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Using Best Professional Judgment to Create Biological Benchmarks for Habitat Assessment of Wetlands and Oak Savannas in Northwestern Indiana

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USING BEST PROFESSIONAL JUDGMENT TO CREATE BIOLOGICAL BENCHMARKS FOR HABITAT ASSESSMENT OF WETLANDS AND OAK SAVANNAS IN NORTHWESTERN INDIANA

by

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ABSTRACT

The Tolleston Strandplain at the southern end of Lake Michigan offers a unique "dune and swale" topography supporting oak savannas on the dunes and a mosaic of wetland communities in the swales. Following years of human degradation, the sites in this area are now being restored. In this effort, assessments of vegetative quality in these sites have been necessary for proper management decisions. However, it is poorly understood what indices best reflect the vegetative quality of these oak savannas and wetlands. A potential method for determining the best indices for these community types is to use benchmarks that employ expert best professional judgment (BPJ). In order to confirm the viability of BPJ for creating benchmarks, Kappa analysis was used to determine the level of agreement among seven experts. They placed each of 63 transects from this unique landscape into one of four quality categories: 1) "good to very good," 2) "medium," 3) "poor," and 4) "very poor." Discriminant analysis was used to determine the means and weights of the assessment metrics used by each expert. The experts had poor agreement when assessing the oak savannas and fair agreement when assessing the swales. The use of BPJ for creating benchmarks may be in question, but the means and weights of their metrics indicated important parameters that must be considered when creating benchmarks for this ecoregion. Using discriminant analysis, follow-up questions, and a comparison of each expert's quality categories with remnant oak savanna metrics, biases also were discovered which may have influenced the experts' assessments of the sites.

INTRODUCTION

Defining the quality of a habitat has been a topic of much debate in restoration ecology when prioritizing sites for restoration and management. Debate can arise in defining the success and quality of these restored habitats. One topic of debate is the subjectivity of metrics that are used to define quality (Bowles and Jones 2006). It is difficult to determine whether the end target for restoration should be a reflection of pre-settlement landscapes (Hilderbrand *et al.* 2005). It also is difficult to determine the exact composition of these pre-settlement landscapes (Leach and Givnish 1999). Furthermore, flora and fauna in any ecosystem could have varied by location in prehistoric landscapes (Leach and Givnish 1999). One possible remedy for establishing indices for assessing the quality of vegetation in an ecosystem, despite the difficulties of determining pre-settlement conditions, is the use of expert best professional judgment (BPJ) for creating index benchmarks (Teixeira *et al.* 2010; Weisberg *et al.* 2007). Therefore, it is important to determine whether professionals studying specific habitats can agree on definitions of habitat quality and the metrics and benchmarks they are using to create their definitions. This report focuses on these two objectives in the context of flora of wetlands and oak savannas located in northwestern Indiana.

Site History

Indiana was once covered with over 20 million acres of forestland, 2 million acres of prairie, 1.5 million acres of water and wetlands, and approximately 1 million acres of savannas (Jackson 1997; Nuzzo 1986). Just over 4.5 million acres of forestland (Woodall *et al.* 2010), less than 20,000 acres of native prairie (Howe 1994), 190,000 acres of wetlands (McCorvie and Lant 1993), and 1,500 acres of savannas remained in the state of Indiana by the late 1980's and early 1990's (Nuzzo 1986). With fewer natural areas remaining in Indiana, remaining areas have become a high priority for management and restoration.

The Lake Michigan rim coastal system in the northwest corner of Indiana contains a mosaic of moraines to the south, dunes to the east, relic beach ridges to the west, extensive wetland complexes between the ridges, and slow moving rivers and streams throughout the region (KellerLynn 2010; Hartke *et al.* 1975). The sites studied in this project are located in the Tolleston Strandplain among beach ridges established over the past 5,000 years through changes in drainage patterns of Lake Michigan. The pre-settlement plant communities in this region varied from grass communities on the foredunes, coniferous forests north of the Grand Calumet River, and oak savannas south of the river mixed with marshes, sedge meadows and wet prairies (Pepoon 1927). The coniferous communities transitioned to oak savannas through harvesting of pines and cedars and increased fires (Labus 1998; Bacone 1979). It is now primarily characterized by dry oak savannas with intervening wet sand prairies and marshes along its low ridges and swales (Swink and Wilhelm 1994).

The Nature Conservancy and its partners have been working on the Southern Lake Michigan Rim project to restore remnant tracts of native landscape (Nature 1999). Sites are located throughout Lake, Porter, and LaPorte Counties. These counties have been a focus for heavy industrial activity and dense urbanization. The principal goals of restoration in the area have been to replace invasive plant species with native species, improve biodiversity, remove contaminants, and remove any other impairments to key ecological processes (Nature 1999; Labus 1998). The aim has been to approach management of these sites at a landscape level. Because of the high fragmentation of these sites (habitats ranging from 170 acres to 5 acres), the implementation of buffers, corridors, and cooperation with local residents are necessary for success. Specifically, cultural management at these sites has included cutting brush, removing weeds and trash, applying herbicide for the removal of invasive species, and conducting prescribed burns (Labus 1998).

Due to the ongoing management and restoration in the area, the sites studied in this project included both managed and unmanaged sites. The quality of each site has not been dictated by human degradation alone. Natural processes and management in the area also have impacted the quality of the sites. The amounts and stages of management will produce varied results in vegetative quality as well. Therefore, site quality in the area has been influenced by multiple positive and negative human actions and natural processes.

The sand oak savannas found in this region are a rare community type outside this dune and swale topography. Only 0.02% of the original extent of these communities in the Midwest remains (Nuzzo 1986). It is therefore difficult to determine what flora the pre-settlement communities in the original extent contained. Much debate has arisen over how to define the historical structure of oak savannas, but most sources agree these communities were dominated by oaks with 10-80% canopy cover, were composed of many species found in both prairies and woodlands, and were a result of periodic droughts and fires (Nuzzo 1986; Anderson and Bowles 1999; Bacone *et al.*

2007). A few authorities also agree that the canopy cover was usually less than 50% (Curtis 1959; Anderson and Bowles 1999).

A report by Leach and Givnish (1999), however, indicated the ground layer was historically slightly different than most ecologists suspected. Although many have agreed that the ground layers were a community of plant species displaying a transition between prairies and woodlands (Nuzzo 1986; Anderson and Bowles 1999; Apfelbaum and Haney 1991), Leach and Givnish (1999) discovered that this ground layer was more likely a forb-dominated community in prehistoric oak savannas. The average structure in remnant oak savannas they surveyed contained about 64% forb cover, 34% graminoid cover, and 2% fern cover. They identified species richness to be approximately 16 species per m^2 and discovered that 27% of Wisconsin's native species were located in oak savannas. When assessing the canopy cover of these remnant oak savannas, they concluded that it was a mosaic rather than a consistent percentage (Leach and Givnish 1999). Oak savannas were found to be highly diverse and home to more species than a transition community would contain. Due to the proximity of their sites, dominant tree species, and the soil type, Leach and Givnish's (1999) remnant savannas in Wisconsin were very similar to those found in the areas studied in this project.

Most of the ecological problems in these oak savannas have been due to human disturbance in this industrialized area. Garbage and debris were visible in some of these sites, and their proximity to roads and residential areas will make this a continuous problem. Fire suppression also has caused many of these oak savannas to transition into oak woodlands rather than remain open and sustain a high ground layer biodiversity. One of the invasive species in this area causing the greatest problem is *Frangula alnus*. Its ability to create dense stands and its tolerance to many herbicides force management teams to remove them manually (Labus 1998).

In addition to oak savannas, wetland communities are frequent in this area and include: aquatic communities, marshes, swamps, bottomland forests, beach communities, and pannes (Bacone *et al.* 1980; Choi 2000). Some of the wetlands in this study were riverine wetlands adjacent to the Grand Calumet River. The remaining wetland plant communities in this study varied in woody canopy cover and dominant taxa.

The composition of these wetland sites has been significantly altered by human activities which include: loading of nutrients, silts and other pollutants, alteration of local hydrology through channelization, and drainage and filling of the Grand Calumet River and the wetlands surrounding it. Invasive species include: *Phragmites australis, Typha* spp., and *Lythrum salicaria*. These species form homogenous stands along the river and in some wetlands surrounding it (Choi 1998). Overall, control of invasive species is the primary objective for management in the wetlands of this area (Labus 1998).

Assessment Metrics and Best Professional Judgment

Due to the uniqueness of the communities located in this dune and swale topography, it is difficult to determine what indices should be used in this specific setting when assessing the vegetative quality before or after management. This issue could be solved through the use of BPJ to determine common scales and biological benchmarks. This idea of using BPJ to create benchmarks was tested by Teixeira *et al.* (2010). In their study, they provided experts with benthic indices to help them place each site into a quality category. The resulting categories were used to determine whether BPJ had good agreement. Their goal was to construct a common scale for indices across a wide geographic region rather than creating indices for each isolated community. They discovered there was good agreement on quality categorization by professionals, but there was better agreement when the sites were on the extreme ends of the quality spectrum. It was concluded that BPJ was a viable means for creating and calibrating quality indices (Teixeira *et al.* 2010).

In another study, Weisberg *et al.* (2007) also used benthic faunal communities to determine the level of agreement between BPJ. Their goal was to determine the repeatability of BPJ and to determine whether BPJ establishes viable benchmarks for creating assessment indices. Their results were similar to those by Teixeria *et al.* (2010), showing high agreement and validity for using BPJ to determine benchmarks for indicator metrics. The most noticeable disagreements in their study were due to philosophical differences on which metrics to use. These philosophical differences included thoughts on whether invasive species are truly indicators of degradation (Weisberg *et al.* 2007).

In contrast to these previous studies, Bay *et al.* (2009) expressed concerns about BPJ agreement. Professional bias resulted in poor categorization agreement between professionals. Their goal was to test the agreement of experts interpreting chemical concentration measurements, sediment toxicity tests, and benthic infaunal communities. They concluded that the disagreement may have been due to bias of professionals in that particular study and a lack of complete data. However, their study did display an example in which BPJ is a questionable source of benchmarks for creating indices.

Similarly to the benthic infaunal assessments, a number of metrics have been used in order to measure the biological quality and success of management in sites similar to the wetlands and oak savannas in this study. Although multiple aspects of the ecosystems must be studied to gain an overall idea of the quality (i.e., biological, chemical, and physical), this report focuses solely on the flora. The metrics used were quantitative measurements of floristic characteristics which can be used to determine the quality of the site. The Floristic Quality Index (FQI) is one common metric used in Indiana and its surrounding states. It combines species richness with the average coefficient of conservatism (Mean C), a value given to every plant species based on its ability to tolerate habitat degradation and its fidelity to specific natural habitats (Rothrock 2004). Ecologists in many of Indiana's neighboring states and regions also have been using their own form of FQI to determine floral quality of their respective regions (Rothrock 2004). Species richness and Mean C (MC) on their own also are examples of assessment metrics used to determine the quality of flora in given ecosystems. In this report, these indices and more than twenty others will be used in comparison to BPJ values to determine necessary parameters before biological benchmarks can be created.

There are differing opinions on many of the metrics used by ecologists to assess a habitat. For example, MC has been created by a consensus of a few scientists (Swink and Wilhelm 1994), and some ecologists accuse this tool of being subjective and potentially biased toward personal preference and rare species (Landi and Chiarucci

2010; Mushet *et al.* 2002). To prove MC's inadequacies, Bowles and Jones (2006) tested its efficacy, alongside that of species richness and FQI, to determine habitat quality in tallgrass prairies. They found MC and FQI to be problematic while species richness was a good indicator of prairie quality. In contrast, along stream banks FQI was effective while species richness was not (Bowers and Boutin 2008). Francis *et al.* (2000) discovered species richness and MC provide useful information for the status of a natural area, but FQI does not. Research by Bourdaghs *et al.* (2006) revealed FQI and MC are effective metrics for measuring the quality of coastal wetlands, but neither these nor species richness necessarily outperformed the other metrics.

The results from these studies are somewhat troubling for the modern plant taxonomist and restoration ecologist because MC, species richness, and FQI are popular metrics. However, MC could be limited in ecosystems tested by Bowles and Jones (2006) but is still effective in oak savannas and wetlands. It may be valuable to have multiple metrics available considering one type of metric might not be valid in all ecological habitats.

A few examples of quality metrics used in oak savannas include species richness, species diversity, canopy cover, exotic species cover, and forb cover (Leach and Givnish 1999). NatureServe (2006) partnered with the Environmental Protection Agency and other agencies to create a general set of metrics for assessing the integrity of ecosystems across the United States (Table 1). Metrics used by NatureServe for assessing the floristic biotic integrity of wetlands include sapling/seedling cover, canopy structure, tree size, tree condition, woody debris, tree basal area, cover of growth forms (native graminoids, perennial herbs, increasers), species richness, cover of native plants, FQI, indicator plant species, index of biotic integrity (IBI), and invasive species cover. These metrics vary depending on the type of wetland assessed. For example, swamps would require the metrics involving tree cover, whereas marshes would not (Faber-Langendoen *et al.* 2006). Most of these metrics will be compared to BPJ categories in this report, however, not all of them were used by any one professional.

Although the above metrics may provide insight into aspects of the vegetative quality in a given site, BPJ for creating wetland and oak savanna indices has not been tested extensively. The three previously mentioned studies were focused on the agreement of experts in order to determine the viability of BPJ for determining benchmarks in benthic communities. One study conducted by DeBoer *et al.* (2011) did compare BPJ with various floristic quality metrics using data from Michigan wetland restorations. They discovered FQI and MC had strong correlations with BPJ, but mean wetness and total species were poorly correlated with BPJ. However, there is not much data collected to test the viability of BPJ in creating benchmarks for metrics calculated from wetlands and oak savannas of this dune and swale ecoregion.

This report will use similar methods of assessing expert agreement and the viability of BPJ for creating benchmarks to those used in the previous reports on benthic infaunal communities. The objective of this report is to assess the agreement among professionals when evaluating these community types. Good agreement among experts would then validate the use of BPJ for determining benchmarks in this ecosystem. Furthermore, the metrics and quality categories provided by BPJ will be used to determine necessary considerations before creating biological benchmarks for each quality category in these communities.

METHODS

Vegetation Sampling

This research was part of a multi-year project to measure the floristic quality of managed and unmanaged wetlands and oak savannas in Lake County, IN. Assessments for this project consisted of 63 transects: 31 measured the summer of 2011 and 32 from 2012. Of these 63 transects, 27 were oak savannas, 10 were riverine wetlands, and 26 were swales. Sites for 2011 were chosen based upon areas slated for restoration and apportioned based upon the size of the area. Sites analyzed in 2012 were chosen to encompass the full range of habitat quality (Figures 1 and 2).

During the summers of 2011 and 2012, a research team consisting of two graduate students (Josh Britton and Julie Evans in 2011; Leslie Gottschalk and Brad Gordon in 2012), Dr. Paul Rothrock from Taylor University, and one outside expert (George Manning) sampled the selected sites. These teams trained together before sampling to ensure methods were performed consistently. Sampling occurred during June and July of both summers to ensure plants were in peak growth and able to be identified. Each of the assigned sites contained one to twelve transects depending on the size and heterogeneity of the site. The endpoints of each transect were marked using a GPS unit, and the transects were set as straight as possible in order to avoid a biased result from bending the transect to capture the best data (Sastre and Lobo 2009). Along these transects, 15 1-m^2 quadrats were surveyed in 6-meter intervals, resulting in transects 84 meters in length. If the wetland or oak savanna was limited in length, the quadrats were placed in 5-meter intervals (70 meter transects). Other researchers have used ¼-m² quadrats for similar studies (Bowles and Jones 2006), but these smaller quadrats can have a low correlation with BPJ categories (DeBoer *et al.* 2011). Species' aerial cover, quadrat photos, and canopy cover photos were collected for each quadrat. The % canopy cover was later estimated by removing blue, converting the images to black and white, reducing pixel density, and reading the percent of high and medium density pixels in Photoshop®. Unique canopy cover species were recorded for quadrats containing canopy species besides *Quercus velutina*, and % bare ground was recorded for sites surveyed in 2012.

Data Compilation and BPJ Categorization

The species cover data were analyzed by the *Floristic Quality Assessment Computer Program* Version 1.0 (Wilhelm and Masters 1999) using the Indiana Floristic Quality Analysis (FQA) database. The software calculates transect and quadrat MC, FQI, mean wetness, and species richness, with and without adventive species. The quadrat-level metrics are created by calculating the values for each individual quadrat and then averaging them for all 15 quadrats along the transect. It also calculated totals for each C value as well as frequency, total transect cover, relative frequency, relative cover, and relative importance values for each species and for each physiognomic type.

FQA reports were compiled into pdf files with photos taken on site and site maps created with ArcGIS® 10 software. These files were then sent to seven experts. The experts were selected by Dr. Paul Rothrock and Paul Labus based on their experience with wetland and oak savanna flora and with ecosystem assessments in this unique area. Only seven were selected because of the limited number of ecologists who have worked extensively in this landscape. The experts were asked to provide BPJ by placing each transect in one of the following categories based on remnant natural quality: (1) “good to very good”: routine program is sufficient to maintain quality; (2) “medium”: some noteworthy restoration is desirable above and beyond routine maintenance; (3) “poor”: major restoration needed but site could reach medium natural quality within a short time frame (3-5 years) or a target end-point for the restoration of a previously very poor site; and (4) “very poor”: highly degraded wooded site or very major restoration needed and likely needing a long time frame to reach medium natural quality, assuming that goal is possible. The experts were asked to categorize the sites in the following: (1) based upon FQA reports alone; (2) based upon FQA reports and photos; and (3) based upon FQA reports, photos, and site locality information. This was requested in order to determine how much information was necessary to receive the best agreement among BPJ categories and if site information would cause biased results due to the possibility of the experts having been to the site.

Finally, each expert answered retrospectively the following items: 1) whether they emphasized the quality of ground cover flora, structure of the site (pertaining to vegetation that needs to be removed or brought under control), or both for the oak savannas and for the wetlands; 2) how they define oak savannas; and 3) whether they would focus more on restoring these sites to remnant or pre-settlement conditions, on improving biodiversity without an emphasis on remnant conditions, or on a combination of both. Their answers to these questions were eventually compared to the results of the statistical analysis to determine what may have influenced their decisions or caused possible biases.

Data Analysis

Kappa analysis was used to determine the agreement among experts based on how many sites they placed in the same category (Cohen 1960; Landis and Koch 1977; Banerjee *et al.* 1999; Titus *et al.* 1984). This statistical analysis also was used by Teixeira *et al.* (2010) to determine whether experts agreed when placing sites into quality categories. Kappa with quadratic weighting was used because the significance of disagreement between BPJ categories of “very poor” and “good to very good” was greater than that of disagreement between “medium” and “poor” (Cohen 1968; Banerjee *et al.* 1999). These calculations were completed using the *VassarStats Kappa Calculator* (Lowry 2001). This calculator allowed comparisons of only two experts at one time. Therefore, degrees of agreement (Monserud and Leemans 1992; Table 5) were applied to each expert’s mean Kappa value to determine agreement with every other expert. The means of all the Kappa values were calculated to determine the degree of agreement among all the experts for each community type.

After determining the level of agreement among BPJ categories, each expert’s quality categories were compared to the respective metrics used to determine those categories. These comparisons were made using discriminant analysis (McCune and Grace 2002) in Minitab® Statistical Software. After standardizing, the linear discriminant function of each metric for each category was used to determine which metrics had the greatest weight when determining transect quality. The means of each metric also were determined for each quality category using discriminant analysis. These means were calculated without standardizing the metrics.

The final analysis was conducted to compare each of the BPJ categories to the remnant oak savanna metrics listed by Leach and Givnish (1999). This was done to determine which experts' quality categories correlated with remnant community measurements. Metrics including species richness (quadrat average), native forb relative cover, adventive relative cover, fire-intolerant/shade-tolerant woody species relative cover, and canopy cover were used in this comparison. These were chosen for this comparison due to the emphasis Leach and Givnish (1999) placed on their uniqueness to oak savannas. Fire-intolerant/shade-tolerant woody species chosen were based on those from previous fire frequency studies which declined with increased fire or increased with very dense canopy cover (Anderson and Bowles 1999; Apfelbaum and Haney 1991; Peterson and Reich 2001).

Each expert's quality categories were compared to the remnant oak savanna metrics to determine how well their categories correlated with the defined remnant oak savannas in Leach and Givnish's (1999) study. Discriminant analysis was used to calculate this because of its ability to determine how many quality categories were chosen according to the trend of the metrics. The remnant oak savanna metrics from Leach and Givnish's (1999) study used to determine the experts' correlations with remnant communities were placed into the following groups: (1) all remnant metrics, (2) only ground cover metrics (species richness, forb cover, and adventive cover), and (3) only structure metrics (adventive cover, fire-intolerant/shade-tolerant woody species cover, and canopy cover). Each group of metrics was compared to each expert's quality categories to determine if they correlated better with ground cover aspects or structural aspects of remnant oak savannas.

RESULTS

BPJ Quality Categories and Metrics

Although all the experts had similar levels of experience working in this ecoregion, there was a variety of category placements. When choosing into which quality category each transect should be placed, the experts varied in judgment. Although all the experts chose the same quality category for some sites, the majority of sites received a variety of categories from the experts' judgments (Table 2).

All 7 experts agreed on the quality categories for 8 of the 63 sites (Table 2). Of those 8 sites, 5 were riverine wetlands which were clearly degraded by *Phragmites australis* and *Typha* spp. For 13 sites, as many as 6 of the 7 experts agreed on the categories (5 of which were the remaining riverine wetlands), 5 of 7 agreed on 11 of the sites, 4 of 7 agreed on 20 of the sites, and 3 of 7 agreed on 11 sites. The 21 sites where 6 or 7 of the experts agreed, 7 of those sites were placed in the "good to very good" category and 10 were placed in the "very poor" category by the majority of the experts.

Each expert's list of metrics used to determine the quality categories of oak savannas differed from other experts' lists (Table 3). Canopy cover was the most commonly used metric for assessing the quality of oak savannas, while native MC (both quadrat average and transect average), species richness (quadrat average), and FQI native (quadrat average) also were used by more than one expert. The remaining 17 metrics were used by no more than one expert. For the metrics used to assess the swales, only 6 of the 19 total metrics were used by more than one expert (Table 4). In both the oak savannas and swales, one expert (BPJ 6) used no unique metrics which no other expert used.

The types of metrics used by the experts also varied. In the oak savannas, 8 of the 22 metrics focused on the structure of the habitat. These metrics focused on components of the site which need managed or removed in order to prepare for introduction of higher quality species. These metrics included canopy cover, invasive species cover, or over-dominant species (those leading toward a monoculture or negatively influencing the growth of high quality species). In the swales, 6 of the 19 metrics assessed the structural component of the sites. In both site types, the remaining metrics, excluding Distance from Human Settlement, emphasized the quality of species in the ground layer.

The BPJ 5 Ordination Assessment Metric listed in Tables 3 and 4 was created by one of the experts (BPJ 5). This metric utilized native MC (quadrat and transect) and native FQI (quadrat and transect). The values of these four metrics were given scores based on their ranges. These scores were then weighted as follows:

(Quadrat MC x 2) x (Transect MC x 1.5) x (Transect FQI x 1.1) x (Quadrat FQI)

Kappa Analysis

Kappa analysis was used to calculate the level of agreement among experts when determining in which quality category each site belonged. The mean Kappa value calculated from all sites combined (oak savanna, riverine, and swale) was 0.672, indicating good agreement (Monserud and Leemans 1992; Table 5). The mean values for oak savannas and swales combined was 0.497, while the values for oak savannas and swales individually were 0.360 and 0.507 respectively. The agreement among experts on what quality categories to assign sites declined from good to fair (0.672 to 0.497) when the riverine wetlands were removed from the analysis. When assessing agreement for oak savannas only, agreement fell to poor, and agreement fell to fair when assessing the swales only (Monserud and Leemans 1992). Riverine wetlands were unable to be assessed with Kappa analysis on their own because too few sites were analyzed, and all the sites were placed in the “very poor” quality category by all but one expert.

Each expert’s mean Kappa value also varied with site type (Table 6). All experts, except BPJ 3, agreed with the other experts more often when assessing swales than when assessing oak savannas. Expert BPJ 4 agreed with the other experts more than any other expert agreed with the others. In contrast, experts BPJ 1 and BPJ 2 had the poorest agreement with the other experts when assessing oak savannas, and expert BPJ 3 had the poorest agreement with the other experts when assessing swales. Furthermore, expert BPJ 7 had the poorest overall agreement with the other experts when assessing all the sites combined.

Metric Means and Response Signatures

Using discriminant analysis, it was determined that most metrics used by the experts to categorize the sites had a response signature in which the metric values seemed to respond to the change in quality categories (Tables 7 and 8). For the oak savannas, 15 of the 22 metrics displayed a response of values with quality categories. For the swales, 12 of the 19 metrics displayed a response between values and quality categories. In both site types, 5 of the 7 metrics without a correlation had a value in one of the categories that was much higher than the values of the other categories.

Metric Weights

Discriminant analysis also calculated the weight of each metric used to determine which sites belonged in each quality category (Figures 3 and 4). The weight of each metric on the experts' decisions varied. For example, % Canopy Cover was the most important metric for expert BPJ 7 while it was the least important metric for expert BPJ 6. The metrics also varied by quality category. In the swales, MC Native (quadrat) was the most important metric for expert BPJ 6 but was the least weighted metric for experts BPJ 3 and BPJ 5 in the "very poor" category. RCOV FRAALN was the least important metric for expert BPJ 4 when placing sites in the "good to very good," "medium," and "poor" categories, but it was the most important metric when placing sites in the "very poor" category. This switch in weight was the case for many of the experts' metrics (Figure 3). Furthermore, metrics used by expert BPJ 6 and two used by expert BPJ 7 held consistent weights for all their categories, but all other metrics' weights changed with each category.

When comparing the weights of structural metrics to ground cover quality metrics, the structural metrics increased in importance compared to the ground cover quality metrics when poorer quality sites were encountered. For all 6 experts who used % Canopy Cover as a metric when assessing oak savannas, the weight of that metric increased as they decided to place the sites in poorer categories. This also was true for other structural metrics including RIV Non-Natives, RCOV FRAALN, CORRAC/PRUVIR/Trees % Cover, and Adventives Relative Cover. Bracken Fern Relative Cover was the only structural metric to noticeably decline in weight as the sites were placed in poorer categories.

The weightings for swale metrics largely mirrored weightings from the oak savanna metrics. Each metric's weight changed from one category to the next. All 6 structural metrics in the swales seemed to increase in weight when the experts determined the sites belonged in poorer categories. However, Exotic Species (transect), *Cephalanthus occidentalis* % Cover, and one expert's use of Adventive + *Phragmites australis* % Cover had a lesser weight for placing sites in the "very poor" category than for the "poor" category. Otherwise, all the structural metrics increased in weight as the quality decreased. In contrast, all of the ground cover quality metrics aside from Species Richness (transect) decreased in weight as the quality decreased.

Comparisons with Remnant Oak Savannas

Following the assessment of expert agreement and comparison of metrics, each expert's quality categories were compared to metric values that would best assess a site's similarity to a remnant oak savanna (Leach and Givnish 1999). According to discriminant analysis, expert BPJ 7 classified the most sites correctly into the quality categories based on all of the remnant metrics (Table 9). Expert BPJ 3 had the fewest correctly classified sites. When comparing BPJ quality categories to the structural metrics for distinguishing a remnant oak savanna, expert BPJ 7 had the greatest number of correctly classified sites and experts BPJ 1 and BPJ 3 had the fewest. When comparing the remnant ground cover quality metrics to BPJ categories, expert BPJ 1 had the greatest number of correct classifications and expert BPJ 3 had the fewest.

DISCUSSION

Although the experts seemed to have good agreement when assessing all sites, they had poor agreement assessing the oak savannas, fair agreement assessing the swales, and fair agreement with the two combined. The difference in agreement between all the sites versus the oak savannas and swales separately is due to the experts' near perfect agreement on the riverine wetlands. These sites were severely degraded and/or overwhelmed by invasive species. Thus, experts had little doubt classifying these sites as "very poor."

Fair agreement among experts for the swales was likely due to the variety of wetland types observed. It also was difficult to know what the wetlands types were in pre-settlement conditions. This uncertainty likely made it challenging to know what metrics to use for all the sites (Mack 2009). Furthermore, the canopy cover of these sites was very inconsistent. Thus, the biodiversity may have increased with reduction of the canopy even if the species were not those typical for that wetland type (Mack 2009).

Poor agreement among experts for the oak savannas was an unexpected result due to the good agreement in the studies by Teixeira *et al.* (2010). Fair agreement in the swales was slightly lower than expected as well. The poor agreement among experts when assessing oak savannas and fair agreement when assessing swales makes BPJ a questionable source for establishing biological benchmarks in this ecoregion. It is especially important to note that the experts in the report by Teixeira *et* *al.* (2010) had good agreement (Kappa value = 0.65). In contrast, in this study agreement was merely fair (for wetlands; Kappa value = 0.507) to poor (for oak savannas; Kappa value = 0.360). In Weisberg *et al.* (2007), Spearman correlation coefficient of 0.91 was calculated based on the experts' ranking of benthic communities. Although their experiment used a ranking system rather than a categorizing system, it still produced good agreement. It also is noteworthy that the experts in the report by Weisberg *et al.* (2007) used 7 metrics and those in the report by Teixeira *et al.* (2010) used 8 metrics. The experts in this report used 22 metrics for oak savannas and 19 metrics for the swales. Not only did the experts in this report have poorer agreement on what quality categories to assign to each site, but they also had a greater disagreement on what metrics to use for assessing the sites.

With a high level of agreement in the previous reports assessing the viability of BPJ for creating benchmarks for benthic communities, it was assumed the same could be expected for other ecological systems. This study followed the methods used by Teixeira *et al.* (2010), but the expert agreement in this study indicated poorer agreement. Due to the poor and fair agreement between experts assessing oak savannas and swales respectively, creating benchmarks for each metric became more difficult. Once this degree of agreement was realized, the remainder of this project was devoted to discovering possibilities for the disagreement and what factors should be considered before creating biological benchmarks to assist in restoration projects. Possible reasons for the experts' poorer agreement than expected are described below.

The first possibility for poor agreement may be the variety of metrics used. With only 5 of the 22 oak savanna and 6 of the 19 swale metrics used by more than one expert, each expert used a unique combination of metrics to assess the sites. This variety of methods for assessing the sites makes agreement less likely. It also is possible that the expert who did not have any unique metrics would have the best agreement with other experts. However, expert BPJ 6 used no unique metrics of either site type but had the third lowest Kappa value for oak savannas, the third lowest for swales, and the fourth lowest with the two types combined. Therefore, using similar metrics did not seem to indicate best agreement in this case. Rather, it seems likely the combination of metrics and weights of each metric had a greater influence on agreement.

The second possible reason for disagreement was the variation in weights of each metric. Each expert emphasized the relative importance of each metric differently. Metrics' weights differed by expert and by quality category. Not only did each expert utilize the metrics differently than others who used the same metrics, but each expert changed the importance of each metric according to the category into which they decided to place the site.

The third possible reason could be due to emphasis placed on ground cover quality versus site structure metrics. Expert BPJ 7 focused on site structure, expert BPJ 5 relied on ground cover quality, and the other experts used a mixture of both metric types. The ground cover quality metrics focus on the current conditions of the vegetation. In contrast, structural metrics assessed the potential threats to the site and what may need to be removed whether the ground cover was of high quality or not. Although expert BPJ 7 used only structural metrics, this expert had the third highest agreement with other experts when assessing the oak savannas and the fourth highest when assessing swales. Likewise, expert BPJ 5 who emphasized ground cover metrics had the fourth highest agreement when assessing oak savannas and third highest when assessing swales. Therefore, these two experts did not deviate strongly from the others despite their different analytical strategies.

The fourth reason for disagreement was the difference in definitions of the site types. The swales were more difficult to define with a lack of data on the variety of original wetland types found in this area. However, disagreement on how to define oak savannas may be a major concern for management decisions for this unique community type. Published reports conclude that oak savannas were historically transitions between prairies and woodlands or very unique communities (Nuzzo 1986; Anderson and Bowles 1999; Apfelbaum and Haney 1991; Leach and Givnish 1999). However, the means of each category's metrics varied from what Leach and Givnish (1999) believed were remnant oak savannas. The average species richness per quadrat for the "good to very good" BPJ category was 13 and Leach and Givnish's mean was 16 per m^2. The ideal species composition also varied among experts in that expert BPJ 2 placed higher relative cover of sedges and ferns in higher quality categories, while expert BPJ 3 moved some sites from the "good to very good" category to the "medium" category if they had high Bracken Fern Relative Cover values. The canopy cover of "good to very good" quality sites also was high when compared with remnant oak savannas. Curtis (1959) and Anderson and Bowles (1999) determined remnant oak savannas to have typically lower than 50% canopy cover while the mean canopy cover of the "good to very good" sites in this project was 62%.

The comparison of BPJ categories to remnant metrics (Leach and Givnish 1999) indicated that experts disagreed on the importance of equating quality with remnant community structure. BPJ 7 had the highest percentage of correct categorizations. This could indicate that this expert's metrics were the best for managing oak savannas with remnant communities in mind. This expert used only structural metrics as well, which could indicate that structural metrics are better for identifying a remnant quality community.

Furthermore, experts BPJ 1 and BPJ 2 had the lowest Kappa values when assessing oak savannas. On this basis, their metrics should be used with caution if their levels of agreement indicate metric quality. However, the percent of sites correct when comparing their categories to remnant metrics indicated they may have more remnant-indicating metrics. They had the two highest percentages when compared to the remnant ground cover quality metrics. Expert BPJ 2 had the second highest percentage when compared to the remnant structure-based metrics. In contrast, expert BPJ 1 was tied for the lowest percent in this comparison. This could indicate that they disagreed with the other experts, but they were better in perceiving remnant goals. They did not, however, both use the same metrics. Their agreement with each other in oak savannas had a Kappa value of only 0.222. Thus, their high percentage when compared to remnant values could likely have been due to expert BPJ 1 emphasizing remnant ground cover quality and expert BPJ 2 emphasizing remnant structure slightly more than ground cover quality.

A fifth potential reason for disagreement rests in the presentation of data to the experts. A few experts mentioned that the photos provided did not offer a complete representation of the sites. This was likely to be the case when providing data and photos versus experts having the opportunity to visit the sites. Limited data also was a cause for disagreement in the study by Bay *et al*. (2009). Although all the experts had visited these sites in years past, some may have been able to remember their appearance and therefore be slightly biased from experiences in the sites. However, changes due to different stages of management would make it unlikely the experts would have recognized the sites from these previous visits.

A sixth possible reason for disagreement was the subjectivity of analysis. Although each expert listed the metrics used to determine the quality category of each site, some subjectivity may be involved in reaching a decision. A reason outside of the basic metrics may have caused the expert to move a site from one category to the next. This also was a perceived problem in the study conducted by Bay *et al.* (2009). Similarly, this has been observed when creating automated diagnostic models in the medical field. When an expert uses a more subjective approach for diagnosing a problem, it is difficult to create benchmarks or models based on their methods. Clinicians who use diagnostic trees demonstrate better methods for creating diagnostic models (Sboner and Aliferis 2005).

The large variety of metrics and quality results which differed from some previous reports could reflect a difference in definitions of oak savannas, or it could indicate a difference in goals for management. Some experts would like to restore these sites to their pre-settlement structure while others may aim for a greater biodiversity no matter what community type results. This latter goal would likely marginalize the definition of oak savannas but emphasize FQA results and biodiversity indexes. If either disagreement on goals or the difference in definitions of oak savannas is the cause for the poor agreement among experts, it will be important for this to be resolved for making future management decisions in these sites. This is especially important if oak savannas are to be preserved.

The experts' responses to the follow-up questions also confirmed the variety of goals for assessing these sites. Four of the seven experts considered the goal of seeking biodiversity slightly more important than remnant or pre-settlement community structures. In that idea, they mentioned that pre-settlement communities are a good reference but not practical with current climate change and industrial influences on this area. One of the experts who preferred a pre-settlement community structure, placed as much emphasis on the appearance of the site when compared to historic photographs versus floristic data. While five of the experts used a mixture of structural and ground cover quality metrics, they all varied in how they weighted each. The other two experts held opposing views on whether structure or ground cover quality should be assessed. When defining oak savannas, the definitions were highly varied. Some experts emphasized a complex mosaic of plant communities, canopy cover, and canopy layers due to frequent fires. Others listed specific canopy cover ranges, grass-dominated ground layers, or forb-dominated ground layers. Two experts even defined these sites as oak barrens rather than oak savannas. Through all of these responses, it is evident that there is little agreement on how to categorize the quality of this assortment of sites.

CONCLUSION

Due to the poor agreement among experts when assessing oak savannas and fair agreement when assessing swales, some parameters must be considered before creating biological benchmarks. The results from this study indicate that the creation of benchmarks is more complex than quantifying the means and ranges of each metric. If BPJ is a reliable source for creating benchmarks, these results indicate that using the mode of each site's quality categories is not the best approach. Due to the large number of metrics used by all the experts, it is impractical to use all of their metrics when making management decisions or discovering the quality of a site following management. However, some lessons were learned from the BPJ quality categories and metrics in this study which should be applied when creating benchmarks in the future.

The benchmarks of each metric from one category to the next did not show a linear progression. Although metrics including % Canopy Cover, MC native (quadrat), and Species Richness (quadrat) gave somewhat linear response signatures from the "very poor" category to the "good to very good" category. Most of the other metrics included major gaps or dramatic changes from one category to the next. Some metrics without a linear response signature had one quality category with an unusual value. In the case of Bracken Fern Relative Cover, the "medium" category had an unusually high value compared to the other categories. The expert who used this metric mentioned this was due to originally having sites in the "good to very good" category, but the expert decided to move them to the "medium" category due to their very high bracken fern cover. All qualities of those sites fit into the definition of a remnant oak savanna, but the bracken fern added another vegetation layer that shaded low growing forbs. As for *Frangula alnus* cover, these metrics had no response signature except having high values in the “very poor” category. This metric may become a major concern only when it has a high value. Potentially, the metric could almost be ignored.

Secondly, the metric weights indicate that some metrics may not be necessary for assessments. Although it may not be accurate to compare weighted values between experts, some metrics may be eliminated based on their very low weights compared to others used by the same expert. For example, FQI native (quadrat) was used by 3 experts when assessing oak savannas. However, discriminant analysis showed this metric was highly correlated with other metrics for two experts and had a negative weight for the third. Similarly, Distance From Human Settlement seemed to have a very low weight and may not be necessary. Therefore, using these metrics may be redundant or insignificant compared to other metrics.

Thirdly, due to the shift from the use of ground cover quality metrics in higher quality sites to structural metrics in lower quality sites, these metric types should be assessed separately. Structural metrics could be initially used when assessing sites. If these metrics do not pass a threshold value marking a transition from the “very poor” or “poor” to the “medium” category, the site may quickly be placed in the lowest quality category. For example, when assessing an oak savanna, the experts’ means indicate a site with metrics means greater than the following values should not be placed in the “good to very good” or “medium” quality categories: % Canopy Cover > 80%, Adventives Relative Cover > 8%, Bracken Fern Relative Cover > 7-10%, CORRAC/PRUVIR/Trees Relative Cover > 14%, *Frangula alnus* Relative Cover > 3-5%, or RIV Non-Natives > 8-10. When assessing swales, any sites with metrics means greater than the following values should not be placed in the “good to very good” or “medium” quality categories: Adventive + *Phragmites australis* % Cover > 14%, *Cephalanthus occidentalis* % Cover > 13-15%, Exotic Species (transect) > 2, Native Shrub Relative Cover > 10%, RIV Non-Natives > 15, or Trees Relative Cover > 3-5%. More analysis must be completed to establish the exact thresholds of these metrics. If the metrics are under the structural metric thresholds, then the ground cover quality metrics could be used to separate the sites into “good to very good” or “medium” quality categories.

Fourthly, there is much debate over the definitions of oak savannas and whether it is more important to preserve biodiversity or try to restore remnant community structure. If assessing biodiversity, metrics including MC, FQI, or species richness would be very important. However, if a remnant structure is the goal, using experts BPJ 2 and BPJ 7’s metrics for assessing remnant structure and experts BPJ 1 and BPJ 2’s metrics for assessing remnant ground cover quality may be best (Table 3).

The expert with the best agreement with the other experts, BPJ 4, may have used the best metrics for representing all the experts. For oak savannas, these metrics included % Canopy Cover, Mean C native (quadrat), Species Richness (quadrat), FQI native (quadrat), RFREQ *Frangula alnus*, and *Frangula alnus* Relative Cover. However, FQI native (quadrat) was highly correlated with the other metrics this expert used, so it would be unnecessary to use for assessing the sites. For swales, the metrics could include Adventive + *Phragmites australis* % Cover, MC native (transect), FQI native (transect), and total Exotic Species (transect).

Although experts had poorer agreement than expected, their BPJ categories can be used to gain a better understanding of oak savanna and wetland assessment. Structure and ground cover quality are both important aspects for assessing oak savannas and wetlands. Structure could be used first to determine if extreme management is necessary. In order to complete the creation of benchmarks, the management goal, whether remnant structure or higher biodiversity, should be clearly stated. Otherwise, experts will continue to disagree on how to assess the unique dune and swale ecoregion of northwestern Indiana.

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Appendix I: Figures and Tables

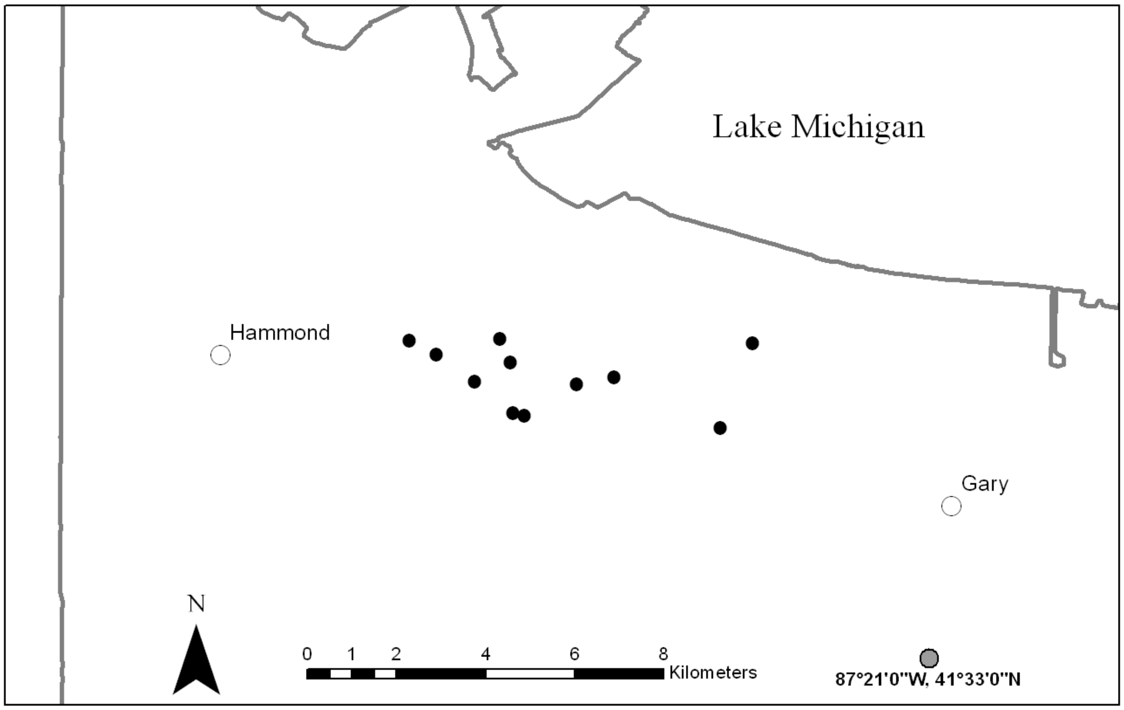

Figure 1. Location of study sites in Lake County, IN. Eleven sites included a total of 63 oak savanna and wetland transects in the unique dune and swale topography of Northwestern Indiana.

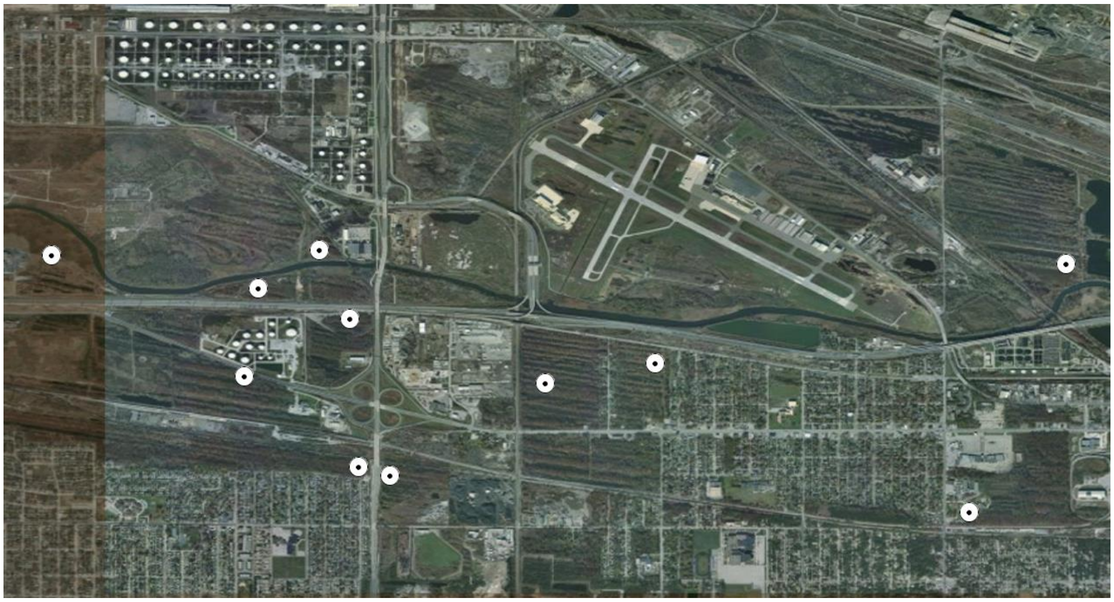

Figure 2. Aerial photo of the eleven study sites in Lake County, IN. Transects were placed along the visible ridges and swales in each site (photo from ArcGIS® 10 software).

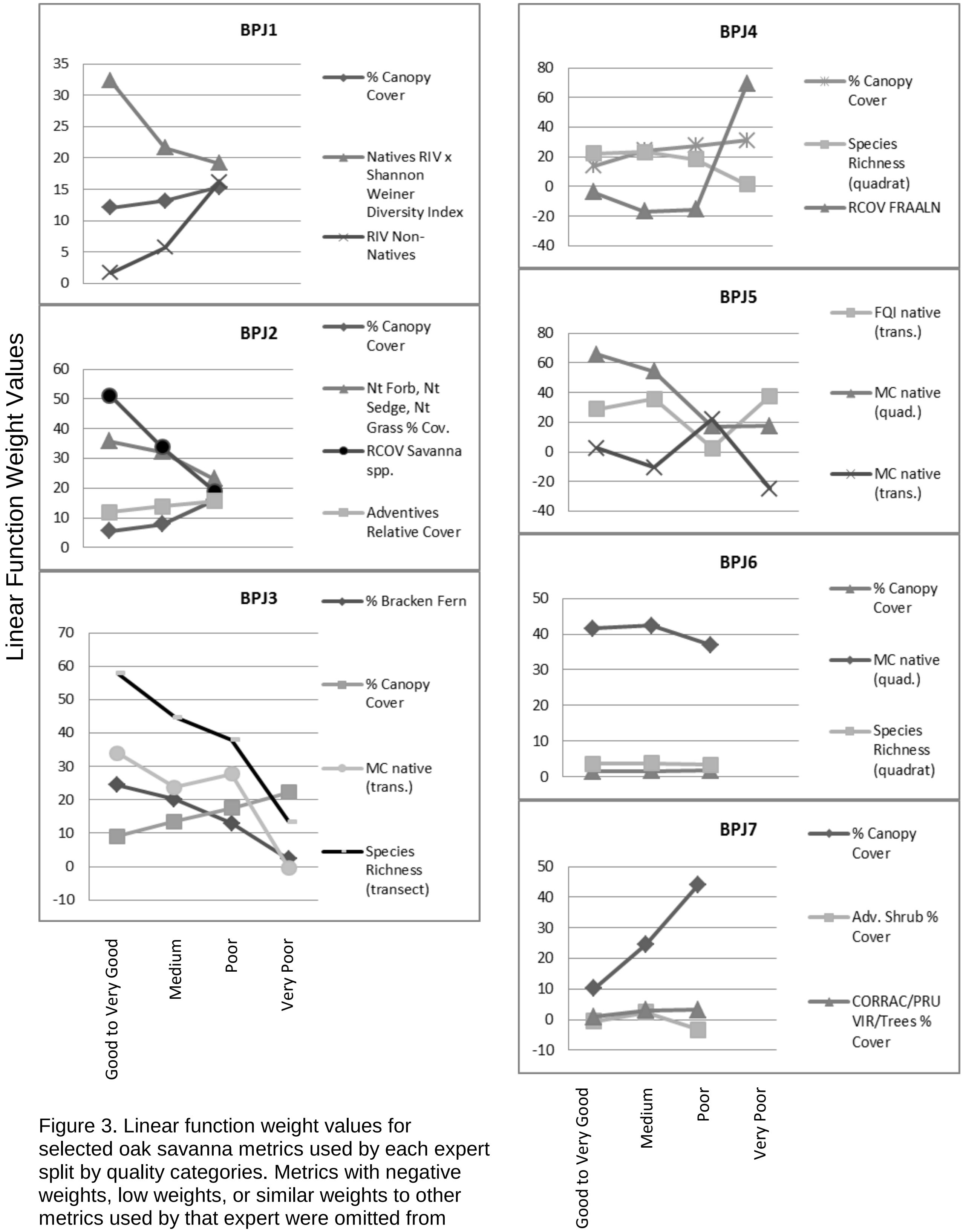

Figure 3. Linear function weight values for selected oak savanna metrics used by each expert split by quality categories. Metrics with negative weights, low weights, or similar weights to other metrics used by that expert were omitted from these graphs.

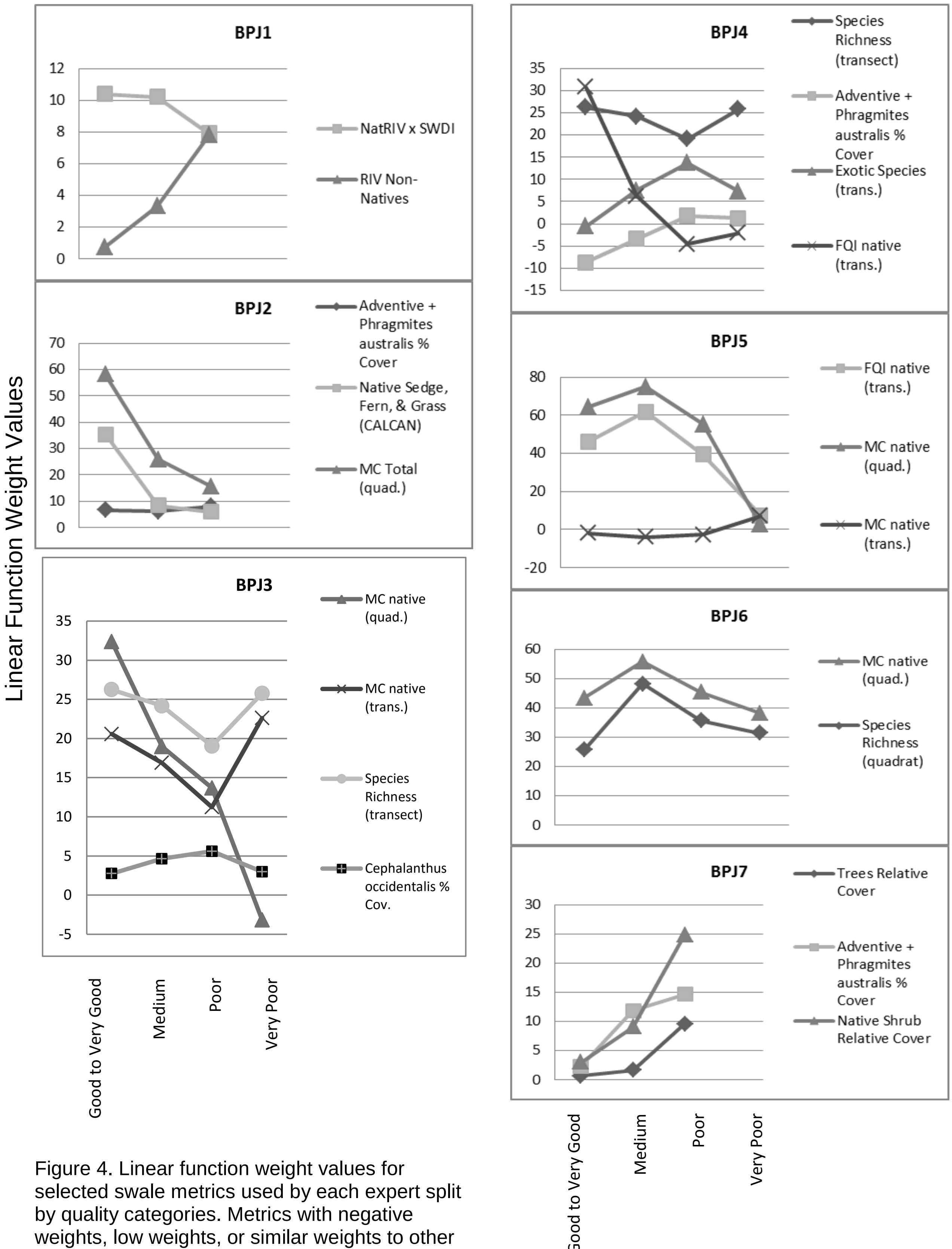

Figure 4. Linear function weight values for selected swale metrics used by each expert split by quality categories. Metrics with negative weights, low weights, or similar weights to other metrics used by that expert were omitted from these graphs.

Table 1. NatureServe's set of biotic condition metrics for the North-Central Oak Barrens System with definition and metric ratings (NatureServe 2006).

Essential Ecological Attribute	**Indicator & Metric**	**Definition**	*Metric Rating Criteria*			
			Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
Community Structure	Tree Canopy Cover	Percent cover of trees >4" dbh.	10-60%	>10-60%	>60-90%	>90%
Community Composition	Percent Cover of Exotic Plant Species	Percent cover of the plant species that are exotic, relative to total cover (sum by species)	<1% cover of exotic plant species	1-15% cover of exotic plant species	>15-50% cover of exotic plant species	>50% cover of exotic plant species
	Canopy Composition	Relative percent cover of *Quercus* spp. native to the region in the canopy.	Relative percent cover of native *Quercus* spp. is >80%	Relative percent cover of native *Quercus* spp. is >65-80%	Relative percent cover of native *Quercus* spp. is 40-65%	Relative percent cover of native *Quercus* spp. is <40%
	Sapling Composition	Relative percent cover of *Quercus* spp. native to the region in the sapling layer.	>50%	>40-50%	>30-40%	<30%
	Herbaceous Composition	Relative percent cover of native forbs in the herbaceous layer	Relative cover of native forbs is >40-50%	Relative cover of native forbs is >30-40 % or 50-60%	Relative cover of native forbs is 20-30% or 60-70%	Relative cover of native forbs is <20% or >70%.

Table 2. Quality categories assigned by the experts to each of the 63 sites. Quality categories: 1 = “good to very good”; 2 = “medium”; 3 = “poor”; 4 = “very poor”.

	Site #	BPJ 1	BPJ 2	BPJ 3	BPJ 4	BPJ 5	BPJ 6	BPJ 7
Savanna	**1**	1	2	2	2	2	2	1
	4	2	3	4	3	2	3	3
	5	2	3	4	3	3	3	3
	6	1	2	3	3	2	3	3
	7	1	2	2	3	2	3	3
	9	1	2	1	1	1	1	2
	10	1	3	1	2	2	2	3
	15	2	2	3	2	2	1	3
	16	1	1	2	3	1	2	3
	17	1	1	2	2	2	2	3
	18	1	1	2	2	2	2	3
	19	2	1	2	3	1	2	3
	29	2	1	2	2	2	1	2
	30	2	1	2	2	2	2	3
	51	2	3	4	3	4	3	3
	52	3	3	4	4	2	3	3
	53	3	2	2	3	2	1	2
	54	1	2	1	1	1	1	1
	55	1	2	2	2	2	1	3
	56	2	2	2	1	2	1	2
	57	1	1	2	3	1	2	3
	58	1	1	2	1	1	1	1
	59	1	2	1	1	2	1	1
	60	1	1	1	1	2	1	1
	61	2	2	2	1	1	1	1
	62	1	1	1	1	1	1	1
	63	3	1	2	2	1	2	3
Riverine	**2**	4	3	4	4	4	4	4
	3	4	4	4	4	4	4	4
	12	4	4	4	4	4	4	4
	13	4	4	4	4	4	4	4
	14	4	4	4	4	4	4	4
	24	4	3	4	4	4	4	4
	25	4	3	4	4	4	4	4
	26	4	3	4	4	4	4	4
	27	4	4	4	4	4	4	4
	28	4	3	4	4	4	4	4
Swales	**8**	2	3	3	3	3	3	3
	11	3	2	2	3	3	3	1
	20	2	3	3	3	4	4	3
	21	2	3	3	3	3	4	3
	22	2	2	2	2	2	3	3
	23	3	2	2	3	2	3	3
	31	3	2	3	3	3	3	2
	32	3	2	2	2	2	2	1

	33	1	1	2	1	1	1	1
	34	1	1	1	1	1	1	1
	35	1	1	1	1	1	1	1
	36	3	2	4	3	3	3	1
	37	2	2	3	2	3	2	1
	38	3	2	3	3	3	2	2
	39	1	2	3	2	3	2	1
	40	3	3	4	4	3	4	3
	41	3	3	3	3	3	4	3
	42	3	3	2	3	3	3	3
	43	2	2	2	2	3	1	1
	44	1	2	3	2	2	2	1
	45	2	2	3	2	3	1	1
	46	1	2	2	2	3	1	1
	47	1	2	2	2	3	1	1
	48	3	2	3	2	3	2	1
	49	2	3	3	3	3	3	3
	50	3	3	4	4	4	3	3

Table 3. Oak savanna assessment metrics used by the experts.

Oak Savanna Metrics Used for BPJ Categories	**Number of Experts Who Used Metric**	**Expert Who Used Metric (BPJ)**
% Canopy Cover	6	1, 2, 3, 4, 6, 7
Mean C native (quadrat)	4	3, 4, 5, 6
Species Richness (quadrat)	3	3, 4, 6
FQI native (quadrat)	3	4, 5, 6
Mean C native (transect)	2	3, 5
Native RIV x Shannon Weiner Diversity Index	1	1
RIV Non-Natives	1	1
Distance From Human Settlement	1	1
RCOV HELDIV, PTEAQU, QUEVEL, CXPENP, & CXMUEM	1	2
Adventives Relative Cover	1	2
Nt Forb, Nt Sedge, Nt Grass RCOV	1	2
Species Richness (transect)	1	3
Mean C Native - Mean C total (transect)	1	3
Mean C Native - Mean C total (quadrat)	1	3
Bracken Fern Relative Cover	1	3
% Bare Ground	1	3
RFREQ *Frangula alnus*	1	4
Frangula alnus Relative Cover	1	4
FQI native (transect)	1	5
BPJ 5 Ordination Assessment Metric	1	5
CORRAC/PRUVIR/Trees Relative Cover	1	7
Adventive Shrub Relative Cover	1	7

Table 4. Swale assessment metrics used by the experts.

Swale Metrics Used for BPJ Categories	**Number of Experts Who Used Metric**	**Expert Who Used Metric (BPJ)**
Adventive + *Phragmites australis* % Cover	3	2, 4, 7
MC native (quadrat)	3	3, 5, 6
MC native (transect)	3	3, 4, 5
FQI native (quadrat)	2	5, 6
FQI native (transect)	2	4, 5
Species Richness (quadrat)	2	3, 6
Distance from Human Settlement	1	1
Native RIV x Shannon Weiner Diversity Index	1	1
RIV Non-Natives	1	1
MC Total (quadrat)	1	2
Nt Sedge/Fern/Grass (CALCAN)	1	2
Cephalanthus occidentalis % Cover	1	3
Mean C Native - Mean C total (transect)	1	3
Mean C Native - Mean C total (quadrat)	1	3
Species Richness (transect)	1	3
Exotic Species (transect)	1	4
BPJ 5 Ordination Assessment Metric	1	5
Native Shrub Relative Cover	1	7
Trees Relative Cover	1	7

Table 5. Degree of agreement ranges for Kappa values (Monserud and Leemans 1992).

Degree of Agreement	No	Very Poor	Poor	Fair	Good	Very Good	Excellent	Perfect
Kappa Values	<0.05	0.05-0.20	0.20-0.40	0.40-0.55	0.55-0.70	0.70-0.85	0.85-0.99	0.99-1.00

Table 6. Kappa values calculated for each expert's agreement with the other 6 experts.

	BPJ 1	BPJ 2	BPJ 3	BPJ 4	BPJ 5	BPJ 6	BPJ 7
All Sites	0.647	0.670	0.701	0.760	0.625	0.642	0.613
Oak Savannas + Swales	0.391	0.500	0.538	0.613	0.482	0.513	0.365
Oak Savannas	0.203	0.203	0.453	0.513	0.373	0.343	0.383
Swales	0.409	0.605	0.356	0.693	0.502	0.448	0.461

Table 7. Means of each oak savanna metric within each quality category. Several "Very Poor" metric means were not recorded because the experts who used those metrics did not categorize any sites in that category.

Oak Savanna Assessment Metric	**Good to Very Good**	**Medium**	**Poor**	**Very Poor**
% Bare Ground	7	12	25	34
% Canopy Cover	62	71	79	87
Adventive Shrub Relative Cover	1	6	4	
Adventives Relative Cover	2	7	9	
BPJ 5 Ordination Assessment Metric	924	295	36	32
Bracken Fern Relative Cover	6	19	7	7
CORRAC/PRUVIR/Trees Relative Cover	5	13	14	
Distance from Human Settlement (meters)	223	216	143	
FQI native (quadrat)	15.4	13.9	11.2	10.0
FQI native (transect)	28.2	25.4	20.4	17.9
Frangula alnus Relative Cover	2	2	2	18
Frangula alnus Relative Frequency	2	4	4	9
MC native (quadrat)	4.5	4.2	3.7	3.3
MC native (transect)	4.5	4.0	3.9	3.2
Mean C Native - Mean C total (quadrat)	0.08	0.09	0.07	0.12
Mean C Native - Mean C total (transect)	0.48	0.44	0.30	0.50
Native RIV x Shannon Weiner Diversity Index	284.39	229.10	225.54	
Nt Forb, Nt Sedge, Nt Grass RCOV	27	43	30	
RCOV HELDIV, PTEAQU, QUEVEL, CXPENP, & CXMUEM	37	13	8	
RIV Non-Natives	7	7	14	
Species Richness (quadrat)	13.2	11.3	10.0	8.9
Species Richness (transect)	52.8	38.6	38.5	28.5

Table 8. Means of each swale metric within each quality category. Several "Very Poor" metric means were not recorded because the experts who used those metrics did not categorize any sites in that category.

Swale Assessment Metric	Good to Very Good	Medium	Poor	Very Poor
Adventive + *Phragmites australis* % Cover	2	13	20	10
BPJ 5 Ordination Assessment Metric	1233	140	38	4
Cephalanthus occidentalis % Cover	0	13	23	2
Distance from Human Settlement (meters)	231	101	175	
Exotic Species (transect)	1	2	3	1
FQI native (quadrat)	12.4	7.4	5.6	3.0
FQI native (transect)	25.8	18.1	14.2	10.3
Mean C Native - Mean C total (quadrat)	0.01	0.11	0.14	0.15
Mean C Native - Mean C total (transect)	0.10	0.40	0.50	0.60
MC native (quadrat)	5.8	4.0	3.4	2.2
MC native (transect)	5.4	4.4	4.1	4.3
MC Total (quadrat)	6.2	3.4	2.2	
Native RIV x Shannon Weiner Diversity Index	154.6	146.3	135.1	
Native Shrub Relative Cover	4	3	35	
Nt Sedge/Fern/Grass (CALCAN)	68	12	12	
RIV Non-Natives	3	11	20	
Species Richness (quadrat)	6	4	3	1
Species Richness (transect)	29	17	13	7
Trees Relative Cover	1	2	11	

Table 9. Percent of oak savanna sites placed in the correct category by each expert based on the trend of remnant metrics (Leach and Givnish 1999) compared to the expert's quality categories.

BPJ	Percent of Sites Correct Using All Remnant Metrics	Percent of Sites Correct Using Structure-Based Metrics	Percent of Sites Correct Using Ground Cover Quality Metrics
1	77.8	51.9	77.8
2	77.8	74.1	70.4
3	70.4	51.9	48.1
4	77.8	66.7	55.6
5	74.1	55.6	59.2
6	77.8	70.4	55.6
7	96.3	96.3	63

Appendix II: Best Professional Judgment Experts

Dr. Young D. Choi – Professor – Purdue University Calumet

Paul Labus – Northwest Indiana Region Director – The Nature Conservancy

Scott Namestnik – Botanist – Senior Project Scientist at Cardno JFNew

Tom Post – Northwest Regional Ecologist – Indiana Department of Natural Resources

Dr. Paul E. Rothrock – Professor – Taylor University

John Shuey – Director of Conservation Science – The Nature Conservancy

Dr. Gerould Wilhelm – Director of Research at Conservation Research Institute

Appendix III: FQA Metric Values for the 63 Transects

Oak savanna transect FQA metric values. MCN = Mean C native, MCT = Mean C total, FQIN = FQI native, FQIT = FQI total, SR = Species Richness, TS = Total Species.

Oak Savanna Transects	Site #	MCN	MCT	FQIN	FQIT	SR	TS
Beamster managed savanna - 2012	1	3.9	3.2	25.8	23.3	44	54
Beamster unmgd savanna 1 - 2012	4	3.3	2.9	13.6	12.8	17	19
Beamster unmgd savanna 2 - 2012	5	3.9	3.2	20.4	18.5	27	33
Brunswick savanna 1 - 2012	6	3.8	3.3	26.3	24.3	48	56
Brunswick savanna 2 - 2012	7	3.7	3.5	23.6	22.7	40	43
Clark Station savanna 1 - 2012	9	5.1	4.3	38.8	35.5	57	68
Clark Station savanna 2 - 2012	10	4.4	3.6	33.2	30.2	57	69
Dupont savanna 5 - 2012	15	4.1	4.0	22.1	21.7	29	30
Gibson E - savanna 1 - 2012	16	4.1	3.7	26.5	25.1	42	47
Gibson E - savanna 2 - 2012	17	4.2	3.9	27.6	26.7	43	46
Gibson W - savanna 1 - 2012	18	4.1	3.7	24.7	23.4	36	40
Gibson W - savanna 2 - 2012	19	4.2	3.8	18.8	17.9	20	22
Tolleston savanna 1 - 2012	29	4.0	3.6	25.0	23.8	40	44
Tolleston savanna 2 - 2012	30	4.0	3.7	23.8	22.9	35	38
Clark Station Savanna 1 - 2011	51	3.0	2.5	17.9	16.4	35	42
Clark Station Savanna 2 - 2011	52	3.4	3.0	20.1	18.8	35	40
Dupont savanna 1 - 2011	53	4.3	3.7	26.8	24.6	38	45
Dupont savanna 2 - 2011	54	4.4	4.1	31.5	30.3	51	55
Dupont savanna 3 - 2011	55	3.7	3.3	25.5	24.0	47	53
Dupont savanna 4 - 2011	56	4.1	3.5	29.5	27.3	53	62
Gibson Woods savanna 1 - 2011	57	4.2	3.9	26.1	25.1	38	41
Ivanhoe East savanna 1 - 2011	58	4.5	3.9	27.9	25.9	38	44
Ivanhoe East savanna 2 - 2011	59	4.0	3.6	30.2	28.7	57	63
Ivanhoe West savanna 1 - 2011	60	4.5	4.1	29.3	28.0	42	46
Ivanhoe West savanna 2 - 2011	61	4.8	4.2	31.7	29.4	43	50
Ivanhoe West savanna 3 - 2011	62	4.6	4.4	33.7	32.7	53	56
Martin Oil savanna - 2011	63	4.0	3.6	18.5	17.8	22	24

Oak savanna quadrat FQA metric values. MCN = Mean C native, MCT = Mean C total, FQIN = FQI native, FQIT = FQI total, SR = Species Richness, TS = Total Species, %CC = % Canopy Cover.

Oak Savanna Transects	Site #	MCN	MCT	FQIN	FQIT	SR	TS	%CC
Beamster managed savanna - 2012	1	3.9	3.4	14.0	13.2	13.1	14.9	55
Beamster unmgd savanna 1 - 2012	4	4.2	3.7	9.0	8.5	4.8	5.3	88
Beamster unmgd savanna 2 - 2012	5	3.4	3.1	10.6	10.0	9.6	10.8	78
Brunswick savanna 1 - 2012	6	3.7	3.5	13.2	12.8	12.5	13.4	78
Brunswick savanna 2 - 2012	7	3.8	3.7	12.4	12.2	10.7	11.1	82
Clark Station savanna 1 - 2012	9	4.6	4.1	18.2	17.2	15.9	17.8	67
Clark Station savanna 2 - 2012	10	4.3	3.7	17.1	15.8	15.7	18.4	75
Dupont savanna 5 - 2012	15	3.7	3.4	11.1	10.7	9.2	9.9	74
Gibson E - savanna 1 - 2012	16	4.6	4.2	16.5	15.7	13.0	14.4	81
Gibson E - savanna 2 - 2012	17	4.2	4.0	15.0	14.7	13.1	13.7	76
Gibson W - savanna 1 - 2012	18	4.3	4.1	14.0	13.7	10.8	11.4	77
Gibson W - savanna 2 - 2012	19	4.6	4.0	12.4	11.6	7.5	8.6	76
Tolleston savanna 1 - 2012	29	4.1	3.8	12.8	12.2	10.1	11.3	69
Tolleston savanna 2 - 2012	30	4.1	3.9	14.4	14.1	12.5	12.9	75
Clark Station Savanna 1 - 2011	51	2.8	2.4	8.8	8.1	10.2	11.9	86
Clark Station Savanna 2 - 2011	52	3.7	3.2	11.1	10.4	9.3	10.7	88
Dupont savanna 1 - 2011	53	4.4	3.6	12.2	11.0	8.1	9.9	61
Dupont savanna 2 - 2011	54	4.1	3.9	14.6	14.1	12.9	13.7	50
Dupont savanna 3 - 2011	55	4.1	3.9	14.6	14.1	12.9	13.7	75
Dupont savanna 4 - 2011	56	3.8	3.5	14.0	13.4	13.4	14.7	67
Gibson Woods savanna 1 - 2011	57	4.3	4.0	13.4	12.8	9.8	10.7	79
Ivanhoe East savanna 1 - 2011	58	4.9	4.4	16.0	15.0	10.5	11.9	50
Ivanhoe East savanna 2 - 2011	59	4.5	4.1	15.5	14.7	11.9	13.1	50
Ivanhoe West savanna 1 - 2011	60	4.5	4.3	16.3	16.0	13.5	14.1	59
Ivanhoe West savanna 2 - 2011	61	4.6	3.8	14.5	13.2	10.0	12.1	63
Ivanhoe West savanna 3 - 2011	62	4.9	4.6	19.7	19.1	16.4	17.6	47
Martin Oil savanna - 2011	63	4.6	4.1	11.9	11.4	7.1	7.9	79

Riverine transect FQA metric values. MCN = Mean C native, MCT = Mean C total, FQIN = FQI native, FQIT = FQI total, SR = Species Richness, TS = Total Species.

Riverine Transects	Site #	MCN	MCT	FQIN	FQIT	SR	TS
Beamster riverine 1	2	2.8	2.1	9.3	8.0	11	15
Beamster riverine 2	3	0.0	0.0	0.0	0.0	0	1
Dupont riverine 12-1	12	1.5	1.5	2.1	2.1	1	2
Dupont riverine 12-2	13	3.7	2.9	9.8	8.7	7	9
Dupont riverine 12-3	14	3.7	2.4	9.0	7.3	6	9
Seidner riverine 1	24	3.7	3.2	12.4	11.4	11	13
Seidner riverine 2	25	3.6	2.9	10.7	9.6	9	11
Seidner riverine 3	26	3.0	2.1	6.7	5.7	5	7
Seidner riverine 4	27	1.8	1.2	3.5	2.9	4	6
Seidner riverine 5	28	2.8	1.8	6.3	4.9	5	8

Riverine quadrat FQA metric values. MCN = Mean C native, MCT = Mean C total, FQIN = FQI native, FQIT = FQI total, SR = Species Richness, TS = Total Species.

Riverine Transects	Site #	MCN	MCT	FQIN	FQIT	SR	TS
Beamster riverine 1	2	2.0	1.0	2.8	2.0	1.8	3.6
Beamster riverine 2	3	0.0	0.0	0.0	0.0	1.0	1.0
Dupont riverine 12-1	12	0.1	0.1	0.1	0.1	1.1	1.1
Dupont riverine 12-2	13	0.8	0.7	1.3	1.3	1.5	1.6
Dupont riverine 12-3	14	1.1	0.8	1.7	1.5	1.5	2.5
Seidner riverine 1	24	1.3	0.7	2.1	1.6	1.9	3.2
Seidner riverine 2	25	1.3	1.1	2.2	2.0	2.1	2.5
Seidner riverine 3	26	0.8	0.5	1.0	0.8	0.7	1.8
Seidner riverine 4	27	0.1	0.1	0.2	0.2	1.2	1.3
Seidner riverine 5	28	1.9	1.0	2.3	1.7	1.2	2.7

Wetland swale transect FQA metric values. MCN = Mean C native, MCT = Mean C total, FQIN = FQI native, FQIT = FQI total, SR = Species Richness, TS = Total Species.

Wetland Swale Transects	Site #	MCN	MCT	FQIN	FQIT	SR	TS
Brunswick swale - 2012	8	3.9	3.5	15.2	14.3	15	17
Clark Station swale - 2012	11	4.1	3.7	17.4	16.5	18	20
Gibson E - swale 1 -2012	20	3.2	2.4	9.7	8.4	9	12
Gibson E - swale 2 - 2012	21	3.4	2.9	12.2	11.4	13	15
Gibson W - swale 1 -2012	22	4.5	4.0	21.1	19.8	22	25
Gibson W - swale 2 - 2012	23	4.5	3.6	19.7	17.6	19	24
Tolleston swale 1 - 2012	31	3.9	3.3	18.3	16.9	22	26
Tolleston swale 2 - 2012	32	4.3	4.1	25.7	25.0	36	38
Clark Station wetland 1 - 2011	33	5.1	4.6	22.6	21.5	19	21
Clark Station wetland 2 - 2011	34	5.0	4.8	32.9	32.5	44	45
Clark Station wetland 3 - 2011	35	5.9	5.9	21.9	21.9	14	14
DuPont wetland 1 - 2011	36	4.0	2.7	8.0	6.5	4	6
DuPont wetland 2 - 2011	37	3.6	3.4	13.9	13.5	15	16
DuPont wetland 3 - 2011	38	3.8	3.0	13.0	11.6	12	15
DuPont wetland 4 - 2011	39	3.8	3.4	15.8	14.9	17	19
Gibson Woods wetland 1 - 2011	40	3.8	3.3	14.2	13.3	14	16
Gibson Woods wetland 2 - 2011	41	4.6	3.9	18.5	17.0	16	19
Gibson Woods wetland 3 - 2011	42	4.1	3.4	16.0	14.6	15	18
Ivanhoe East wetland 1 - 2011	43	4.2	3.8	13.9	13.3	11	12
Ivanhoe East wetland 2 - 2011	44	4.2	3.4	15.0	13.5	13	16
Ivanhoe East wetland 3 - 2011	45	3.4	3.2	13.5	13.1	16	17
Ivanhoe West wetland 1 - 2011	46	5.6	5.6	12.5	12.5	5	5
Ivanhoe West wetland 2 - 2011	47	4.8	4.8	13.4	13.4	8	8
Ivanhoe West wetland 3 - 2011	48	4.9	4.3	12.9	12.0	7	8
Ivanhoe West wetland 4 - 2011	49	5.0	5.0	10.0	10.0	4	4
Martin Oil wetland - 2011	50	5.0	5.0	8.7	8.7	3	3

Wetland swale quadrat FQA metric values. MCN = Mean C native, MCT = Mean C total, FQIN = FQI native, FQIT = FQI total, SR = Species Richness, TS = Total Species.

Wetland Swale Transects	Site #	MCN	MCT	FQIN	FQIT	SR	TS
Brunswick swale - 2012	8	2.5	2.0	4.2	3.8	2.7	3.5
Clark Station swale - 2012	11	4.1	3.6	8.0	7.5	3.8	4.3
Gibson E - swale 1 -2012	20	2.1	1.9	3.0	2.8	1.9	2.2
Gibson E - swale 2 - 2012	21	2.5	1.8	4.2	3.6	2.4	3.1
Gibson W - swale 1 -2012	22	4.3	3.1	7.8	6.6	3.5	4.9
Gibson W - swale 2 - 2012	23	4.3	3.6	7.5	6.9	3.6	4.3
Tolleston swale 1 - 2012	31	3.5	2.5	7.6	6.5	4.9	6.7
Tolleston swale 2 - 2012	32	3.5	3.3	10.2	9.9	8.6	9.1
Clark Station wetland 1 - 2011	33	6.1	6.0	12.9	12.8	4.7	4.8
Clark Station wetland 2 - 2011	34	6.1	6.0	17.4	17.3	9.3	9.5
Clark Station wetland 3 - 2011	35	6.5	6.5	14.5	14.5	5.1	5.1
DuPont wetland 1 - 2011	36	3.1	2.7	3.4	3.1	1.2	1.5
DuPont wetland 2 - 2011	37	3.1	3.1	4.9	4.8	2.5	2.6
DuPont wetland 3 - 2011	38	2.7	2.5	4.9	4.7	3.1	3.5
DuPont wetland 4 - 2011	39	3.5	3.1	6.4	6.0	3.2	3.7
Gibson Woods wetland 1 - 2011	40	2.7	1.8	3.8	3.2	1.5	2.2
Gibson Woods wetland 2 - 2011	41	3.3	2.2	5.1	4.3	2.2	3.3
Gibson Woods wetland 3 - 2011	42	2.7	1.9	4.4	3.8	2.2	3.3
Ivanhoe East wetland 1 - 2011	43	3.4	3.1	5.2	5.0	2.4	2.7
Ivanhoe East wetland 2 - 2011	44	4.6	4.2	7.4	7.0	3.1	3.5
Ivanhoe East wetland 3 - 2011	45	3.0	2.9	4.5	4.4	2.0	2.3
Ivanhoe West wetland 1 - 2011	46	4.7	4.7	7.3	7.3	2.5	2.5
Ivanhoe West wetland 2 - 2011	47	4.7	4.7	7.0	7.0	2.3	2.3
Ivanhoe West wetland 3 - 2011	48	4.4	3.7	6.1	5.6	2.0	2.5
Ivanhoe West wetland 4 - 2011	49	4.6	4.6	6.5	6.5	2.0	2.0
Martin Oil wetland - 2011	50	1.0	1.0	1.1	1.1	0.3	0.3