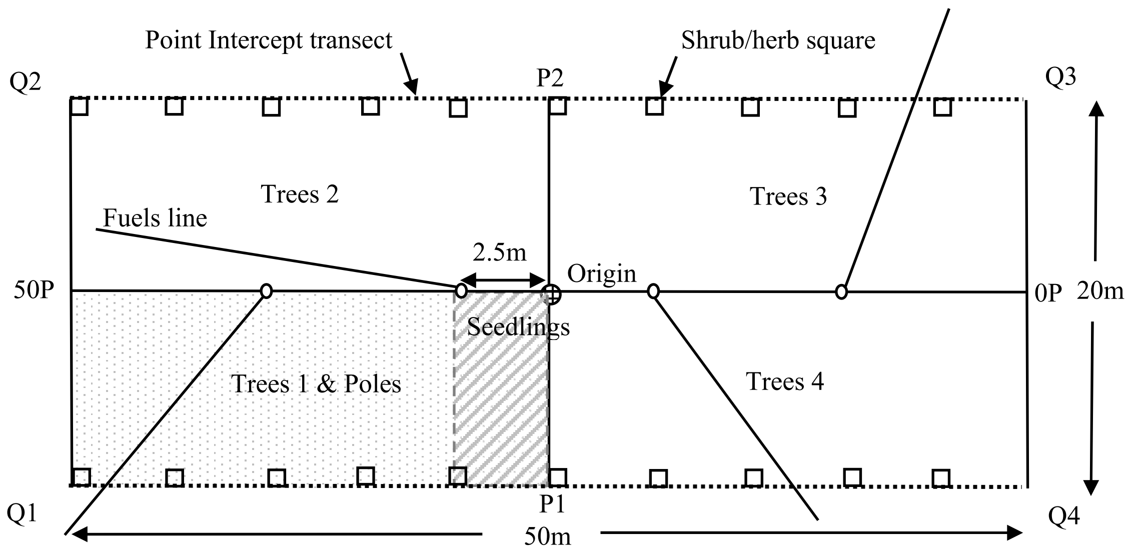

Figure 8. Full sized FMH forest plot.

7.4.3.2 Project Level Monitoring Plots

Project level monitoring is taking place within various burn units throughout the Lakeshore. These plots are not placed specifically within any vegetation type; however most of them occur in oak woodland so they are discussed here.

Project level monitoring plots were established in the fall of 2004 to help determine if short-term prescribed fire objectives were being met on a burn unit basis. Questions regarding fuel consumption and vegetation change could not be answered with any confidence using the standard FMH plots. Project level plots were designed to be easily installed and quickly measured allowing for a greater number of plots to be established. A detailed description of the methods follows (Fig. 9).

7.4.3.2.1 Plot Selection & Establishment

Within the Lakeshore's oak savanna or oak woodland monitoring types, 10 - 30 plots should be established per burn unit, depending on the size of the unit. Plots will be located systematically with a random start at least 40 m apart. Plot centers are marked with a re-bar or conduit stake labeled with the plot number. The azimuth and direction from one plot to the next are recorded and all plot locations are geo-referenced using the Global Positioning System.

7.4.3.2.2 Overstory

All live and dead trees >5.0 cm DBH (1.37 m) will be tallied by species using a 10 BAF prism. An ocular estimate of the DBH of each tree will also be recorded.

7.4.3.2.3 Large Woody Stems

Within a 5 m radius plot all live woody stems (woody vines, shrubs, and trees) ≤5.0 cm DBH but taller than 1.37 m (4.5') are tallied by species. Estimates should be done for tallies >25 stems. To assess mortality by size, counts are done per the following size classes: ***1*** (1.37 m tall to 1.0 cm DBH), ***2*** (1.1 cm to 2.5 cm DBH), and ***3*** (2.6 cm to 5.0 cm DBH). Only stems with at least half of the basal stem within the plot are counted. Trees forked below DBH are tallied as two trees. Stems that, because they are bent over, do not reach 4.5' but are obviously longer than 4.5' are counted.

7.4.3.2.4 Seedlings

All live tree species shorter than breast height are tallied by species within a 3.5 m (11.5') radius plot. Estimates should be done for tallies >25 stems.

7.4.3.2.5 Herbaceous and Other

Within an 11.35 m (37.24') radius plot, a check is performed for the presence of select herbaceous, shrub and tree species (with >50% of the stem in the plot) that indicate whether the understory is typical of a woodland or savanna. The current year's annuals, live or dead and perennials, live only, are counted. Species by type are: savanna- *Schizachyrium scoparium, Ceanothus americanus, Coreopsis lanceolata, Helianthus divaricatus, Koeleria cristata, Lupinus perennis, Panicum virgatum, Sorghastrum nutans and Tradescantia ohiensis*; woodland- *Acer rubrum, Acer saccharum, Amelanchier arborea, Aralia nudicaulis, Cornus florida, Hamamelis virginiana, Osmorhiza* spp., *Polygonatum* spp., *Quercus rubra and Viburnum acerifolium*. In 2006 the following species were added: savanna - *Liatris* spp., *Lithospermum carliniensis* and *canescens*, and *Pteridium aquilinum;* woodland - *Aquilegia Canadensis, Maianthemum canadense* and *Parthenocissus quinquefolia;* exotics species - *Ailanthus altissima, Berberis thunbergii, Celastrus orbiculatus, Elaeagnus umbellate, Euonymus alatus, Ligustrum vulgare, Lonicera spp., Rhamnus carthartica, Robinia pseudoacacia, Rosa multiflora* and *Saponaria officinalis*. The presence of garlic mustard and other exotics were noted in 2005. Comments about the disturbance history of the area, and post-burn comments about the amount of re-sprouting will also be made.

7.4.3.2.6 Fuels

At each plot one, ten and hundred hour fuels are sampled along a single 7.62 m (25') transect originating from the plot center. The azimuth chosen is random but may be restricted for reasons stated in the FMH (2003). The transect end is marked with rebar labeled "FUELS PLOT##". Fuel counts as well as transect slope are recorded. One and ten hour fuels are counted along the **last** 6' of the transect, while 100 hour fuels are counted along the entire 25 feet. Litter depths are taken at 5', 10', 15', 20' and 24' from the center. Duff depth is no longer recorded as of 2004.

Due to the scarcity of 1000 hour fuels, this type is sampled within an 11.35 m (37.24') radius circular plot (0.1 acre). The plot size remains the same for all plots within the burn unit, and once established it cannot be adjusted for the next pre-burn sampling. Since monitoring types are often mixed within a burn unit, plot sizes must also remain the same among monitoring types within a burn unit. Changing plot radii among burn units should also be avoided. However, it may be changed if, due to the time required to sample or lack of an adequate sample (2-3 logs per plot), the radius is completely inappropriate.

Five to ten 1000 hour plots should be sampled per burn unit. Plots should be distributed evenly throughout the site, by establishing them at regular intervals among the macro plots. The placement of the first plot is selected randomly from macro plots.

Average diameter in tenths of inches and length to the nearest foot of each log is recorded. Portions of logs less than 3" in diameter or outside the plot are not included in the measurements. For logs which have a good deal of taper, one center and 2 end diameters are taken, otherwise one center diameter is sufficient. Length measurements can be done ocularly, depending on the experience of the personnel. Each log is recorded as sound or rotten. Plots must be adjusted for slope for slopes >25%. The slope correction table (Table 2) below can be used to determine if the log is "in" or "out".

7.4.3.2.7 Physical Features

Slope, aspect and landscape position (narrow ridge, broad ridge, no ridges) (summit, shoulder, midslope, footslope, toe slope, floor, all flat) are recorded. These features are only recorded at the installation since they won't change over time.

7.4.3.2.8 Sampling Schedule

Fuel transects will be sampled, pre and post burn, within one month of the burn. Vegetation will be sampled the summers prior to and following burning.

7.4.3.2.9 Burn Severity and Fuel Consumption

Burn severity measurements are not done for these plots. Fuel consumption is estimated by re-sampling the fuels lines within a month after burning. Data on trees, shrubs and herbs is collected the first growing season after burning as per the schedule.

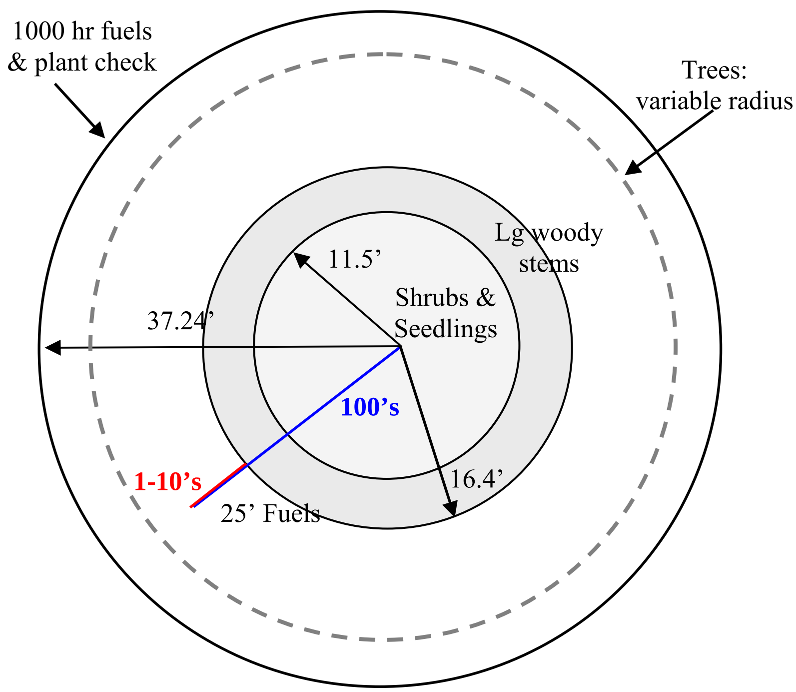

Figure 9. Project Level sampling plot.

Table 2. Slope correction table.

For 37.24' radius plots

Slope %	Sample is "In" at:
5	37.29'
10	37.43'
15	37.66'
20	37.98'
25	38.39'
30	38.88'

35	39.46'
40	40.11'
45	40.84'
50	41.64'
55	42.50'
60	43.43'

7.4.3.3 Howes Prairie Plots

Sampling protocols at Howes Prairie are modeled after Noel Pavlovic's plots that were already established at the site. Most of the site is oak woodland so methods are included in this section. However, oak savanna and mesic prairie are also being sampled at Howes Prairie with these same methods. Below is a brief synopsis of the past sampling that has been done there.

The ecosystem at Howes Prairie and Lupine Lane has been the subject of research studies for the past few decades (Cole and Pavlovic 1988, Taylor 1990). During this period Noel Pavlovic installed 60 study plots at Howes Prairie and 8 at Lupine Lane. Plots were established randomly in 4 habitat types, oak woods, mesic woods, dry prairie and wet prairie. Plots consist of a 1/100 ha (5.64m radius) circular plot where trees are tallied. Trees were once tagged, but can now only be tracked by their distance and azimuth from the plot center. Shrub and sapling percent cover were measured along two 11.28 m N/S and E/W line intercept transects. Seedling density was determined via stem tallies within a 1.5 m radius plot. Percent covers of herbaceous species were estimated within ten 0.5 m^2 rectangular plots regularly placed throughout the 1/100 ha plot (Cole and Pavlovic 1988)

In the late 1990's Pavlovic's studies were effectively complete and in 2005 fire effects monitoring of this area was absorbed by the INDU monitoring crew. To maintain consistency in data collection over time, Pavlovic's protocols were adopted with some modifications due to time constraints. Twenty-three of the 60 plots at Howes Prairie were selected for monitoring, 5 in each vegetation community and 3 unburned control plots. Six of the eight plots were selected at Lupine Lane (plots 1-6). Two additional plots were installed since plots 7 and 8 were lost.

These plots each took 2-3 hours to complete, the herbaceous layer taking ~90% of the time. Therefore, sampling of the herbaceous layer was changed to nested frequency plots. One planar intercept fuels transect was added per plot to sample dead and down fuel. Sampling methods for trees and shrubs was not changed.

7.4.3.3.1 Trees

The species, dbh, and status (live or dead) of all trees >2.5 cm dbh, will be recorded within a 5.64 m radius plot (1/100 ha) (Fig. 10). Individual trees will not be tracked.

7.4.3.3.2 Saplings and Shrubs

The percent cover of all trees ≤ 2.5 cm dbh and all shrubs of any size will be assessed by species via the line intercept method. Dead plants or dead portions of live plants are not recorded. The interception length is recorded along two 11.28 m transects that are run north/south and east/west

(Fig. 10) through the center point. The interception length must be at least 5 cm long to be recorded. Spaces must be at least 5 cm long to warrant stopping and starting another measure of the same species.

7.4.3.3.3 Seedlings

Seedling density of all live trees less than 1.37 m tall will be determined via tallies per species within a 1.5 m radius plot.

7.4.3.3.4 Herbaceous

Nested frequency plots will be used to assess changes in species diversity and relative abundance. The presence of **all** plant species rooted in the plot is recorded within each of five rectangular plots (0.25, 1.0, 4.0 & 8.0 m^2) (Fig. 10). All herbaceous plants are included regardless of height and all woody vines, shrubs and trees less than 1.37 m tall. The southwest corner of the plot is the plot center stake for the fixed radius plots. An additional stake will be placed 4m east to define the plot perimeter. Only additional plants need to be counted in consecutively larger plots.

The percent cover of substrates is estimated within the 4 m^2 quadrat; include all substrates even if they are covered by vegetation. Tree boles, bare soil, litter and rock are considered substrates.

7.4.3.3.5 Plot Photos

A photo is taken of the plot from the end of the 25' fuels lines toward the plot center. A dry erase story board will be used to document the site, date, plot number and burn status e.g. 03 yr 01.

7.4.3.3.6 Canopy Cover

In all wooded plots, one canopy photo will be taken using a fish eye lens from the plot center. Refer to the FMH portion of this section for details.

7.4.3.3.7 Fuels Transect

One 25' Brown's transect will be run due east from the plot center over the 4m nested frequency plot stake. Sampling of 1000 hour fuels is done in 5 evenly distributed wooded plots. The protocols for measuring woody fuels and litter depth are the same as described for the project level monitoring plots.

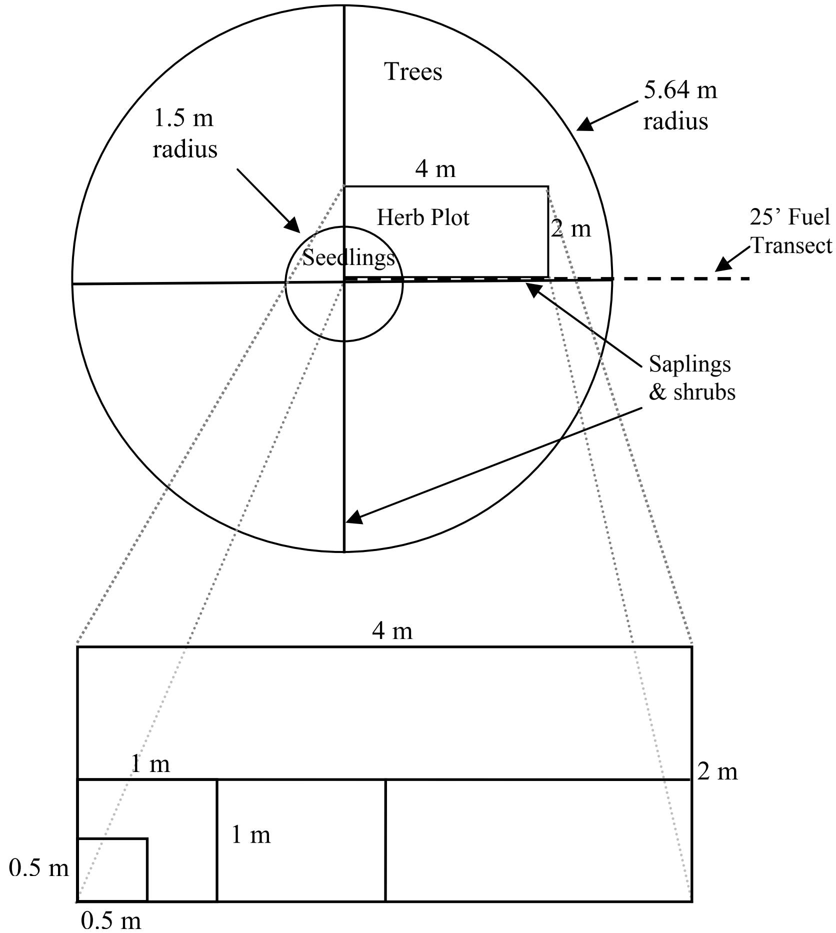

Figure 10. Howes Prairie sampling plot.

7.4.3.4 Hobart Prairie Grove Plots

Hobart Prairie grove consisted of ~30 acres of old fields and ~200 acres of overgrown oak savanna. This latter type is best described as early successional mesic forest containing maple hickory and oak. The forest was previously monitored by Noel Pavlovic using 21 randomly placed circular, nested frequency plots. In 2005 sampling was done similarly but only 14 plots were sampled and two additional plots were installed. Plot sizes are 0.25, 1.0, 2.0, 4.0 and 8.0 m^2 (0.28, 0.56, 0.8, 1.13 &1.6 meters radius respectively) each plot is circular and is nested around the plot center. The presence of each species will be recorded per plot.

In addition to the frequency measures, the woody fuel load, litter depth, overstory, understory (seedlings and shrubs), and physical features will be monitored as per the protocol stated for burn level monitoring. The nested frequency plots will replace the species checklist otherwise the plot setup is identical to figure 9.

7.4.4 Black Oak Savanna

Seventeen standard FMH forest plots are installed in oak savannas throughout the Lakeshore. Methods for all variables follow those stated for oak woodlands expect for those stated below.

7.4.4.1 FMH Plots

7.4.4.1.1 Shrubs and Herbaceous

Methods are the same as for the oak woodland type except that as of 1999, only one point intercept line, Q4 to Q1, is measured instead of two. However, shrubs are still sampled in the 10 – 1 X 1 m squares along Q3 to Q2.

7.4.4.2 Howes Prairie Plots

Any oak savanna types sampled at Howes Prairie is done following the protocols stated for this site in the Oak Woodland section above.

7.4.5 Tallgrass Prairie

Mnoké Prairie is currently undergoing restoration via various treatments and is the only tallgrass prairie being monitored at INDU. Prior to 2005, all non-fire treatments took place within the area that did not contain the 20 FMH monitoring plots. However, after consultation with John Kwilosz, the plots were determined to be useful for monitoring the effectiveness of the restoration treatments. Treatments include burning, mowing, herbicide and seeding/planting. Treatments were performed throughout 2005 and will only be done once. Plots were grouped based on their plant composition using Principle Components Analysis (Table 3). Three plots were excluded because they were much wetter than the rest (plots 12, 16 & 20). Each group was divided among three treatments burn only, burn and seed, and burn, seed and mow. Burn only is the control since all plots will be burned. Trees and shrubs in all plots were cut and stumps were treated with herbicide.

Table 3. Mnoké Prairie plot groupings.
Column headings indicate the plot grouping thresholds based on grass composition (Poa – Bluegrass spp., BRIN – *Bromus inermus*, smooth brome). Row headings indicate the treatment(s) applied to each plot.

Composition by Treatment	>50% Poa 0% BRIN	>50% Poa <10% BRIN	50% Poa & 0% BRIN	45% Poa & 35% BRIN	<50% Poa & 60-90% BRIN	<50% Poa & 0% BRIN
Burn Only (Control)	2,3	7	1	6	4	
Burn & Seed	5,14	8	13	15		17
Burn, Seed & Mow	10	18	9	19	11	

7.4.5.1 FMH Plots

Original plot sampling was as follows.

7.4.5.1.1 Shrubs and Herbaceous

All plants and substrates were sampled via the point intercept method every 0.3 m along a 30.3 m transect. Shrub stems were tallied by species in one 2 X 30 m plot (1996) centered on the herb transect, then in six 1 m^2 quadrants (1998) placed along the right side of the transect (Fig. 11). In 2004, shrub and herbaceous ocular percent cover were recorded for each 1 m square. This is still being done as of 2005. Within 2 m about the transect all species not previously sampled are recorded. Refer to the FMH Plots portion of the Oak Woodland section for specific details regarding sampling of herbs and shrubs.

In September of 2004, minor additions were made to these methods to monitor restoration treatments. A 32 X 4 m plot was established centered on the transect where treatments take place (Fig. 11). A rough map is made of the plot during each visit to mark the locations of significant plants. Shrubs and herbs are sampled in the same manner as before.

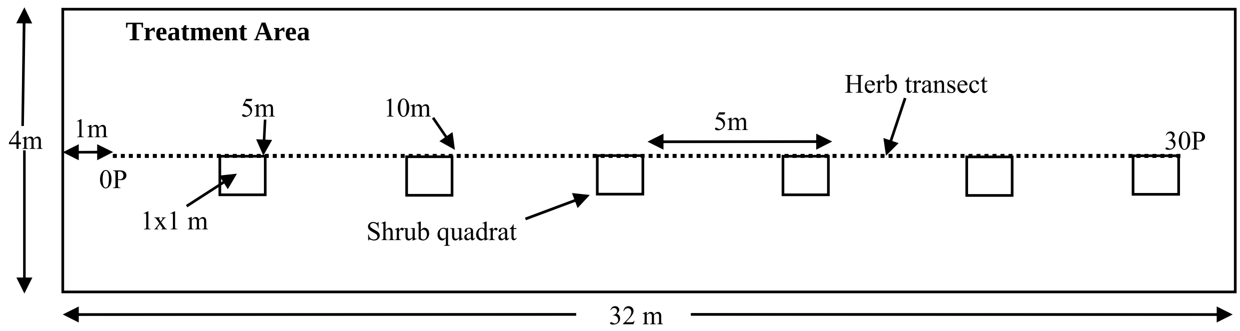

Figure 11. Mnoké Prairie sampling plot.

7.4.5.1.2 Plot Photos

Photos of the plot are taken from both ends of the 30 m transect. A dry erase story board will be used to document the site, date, plot number and burn status e.g. 03 yr 01.

7.4.5.1.3 Fire Severity

Burn severity is assessed at 7 locations (1, 5, 10, 15, 20, 25 & 30 m) along the 30 m transect. Procedures follow those described in the FMH handbook except form FMH 22 was modified slightly to accommodate the grassland community at the Lakeshore. Photos of the plots are also taken as described above.

7.4.6 Mesic Sand Prairie

This monitoring type though available at other locations is only being monitored at Howes Prairie. Sampling protocols follows those outlined for Howe's Prairie in the above Oak Woodland section. If trees and/or shrubs are absent it is noted and sampling for those attributes is not done.

7.4.7 Graminoid-dominated (peat-based) Wetland

The fire monitoring crew is not involved with monitoring this type. As of 2006, the wetlands biologist, Dan Mason, is taking care of the monitoring.

7.4.8 Degraded Wetland

This currently only pertains to one site, Derby Ditch. The only monitoring done here is the establishment of photo points.

7.4.8.1 Photo Points

Photos were taken at 15 geo-referenced locations around the perimeter of the burn unit and descriptions of each photo were recorded. Photos will be retaken one year after burning with the aid of reference photos.

7.5 Fire Monitoring

7.5.1 Fuel Moisture

Fuel moisture measurements are taken the day of or prior to the burn. Moisture estimates may come form one or more of the following, the calculated fine dead fuel moisture, 10 hour fuel moisture stick, or direct fuel moisture sampling of live and dead fuels.

Calculations of fine dead fuel moistures are based on temperature, humidity, shading, elevation, aspect and time of day and year. Tables used to perform the calculations are found in the Fireline Handbook (1998).

Ten hour fuel sticks are weighed and the moisture is calculated based on its oven dry weigh and scale weight.

To obtain more precise fuel moistures, samples are collected per fuel type in air-tight tins. The tins are labeled and tabulated as to their contents. The tins and contents are weighed and oven dried at 100°C for 24 hours and weighed again. The moisture is then calculated.

7.5.2 Weather Parameters

Temperature, wind and relative humidity are recorded every hour during the burn. Weather may be obtained from a weather station or field observer using a sling psychrometer.

7.5.3 Fire Behavior

Fire behavior measurements include flame length, flame zone depth and rate of spread

8. DATA SHEET EXAMPLES

All forms used for FMH protocols are in the NPS Fire Monitoring Handbook (2003). Links to or hard copies of all other forms are provided in appendix D. If an FMH form is used but was modified, it was labeled, “FMH INDU”. Forms created for new protocols in FMH plots are labeled, “INDU FMH”. All other forms developed for non-FMH plots and/or protocols are labeled, “INDU”.

9. DATA MANAGEMENT AND ANALYSIS

9.1 STANDARD DATA

Data will be managed by the INDU Fire Effects Monitoring Crew. All non-photographic FMH and Project level monitoring data are entered and checked in FEAT (Fire Effects Assessment Tool) by the crew. These data files are backed-up by the lead fire monitor and copies are sent to the eco-region fire ecologist. Original hard copies of all data are kept at the INDU Fire Effects Office. Descriptions and directions to plot locations are stored at the INDU Fire Management and Fire Effects offices. A geographical information systems (GIS) data layer of the plot locations is stored at the park's GIS office and in the future in the FEAT database. All data will be shared with Resource Management.

Data for Howes and Hobart Prairies collected by Noel Pavlovic reside in his computer. Data collected by the fire effects monitoring crew at these two sites are entered in FEAT.

Data analysis will take place on an "as need" basis. In general, data analysis will be used to determine minimum plot numbers, whether objectives are being met and to assist in modifying protocols. New results will be summarized annually and reported to the regional fire ecologist and park.

9.2 PHOTOGRAPHS

9.2.1 Plot Photos

Some but not all photographic slides taken of the monitoring plots were scanned and copied to a CD. These slides and CD's are stored together with the hard copies of the data.

9.2.2 Canopy Photos

Canopy photos are first analyzed using Gap Light Analyzer (GLA) software. These data are then exported to a spreadsheet and stored in association with other fire effects data. These data may be entered into the updated version of FEAT scheduled to be out in 2008. The photos themselves are copied to a CD.

9.3 QUALITY CONTROL

Plant identification errors will be mitigated through training, collecting voucher specimens, reading plots during peak phenology, and utilizing herbarium specimens and other experienced personnel.

The impacts of monitoring procedures, such as compaction and disturbance of fuel bed and vegetation, are lessened through crew awareness, and collection of voucher specimens outside the plot.

Data quality will be ensured through proper crew training to guarantee consistency in data collection and entry procedures. Before leaving a plot, all data sheets will be checked by the lead crewmember for accuracy and completeness. Data entry errors will be minimized through cross-checks with the original forms and data analysis and manipulation.

Plot protocols are reviewed annually to call attention to procedural errors or inconsistencies. A program review by the regional and/or eco-region fire ecologist should take place every 3-5 years or as needed to maintain consistency of data collection and analysis, and to re-assess program requirements. More frequent reviews may be needed if there are significant staffing changes, additional ecological or other special concerns.

10 RESPONSIBLE PARTIES

This Fire Effects Monitoring Plan was written by Scott Weyenberg, Fire Ecologist for the Great Lakes Eco-region with assistance from Amy Ortner, Lead Fire Monitor at the Lakeshore.

Administrative duties are assigned as follows:

- Great Lakes Eco-region Fire Ecologist – plan revision and data analysis.
- INDU Lead Fire Monitor – crew supervision, data management, park liaison.
- INDU Fire Effects Monitoring Crew– data collection and data entry.
- Midwest Region Fire Ecologist – program reviews.

11 FUNDING NEEDS ASSESSMENT

FIREPRO funding supports all monitoring activities. The crew desperately needs more money for staffing to keep up with the needs of the monitoring program.

12 ADAPTIVE MANAGEMENT

To more adequately achieve objectives, monitoring results should serve as feedback to the Lakeshore’s fire and resource management staffs so appropriate adjustments can be made to prescribed fire prescriptions. However, care should be taken to avoid making hasty management decisions based on only a few years’ data. Effective long-term fire management will require a comprehensive understanding of the various interactions between vegetation and fire, which can only be obtained from long-term monitoring and analysis.

The ecological models and reference sections of this plan may serve as a brief summary of current knowledge, which can guide management decisions. The information summarized for tallgrass prairie, oak savanna, woodlands and forests come from a only a small portion of the available literature, while information pertaining to the types which are more unique to the Lakeshore come from only a few general sources or expert opinion.

Status reports concerning the program and progress toward or away from specified objectives will come in the form of annual reports and results summaries. Annual reports are submitted to the Lakeshore and the regional and national ecologists. This report is intended to highlight program changes, successes, failures and future plans. Results summaries of any pertinent data analysis will be submitted as available. These are intended to report on the status of a particular monitoring type or a specific site. All analyses are up to the discretion of the ecologist, but in general they will focus on identifying trends and determining whether objectives are being met. When appropriate, suggestions will be made to help fire and resource management to realize their objectives. Also, results of the previous years monitoring data will be presented at the Lakeshores prescribed fire annual planning meeting

13 CONSULTATION AND COORDINATION

The INDU Fire Effects Monitoring Crew must coordinate and consult regionally with other parks, fire management staff, and the Great Lakes Eco-region and Midwest Region Fire Ecologists. The resource management staff is responsible for coordinating and consulting with all other cooperators. Persons consulted in the development and/or review of this document are:

- Bob Daum, Chief of Resource Management
- Jim DeCoster, (Former) Fire Ecologist for the Midwest Region
- KellyAnn Gorman, (Former) Fire Ecologist for the Great Lakes Eco-region
- Scott Weyenberg, (Current) Fire Ecologist for the Great Lakes Eco-region
- Ralph Grundel, Animal Ecologist for the US Geological Survey Biological Resources Division at INDU
- Randy Knutson, Wildlife Biologist for INDU
- John Kwilosz, Restoration Specialist for INDU
- Amy Ortner, Lead Fire Monitor for INDU
- Dan Mason, Botanist for INDU
- Noel Pavlovic, Plant Ecologist for the US Geological Survey Biological Resources Division at INDU
- Julie Stumpf, Plant Ecologist for the Midwest Region
- Dan Swanson, Fire Ecologist for the Ozark Highlands Eco-region
- Suzanne Sanders, I & M Network Inventory Specialist

14 PEER REVIEW

Peer and technical review for this plan was provided by:

Noel Pavlovic, Plant Ecologist
USGS Biological Resources Division
Lake Michigan Ecological Research Station, Porter, IN

Jim DeCoster, Plant Ecologist
National Park Service, I & M Network
Southern Colorado Plateau Network
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16 APPENDICIES

Appendix A. Vegetation maps.

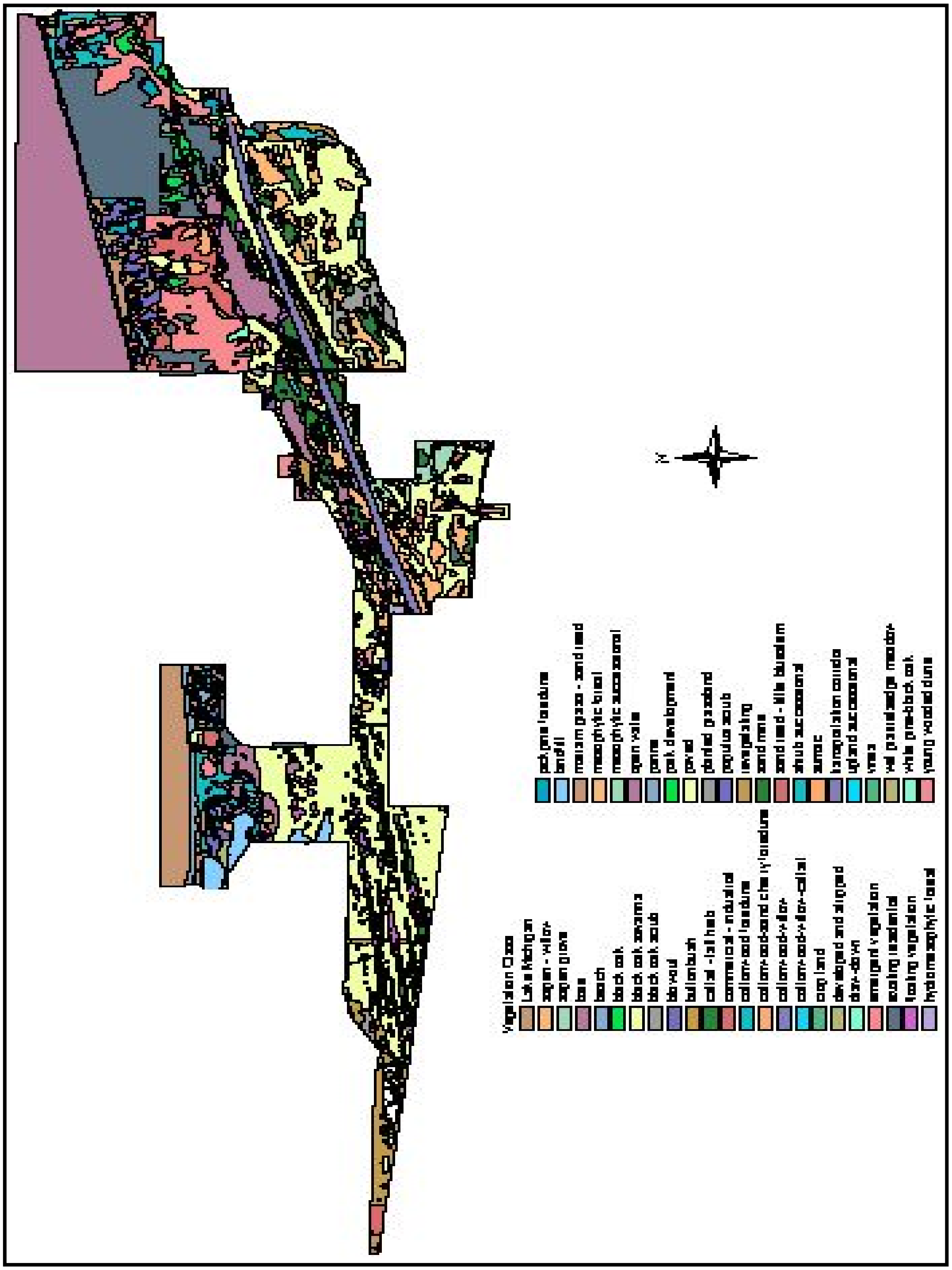

Figure 12. West Unit Vegetation map.

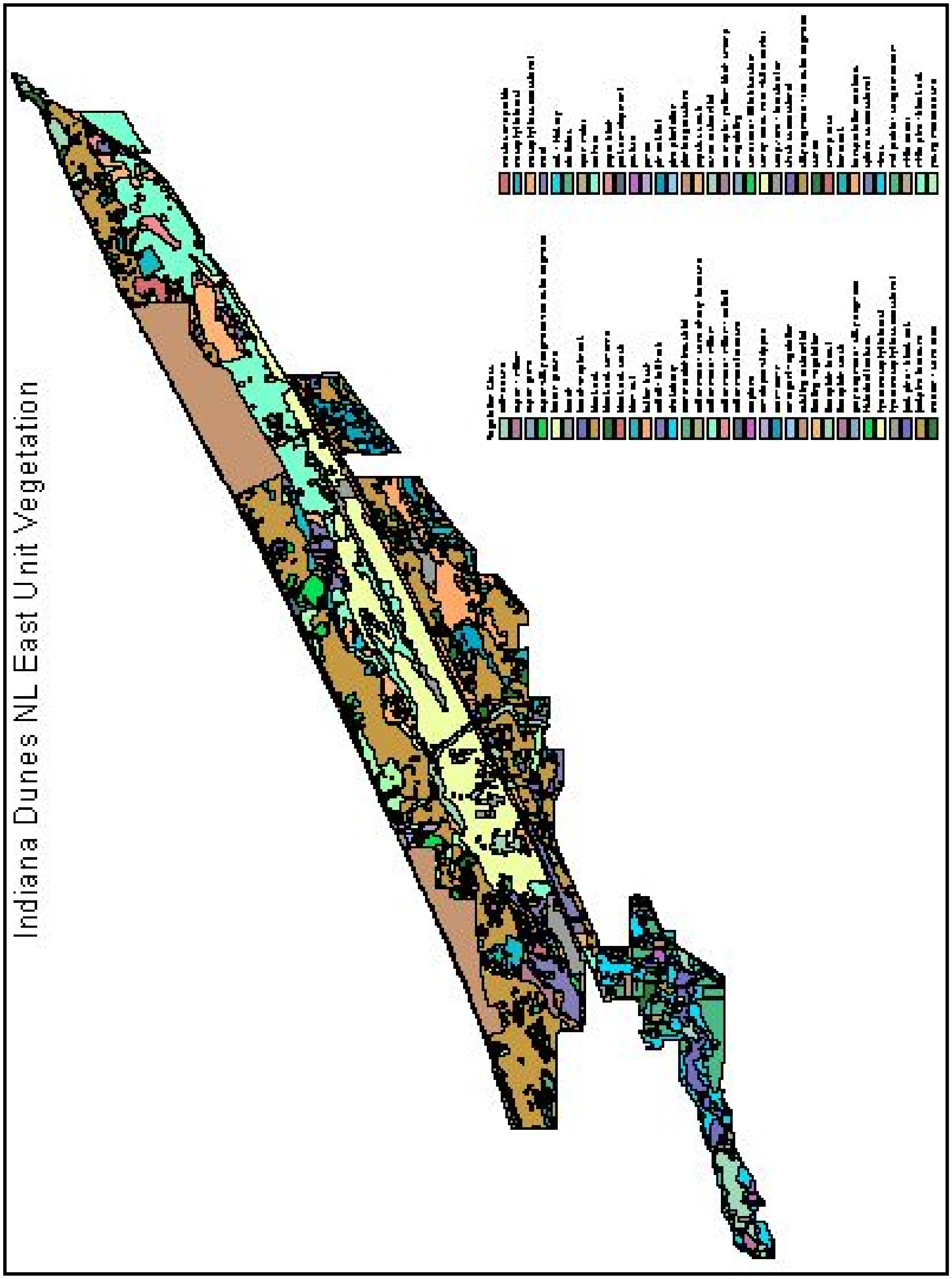

Figure 13. East Unit vegetation Map.

Appendix B Plot Locations

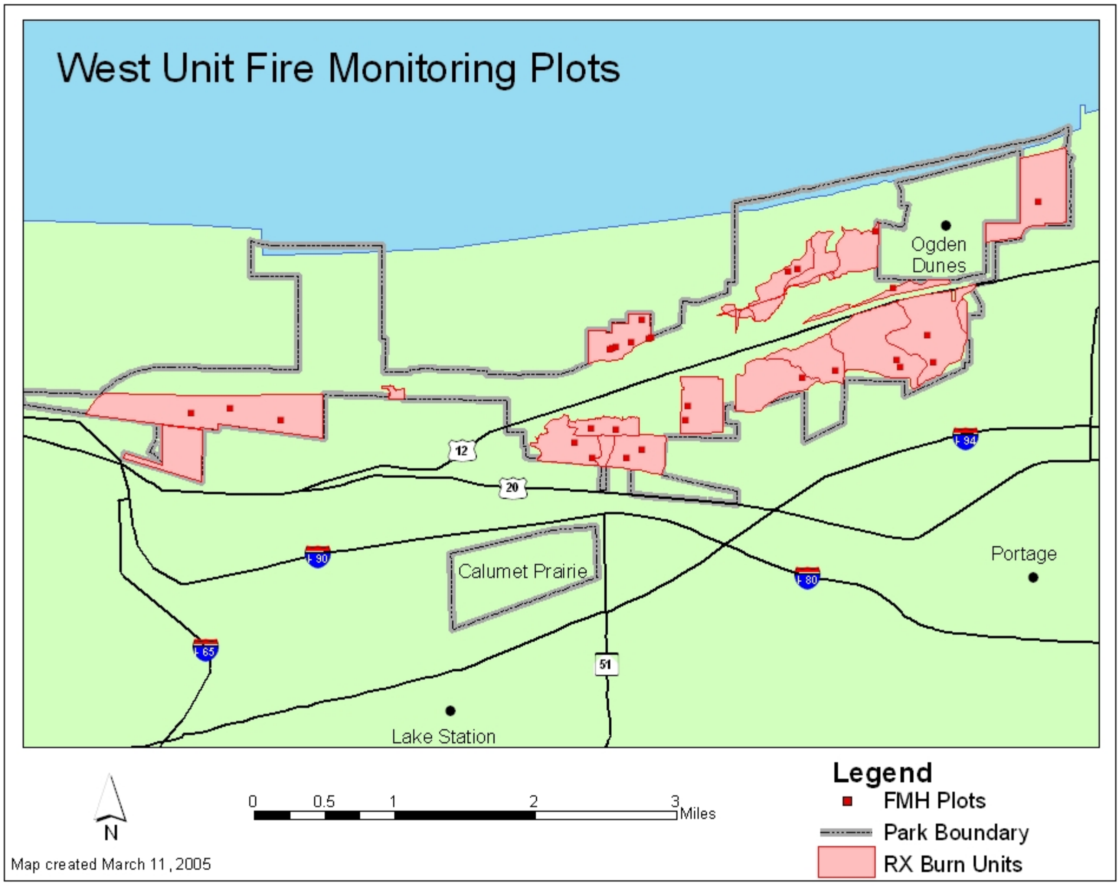

Figure 14. West Unit plot locations.

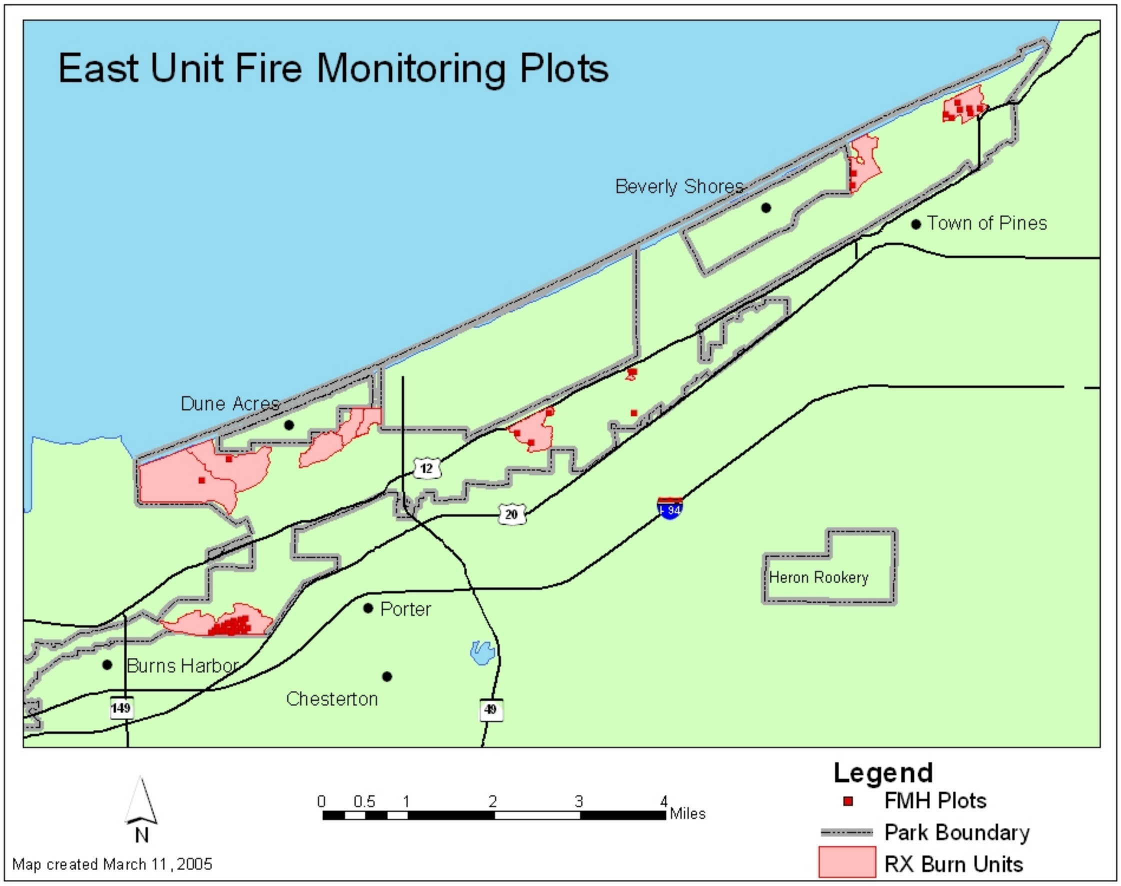

Figure 15. East Unit plot locations.

Appendix C Protocol Summary Tables.

Table 4. Mnoké tallgrass prairie protocol summary table (FMH grass plot)

GENERAL PROTOCOLS						
Pre-burn	Control Plots (Opt)		N	Herb Height (Opt)	Y	
	Herbaceous Density (Opt)		N	Abbreviated Tags (Opt)	Y	
	OP/Origin Buried (Opt)		N	Herb. Fuel Load (Opt)		N
	Voucher Specimens (Opt)	Y		Brush Fuel Load (Opt)		N
	Count Dead Branches of Living Plants as Dead (Opt)					N
	Width of Sampling Area for Species Not Intercepted but Seen in Vicinity of Herbaceous Sampling Area:				4m	
	Sampling Area, Shrubs:	6 - 1.0m x1.0m		Stakes Installed:	2	
	Herb Frame Dimensions:	1.0m x1.0m				
	Herbaceous Density Data Collected At: NA					
Burn	Duff Moisture (Opt)		N	Flame Depth (Opt)	Y	
Post-burn	100 Pt. Burn Severity (Opt)		N	Herb. Fuel Load (Opt)		N
	Herbaceous / Shrub Data (Opt): FMH-15 / 16 / 17 / 18 (1 - 30 m transect, 1, 2, & 5 year reads)				FMH 16	

Table 5. FMH forest plot protocols summary table.

GENERAL PROTOCOLS						
Pre-burn	Control Plots (Opt)	Y		Herb Height (Opt)	Y	
	Herbaceous Density (Opt)		N	Abbreviated Tags (Opt)	Y	
	OP/Origin Buried (Opt)		N	Herb. Fuel Load (Opt)		N
	Voucher Specimens (Opt)	Y		Brush Fuel Load (Opt)		N
	Count Dead Branches of Living Plants as Dead (Opt)					N
	Width of Sampling Area for Species Not Intercepted but Seen in Vicinity of Herbaceous Sampling Area:				4 m	
	Sampling Area, Shrubs:	10 @ 1 x 1 m		Stakes Installed:	17	
	Herb Frame Dimensions:	1.0 x 1.0 m				
	Herbaceous Density Data Collected At: NA					
Burn	Duff Moisture (Opt)		N	Flame Depth (Opt)	Y	
Post-burn	100 Pt. Burn Severity (Opt)		N	Herbaceous Fuel Load (Opt)		N
	Herbaceous / Shrub Data (Opt): FMH-15 / 16 / 17 / 18 1 - 50m transect, Q4 - Q1				FMH 15	
FOREST PLOT PROTOCOLS						
Overstory (>15 cm)	Live Tree Damage (Opt)	Y		Live Crown Position (Opt)	Y	
	Dead Tree Damage (Opt)		N	Dead Crown Position (Opt)	Y	
	Record DBH Year-1 (Opt)	Y				
	Sample Area:	50 x 20 m		Quarters Sampled: Q1 ♦ Q2 ♦ Q3 ♦ Q4 ♦ NA		
Pole-size (2.5 - 15)	Height (Opt)	Y		Poles Tagged (Opt)		N
	Record DBH Year-1 (Opt)	Y		Dead Pole Height (Opt)	Y	
	Sample Area:	25 x 10 m		Quarter Sampled: Q1 ♦ Q2 ♦ Q3 ♦ Q4 ♦ NA		
Seedling (< 2.5 cm)	Height (Opt)		Y	Seedlings Mapped (Opt)		N
	Dead Seedlings (Opt)		N	Dead Seedling Height (Opt)		N
	Sample Area:	2.5 x 10.0 m		Quarter Sampled: Q1 ♦ Q2 ♦ Q3 ♦ Q4 ♦ NA		
Fuel Load	Sampling Plane Lengths: 6' 1 hr ♦ 6' 10 hr ♦ 25' 100 hr ♦ 50' 1,000 hr-s ♦ 50' 1,000 hr-r					
Herbs	Cover & Ocular Data Collected at: Q1 - Q4 ▯ Q3 - Q2					
Post-burn	Char Height (Opt)	Y		Poles in Assessment (Opt)		N
	Collect Severity Along: Fuel Transect(s) ♦ Herbaceous Transect(s)					

Table 6. Project Level protocol summary table.

Project Level Monitoring Protocols			
Subject	**Plot Size & Method**	**Attributes (precision)**	**Status**
Trees (5.1 cm+)	Variable Radius (10 BAF)	Tally/spp, Ave. DBH/spp (1")	Live & Dead
Woody Stems (1.37 m tall to 5.0 cm DBH)	5 m (16.4') Fixed Radius Plot	Tally/spp/size class **1**(1.37m – 1.0cm); **2**(1.1-2.5cm); **3** (2.6-5.0)	Live only
Seedlings (0-1.37 m tall)	3.5 m (11.5') Fixed Radius Plot	Tally/spp	Live only
Herbaceous	11.35 m (37.24') Fixed Radius Plot	Presence/Absence	Annual (L/D) Perennials (Live only)
	Fuels		
1000 hour	11.35 m (37.24') Fixed Radius Plot	Diameter & length/log (0.1")	Sound & Rotten
100 hour	25' Brown's Transect	Tally	All
10 & 1 hour	Last 6' Brown's Transect	Tally/size class	All
Litter	At 5, 10, 15, 20 & 24' points of 100 hour line.	Depth (0.1")	NA

Table 7. Howes Prairie protocol summary table.

Howe's Prairie Monitoring Protocols			
Subject	**Plot Size & Method**	**Attributes (precision)**	**Status**
Trees (2.6 cm+)	5.64 m Fixed Radius Plot	Spp, DBH (0.1"), status	Live and Dead
Saplings (1.37 m tall to 2.5 cm DBH) **& Shrubs** (1.37 m tall or larger)	2 -11.28 m Line Intercept Transects (Threshold length 5.0 cm)	Length of cover/spp	Live only
Seedlings (0-1.37 m tall)	1.5 m Fixed Radius Plot	Tally/spp	Live only
Herbaceous (all plant spp)	0.25, 1.0, 4.0 & 8.0 m^2 Nested Frequency Plots	Presence/Absence, Ocular % cover of substrate (4 m^2 plot)	Annual (L/D) Perennials (Live only)
Canopy Openness	Fish-eye photos	NA	NA
	Fuels		
1000 hour	11.35 m (37.24') Fixed Radius Plot	Diameter & length/log (0.1")	Sound & Rotten
100 hour	25' Brown's Transect	Tally	All
10 & 1 hour	Last 6' Brown's Transect	Tally/size class	All
Litter	At 5, 10, 15, 20 & 24' points of 100 hour line.	Depth (0.1")	NA

Table 8. Hobart Prairie Grove protocol summary table.

Hobart Prairie Monitoring Protocols			
Subject	**Plot Size & Method**	**Attributes (precision)**	**Status**
Trees (5.1 cm+)	Variable Radius (10 BAF)	Tally/spp, Ave. DBH/spp (1”)	Live and Dead
Woody Stems (1.37 m tall to 5.0 cm DBH)	5 m (16.4’) Fixed Radius Plot	Tally/spp/size class **1**(1.37m – 1.0cm); **2**(1.1-2.5cm); **3** (2.6-5.0)	Live only
Seedlings (0-1.37 m tall)	3.5 m (11.5’) Fixed Radius Plot	Tally/spp	Live only
Herbaceous (all plant spp)	0.25, 1.0, 4.0 & 8.0 m^2 Circular Nested Frequency Plots	Presence/Absence, Ocular % cover of substrate (8 m^2 plot)	Annual (L/D) Perennials (Live only)
		Fuels	
1000 hour	11.35 m (37.24’) Fixed Radius Plot	Diameter & length/log (0.1”)	Sound & Rotten
100 hour	25’ Brown’s Transect	Tally	All
10 & 1 hour	Last 6’ Brown’s Transect	Tally/size class	All
Litter	At 5, 10, 15, 20 & 24’ points of 100 hour line.	Depth (0.1”)	NA

Appendix D Data Sheet Examples

D-1 FMH Forms

The Following forms are used directly from the FMH handbook (2003):
FMH-5 Plot Location Data Sheet
FMH-7 Forest Plot Data Sheet
FMH-8 Overstory Tagged Tree Data Sheet
FMH-11 Full Plot Tree Map
FMH-12 Quarter Plot Tree Map
FMH-15 50m Transect Data Sheet
FMH-16 30m Transect Data Sheet.

D-2 Modified FMH Data Sheets

FMH-9 Pole Size Tree Data Sheet
FMH-10 Seedling Tree Data Sheet
FMH-17 Shrub Density Data Sheet
FMH-19 Forest Plot Fuels Inventory Data Sheet
FMH-20 Tree Post-burn Assessment Data Sheet
FMH-21 Forest Plot Burn Severity Data Sheet
FMH-22 Brush/Grassland Plot Burn Severity Data Sheet
FMH-23 Photographic Record Data Sheet
INDU FMH Canopy Photo Data Sheet
INDU FMH Shrub/Herb Ocular Cover Class & Density Data Sheet
INDU FMH Shrub/Herb Ocular Percent Cover & Density Data Sheet
INDU FMH Tall Shrub Data Sheet
INDU FMH Vines Data Sheet

D-3 Project Level Data Sheets

INDU 1, 10 & 100 Hour Fuels Data Sheet
INDU 1000 Hour Fuel Data Sheet
INDU Overstory Basal Density Data Sheet
INDU Herbaceous Indicator Species Data Sheet
INDU Plot Location Data Sheet
INDU Seedlings and Large Woody Stems Data Sheet

D-4 Howes Prairie/Lupine Lane Data Sheets

HP_LL Canopy Photo Data Sheet
HP_LL Nested Frequency Data Sheet
HP_LL Sapling/Shrub Layer Line Intercept Data Sheet
HP_LL Seedling Tally Data Sheet
HP_LL Tree Data Sheet

D-5 Hobart Prairie Grove Data Sheets

HPG Nested Frequency Data Sheet

D-6 Post Burn Summary Form

(for spacing and size the font used was Verdana 10)

INDIANA DUNES NATIONAL LAKESHORE

Name of Prescribed Fire

Prescribed Fire
Month Day, Year

Summary

Location of burn. Size in acres. Descriptions of the boundaries . General description. Fuel models and amounts if available or estimations. Other info such as units. Main goal(s) of burn. Anything out of the ordinary. Numbers and names of fire effects monitors.

History

Prescribed burn history. Boundary changes. Any other specific historical information.

Burn Goals and Objectives

1.
2.
3.
4.
5.
6.
7.

Prescribed Burn Ignition Patterns (see attached maps)

Place and time of test burn. Ignition patterns. Type of lighting devices. Interior lighting? Strip lighting how far in and how many people. Time ignition complete. Was ignition done as what plan calls for? Anything unusual or specific.

Holding and Mop up

Resources and equipment. General holding actions. Critical holding areas. Spots or slop-overs. Mop up procedures and when complete.

Smoke Issues

How was smoke rising and dispersing. Was it moving differently on the ground vs. transport winds. Were the winds the same as what the forecasts called for. Road visibility? Any smoke reports from people on burn. Any smoke issues from the communities. Was ignition changed for smoke reasons?

Political Issues

Any complaints/calls concerning burn. Any problem with local fire departments? Any Unusual or special concerns for this burn?

Fire Effects Vegetation and Fire Monitoring

Pre-burn Fire Monitoring
History of FMH plots. Veg. Types. Fuel sampling done? Fuel moisture reading before burn? Remote weather station or HOBO?

Fire Monitoring-Weather
When spot weather was taken. How often weather obs. were taken and broadcast. General weather summation and anything unusual which might have affected the weather. Was weather what forecasts called for.

Observation Time	Location of Observation	Wind Speed (mph)	Wind Direction	Dry Bulb (F)	Relative Humidity (%)
10:45	mid-slope S facing slope	2	NW	43	56
11:20	dune ridge	5	NW	--	--
11:50	dune ridge	3-4	NW	41	61
12:40	flat area near point K	5	W	41	61

Fire Monitoring-Fire Behavior
Fire behavior including forward and backing rates of spread, flame zone depth, and flame length were monitored during the burn. Fire observations were taken …______. In general …..______.

Observation Time	Fuel Type	Fire Type B/H/F	Rate of Spread (Ch/hr)	Flame Length	Flame Zone Depth
11:00	leaf litter	B	0.8	0.25-0.5’	0.25’
11:35	leaf litter	B	0.9	1’	1’
11:35	leaf litter	H	5.5	1-2’	2-3’
11:35	leaf litter	H	5.0	2-3’	2-3’
12:10	grass	H	9.9	1-2’	2’
12:15	shrubs	H	--	4-5’	5-6’
	grass	H	16.4	3-4’	3-5’
Unit 5	sparse grass	H	--	1-3’	1’

Fire Monitoring-Smoke Observations
Observations , times , places

Post-fire Effects Monitoring
Any procedures. Description of FMH post burn conclusions.

Conclusions

General observations. Any problems or success. Discuss if objectives were accomplished or not if possible, do not make assumptions.