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Logic-Based Approach to Evaluating Plant Communities at Effigy Mounds National Monument, Iowa

Natural Resource Report NPS/HTLN/NRR—2010/181

ON THE COVER
Herbert Hoover birthplace cottage at Herbert Hoover NHS, prescribed fire at Tallgrass Prairie NPres, aquatic invertebrate monitoring at George Washington Carver NM, the Mississippi River at Effigy Mounds NM.

Logic-Based Approach to Evaluating Plant Communities at Effigy Mounds National Monument, Iowa

Natural Resource Report NPS/HTLN/NRR—2010/181

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Abstract

We present a logic model-based framework to evaluate the condition of multiple plant communities at Effigy Mounds National Monument, Iowa. The logical framework for the analysis was based on plant community metrics collected as part of Heartland Inventory and Monitoring Network vegetation monitoring program. Monitoring site data were integrated with spatial data from both the USGS-NPS vegetation mapping project and NPS Natural Resource Condition Assessment conducted at the park. A new study area was developed that extended the area of inference from site based data to polygons on the landscape. The study area included all parts of the main unit of the park that corresponded to a particular community type for which monitoring data were available. Community indicators were logically related in a hierarchical framework according to informative attributes for each community. Monitoring data collected between 1998 and 2005 were used to develop reference conditions for each indicator. Monitoring data collected since 2005 served as input data for the evaluation. The logic model was executed in EMDS, a decision support system framework that operates within ArcGIS. Each element of the logic model was evaluated and scores were reported at the patch scale. Evaluation results are presented as a series of maps for all attributes of a community and as an overall evaluation of all community resources for the main unit of the park. Community and attribute improvement as measured against the initial monitoring period are presented at the study area scale. The logic model can be readily adapted to address management objectives or additional information. This work forms the foundation for conducting adaptive management within a decision support system.

Acknowledgments

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Introduction

Hardwood forest and prairie communities have been altered over centuries by different land use requirements (Knopf and Samson 1997; Johnson et el. 2002; McShea and Healy 2002). For many National Park Service (NPS) units, communities in altered conditions existed prior to NPS status. For some parks, it is the very change in the landscape that warranted NPS designation, as is the case for Effigy Mounds National Monument, Iowa (EFMO). The park represents nearly 2000 years of mound building activity and associated human presence in the driftless area of northeastern Iowa along the Mississippi River. Beyond native uses, European settlement brought farming and extensive logging in the decades before the park's inception in 1949 (O'Bright 1989). The plant communities of the Paleozoic Plateau were replaced by agricultural practices and modified by logging, with only those areas unfit or inaccessible remaining in their more natural condition. However, fire management practices on federal land continued to alter and shape communities by disrupting the natural disturbance regime. For portions of those communities at EFMO that avoided plow and axe, their condition was altered through fire management (O'Bright 1989; Grabner et al. 2000).

To successfully manage natural resources two questions should be addressed: 1) what is the current condition of the resource to be managed and 2) what is the overall condition to achieve through managed actions? In 2003, with congressional approval and funding, the Natural Resource Condition Assessment (NRCA) program was established by the Water Resource Division of the NPS Natural Resource Program. Specifically the program is "a spatially explicit multi-disciplinary synthesis of existing scientific data and knowledge, from multiple sources, to help answer the question: what are the current conditions for important park natural resources?" (NRCA internal guidance 2009). Furthermore, NRCA outcomes are to be used to aid parks in developing condition-based management.

This project does not include any new field data collection but rather uses existing data sets. Primary input for this work is from the USGS-NPS vegetation mapping project for EFMO (Hop et al. 2005), Heartland Inventory and Monitoring Network (HTLN) vegetation community monitoring project (DeBacker et al. 2004) and the 2008 natural resource condition assessment for EFMO (unpublished report). Here the focus is on expanding the utility of site-based vegetation data to spatially address community attributes.

This work integrates spatial and vegetation community monitoring data into a decision support system for evaluating the current condition of select plant communities at EFMO. We undertook this study with three primary objectives:

1) Integrate descriptive data from the vegetation map and NRCA with vegetation community monitoring data.

2) Integrate HTLN vegetation community monitoring with the vegetation map to create an expanded reference frame.

3) Use the integrated data and spatial products to analyze the current condition of select plant communities using a logic-based approach.

The decision support system (DSS) consists of a logic model with a spatial evaluation and map-based output. We evaluate five upland plant communities, three forested and two prairies, in the main unit of the park. For each community (resource) in the logic model, we evaluate the degree to which the condition is acceptable. In the logic model for forested resources, we evaluate the resource condition using four attributes: overstory structure, overstory composition, oak regeneration and understory structure. In the logic model for prairie resources, we evaluate the resource condition using three attributes: native species diversity, species composition and prairie structure. Each attribute has one or more indicators for which data are evaluated. The logic model shows the condition of each evaluated resource relative to an acceptable condition range. The logic model and analysis are run using the EMDS (Reynolds et al. 2003) extension to ArcGIS.

Ecosystem Management Decision Support (EMDS) has been used in a number of different ways to address issues in environmental assessment and adaptive management (Reynolds 2006). In addition to its utility as a modeling framework (Reynolds 1999) some other applications include departure analysis of forest structure from reference conditions (Reynolds and Hessburg 2005); evaluate fire danger and prioritize fuel treatments (Hessburg et al 2007); conduct watershed condition assessment (Jensen et al 2000); analysis and communication of monitoring data (Reynolds and Reeves 2003); landscape departure analysis (Gartner et al 2008); address suitability of conservation areas (Hope et al 2008); and environmental impact of road systems (Girvetz and Shilling 2003). Its use here as a logic-model framework for evaluating community condition is a basic application of EMDS and the first step toward performing adaptive management in EMDS.

We show that point data collected from fixed vegetation monitoring sites can be used with spatial vegetation community data to create a larger reference frame. The reference frame is the area to which site data can be inferred, or considered to be representative of the study area. For the study area, we construct a logical hierarchy of monitoring metrics that address characteristics at the community scale within the park. We demonstrate the use of this integrated system in a logic-model for the main unit of EFMO, focusing on 297 patches delineated by community type.

Methods

Study Area

Effigy Mounds National Monument is located in northeast Iowa along the Mississippi River and contains hardwood and riparian forests and prairies (Fig. 1). Long term HTLN vegetation community monitoring began at EFMO in 1997 and currently consists of 29 sites in three different community types (Fig. 2). The main unit of the park that contains HTLN vegetation monitoring sites was selected as the study area for this modeling approach. The original HTLN reference frame was developed according to DeBacker et al (2004).

Figure 1. Parks in the Heartland Inventory and Monitoring Network with Effigy Mounds National Monument, Iowa indicated with red box.

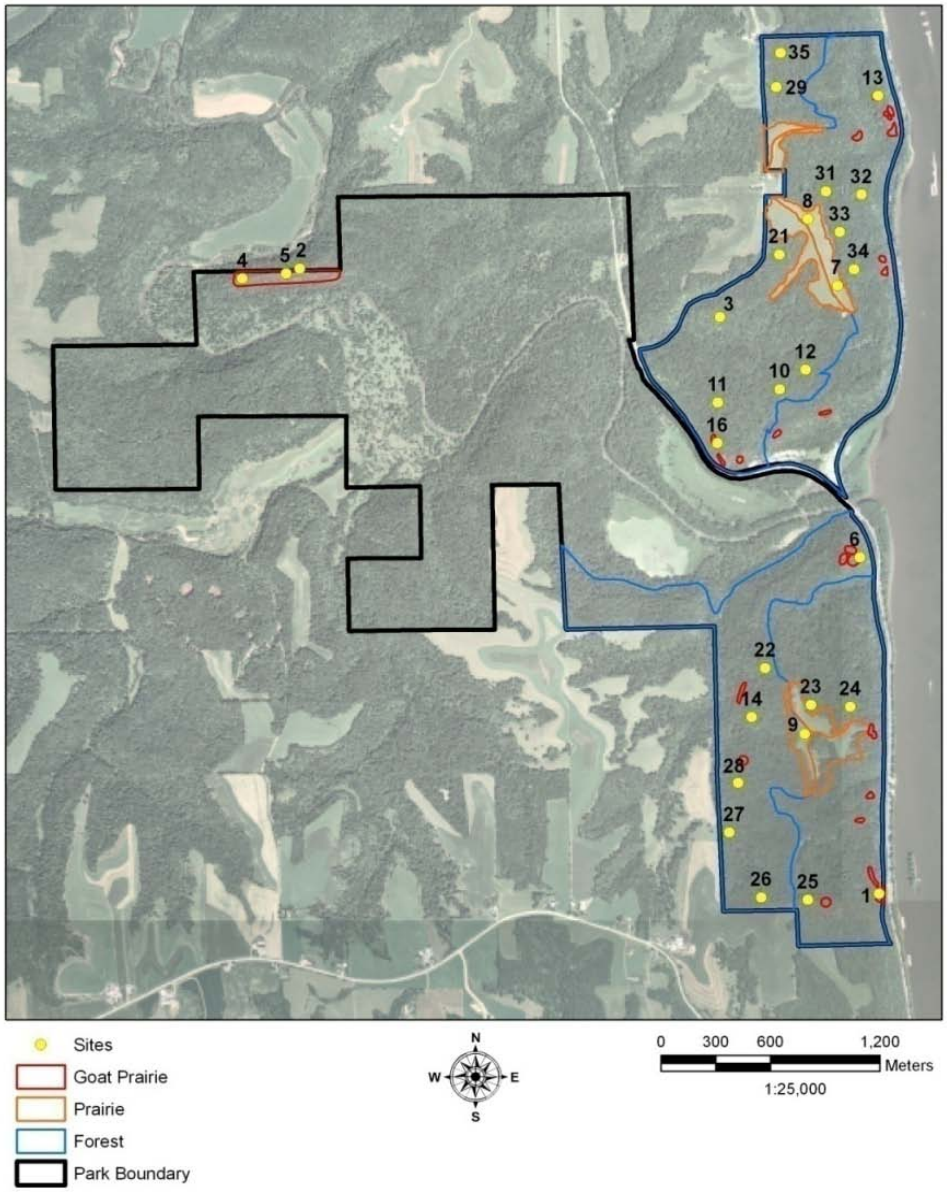

Figure 2. Heartland Inventory and Monitoring Network vegetation monitoring sites (n=29) and their associated community reference frame for Effigy Mounds National Monument, Iowa.

For this logic model-based approach, the reference frame for each HTLN vegetation monitoring site was expanded throughout the upland areas of the main park unit (1022 ha). An initial set of 451 patches in the main park unit form the foundation from which the study area is defined (Fig. 3). The study area represents the most current spatial delineation of upland community types for the main unit of the park. This work is focused on changes in the current condition of select upland communities at both the patch and landscape scale. The logic model is run independently for each patch in the study area and results are mapped individually and displayed by community type.

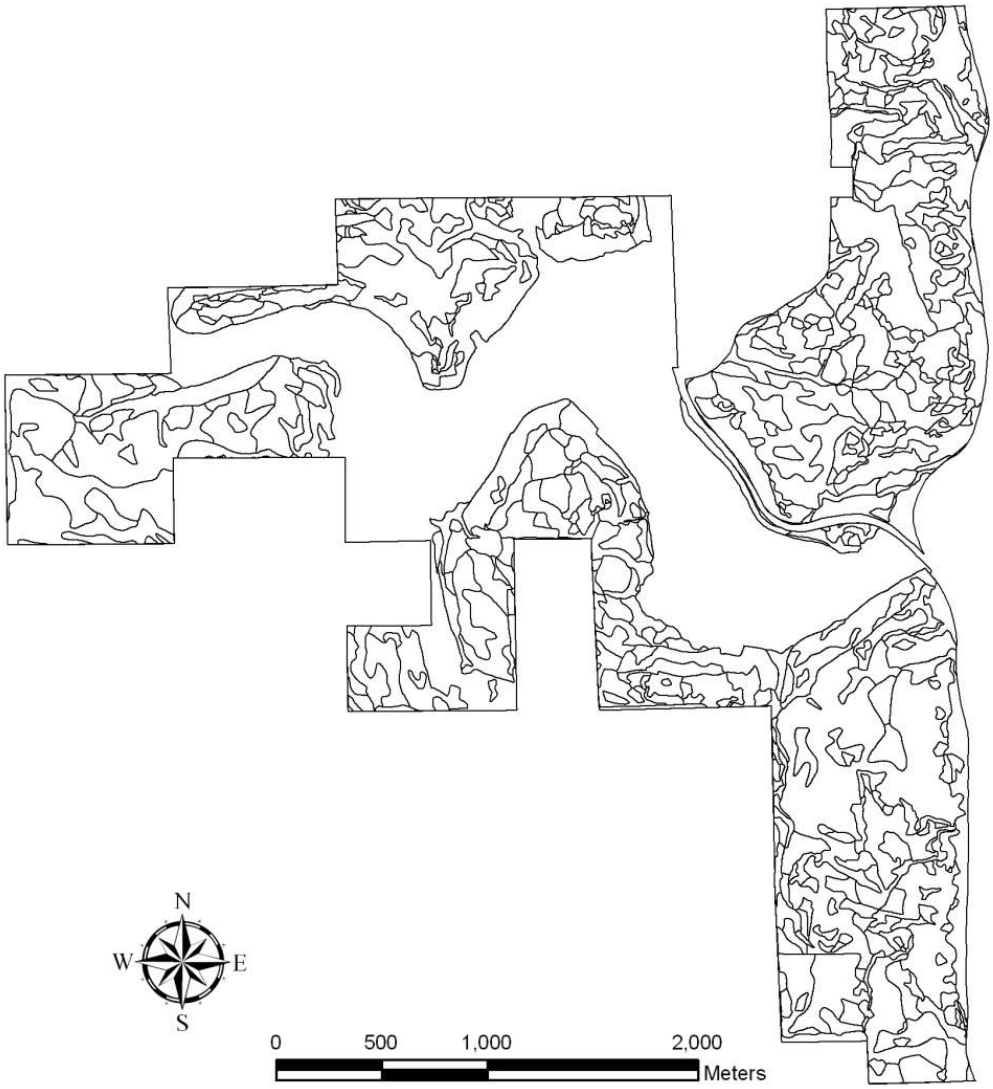

Figure 3. Patches in the study area of Effigy Mounds National Monument, Iowa (n=451). Minimum patch size is 0.1 ha.

The study area was refined by identifying those patches that contained a vegetation monitoring site and then comparing the current community against the reference community type. Plant community descriptions follow the United States National Vegetation Classification System (NVCS) hierarchy (Grossman et al. 1998). Current community type refers to the 2005 vegetation map (Fig. 4). Reference community refers to the 2008 NRCA (Fig. 5).

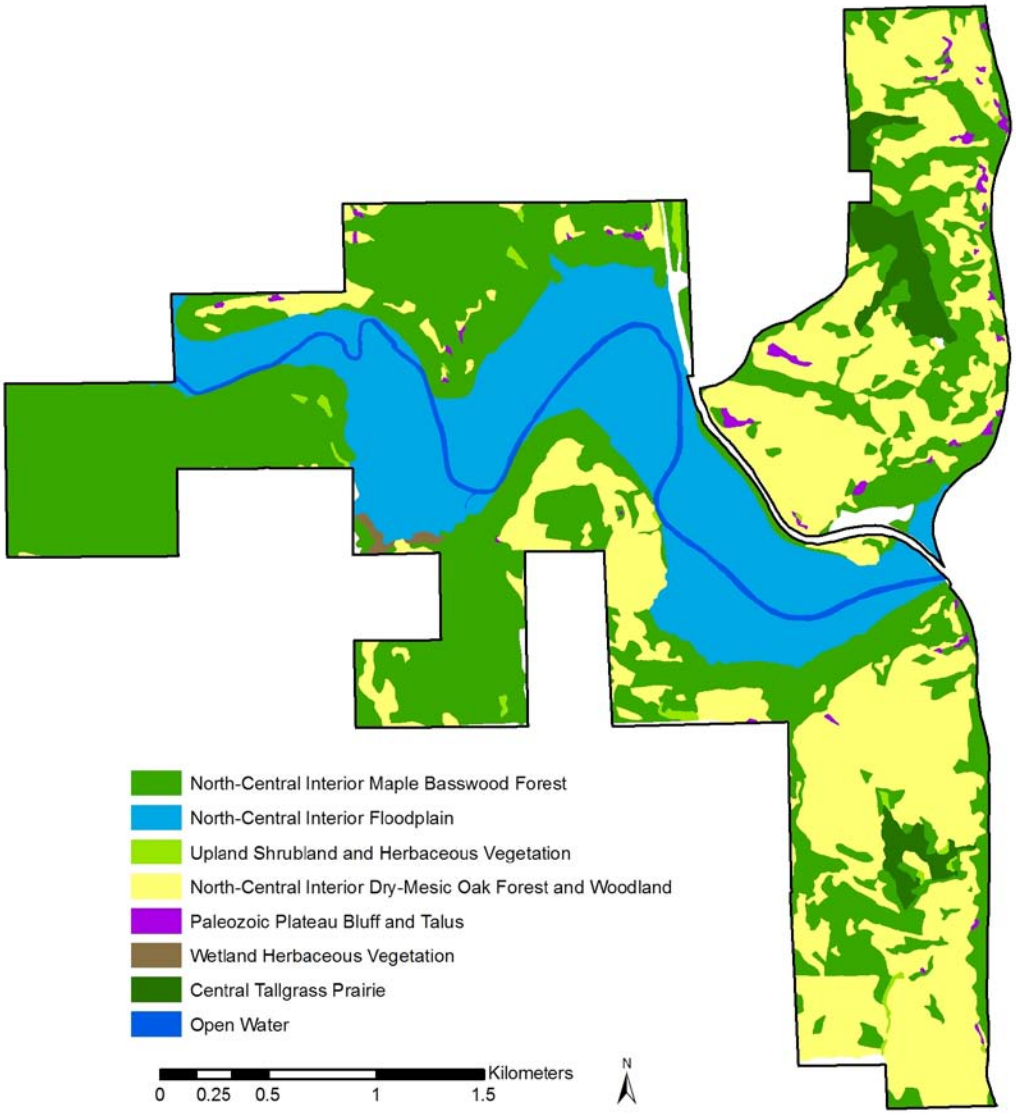

Figure 4. Current condition community types as identified in the vegetation map for Effigy Mounds National Monument, Iowa.

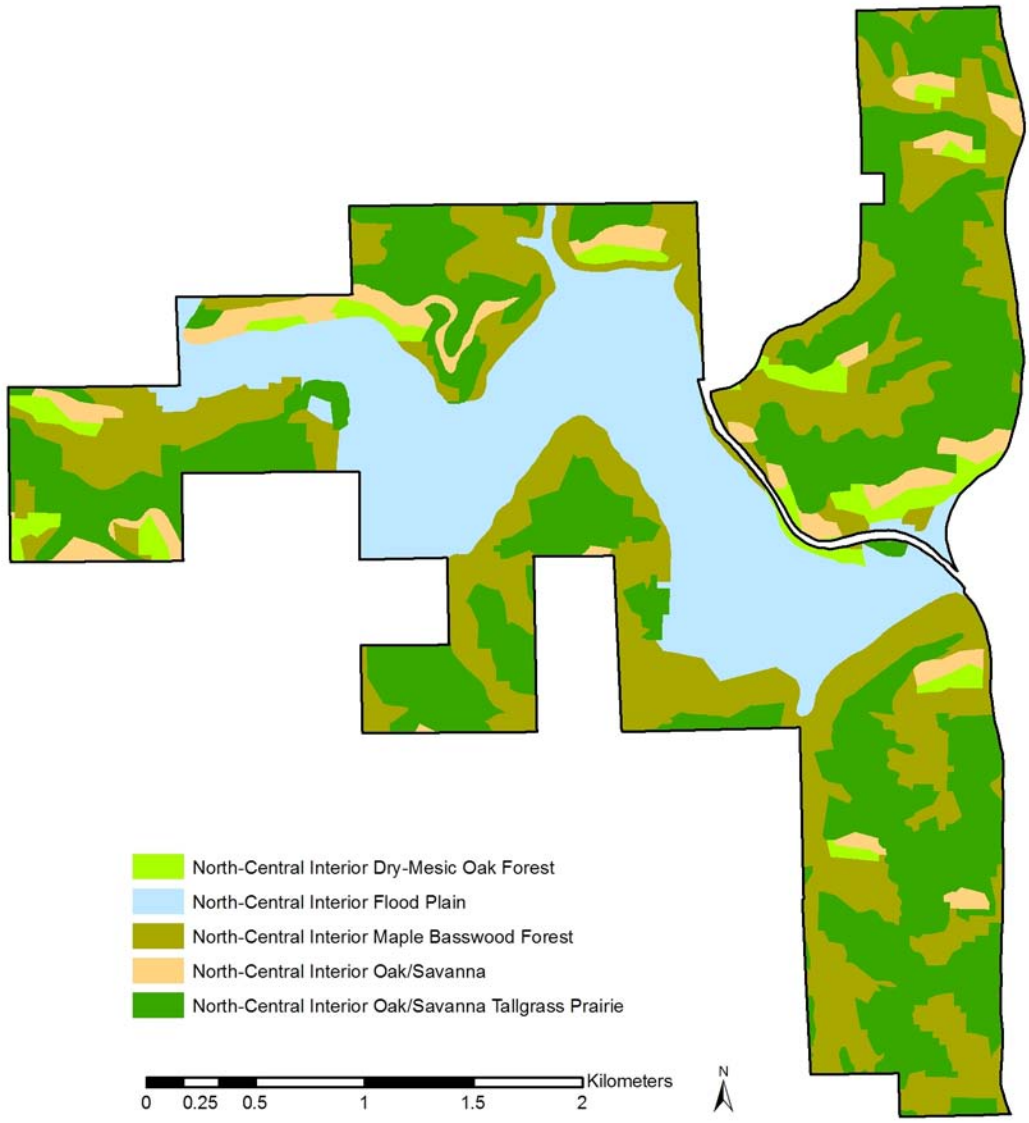

Figure 5. Reference community types as identified in the Natural Resource Condition Assessment for Effigy Mounds National Monument, Iowa.

As part of the vegetation map, high quality and disturbed community type phases were described and mapped at the patch scale according to the classification hierarchy. Here high quality phases correspond to the reference type while disturbed phases represent a departure of the current type from the condition assessment. Plant communities in the study area represent associations, phases or formation levels in the NVCS classification hierarchy (Table 1). Classification level and community type were determined by the patches that contain vegetation monitoring sites and have been identified as communities of interest by the park and HTLN.

Table 1. Plant community codes, labels and related NVCS association used in the study. See Hop et al. (2005) for a complete description of the community types.

Code	Resource	NVCS classification
DO	Dry Oak	High quality phase of Dry-Mesic Oak Woodland and Forest
WO-CO	White Oak-Chinquapin Oak	High quality phase of Dry-Mesic Oak Woodland and Forest
MB	Maple-Basswood	Disturbed phases of Maple-Basswood Forest
CTP	Central Tallgrass Prairie	Central Tallgrass Prairie
RGP	Remnant Goat Prairie	Formation of Upland Shrubland and Herbaceous Vegetation

The 29 monitoring sites occurred in five community types identified by the vegetation map. All patches of the phase or formation for a community type were selected in the study area for analysis (Fig. 6).The refined study area is composed of 297 patches that total 577 ha (Table 2).

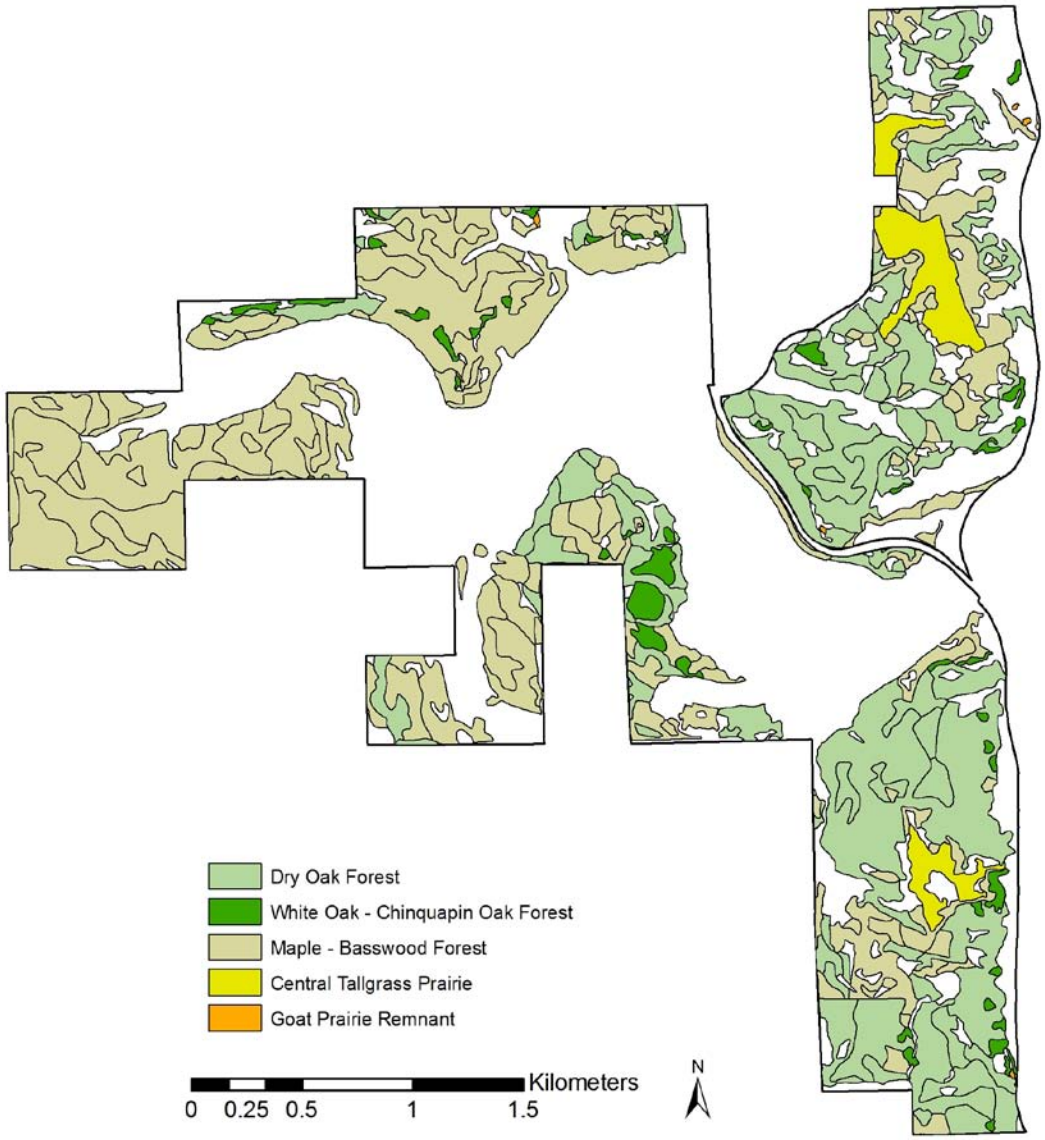

Figure 6. Vegetation patches in the study area of Effigy Mounds National Monument, Iowa (n=297). Minimum patch size is 0.1 ha.

Table 2. Patch characteristics by resource type for the study area.

Resource	patch count	total area (ha)	mean patch size (SD)
Dry oak forest	86	236.2	2.8 (5.5)
White oak - Chinquapin oak	47	18.7	0.4 (0.4)
Maple - Basswood forest	155	297	1.9 (3.3)
Central Tallgrass Prairie	3	24.9	8.3 (5.4)
Remnant Goat Prairie	6	0.6	0.1 (0)

Data Sources

For each community type, a set of attributes and indicators was identified. Indicators refer to those characteristics of the community that are derived from vegetation monitoring data collected at the site scale and inferred to the study area (e.g. density of trees in size class 5). Attributes are those aspects of a community that combine one or more indicators (e.g. overstory structure) and address higher order community characteristics. For each indicator, a reference condition was assigned based on monitoring data collected between 1998 and 2005. Data up through 2005 were used to correspond to the community designations in the 2005 vegetation map. Here reference condition is the range of values that represent a lower and upper limit of measurements for a single indicator and applied to all patches of a community type. Reference condition ranges are indicator and community type specific.

The vegetation map is used to establish the spatial extent of the current plant community types. Thematic and community description accuracy assessments are an important component of the NPS Inventory and Monitoring Vegetation Mapping Project (NPS). Accuracy assessment entails validation and verification of map classes based on field sample data. Therefore mapped community classes on the vegetation map have been verified to meet accuracy standards. The spatial extent, community designation and accompanying description presented in the vegetation map provide all of the necessary components to cross walk HTLN point data to the spatial extent of the community.

Network data collected after 2005 serves as input data to assess the degree to which the current condition is acceptable for each indicator at the patch scale. Input data for those patches that contain an HTLN site comes directly from the monitoring data collected at that site. However for the majority of patches, the input data is the mean current indicator value as calculated from all monitoring sites within the community type for that indicator. Two assumptions are made to infer from site level data to individual patches at the park scale. The first assumption is that the range of variability captured for any variable across multiple sites and sampling times represents the range of variability of all similar areas on the park that have experienced a similar set of conditions (topo-edaphic, weather and/or management). The second assumption is that those similarities continue to hold through time, such that a mean value derived from all sites is a conservative estimate of input values for those patches whose condition is being inferred from site level data. Attributes and indicators are similar among forest and prairie types. The indicators refer to vegetation monitoring data collected according to HTLN protocol (see James et al. 2009). Forest community overstory attributes of structure and oak species regeneration are based on concepts of forest stand structure classes (Oliver and Larson 1996) and incorporate forest cover type from both the NVCS description of each forest type and the overstory compositional measure of relative basal area (Eyre 1980).

Reference condition for forested communities is a combination of overstory (OS) structure, oak recruitment (Oak regen) and understory (US) structure. Overstory structure is evaluated for all tree species by diameter at breast height (dbh) size class (SC, Table 3). Basal area (BA) is calculated as m^2/ha for each size class. Density is the number of stems per hectare. Overstory volume (OS volume) and overstory density (OS density) are calculated for all three forested community types. Overstory composition is calculated for dry oak and maple-basswood community types only. It is evaluated based on the basal area of each species relative to the total basal area per hectare. The dry oak resources in the study area are all considered to be high

quality phases while maple-basswood resources are disturbed phase types for their respective mapped NVCS association. The selected species reflect the dominant species in both phases for their respective community types.

Table 3. Diameter at breast height (dbh, cm) size class ranges for overstory trees.

Size Class	dbh (cm)
1	5 - 14.9
2	15 - 24.9
3	25 - 34.9
4	35 - 44.9
5	45+

Oak regeneration is summarized for all oak species seedlings and size class 1 stems. Here the focus is on the total amount of oak regeneration and recruitment rather than individual oak species. Furthermore, assessing oak regeneration across all upland forested areas of the park is of importance to the park, and therefore this attribute is not limited to only oak dominated resources.

Forest understory structure and prairie structure are based on foliar cover of guild types within the community. Selected guild types and their associated measures of abundance provide insight into community dynamics such as native woody species recruitment or invasive species encroachment.

Prairie diversity reflects the community's species richness along with their abundance as measured by foliar cover. Here two common measures of species diversity have been rescaled in order to aid interpretation alongside species richness counts. Both Shannon diversity index and Simpson's index have been converted to report diversity as the number of species the community would have if all species occurred in equal abundance (see Jost 2006 and James et al 2009 for background and implementation, respectively). Low diversity counts relative to species richness reflect dominance of a few species while high species counts indicate that most species occur in near equal abundance. Here species diversity measures are calculated for only native species.

Non-native or invasive species do not contribute to the natural or referenced community diversity. However, they do detract from the community and are considered as part of the overall species composition assessment. Historically and ideally, the number of exotic species would be zero, thus resulting in pre-European community composition and diversity levels. Here the focus is on native species richness and how evenly they are dispersed within the community while considering presence of exotic species.

Indicators based on HTLN monitoring metrics provide the foundation for continued re-assessment of the current condition as well as refinement of the reference condition such that the most up-to-date information is included in the logic model.

Broad Outline

The condition of a subset of plant communities is evaluated in the main unit of the park. We show how plant community characteristics can be evaluated for a range of conditions using a logic model-based approach in a decision support system. Model evaluation scores are used to

determine community condition. For individual patch evaluations, the degree to which an indicator meets or exceeds a value is scored. Resource improvement of a single community or at the park scale is inferred when more than 50% of the evaluation scores exceed 0.5.

Implementation Steps

Spatial assessment and quantitative monitoring data were used to extend the area of inference from HTLN vegetation monitoring sites to plant communities at the park scale. Reference conditions were defined for measurable characteristics of each of the five community types derived from HTLN monitoring data and applied to the patches of the current vegetation condition as identified in the vegetation map. A logic model was constructed within the EMDS modeling system to demonstrate how all indicators contribute to the overall evaluation of the community type and study area. Each patch within a community was evaluated for evidence of being within the reference condition for the resource type. Fundamental resources of the logic model represent the community type, which are composed of attributes and indicators with the latter being the lowest level in the model for which data are evaluated. A logic outline for each resource in the study area is presented in Tables 4 – 8.

Table 4. Logic outline and reference conditions for dry oak community type (DO resource).

Resource	Attribute	Indicator	Indicator-2	Proposition	Reference
DO				Dry oak type is in acceptable condition	
(union)	Canopy cover			Forest canopy cover is acceptable	≥ 60
	OS Structure			Overstory structure is acceptable	
	(union)	OS volume		Overstory volume of all tree species is acceptable	
		(+)	SC 2 BA	Basal area of all tree species in size class 2 is acceptable	.90 - 1.21
			SC 3 BA	Basal area of all tree species in size class 3 is acceptable	1.25 - 2.48 - 7.02 - 9.5
			SC 4 BA	Basal area of all tree species in size class 4 is acceptable	3.54 - 11.56
			SC 5 BA	Basal area of all tree species in size class 5 is acceptable	2.33 - 27.52
		OS density		Overstory density of all tree species is acceptable	
		(+)	SC 2 density	Density of all tree species in size class 2 is acceptable	27 - 40 - 145 - 173
			SC 3 density	Density of all tree species in size class 3 is acceptable	17 - 33 - 100 - 146
			SC 4 density	Density of all tree species in size class 4 is acceptable	27 - 93
			SC 5 density	Density of all tree species in size class 5 is acceptable	10 - 110
		OS composition			
		(+)	AcerSacc	Relative basal area of *Acer saccharum* is acceptable	.01 - .46
			TiliAmer	Relative basal area of *Tilia americana* is acceptable	.002 - .43
			Carya spp	Relative basal area of Carya species is acceptable	.001 - .20
			QuerAlba	Relative basal area of *Quercus alba* is acceptable	.001 - .61
			QuerRubr	Relative basal area of *Quercus rubra* is acceptable	.114 - .71
			QuerMacr	Relative basal area of *Quercus macrocarpa* is acceptable	.51 - .55
	Oak regeneration			Oak regeneration is acceptable	
	(union)	Oak seedling RD		Relative density of oak seedlings is acceptable	.001 - .111
		Oak SC 1 RD		Relative density of oak trees in size class 1 is acceptable	.001 - .514
	US structure			Understory guild representation is acceptable	
	(union)				
		native grass		Foliar cover of native grass is acceptable	.05 - 3.3
		native forbs		Foliar cover of native forbs is acceptable	4.7 - 55.9
		native grass-like		Foliar cover of native grass-like species is acceptable	.05 - 17.5
		fern		Foliar cover of fern species is acceptable	.05 - 3.1
		native woody		Foliar cover of native woody species is acceptable	12.4 - .4
		non-native		Foliar cover of non-native species is acceptable	7.2 - .1

Table 5. Logic outline and reference conditions for white oak-chinquapin oak community type (WO-CO resource).

Resource	Attribute	Indicator	Indicator-2	Proposition	Reference
WO-CO				White oak-Chinquapin oak type is in acceptable condition	
(union)	Canopy cover			Forest canopy cover is acceptable	≥ 25
	OS Structure			Overstory structure is acceptable	
	(union)	OS volume		Overstory volume of all tree species is acceptable	
		(+)	SC 2 BA	Basal area of all tree species in size class 2 is acceptable	1.47 - 1.89 - 5.25 - 6.64
			SC 3 BA	Basal area of all tree species in size class 3 is acceptable	3.37 - 5.44 - 8.71 - 11.63
			SC 4 BA	Basal area of all tree species in size class 4 is acceptable	1.26 - 13.37
			SC 5 BA	Basal area of all tree species in size class 5 is acceptable	1 - 16.79
		OS density		Overstory density of all tree species is acceptable	
		(+)	SC 2 density	Density of all tree species in size class 2 is acceptable	41 - 65 - 165 - 228
			SC 3 density	Density of all tree species in size class 3 is acceptable	50 - 80 - 128 - 159
			SC 4 density	Density of all tree species in size class 4 is acceptable	11 - 109
			SC 5 density	Density of all tree species in size class 5 is acceptable	1.0 - 89
	Oak regeneration			Oak regeneration is acceptable	
	(union)	Oak seedling RD		Relative density of oak seedlings is acceptable	.001 - .442
		Oak SC 1 RD		Relative density of oak trees in size class 1 is acceptable	.001 - .469
	Diversity			Understory native species diversity is acceptable	
	(union)	Shannon diversity		Shannon number of native species is acceptable	29.3 - 52.1
		Simpson diversity		Simpson number of native species is acceptable	15.4 - 29.9
	Composition			Species composition is acceptable	
	(union)	evenness		Native evenness is acceptable	.787 - .925
		native species		Number of native species is acceptable	56 - 79
		exotic species		Number of exotic species is acceptable	9.0 - 2.0
	Structure			Understory guild representation is acceptable	
	(union)	native grass		Foliar cover of native grass is acceptable	.5 - 8
		native forbs		Foliar cover of native forbs is acceptable	3.2 - 19.7
		native grass-like		Foliar cover of native grass-like species is acceptable	.3 - 7.8
		fern		Foliar cover of fern species is acceptable	.05 - .3
		native woody		Foliar cover of native woody species is acceptable	6.2 - 0.2
		non-native		Foliar cover of non-native species is acceptable	4.6 - 0.1

Table 6. Logic outline and reference conditions for maple-basswood community type (MB resource).

Resource	Attribute	Indicator	Indicator-2	Proposition	Reference
MB				Maple-Basswood forest type is in acceptable condition	
(union)	Canopy cover			Forest canopy cover is acceptable	≥ 60
	OS Structure			Overstory structure is acceptable	
	(union)	OS volume		Overstory volume of all tree species is acceptable	
		(+)	SC 2 BA	Basal area of all tree species in size class 2 is acceptable	3.34 - 4.08 - 6.55 - 7.23
			SC 3 BA	Basal area of all tree species in size class 3 is acceptable	6.81 - 6.91 - 9.29 - 9.85
			SC 4 BA	Basal area of all tree species in size class 4 is acceptable	4.57 - 11.09
			SC 5 BA	Basal area of all tree species in size class 5 is acceptable	.001 - 5.19
		OS density		Overstory density of all tree species is acceptable	
		(+)	SC 2 density	Density of all tree species in size class 2 is acceptable	100 - 145 - 205 - 220
			SC 3 density	Density of all tree species in size class 3 is acceptable	100 - 120 - 140 - 150
			SC 4 density	Density of all tree species in size class 4 is acceptable	40 - 90
			SC 5 density	Density of all tree species in size class 5 is acceptable	1.0 - 20.0
		OS composition			
		(+)	AcerSacc	Relative basal area of *Acer saccharum* is acceptable	.005 - .042
			TiliAmer	Relative basal area of *Tilia americana* is acceptable	.018 - .137
			Carya spp	Relative basal area of Carya species is acceptable	.113 - .379
			QuerAlba	Relative basal area of *Quercus alba* is acceptable	.001 - .123
			QuerRubr	Relative basal area of *Quercus rubra* is acceptable	.022 - .078
	Oak regeneration			Oak regeneration is acceptable	
	(union)	Oak seedling RD		Relative density of oak seedlings is acceptable	.001 - .012
		Oak SC 1 RD		Relative density of oak trees in size class 1 is acceptable	.001 - .057
	US structure			Understory guild representation is acceptable	
	(union)				
		native forbs		Foliar cover of native forbs is acceptable	8.2 - 15
		native grass-like		Foliar cover of native grass-like species is acceptable	.1 - 1.5
		fern		Foliar cover of fern species is acceptable	.5 - 6
		native woody		Foliar cover of native woody species is acceptable	7 - 3.2
		non-native		Foliar cover of non-native species is acceptable	.6 - .1

Table 7. Logic outline and reference conditions for central tallgrass prairie community type (CTP resource).

Resource	Attribute	Indicator	Proposition	Reference
CTP			Central tallgrass prairie type is in acceptable condition	
(union)	Diversity		Understory native species diversity is acceptable	
	(union)	Shannon diversity	Shannon number of native species is acceptable	8.1 - 27.6
		Simpson diversity	Simpson number of native species is acceptable	3.5 - 11.1
	Composition		Species composition is acceptable	
	(union)	evenness	Native evenness is acceptable	.564 - .764
		native species	Number of native species is acceptable	36 - 77
		exotic species	Number of exotic species is acceptable	10.0 - 4.0
	Structure		Understory guild representation is acceptable	
	(union)	native grass	Foliar cover of native grass is acceptable	21.4 - 85.7
		native forbs	Foliar cover of native forbs is acceptable	20.2 - 72.7
		native grass-like	Foliar cover of native grass-like species is acceptable	.1 - 2.7
		native woody	Foliar cover of native woody species is acceptable	15.8 - 3.5
		non-native	Foliar cover of non-native species is acceptable	20.9 - 1

Table 8. Logic outline and reference conditions for remnant goat prairie community type (RGP resource).

Resource	Attribute	Indicator	Proposition	Reference
RGP			Remnant goat prairie type is in acceptable condition	
(union)	Diversity		Understory native species diversity is acceptable	
	(union)	Shannon diversity	Shannon number of native species is acceptable	32.8 - 47.1
		Simpson diversity	Simpson number of native species is acceptable	11.1 - 23.2
	Composition		Species composition is acceptable	
	(union)	evenness	Native evenness is acceptable	.784 - .83
		native species	Number of native species is acceptable	84 - 104
		exotic species	Number of exotic species is acceptable	7.0 - 4.0
	Structure		Understory guild representation is acceptable	
	(union)	native grass	Foliar cover of native grass is acceptable	7 - 17.8
		native forbs	Foliar cover of native forbs is acceptable	14 - 36.3
		native grass-like	Foliar cover of native grass-like species is acceptable	.6 - 6.6
		fern	Foliar cover of fern species is acceptable	4.4 - 9
		native woody	Foliar cover of native woody species is acceptable	8.5 - 6.6
		non-native	Foliar cover of non-native species is acceptable	4.6 - 1.1

Attribute and indicator selection was restricted to those variables or metrics that could be summarized from HTLN vegetation monitoring data. Forest attributes were chosen that reflect aspects of forest stand structure and development. Emphasis is placed on oak regeneration for each forested resource. Oak regeneration is a management concern at the park and its inclusion as an attribute of each forest resource provides park-wide information about the degree of oak regeneration and recruitment that occurs. Canopy cover is used simply to make a distinction between woodland/forests and savannah/prairie resources; this is reflected in the reference threshold rather than reference range. Prairie/understory attributes and indicators compare native species against exotic species in terms of composition and abundance (as measured by foliar cover).

Logic Model Design

The logic model for evaluating the study area and its associated resources was graphically designed with NetWeaver Developer (Rules of Thumb, Inc., North East, PA). A representation of the top levels of the logic model is presented to illustrate the relationship among resources and attributes within resource type (Fig. 7). Below the attribute level are indicators (see Table 4 - 8 for indicators by resource attribute).

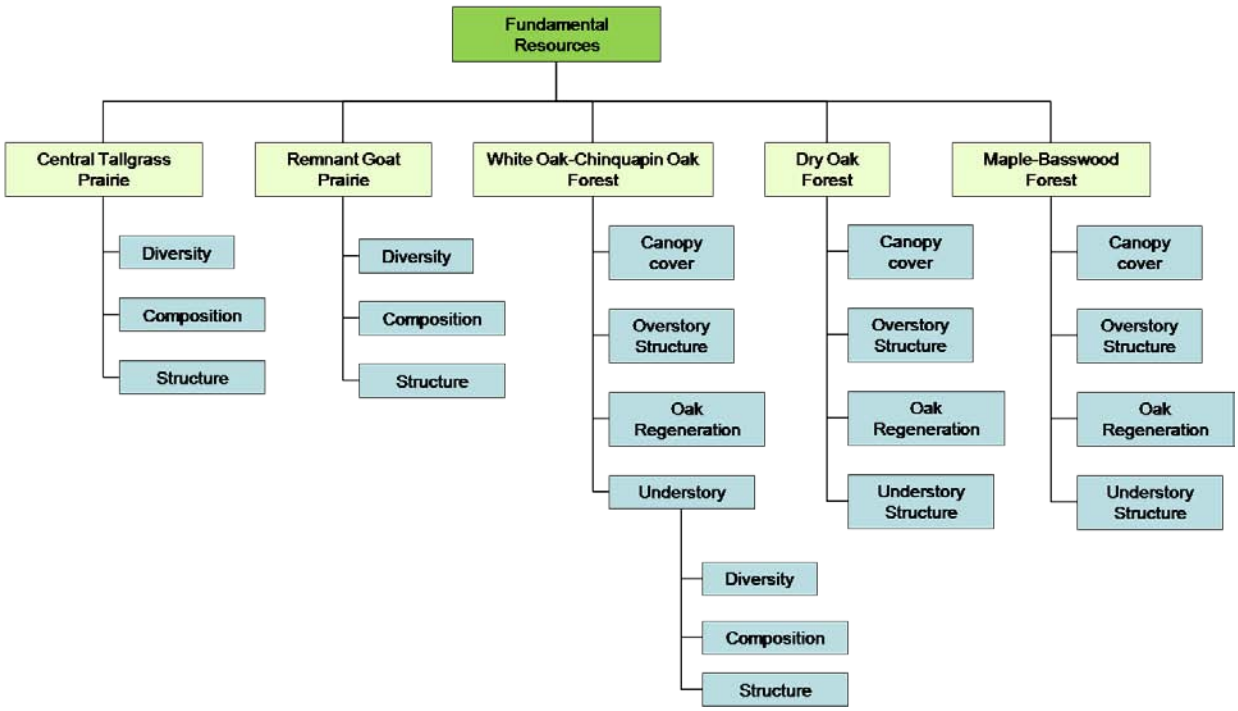

Figure 7. Dendrogram showing how community types within the study area are evaluated. The complete evaluation of each resource is based on the evaluation of attributes displayed.

Indicators, attributes and resources are evaluated at their next higher level in the model according to logical operators. These operators reflect the logical relationship within levels and how each topic contributes to the evaluation of the resource condition. For each resource and attribute, the logical operator is presented in parentheses (Table 4 - 8). Model topics joined by the *union* operator incrementally contribute to the overall evaluation of the next higher level of the model (attributes are joined by a union operator to evaluate the community). Because of the union operator, low support for one attribute can be offset by full support from other attributes.

In some cases, attributes are composed of indicators related by a mathematical operator (+). This type of operator adds all of the evaluation scores for each indicator together and passes the resulting value to the attribute for higher level evaluation in the logical hierarchy.

For each topic in the model (from study area to resource down to indicator) an evaluation proposition is stated. The proposition defines what is being evaluated at that level in the model (e.g. native species richness or size class 3 density) and always tests for a model topic being acceptable. Full support (strength of evidence = 1.0) for the proposition that native species richness is acceptable in the Central Tallgrass Prairie community is determined by comparing the current input value against the reference condition (Fig. 8). The reference condition is the evaluation ramp function in EMDS. The ramp function indicates that native species richness of 77 species or greater provides full support for the proposition while 36 or fewer native species provides no support (zero strength of evidence) for the condition being acceptable. The value 36 is the lower bound of the 80% median range of native species richness reference range in Central Tallgrass Prairie communities of the main unit of the park. The value 77 is the upper bound of the 80% median range for the indicator, all at the patch scale. This is the most common

evaluation ramp function used in the analysis. All indicators with a reference composed of a range between two values have this type of ramp function and subsequent analysis is similar to native species richness (Fig. 8). Further, the reference ranges represents the 80% median range of values for data collected between 1998 and 2005.

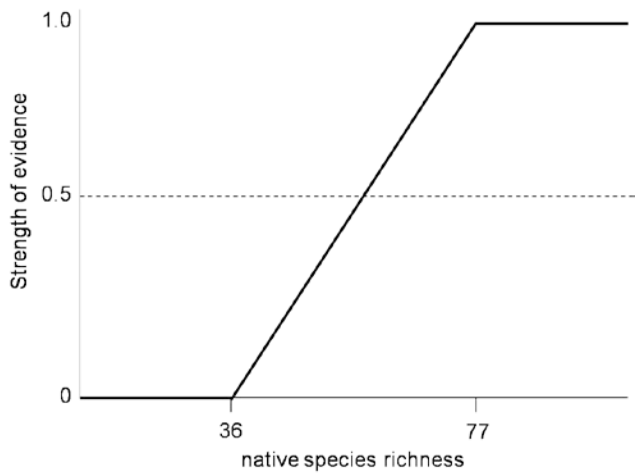

Figure 8. EMDS ramp function used to evaluate native species richness in the Central Tallgrass Prairie community resource.

Ramp functions reflect the type of evaluation required to assess the specific indicator and are based on ecological understanding of the underlying data being evaluated. For certain aspects of forest stand structure (i.e. density of size class 3 trees), too much or too little density may be unacceptable for the community (Fig. 9). For this size class of overstory trees, a middle range of density best reflects the acceptable condition of overstory density for the dry oak community.

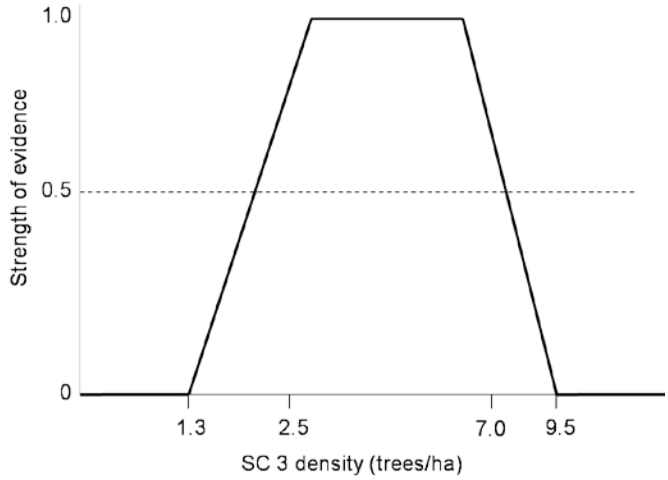

Figure 9. EMDS ramp function used to evaluate density of size class 3 trees in the forested community resource.

Indicators with reference values and associated ramp functions similar to SC 3 density (Fig. 9) represent the idea that more is not always better. For these indicators, an optimum range of values have been identified. The optimum range (full support, strength of evidence is 1.0) is the 25% median range of data collected between 1998 and 2005. Above the 90% range or below the 10% median range, there is no support for the proposition (strength of evidence is zero). In Tables 4- 8, reference ranges with four values are of this type of evaluation ramp function in EMDS.

The complete logic model for evaluating the current condition of plant communities of interest represents one possible logical interpretation of community structure and composition. The study area and all lower levels in the hierarchy can be modified to include new management objectives or logical relationships. The flexibility of the model means that any topic can be removed or added and most importantly, reference conditions can be updated throughout the adaptive management process. Community level evaluation at the patch scale was conducted using the NetWeaver logic engine (Miller and Saunders 2002) in EMDS (Reynolds et al. 2003).

Results

Overview

Results are reported as scores and reflect strength of evidence for the proposition. Evaluation scores range in value from 0 to 1.0. A score closer to 1.0 indicates a greater degree of support for the proposition (indicator exceeds a certain level or resource condition is acceptable); while a value of zero indicates no support for the proposition. The degree to which a proposition is neither fully supported nor not supported is assigned as well. Incomplete support is reported in four categories (very low to strong support for the proposition). Again propositions are expressed to evaluate the degree to which the condition is acceptable. Patch evaluations are produced at the indicator, attribute and resource levels of the logic model. The evaluation score is presented as color coded categories on the mapped output from EMDS at the patch scale (Table. 9).

Table 9. EMDS categories and their associated score range for reporting strength of evidence.

Color	Category	Score
	No support	0
	Very low	0.1-0.25
	Low	0.26-0.50
	Moderate	0.51-0.75
	Strong	0.76-0.99
	Full support	1

Community wide results are based on the frequency of patch evaluation scores. For each resource and its associated attributes, improvement in the current condition over the recent monitoring period is inferred if 50% of the patches have evaluation scores greater than 0.5. These results are presented as a series of frequency histograms for each resource and its attributes.

Study Area

The dry oak and maple-basswood forests are the dominant types in the study area, accounting for 81% of all patches and 92% of the total study area. The majority of HTLN vegetation monitoring sites are located in high quality phases of the dry oak association and disturbed phases of the maple-basswood association. For these community types, the study area is composed of high quality oak phase patches and disturbed maple-basswood phase patches identified in the vegetation map. The remaining resource types for the study area are unique community types of interest that include sites. Comparing the study area to the condition assessment highlights those areas of the dry-oak forest that agree with the NRCA. Conversely, disturbed maple-basswood patches indicate where the current type departs from the condition assessment (either high quality maple-basswood or oak hardwood forest types).

Improvement of the resource condition is a measure of the indicator changes that have recently occurred (since 2005). Moreover, it reflects the recent change in the current condition during the period of HTLN monitoring. Overall condition of the study area has improved as inferred from 97% of the patches having resource evaluation scores above 0.5 (Fig. 10). Nearly all of the

resource within the study area have improved with the exception of the remnant goat prairie community.

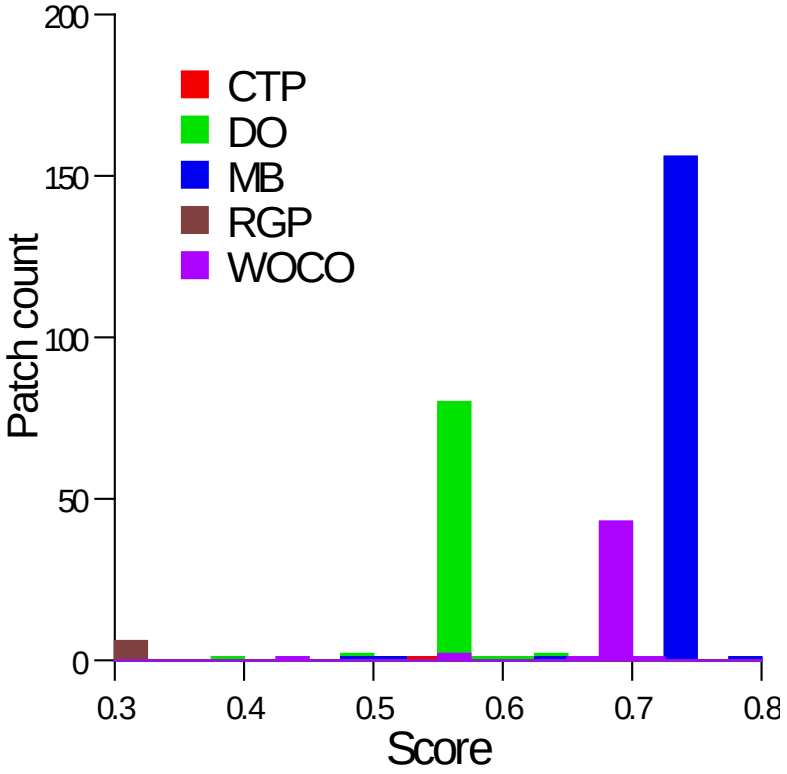

Figure 10. Patch frequency of resource scores for the study area displayed by community type. Resources are central tallgrass prairie (CTP), dry oak forest (DO), maple-basswood forest (MB), remnant goat prairie (RGP) and white oak-chinquapin oak forest (WOCO).

EMDS results for the study area indicate not only the overall resource condition but where on the landscape the condition has changed (Fig. 11). Composite evaluation maps for each resource and their attributes are presented below (Fig. 17–21).

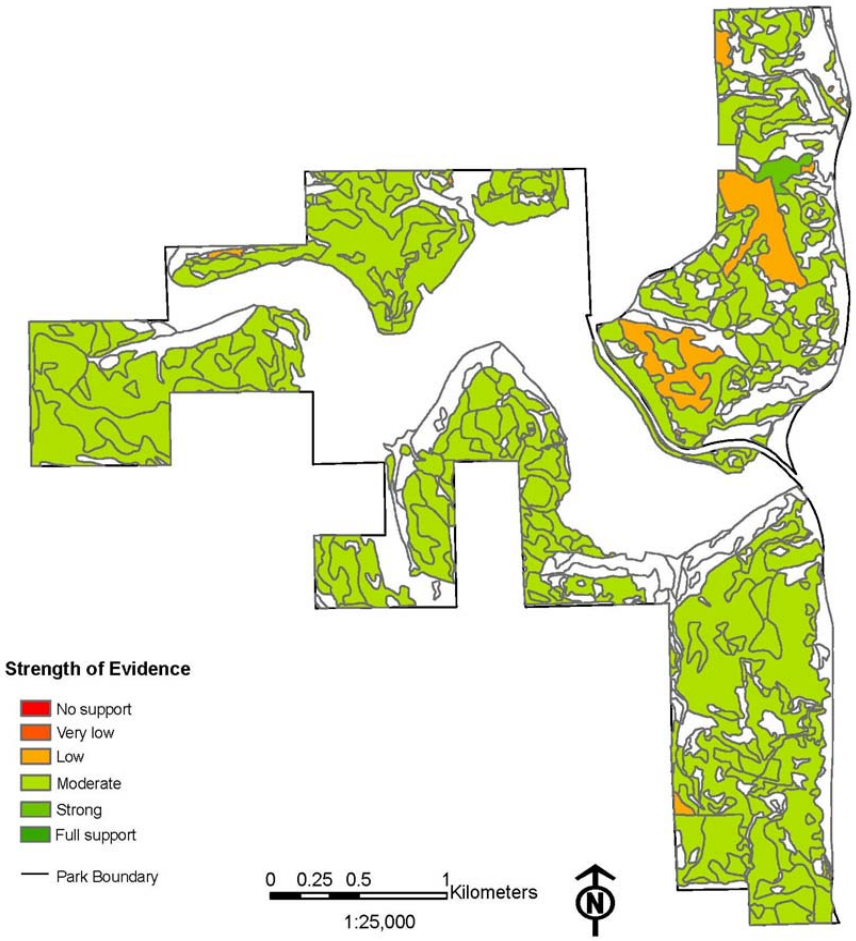

Figure 11. Overall evaluation of fundamental resources for Effigy Mounds National Monument, Iowa.

Dry oak forest

The high quality dry oak community condition improved during the monitoring period with 97% of the patches having overall evaluation scores above 0.5 (Fig. 12, Dry Oak). Very low to no support for oak regeneration and recruitment is the primary contributor to the overall moderate evaluation scores for the dry oak patches (Fig. 12, Oak regen). Overstory structure shows mixed results among patches with some large patches in the southern portion of the main unit having strong support for the proposition being acceptable (Fig. 17). These same large patches have low support for acceptable understory, along with another large patch nearby (Fig. 17).

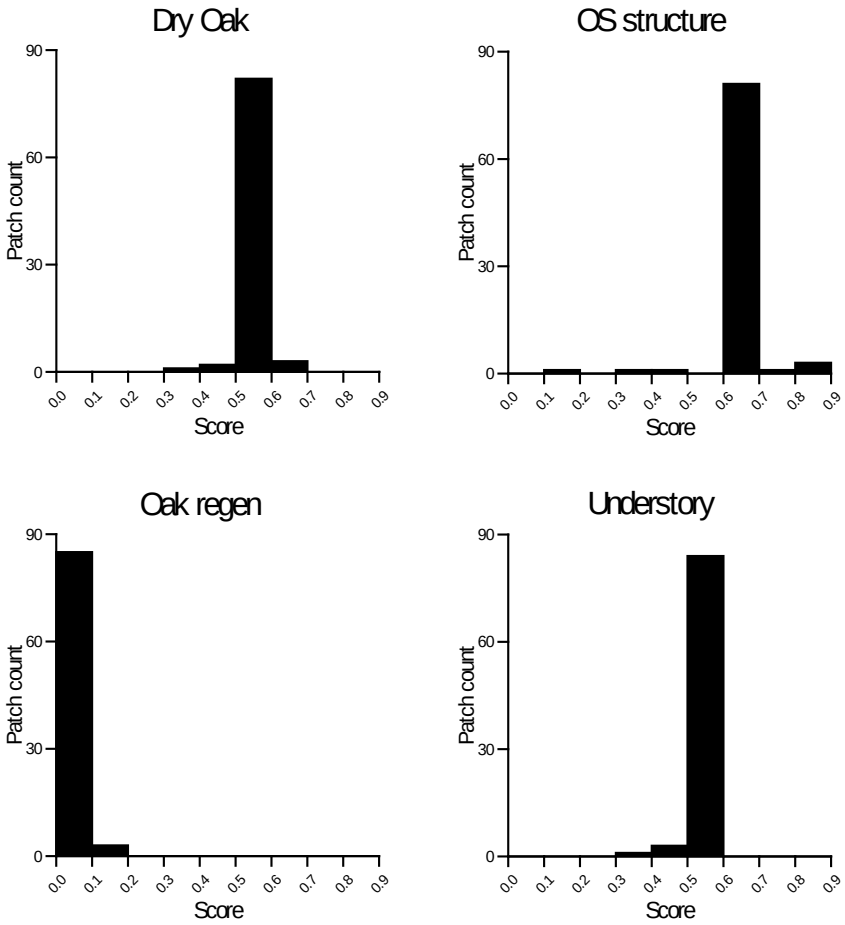

Figure 12. Patch frequency of evaluation score histograms for the overall dry oak forest resource and its associated attributes. Each attribute contributes equally to the resource evaluation.

White oak-Chinquapin oak forest

The white oak-chinquapin oak forest type does not occupy a large area or number of patches in the study area (19.0 ha and 48 patches, respectively; Table 1). This phase was identified because it encompasses the oak savannah communities of interest by both the park and HTLN. The resource has improved since the period of initial monitoring with 98% of patches having overall scores > 0.5 (Fig. 13, white oak-chinquapin oak). Similar to the dry oak community, oak regeneration has decreased across the resource (Fig. 13, oak regen). Overstory structure has improved while the understory remains stable (Fig. 13). A single patch in the northwest portion of the study area has low overall support while the remaining patches have moderate. That same patch has very low support for acceptable overstory structure and low support for acceptable understory structure (Fig. 18).

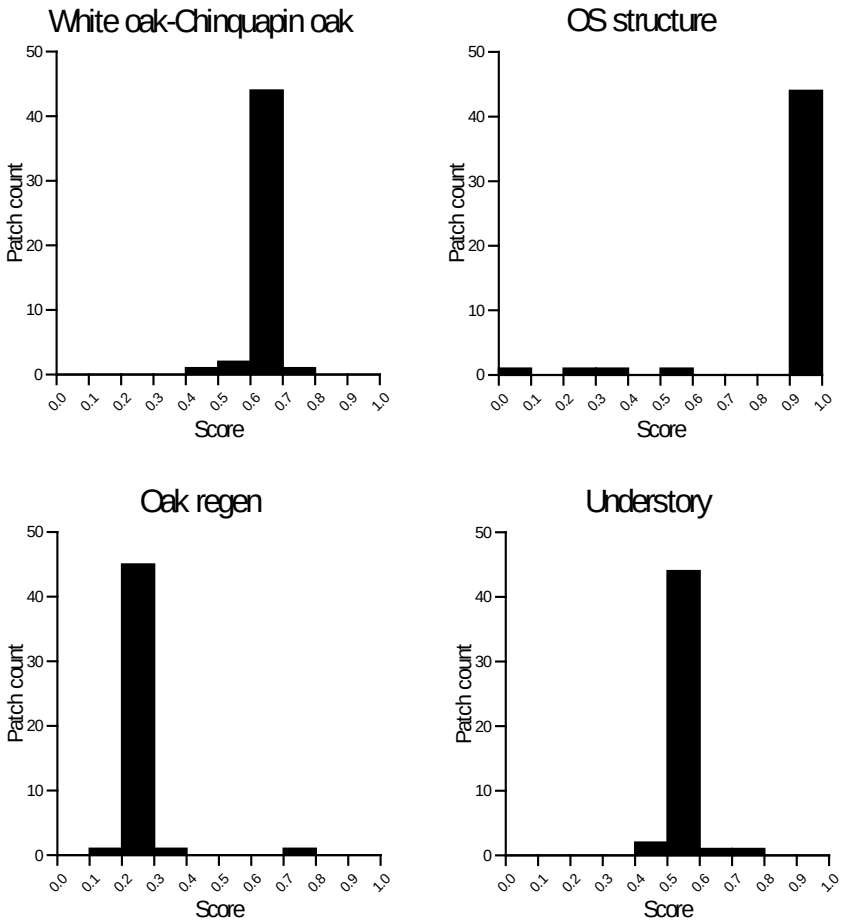

Figure 13. Patch frequency of evaluation score histograms for the overall white oak–chinquapin oak resource and its associated attributes. Each attribute contributes equally to the resource evaluation.

Maple-basswood forest

Disturbed maple-basswood patches dominate the study area (n=155). These areas are identified in the vegetation map as being either disturbed types of maple-basswood forest or former oak hardwood forest. The current condition of the maple-basswood forest has improved (Fig. 14, maple-basswood). While the understory condition remains stable, the condition of both the overstory structure and oak regeneration has improved (Fig. 14). For most patches, the overstory structure and oak regeneration attributes have moderate to strong support for the proposition (Fig. 19). Only two patches show no support for acceptable oak regeneration (Fig. 19).

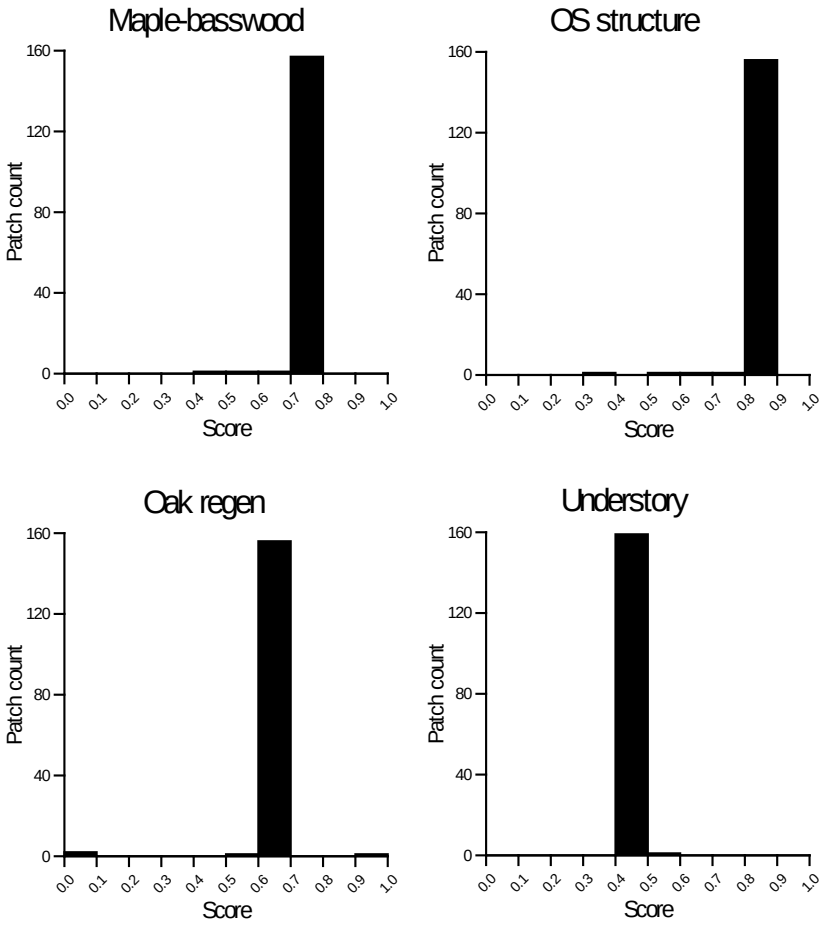

Figure 14. Patch frequency of evaluation score histograms for the overall maple-basswood forest resource and its associated attributes. Each attribute contributes equally to the resource evaluation.

Central Tallgrass Prairie

This resource type only occupies three patches across the study area. However both the vegetation map and condition assessment identified this community in their analyses, with the later relating it to the spatial extent of the dry oak forests. Overall the community has remained stable (Fig. 15). Diversity and composition remained stable while structure is slightly lower since the initial monitoring period (Fig. 15). Species diversity and composition have the same spatial pattern of support for prairie patches as does the overall condition evaluation for the central tallgrass prairie (CTP) resource (Fig. 20). There is low support for the proposition that prairie structure is acceptable. The three patches of CTP represent the prairie restoration efforts of the park.

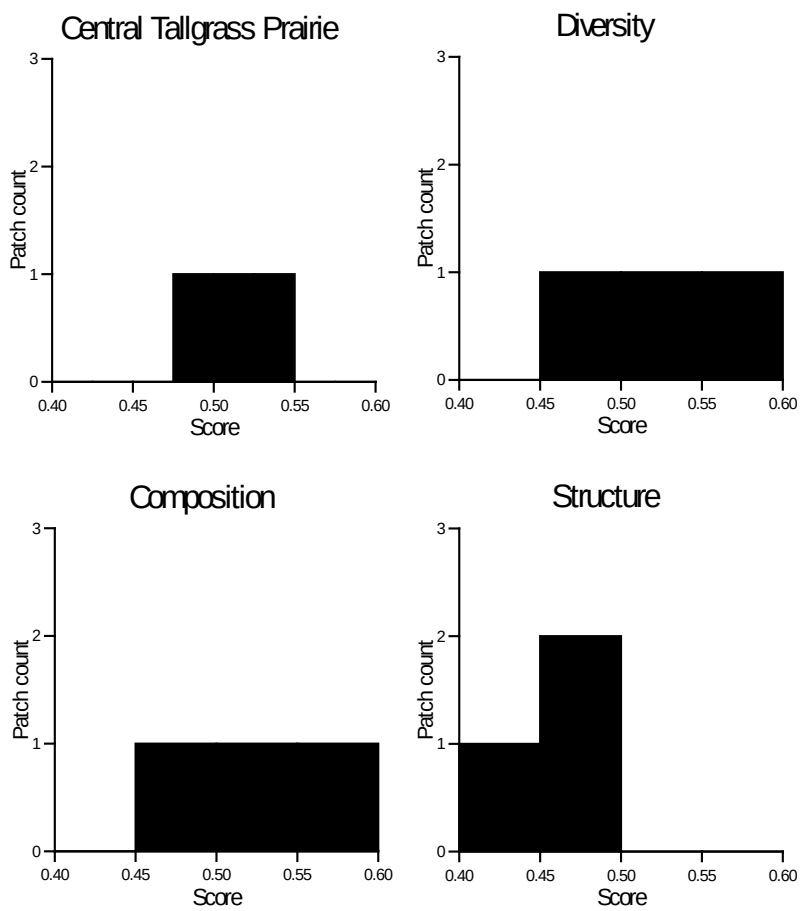

Figure 15. Patch frequency of evaluation score histograms for the overall central tallgrass prairie resource and its associated attributes. Each attribute contributes equally to the resource evaluation.

Remnant Goat Prairie

Results for the six small patches of remnant goat prairie are based on data from a single HTLN vegetation monitoring site. Each patch is 0.1 ha in size, equivalent to the area covered by a HTLN vegetation monitoring site. Therefore monitoring data is being inferred to the five additional patches of remnant goat prairie in the study area. For this reason, all six patches have the same results. For the remnant goat prairie resource, overall condition has not improved (Fig. 16). Figure 21 shows an expanded view of the RGP patches in the study area with the evaluation of the overall resource being shown. There is no support for the proposition that species diversity is acceptable for all patches. There is low support for species composition evaluation and moderate support for structure evaluation. Combined the attributes provide overall low strength of evidence that the current condition is acceptable for remnant goat prairie patches.

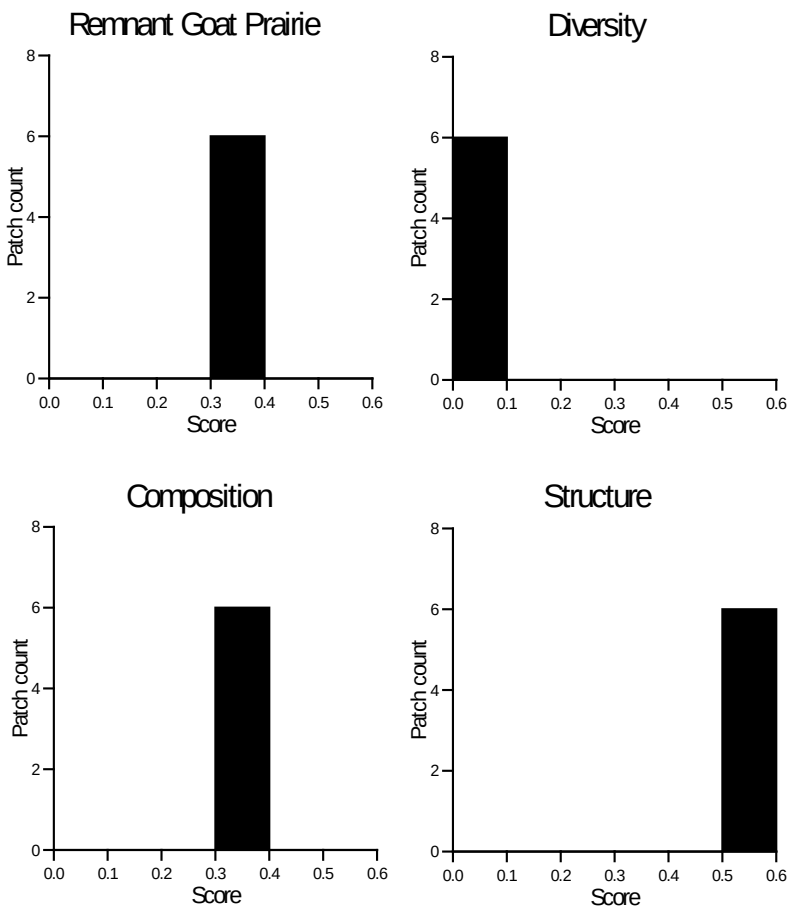

Figure 16. Patch frequency of evaluation score histograms for the overall remnant goat prairie resource and its associated attributes. Each attribute contributes equally to the resource evaluation.

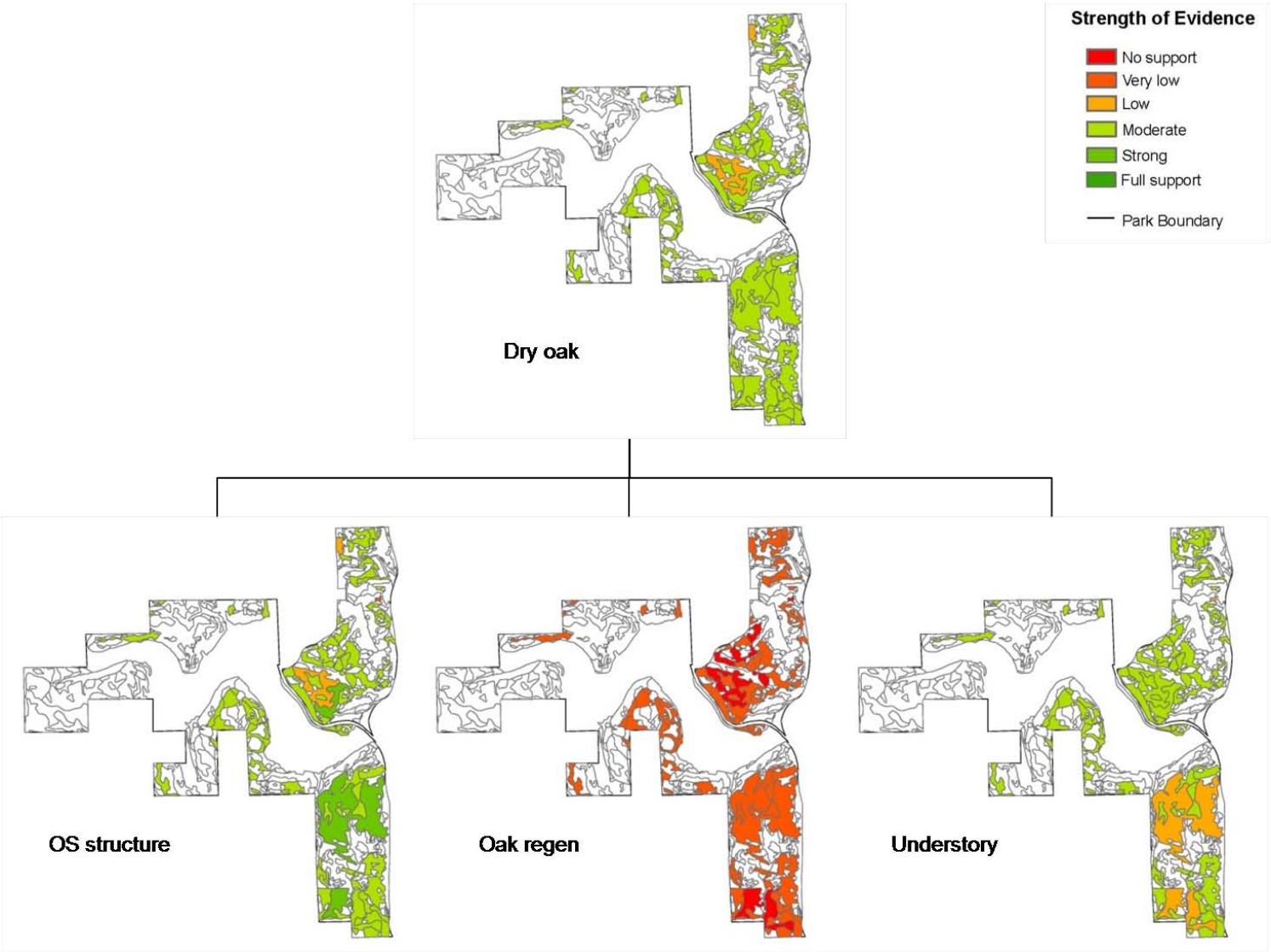

Figure 17. Composite of attribute evaluations contributing to the overall evaluation for dry oak forest type.

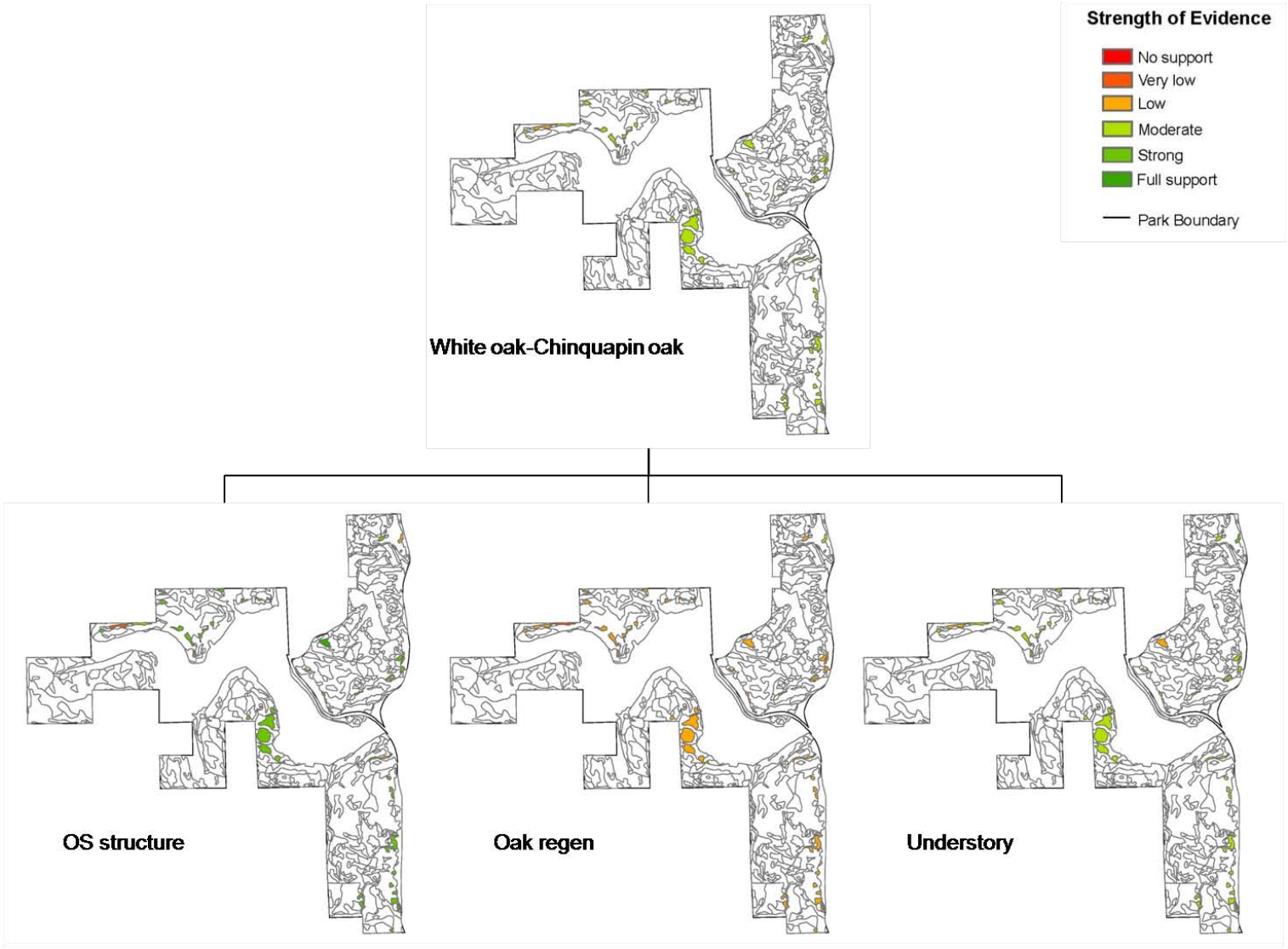

Figure 18. Composite of attribute evaluations contributing to the overall evaluation for white oak-chinquapin oak forest type.

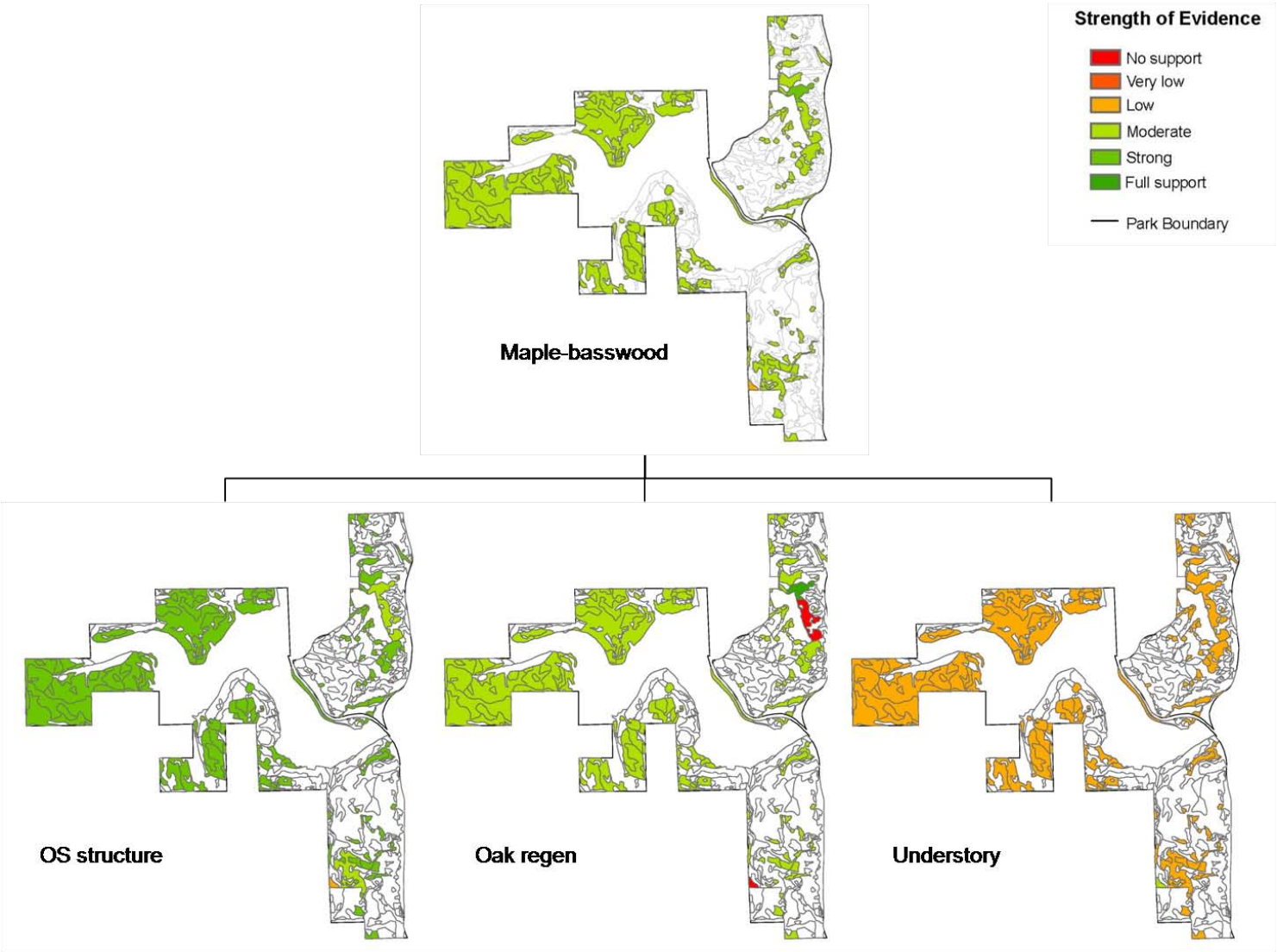

Figure 19. Composite of attribute evaluations contributing to the overall evaluation for maple-basswood forest type.

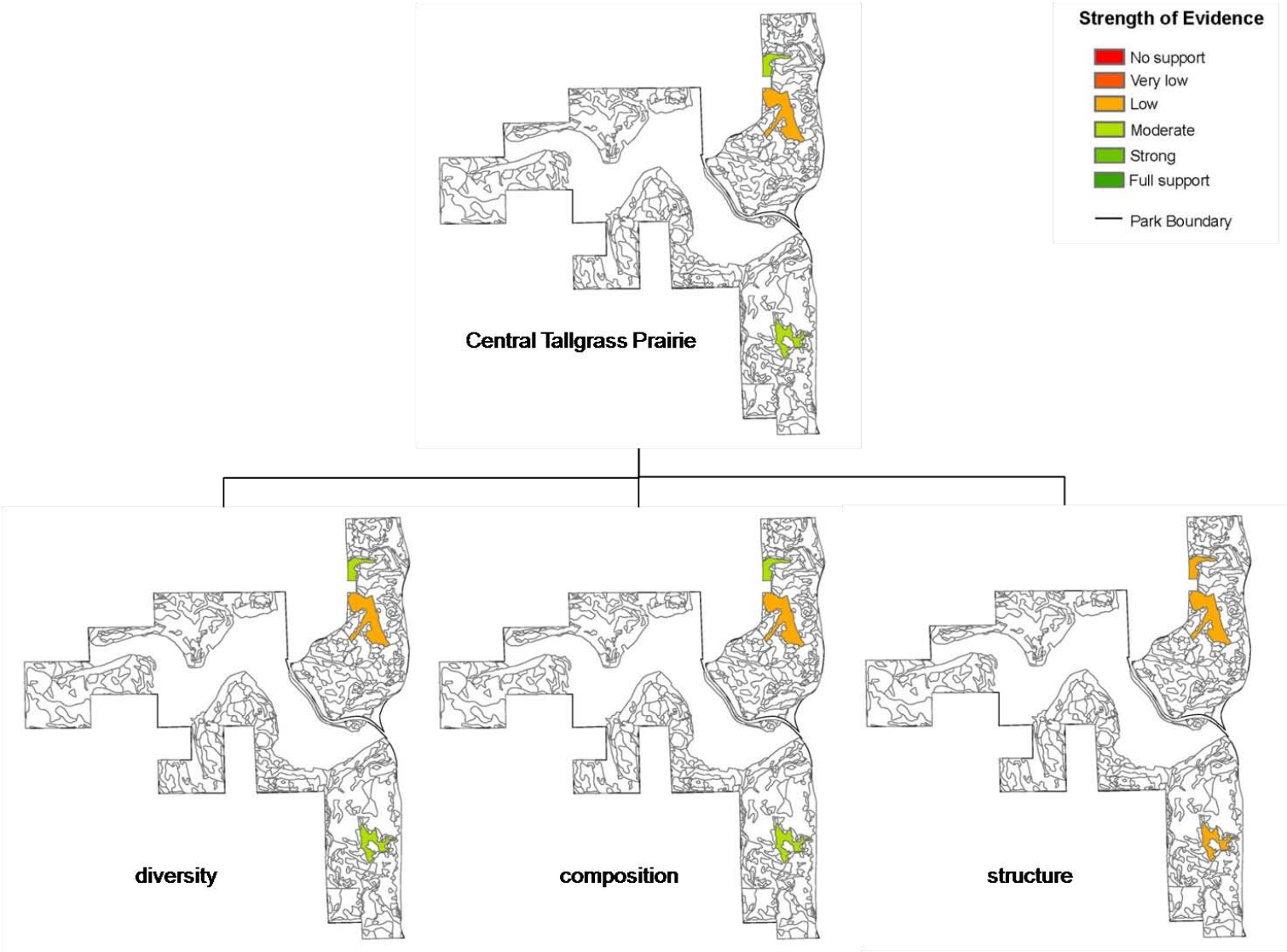

Figure 20. Composite of attribute evaluations contributing to the overall evaluation for central tallgrass prairie type.

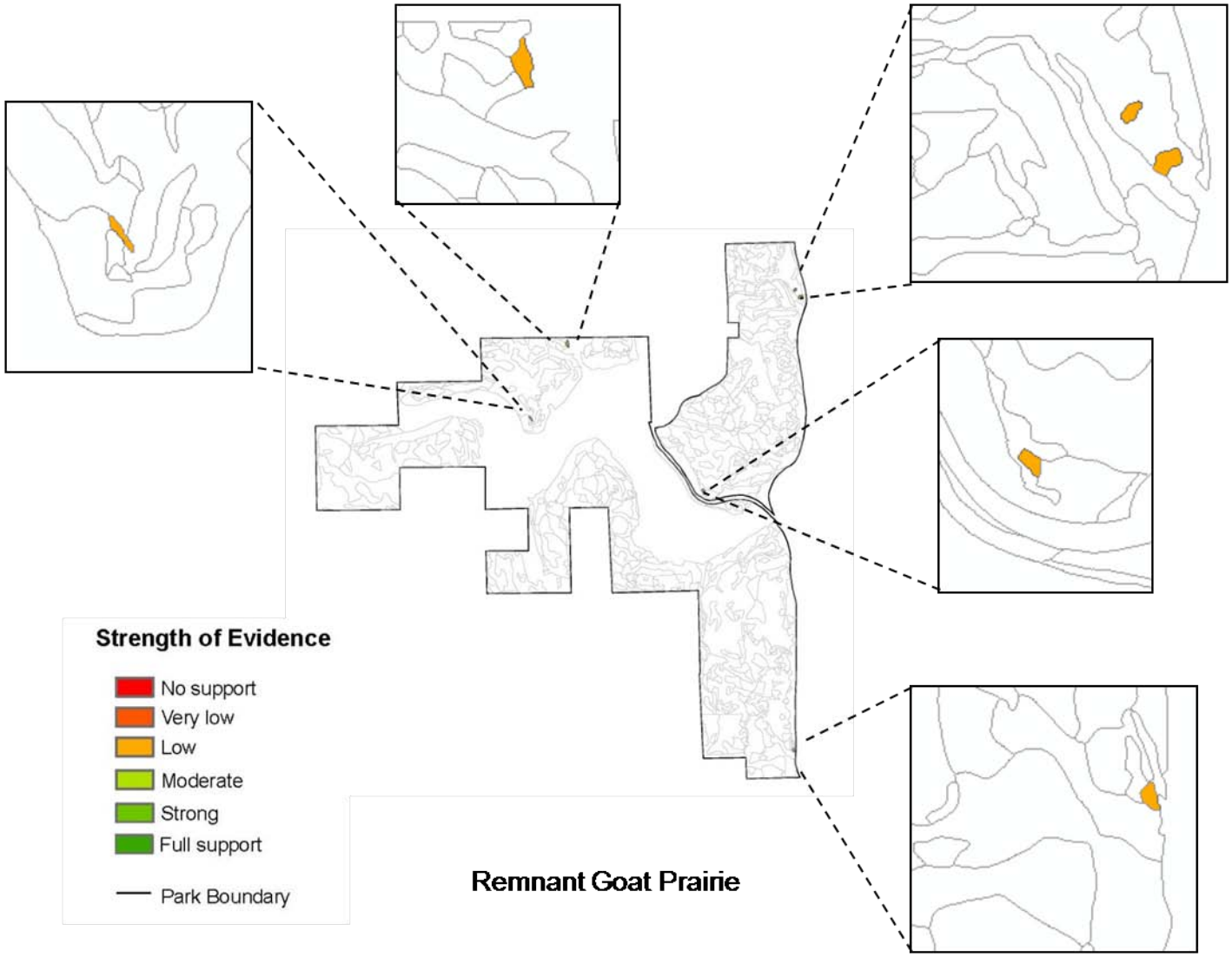

Figure 21. Overall evaluation for remnant goat prairie resource type.

Discussion

The focus of this work was to: 1) utilize additional spatial data to extend the reference frame of monitoring site data to include larger areas of the park; 2) use monitoring site data to design a logical framework at the community scale; and 3) apply the logical framework to a spatially explicit evaluation of the current condition for each community in the new study area.

The HTLN reference frame for the 29 vegetation community monitoring sites was expanded to include the main unit of EFMO. Integrating fine scale monitoring site data with larger scale community descriptions and spatial data allowed site data to be extrapolated to a larger area of the park. The original HTLN reference frame was expanded to include five community types of interest to the park. Based on site level data, a set of indicators were selected for the logical framework. Limiting the set of indicators to those derived from HTLN data simplified the logical framework for characterizing each community type.

Input and reference conditions for this work were based on a small number of monitoring sites as compared to the study area and represent a narrow monitoring time frame. However limited sample size and sample years do not detract from the utility of the methods. As more complete spatial and descriptive information becomes available and/or management objectives are quantified both the input and reference conditions can be refined without redesigning the logic model or study area maps. The flexibility inherent in the logical framework allows for multiple management options to be explored. Furthermore, the spatial presentation of results allows for "on-the-ground" visualization of how each scenario will be distributed across the study area.

Dry oak forest

Patches of dry oak forest type represent the high quality phases of the Dry-Mesic Oak Woodland and Forest association. The set of reference conditions for this resource type was based on data from fourteen monitoring sites. Even though the current overstory structure reflects high quality oak-hickory forests, there is very little oak regeneration or recruitment being detected. One possible interpretation is that the current overstory was established under conditions that reflect a disturbance regime that promoted the development of the oak-hickory forest and over time, the disturbance regime was altered such that it inhibited oak regeneration. Regardless of the mechanism that lead to the current condition, as the overstory trees begin to die, they will not be replaced by oak species. This lack of oak regeneration points to areas on the park where the cover type will shift away from being oak dominated as succession occurs.

White oak-Chinquapin oak forest

This resource type is a special case of the Dry-Mesic Oak Woodland and Forest association and was delineated based on the interest in oak savannah communities in the park. Reference conditions for the 48 patches were summarized from six monitoring sites. Unlike the dry oak forest patches, oak regeneration was detected, but with only low strength of evidence. Further the condition of oak regeneration has declined within the community. The white oak-chinquapin oak forest resource type has improved slightly since the initial monitoring period.

Maple-basswood forest

All 155 patches of the maple-basswood forest resource reflect disturbed phases of the association. The reference conditions were derived from summarized data from five monitoring sites. Most notable about this evaluation is the spatial extent of this resource. In the main unit of the park, it accounts for 51% of the total study area. Both the amount of maple-basswood forest and its arrangement in the park could have management implications insofar as efforts to restore oak dominated forests to the main unit of the park. The maple-basswood resource appears to be in recovery from large scale disturbance (logging) or in transition away from a maple-basswood type. The latter is reflected in the moderate support for oak regeneration detected. For this resource, management actions could be taken to either restore high quality phases of the maple-basswood forest association type or replace it with oak dominated association.

Central Tallgrass Prairie

Patches of central tallgrass prairie reflect the restoration efforts of the park. The low to moderate support at the attribute level suggest that prairie restoration has remained stable in terms of native species diversity, number of invasive species and guild representation and abundance. For this type, the logical framework and subsequent analysis acts more to evaluate the degree to which the area has been restored rather than the departure from a pre-European condition. The difference between the two types of evaluation is reflected in the reference conditions. Here the reference condition is derived from data collected following restoration and therefore reflect the state of the restoration. If the reference conditions were based on historical or pre-European values then the degree of departure of the current condition from the historic condition would be analyzed.

Remnant Goat Prairie

The lack of support for native species diversity is most pronounced in the remnant goat prairie evaluation. We can look to the other attributes for more information regarding the loss of native species diversity. Low support for species composition indicates that there is not a corresponding decrease in native species richness or a rise in the number of invasive species. Furthermore, moderate support for guild structure shows that native guild representation has remained stable over time. Therefore the lack of native species diversity might be the result of a decrease in foliar cover of previously abundant species rather than a loss of numerous native species.

Overall conclusions

A logical framework was constructed using HTLN vital signs data and spatial datasets to successfully evaluate the current state of five vegetation communities in the main unit of EFMO. This work demonstrates how numerous indicators and attributes can be logically related based on their ecological information in a community. Furthermore, a spatially explicit method was employed to present integrated results both among resource types and within the logical hierarchy of each resource type.

For all communities evaluated in the study area, oak regeneration and recruitment is a concern. Since results are mapped at the patch scale, areas of strong support can be located and investigated in order to assist those areas with very low support, not only for the oak regeneration attribute, but for any set of indicators. This highlights areas where the condition is supported (requiring one type of management) and areas where the same condition is not supported, thus requiring a different management approach for the same indicator. By logically

arranging indicators in a community based hierarchy and spatially evaluating each level of the analysis, multiple aspects of natural resources can be investigated and mapped.

The EMDS modeling framework can be separated into two components: 1) the evaluation approach that uses a logic engine to reason about multi-faceted ecosystem components and 2) the decision component which uses a decision engine to determine management priorities (Reynolds 2006). Integrating these key features within EMDS provides an explicit two-phase system for transparent adaptive management (Reynolds 2005). Here only the first component (evaluation phase) of EMDS was presented. Refining reference conditions or the reference frame would be the next step toward modeling adaptive management within the EMDS framework.

This application can be extended to include formal decision criteria and scenarios. Using the same knowledge-based approach, logical criteria can be formulated to address specific management decisions. For the case of EFMO, in which significant cultural resources (effigy mounds) exist within the natural resources, decision criteria may be developed that address forest structural changes in those patches containing mounds within a certain distance of visitor trails. Those patches containing mounds near trails would be identified as having a greater management priority than a patch not containing mounds, when both patches have the same evaluation score for overstory structure. This is only one example of applying decision criteria in the EMDS framework to facilitate natural resource management in areas with significant cultural resources.

With the implementation of natural resource condition assessment program, defining reference conditions and evaluating the degree of departure of current conditions from those reference conditions has increased in priority. Logic model frameworks, such as EMDS can aid in interpreting condition assessments at multiple spatial and community scales. The flexibility, transparency and level of detail of documentation that goes into developing logic models can help to minimize subjectivity among science, management and policy.

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