FLORISTIC QUALITY ASSESSMENT FOR VEGETATION IN ILLINOIS A METHOD FOR ASSESSING VEGETATION INTEGRITY

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ABSTRACT: Floristic Quality Assessment (FQA) is proposed as a method to assess floristic integrity in Illinois. For the application of FQA, each taxon in the Illinois vascular flora was assigned an integer from 0 to 10 termed a coefficient of conservatism (C). Two basic ecological tenets that the coefficients represent are that plant species differ in their tolerance to disturbance and disturbance types, and that plant species display varying degrees of fidelity to habitat integrity.

With these principles as a guide, the coefficient applied to each taxon represents a rank based on observed behavior and patterns of occurrence in Illinois plant communities and our confidence that a taxon is remnant (natural area) dependent. Species given a C value of 0-1 are taxa adapted to severe disturbances, particularly anthropogenic disturbances, occurring so frequently that often only brief periods are available for growth and reproduction. Species ranked with a C value of 2-3 are associated with somewhat more stable, though degraded, environments. Those species with coefficients 4-6 include many dominant or matrix species for several habitats; they have a high consistency of occurrence within given community types. Species with C values 7-8 are taxa we associate mostly with natural areas, but that can be found persisting where the habitat has been degraded somewhat. Those species with coefficients 9-10 are considered to be restricted to high-quality natural areas.

A floristic quality index (FQI) and a mean coefficient of conservatism ($\overline{C}$) are two of the values derived from floristic inventory data. Other derived parameters include species richness, relative importance, percent of taxa that are native and adventive, number of rare species, and guild diversity (including wetness and conservatism ranks, and physiognomic classes). We suggest that FQA is a promising tool that can be used to discriminate natural quality of vegetation on the Illinois landscape and to make time-series comparisons in ecological studies. We suggest the use of certain parametric and nonparametric statistical tests, such as analysis of variance, mean-separation techniques, and goodness-of-fit tests, that can aid in distinguishing nonrandom differences in floristic quality.

INTRODUCTION

Patterns of vegetation are reliable indicators of several biotic and abiotic factors. Biotic interactions among species and abiotic factors (including edaphic and climatic characteristics) influence plant assemblages in many complex ways that lead to the expression of differences at the species, community, and ecosystem levels. Overlying these influences is disturbance history. Disturbances differ in frequency, intensity, and duration. Infrequent disturbances of low intensity and short duration can have relatively negligible impacts on the integrity of a plant community. However, as frequency, intensity, and/or duration increase, damage and ultimately degradation can occur, resulting in predictable changes in plant community characteristics, particularly composition. Differentiating vegetation on the basis of level of degradation is an important step in attempting to conserve biodiversity. For example, preserve selection and design (size and shape) of areas often are influenced by qualitative differences in vegetation. This paper describes a method for discerning floristic integrity in Illinois.

Floristic Quality Assessment (FQA) is a method that uses a floristic quality index (FQI), introduced by Wilhelm (1977) and Swink and Wilhelm (1979, 1994), and modified here for the Illinois vascular flora. FQA integrates FQI with other vegetation parameters. These include mean coefficient of conservatism, species richness, percent native and adventive species, guild diversity for various physiognomic and conservatism classes, number of threatened and endangered species, and type of natural community and grades following the classification and grading criteria established by the Illinois Natural Areas Inventory (White 1978). FQA can be used to make spatial as well as time-series comparisons, and in this way FQA can be effective in tracking vegetation changes in restoration, reconstruction, or control situations, and in evaluating parameters across environmental and disturbance gradients. Species abundance measures also can be included in FQA evaluations. In this paper we discuss key terminology, describe the method of FQA for the Illinois vascular flora, offer suggested applications and statistical analyses, and urge experimental tests of hypotheses related to floristic quality. We caution that any vegetative assessment based on a single index is likely to be insufficient to account for all possible relevant aspects. As an introduction, a short history of habitat assessment methods, particularly those used in Illinois, is given. Selected issues in plant-community ecology are included as background information.

Background on Assessment Methods for Natural Areas

Methods for making qualitative assessments of biological communities have had expanding roles in the conservation of lands and habitats as development pressures increase. An Index of Biological Integrity has been developed based on characteristics of fish community composition (Karr et al. 1986) and for ant populations (Majer and Beeston 1996). Migratory bird species have been ranked according to perceived prioritization of habitat and species conservation goals (Hunter et al. 1993). There is a recognized need for simple, sensitive, readily interpretable, and ecologically meaningful methods of classifying vegetation according to levels of ecological integrity (Keddy et al. 1993), particularly for use by the nonspecialist (Grime 1974). In addition, a rapid method of assessment often is needed, particularly when evaluating large portions of a landscape (e.g., proposed highway-construction corridors that cross numerous remnants of native vegetation and natural community types). Ordination techniques can be used effectively to examine relationships among vegetation (and abiotic) sample data. However, these indirect measures are not particularly rapid and are value-neutral, limiting their application for making qualitative assessments of biotic communities, particularly in the heterogeneous landscape.

Two developments have been key in the identification and protection of natural areas in Illinois. First, in 1963, the Illinois Nature Preserves Commission was formed to administer the development of a system of nature preserves as representative examples of the natural history of the state. Second, during the mid 1970s, the Illinois Natural Areas Inventory (INAI) was an effort to conduct a comprehensive county-by-county inventory of natural areas (White 1978). A method for assessing habitat qualities was developed for the INAI, to aid in the identification of significant remnants of natural communities. Several site characteristics were integrated in the natural community grading method, including aspects of vegetation such as perceived successional stage, evidence of disturbance, and presence and relative-abundance patterns for species characteristic of particular habitats and levels of disturbance. The INAI used a discontinuous, determinant grading scale, where habitat remnants received a grade of A, B, C, D, or E (defined under Illinois Natural Areas Inventory Grades in the glossary) in accordance with increasing degrees of disturbance reflected in the community characteristics (White 1978). Herein, reference to INAI natural areas will be made with capital letters (Natural Area).

Independent of the INAI was the development of a method of natural area identification using a continuous, indeterminate scale called a Natural Area Rating Index (NARI) based on floristic composition (Wilhelm 1977, Swink and Wilhelm 1979, Wilhelm and Ladd 1988). The NARI was developed as an aid in discriminating natural quality of vegetation among open lands in the Chicago region and is based on an index derived from the composition of vascular plants at a site. Because vegetation spans the entire disturbance gradient from an urban lot or cropland to relatively "pristine" habitats, a continuous scale offers some refinement to qualitative distinctions of floristic characteristics. This characteristic in particular made the Natural Area Rating Index a valuable tool for identifying degraded remnants of native vegetation having recovery potential, given appropriate management.

Principal criticisms of the method have included the following: 1) the coefficient range chosen, which began with –3 for the most invasive adventive species and increased by intervals of 1 to a coefficient of 10 (coefficients of 15 and 20 were used for very rare species), 2) a lack of consideration for species abundance, and 3) the subjective nature of coefficients assigned to each taxon and differences in interpretation of them. Refinements of the method led to a revised scale of coefficients that ranged from 0 to 10; all adventive species were assigned an asterisk with a numerical value of 0. For clarity the method was renamed Floristic Quality Assessment (Swink and Wilhelm 1994).

Abundance measures for species, as described later in this paper, are readily accommodated in FQA and should be included in any assessment of vegetation when possible. It is important to acknowledge that natural quality assessments are subject to bias and require more or less subjective judgments at the current state of community ecological science (Crovello 1970). The FQA method, though subjective, permits dispassionate and repeatable application because its value judgments are predetermined. Assessment methods based on FQA have been developed in Ohio (Andreas and Lichvar 1995), Michigan (Herman et al. 1996), Missouri (Ladd 1993), and southern Ontario (Oldham et al. 1995), and elaborated on by Masters (1997).

In addition to investigating the current composition and structure of the vegetation, any assessment of vegetation quality should also give attention to degradation factors at the landscape, ecosystem, and community levels, and the historic (presettlement) and contemporary natural disturbance regimes.

Principles of Plant Community Ecology Relative to Floristic Quality Assessment

Plants can be classified into groupings based on a variety of species characteristics such as physiognomy, phenology, and ecophysiology, and habitat characteristics such as soil type, light, moisture, and disturbance regimes. In heavily developed landscapes such as Illinois, and similarly in Great Britain, contemporary anthropogenic disturbances to vegetation are often the predominant influences on composition (Hodgson 1986), and thus are dominant among assembly and response rules for communities (*sensu* Keddy 1992). Species sort selectively into this disturbance matrix; the opportunistic species become more common as the landscape becomes more unstable. The coefficients of conservatism used in FQA are an attempt to categorize species according to their response to levels of habitat degradation.

Three general topics in plant community ecology—disturbance ecology, the maintenance of diversity, and successional theory—are particularly relevant to the concept of floristic quality because they provide a framework for understanding patterns and trends, particularly at the population and community levels. Disturbance is a general term referring to any perturbation. Plant communities can be *damaged* when severely disturbed and are *degraded* when recovery to its native biological diversity (original condition) is unlikely under normal circumstances. Degraded lands have lost some aspects of ecosystem structure such as species composition. Degraded lands are termed *derelict* when land use becomes very limited (Brown and Lugo 1994). They can be further distinguished as those that can be *restored* to nearly original condition through some management effort, *rehabilitated* to a condition somewhat similar to the original but where compositional differences remain (Lovejoy 1975) or, at best, *reclaimed* to a limited degree in severe cases such as strip mining.

Many midwestern plant communities were formed and historically maintained with landscape-scale processes that include disturbances such as periodic fire, as well as grazing or browsing impacts by large herbivores (Anderson 1983, 1990). Additional considerations in regard to disturbance regimes are addressed under Ecological Integrity in the methods section and in the discussion of succession below.

Different survival strategies have evolved among organisms for coping with disturbances. Among the hypotheses of mechanisms to account for these strategies are MacArthur and Wilson's (1967) r- and K-selected species, Grubb's (1977) regeneration niche, and Grime's regenerative flexibility for ecological amplitude (Grime 1974, Grime et al. 1988). For the latter, species survival strategies are considered to be shaped by an equilibrium among the ecological forces of competition, stress, and disturbance. These forces serve as axes for ordinating species' responses in Grime's "triangles." These ordinations yield three general life strategies referred to as the C-S-R model: competitors, stress tolerators, and ruderals.

Whittaker (1965) recognized that plant communities could be described by three basic dominance-diversity curves that differ in the cumulative proportion of importance of species. Species-poor communities are strongly dominated by a few taxa; in communities with high species richness, no species is strongly dominant. Many communities are intermediate, composed of a few taxa with high relative abundance and many intermediate and rare species. Several studies suggest that intermediate levels of available resources (nutrients and physical factors) support the greatest diversity (Tilman 1986, Ashton 1989, Tilman and Pacala 1993). Intermediate levels of disturbance also appear important in the maintenance of diversity in many communities (Connell 1978, Tester 1989), although the maintenance of peak levels of plant species diversity in some particularly fire-dependent systems appears to require frequent perturbations (Walker and Peet 1983).

The groupings described above are useful in that they attempt to provide both order to species assemblages and predictability regarding the rate and direction of changes in response to such things as human-influenced disruptions. In all of the models, spatial and temporal heterogeneity within and among habitats is a critical factor in the maintenance of species diversity at the community level of organization or higher.

Succession is a frequently used term for the description of vegetational change through time. Clements (1936) argued that succession was an orderly and predictable process leading to a "climax" community, depending on climate and other factors. Typically, primary succession is initiated on exposed parent materials, while secondary succession involves changes in vegetational characteristics following events such as abandonment of cropland, clear-cutting of forests, or drainage of wetlands. However, climax is an ambiguous term (Crawley 1986) and appears to have little practical meaning if considered without regard to regional disturbance regimes or historical antecedents. In landscapes such as those in the Midwest, the development of many native plant communities was dependent on anthropogenic fires, the practice of which dates back to the postglacial era. In such circumstances the cessation of fire could be regarded as a "disturbance."

Indiscriminate use of the term succession may obfuscate the fact that certain plant communities require periodic perturbations such as fire for the maintenance of structural characteristics and compositional diversity. If unidirectional successional trends in these communities were among our conservation goals, we would not be concerned with vegetational changes such as those from prairie communities to forest-like assemblages or from biodiverse oak-dominated woodlands to maple-dominated forest. Such changes, however, often result in a loss of species richness (Wilhelm 1991, Taft et al. 1995), particularly in our highly fragmented landscape, where species immigration, needed to compensate for local extirpations of species, is seriously challenged.

The term succession, when used for changes in vegetation following severe anthropogenic disturbances, may be misleading. Without detailed experimental studies of various disturbance factors on different vegetation types, we do not know how extensively vegetation “succeeds” or recovers to a more stable condition. Without knowledge of the immigration potential for replacement species, we have no way to predict accurately the composition or structure of subsequent communities. Consequently, the assumptions of directional trends in secondary succession leading toward the original (presettlement) plant community may have lost relevance where the landscape is highly fragmented. Using terminology from disturbance ecology (e.g., degraded, derelict) when describing the natural condition of a site may be clearer than speculation about successional phases (e.g., early successional, late successional) of disturbed vegetation. Apparently, many degraded sites persist in states of perpetual botanical purgatory (Taft 1996).

METHODS

In Floristic Quality Assessment (FQA), floristic inventory data are used to calculate several parameters of vegetation. These include the following measures, each defined and described in greater detail in subsequent sections: 1) species richness, 2) floristic quality index (FQI), 3) mean coefficient of conservatism ($\overline{C}$), 4) guild diversity (frequency distribution among physiognomic and conservatism classes), 5) species relative importance, 6) number and percent rare and adventive species, and 7) wetness characteristics. These data are presented in a summary table. The FQI and $\overline{C}$ are derived from coefficients of conservatism assigned to each taxon in the Illinois vascular flora. Important terms related to FQA are defined in the glossary; key concepts and terminology underlying the general philosophy of FQA are discussed below. Recommendations for applying and analyzing selected FQA results are included. We undertake this effort with the knowledge that contending with the entire flora of Illinois overextends our collective experience to some extent. The judgments presented here are based primarily on our cumulative total of over 60 years of botanical and ecological field study throughout Illinois and the Midwest.

Botanical nomenclature in the text and appendix approximates Mohlenbrock (1986). Many hybrids and certain subspecific taxa such as *forma* are not included; some varieties were omitted when we perceived them not to vary ecologically from the typical variety. Recently recorded species for Illinois are also included. The listing of species in Appendix I is not to be interpreted as a definitive flora of Illinois; it is intended solely to be reference database for applications of Floristic Quality Assessment.

The list in Appendix I comprises 2,091 native taxa and 955 non-native taxa, for a total of 3,046 taxa, compared with Mohlenbrock’s (1986) total of 3,203 taxa, which included 101 hybrids. It is beyond the scope of this paper to list currently accepted nomenclatural synonomy for each taxon; such a list soon would be out of date. Unfortunately, scientific names of plants in North America are in a state of flux, with often conflicting nomenclatural treatments (Little 1979, Kartesz and Kartesz 1980, Soil Conservation Service 1982, Gunn et al. 1992, Morin 1993, and Kartesz 1994). Only a single common name for each taxon is offered, despite the fact that many taxa are known by a variety of colloquial names. An attempt was made to use common names with the widest appeal; they are taken mostly from Mohlenbrock (1986), Swink and Wilhelm (1994), and Robertson (1994).

Physiognomic designations are subject to interpretation. Terms such as annual, biennial, perennial, shrub, and tree sometimes imperfectly depict the habit of plants, but for the purposes of guild formation in FQA analysis, such designations can be useful in describing structural differences or changes.

Terminology and Concepts

Coefficient of conservatism. For the application of FQA, each taxon in the Illinois vascular flora was assigned an integer from 0 to 10, termed a coefficient of conservatism (C). The coefficients represent two basic ecological tenets: plants differ in their tolerance to disturbance type, frequency, and amplitude, and plants display varying degrees of fidelity to habitat integrity. With these principles as a guide, the C value applied to each taxon represents a relative rank based on observed behavior and patterns of occurrence in Illinois plant communities and our confidence that a taxon is remnant (natural area) dependent. The authors reached consensus on these coefficients through committee effort and, in some cases, with consultation from reviewers of the manuscript. For certain taxa we supplemented our field experience by examining range maps (Mohlenbrock and Ladd 1978) and reviewing comments regarding habitats in several floras (Deam 1940, Gleason 1952, Steyermark 1963, Sheviak 1974, Mohlenbrock 1986, Swink and Wilhelm 1994). The native species most successful in badly damaged habitats were given C values of 0. At the other end of the spectrum, species virtually restricted to natural areas in Illinois received C values of 10. All 957 non-native species were assigned asterisks (*) and are treated as 0s in the calculations for site indices (FQI and $\overline{C}$). These calculations are further discussed in comments under Floristic Quality Index below and in the glossary. Species native to Illinois, but also occurring escaped from cultivation (e.g., *Pinus* spp.), should be ranked as non-native species when found in such situations.

With these criteria for designating coefficients, our approach was somewhat different from past efforts. For example, we are not intending to estimate the degree to which a species is restricted to a certain habitat, or to gauge its modality according to Curtis (1959). Many relatively conservative taxa (e.g., *Amorpha canescens*, *Baptisia leucophaea*, *Cypripedium candidum*, *Drosera rotundifolia*, *Gaylussacia baccata*, *Osmunda cinnamomea*, *Ceanothus americanus*, and *Viola pedata*) occur regularly in more than one plant community, as defined by White and Madany (1978). In addition, we were not attempting to estimate rarity, although some circularity of reasoning was unavoidable when evaluating very rare taxa known only from a few natural areas.

Reasons for rarity in the Illinois flora are many (Taft 1995) and include several recognized by Rabinowitz (1981). Scale of inference influences what is considered a rare species. Many species that are rare within the political boundaries of Illinois are abundant elsewhere. Many conservative taxa are not at risk of extirpation from the state, but are regionally quite rare because of habitat loss and degradation. Commonness and rarity of plant species in England have been considered in terms of ecological, taxonomic, and evolutionary processes within a landscape characterized by tremendous habitat loss and degradation (Hodgson 1986). Although common ad rare species at local scales may be strongly correlated to measurable traits, there is so much variability in ecological, taxonomic, and evolutionary characteristics of species at the statewide scale (Schwartz 1993) that these groupings do not address consistently our criteria for conservatism. Although rarity is not a criterion for assignment of C values, it forms a part of the matrix of parameters in FQA.

The coefficients, in part, can be considered in terms of Grime's (1974) survival strategies. Species given a C value of 0-1 correspond to Grime's ruderal species and those with a C value of 2-3 correspond to ruderal-competitive species. This broad, combined species guild includes taxa adapted to frequent and severe disturbances, including anthropogenic disturbances that often result in only brief opportunities for reproduction. Under such a disturbance regime, only species capable of maintaining populations under such conditions are present, including those that rapidly grow, flower, and produce fruits (e.g., *Ambrosia trifida*, *Amaranthus rudis*, *Cassia fasciculata*, *Conyza canadensis*, *Erigeron annuus*, *Impatiens capensis*, *Lactuca canadensis*, *Lepidium virginicum*, *Oxalis stricta*, *Parietaria pensylvanica*, and *Vulpia octoflora*). Many are capable of persisting in seed banks, and some have wind-dispersed seeds—two strategies that allow species to sort into suitable, newly disturbed habitats. Some longer-lived species capable of persisting with frequent disturbances such as siltation, flooding, and grazing are also included in this group (e.g., *Acer saccharinum*, *Crataegus pruinosa*, *Gleditsia triacanthos*, *Populus deltoides*, *Ribes missouriense*, *Rubus occidentalis*, and *Symphoricarpos orbiculatus*). These taxa constitute approximately 17% of our native flora. In conjunction with many of the adventive elements, these species now dominate the contemporary Illinois landscape.

Species assigned coefficients 4-6 correspond roughly to Grime's competitors. These include many dominant or matrix species for several habitats (e.g., *Andropogon gerardii*, *Carex artitecta, C. pensylvanica*, *C. stricta*, *Carya ovata*, *Panicum virgatum*, *Quercus alba*, *Schizachyrium scoparium*, and *Sorghastrum nutans*) and species that are often expected, or have high consistency, in a given community type (e.g., *Aesculus glabra*, *Arisaema triphyllum*, *Delphinium tricorne*, *Phlox divaricata*, *Silphium integrifolium*, *Smilacina racemosa*, *Thalictrum dioicum*, *Trillium recurvatum*, and *Zizia aurea*). Many can persist with light to moderate disturbances for intermediate periods, but may decline with an increase in intensity, frequency, or duration of disturbance. Some species that are range restricted, such as *Boltonia decurrens*, which is listed as a threatened species by the U.S. Fish and Wildlife Service (USFWS 1988) and the Illinois Endangered Species Protection Board (Herkert 1991), and other species that are rare in Illinois such as *Scirpus paludosus*, and *Tradescantia bracteata*, are included in the 4-6 category. In the contemporary Illinois landscape these species demonstrate considerable tolerance to disturbance and even habitat degradation, but usually not to the extent characteristic of the ruderal-competitor species guild.

On occasion, during the coefficient assessment phase of this project, we needed to evaluate taxa that demonstrate regional behavioral differences in Illinois, such as *Asclepias tuberosa* and *Oxalis violacea.* These species are occasional to common in degraded habitats in far southern Illinois, but in central and northern Illinois they are more restricted to remnant areas. In these instances, we assigned an intermediate value such as 5.

The species having C values of 7-10 are less clearly aligned with Grime's model. Grime et al. (1988) defined the third guild, stress tolerators, to include species that persist where plant productivity is continuously limited by the environment. A more specific definition of Grime's stress tolerators, offered in an editorial by Duffey (1986), includes "species that are slow-growing, long-lived and often rather immobile plants of infertile habitats or late-successional vegetation." Our criteria for species ranked with coefficients 7-10 allow the inclusion of species that may tolerate stress, but through a variety of mechanisms. More germane to qualitative floristic assessments, these taxa do not tolerate much habitat degradation. Consequently, this guild includes some annual and biennials (e.g., *Agalinis gattingeri*, *Draba cuneifolia*, *Hottonia inflata*, *Iresine rhizomatosa*, *Lechea intermedia*, *Oenothera linifolia*, *Polygala incarnata*, and *Utricularia minor*). However, like Grime's stress tolerators, most taxa in this guild are long-lived perennials (e.g., *Asclepias meadii*, *A. viridiflora*, *Carex disperma*, *C. pedunculata*, *C. prasina*, *Clitoria mariana*, *Cystopteris bulbifera*, *Gymnocarpium dryopteris*, *Lilium philadelphicum*, *Mentzelia oligosperma*, *Sedum telephioides*, *S. ternatum*, and *Talinum parviflorum*, *Woodsia ilvensis*). The species ranked with coefficients 7-8 include taxa we associate mostly with natural areas but which can be found persisting where the habitat has been degraded somewhat (e.g., *Actaea pachypoda*, *Caulophyllum thalictroides*, *Ceanothus americanus*, *Lysimachia quadriflora*, *Peltandra virginica*, *Phlox pilosa*, *Spigelia marilandica*, and *Viburnum rufidulum*). Like the matrix species (C values of 4-6), if the disturbance resulting in degradation increases in frequency, intensity, or duration, these taxa are expected to undergo reduction in population sizes and eventually be prone to local extirpation. Species with coefficients 9-10 are considered to be restricted to relatively intact natural areas.

Though there is some commonality between the C-S-R model (Grime et al. 1988) and the concept of conservatism, we lack the experimental autecological evidence to ordinate species into Grime's triangles. Further, species assigned C values of 7-10 do not fit consistently into Grime's C-S-R model, unless the stress-tolerator guild is more broadly defined to include species found primarily in semistable habitat remnants (sometimes referred to as "late-successional" communities).

Unfortunately, taxa included among each major cohort of coefficients (0-3, 4-6, 7-10) span a range that is too broad taxonomically, ecologically, and physiognomically for any objective natural sorting to serve as a guide to species rankings that meet our guiding principles for the coefficients of conservatism (see above). For that reason, we based our judgments for the assignments of the coefficients on the observed behavior of individual elements of the flora within the context of their Illinois ranges. Applying our judgments was necessary since it is likely we will never have sufficient experimental data to make predictions about floristic quality and ecological integrity for the diversity of habitats, species, and disturbance regimes in Illinois using more ostensibly "objective" methods. Furthermore, rapid and repeatable techniques for evaluating the integrity of plant communities are needed now, particularly when assessing complex patterns of vegetation in large sections of the landscape.

Ecological and Community Integrity. There are both functional and structural aspects of ecosystems. Ecosystem function involves the flow of energy and matter, while structure is characterized by biotic interactions, composition, and form. Ecological or community integrity can be viewed as the degree to which self-correcting properties are exhibited when an ecosystem is exposed to disturbance (Regier 1993). Natural disturbances are perturbations that occur routinely in a system and to which the component taxa have tolerance or adaptations. They can occur at many different scales. Tree falls and gopher mounds are examples of small-scale perturbations. Fire is an example of a large-scale natural disturbance in many Midwestern plant communities, and fire frequency and timing are important determining factors for many community characteristics. Fire absence can result in dramatic changes in community structural characteristics (Taft 1997). Perturbations that exceed the intensity, frequency, or duration of the natural disturbance regime can result in loss of species that lack tolerance or adaptations to the new levels. When certain species, or assemblages of taxa, are extirpated from a community, the system's capability for restoration is diminished, and integrity is lowered.

Integrity can be lowered not only by the loss of species and the diminishment of abiotic processes and certain aboriginal practices, but also from the invasion of adventive taxa. Adventive taxa in a system may sort into disturbance or habitat niches, replace many native taxa over time, and interfere with rates of recovery processes (Cohen et al. 1995).

Measuring ecological integrity based on ecosystem function alone may not provide the resolution needed to detect important changes. For example, biomass and productivity may not change dramatically in a palustrine wetland impacted by siltation or altered flooding regimes where only a few tolerant taxa persist (e.g., *Typha* spp. and *Phalaris arundinacea*). However, the structural integrity of a formerly diverse graminoid wetland is lost in this near monoculture, as when, for example, a discharge wetland is converted to a surface runoff wetland as a result of ambient watershed alterations. Integrity of both ecosystem structure and function is reduced in a heavily grazed (or browsed) woodland when soil compaction and intense herbivory result in losses in moisture, nutrient availability, biomass, and diversity, as well as changes in species composition. Floristic Quality Assessment addresses the structural aspects of ecosystem integrity.

Floristic Quality Index. The FQI is a weighted index of species richness (N), and is the arithmetic product of the average coefficient of conservatism ($\overline{C}$) and the square-root of species richness (√N) of an inventory unit. The square-root transformation of N limits the variable influence of area alone on species richness (Swink and Wilhelm 1979, 1994). In practice, it is possible for two sites with the same $\overline{C}$ to have different FQIs, and it is possible for two sites with the same FQI to have different $\overline{C}$ values. Relatively degraded sites can have an FQI similar to or greater than high-quality natural areas if they support a much greater native species richness. This can occur when there are substantial differences in size, levels of habitat heterogeneity, or inventory effort among compared sites. This and other relationships among the FQI, $\overline{C}$, and N are illustrated in figure 1. Thus, rather than relying on a single index to describe floristic integrity, it is usually necessary to include more than one parameter of the composition to estimate more precisely site floristic integrity.

For the floristic parameters FQI, $\overline{C}$, and N, we recommend that calculations be made using all species (native and adventive) as well as native species only. As noted previously, the establishment of exotic species in a natural community often can result in the replacement of native species and interfere with recovery processes. Differences in these values among sites provide measures for the erosion of floristic integrity (Swink and Wilhelm 1994).

Natural Area. A gradient of natural quality exists from the most pristine habitat that largely has escaped postsettlement anthropogenic damage to cropland or pavement. The determination of where along that gradient is the demarcation of “natural area” is a matter of judgment and is goal dependent. The Illinois Natural Areas Inventory (INAI) had the very specific goal of identifying all remnants of natural communities that were viewed as significant statewide for their existing quality. It was not intended to be a comprehensive inventory of all the remnant natural communities worthy of preservation or restoration activities. The results of the INAI revealed that a mere 0.07% of the land area of Illinois remains in a high-quality, undegraded, natural condition (White 1978). These Natural Areas tend to be isolated remnants scattered across the state with concentrations in northeastern and far southern Illinois, as well as along its western border by the Mississippi River. Many more areas persist that retain exceptional or noteworthy natural features, but that fall somewhere between INAI eligibility and recently fallowed land. For this paper we are broadly considering a natural area to be a natural community that is judged to be representative of presettlement vegetation for the site. This general definition includes all Natural Areas; it also includes areas that presently do not meet the standards for the INAI but that, with management and time, probably could be restored to a community with floristic composition, structure, and diversity similar to presettlement condition.

Physiognomy. Tracking physiognomic classes, particularly in time-series comparisons, can be an important component of FQA, since it is theoretically possible for dramatic changes in community structure to occur without changes in the FQI or $\overline{C}$. The physiognomic classes included for each taxon in the appendix are listed under Physiognomy in the glossary.

Application of Floristic Quality Assessment

FQA summarizes floristic data from an inventory unit, or units, including species diversity (e.g., species richness and FQI), mean coefficient of conservatism, number and percent rare and adventive species, relative importance of species, and guild diversity (for physiognomic groups, wetness ranks, and conservatism ranks). All of these parameters can be calculated readily. However, if assessments are made on numerous areas, an automated program (Masters, in preparation) can reduce assessment time. In addition, it produces summary tables of these parameters and generates a list of species along with a common name, conservatism and wetness value, and physiognomic class for each taxon. The INAI grade and community type can be included in a summary of a floristic assessment unit. Species abundance measures taken from an inventory unit (e.g., relative abundance estimates, importance values) also can be entered for each taxon.

Floristic Quality Assessment Program. Most of the parameters in FQA for assessment units can be calculated using the computer program (Masters, in preparation) mentioned above, which is designed to summarize these vegetational traits from floristic data. By entering plant names or a six-letter acronym, the FQA program provides information for a floristic inventory and analysis unit. Both an overall site inventory method and sampling methods are available in the program. For the inventory program, indices and means are calculated for the entire inventory unit. For the sampling option, data from quadrats (which may be random, stratified random, or systematic and may or may not be permanent) are used. This latter option is useful in tracking spatial and temporal gradients of floristic integrity and wetness (see Wilhelm 1992), comparing data from large inventory units, and conducting rapid ecological assessments (Heumann et al. 1993).

Survey Intensity and Spatial and Temporal Scales of Survey Units

Measurements of an ecosystem or community usually are at a smaller scale than the target system. Since the FQI is a weighted index of species richness, larger survey units and greater inventory efforts generally yield higher indices of floristic quality (figure 1), if increased size corresponds to increased richness of conservative species. Determining the extent and configuration of the survey unit often is not a trivial question. Where the unit of floristic analysis is an isolated habitat fragment, the sample area usually is readily apparent. In landscapes with more contiguous vegetation, however, determining the sample unit is less obvious and in many ways dependent on the questions and interests of the investigation. Goals of the analysis may include a complete species inventory, but it should be noted that a complete inventory usually is not possible because of spatial and especially temporal variability in floristic composition. Thus, a single site visit will not comprehensively account for all species in a community or site. With repeated visits over the growing season most species that are actively growing at a site can be identified, but this would not be adequate to evaluate the seed bank. Experience in midwestern vegetation types has demonstrated that a single visit made between early June and late August by a competent botanist can achieve a roughly 80% complete inventory. Subsampling, spatially and temporally, is a practical option, particularly where habitat integrity appears relatively uniform and the survey unit is too large to inventory completely within the time available. Details of the survey method and effort always should accompany any reporting of results from FQA. Indiscriminate comparisons of floristic quality can be misleading if the methods used for the evaluations are not similar. Where area and heterogeneity of habitats or community remnants are considerably different, the mean coefficient of conservatism provides an area-independent variable for comparisons of floristic quality. Wilhelm (Swink and Wilhelm 1979) provides insights for how to treat spatially heterogenous habitats such as dune and swale communities near Lake Michigan.

Data Analysis

When distinguishing the qualitative condition of habitat remnants using FQA, a typical goal is to determine if the composition of two or more sites differs significantly from random expectation in the frequency distribution of the coefficients of conservatism. Three properties of the data influence the approach to be taken to make this determination. If the sample data have an acceptably normal distribution, have equal variances (homoscidastic), and are independent, then parametric statistics may be applied (but see below). If, however, the data lack central-normal tendency or have unequal variances (heteroscidastic), a nonparametric or distribution-free method is suggested (independence of the data is assumed). Central-normal tendency usually occurs with rank data when sample size (e.g., number of species) is greater than about 50.

Methods used for examples in this text include parametric and nonparametric two-sample tests (e.g., two-sample t-tests with unpooled variances, the Mann-Whitney U test, and the Kolmogorov-Smirnov [K-S] two-sample goodness-of-fit test). Comparisons of multiple samples are tested with one-way analysis of variance (ANOVA), Tukey's Honestly Significant Difference (HSD) test, and the Kruskall-Wallis ANOVA. All statistical analyses were made using Systat version 7.0 (Wilkinson 1997).

RESULTS AND DISCUSSION

Coefficients of conservatism assigned to each taxon recognized here for the vascular flora of Illinois are presented in the appendix. The frequency distribution of coefficients of conservatism (0-10) for native species is left-skewed due to a strong peak at coefficient 10 (figure 2). Distribution of species by physiognomic classes indicates that most species in the Illinois flora are perennial dicot forbs, followed by adventive annual forbs (figure 3). Perennial sedges and grasses are notably more important in the native flora than in the adventive flora. The distribution of wetness coefficients for the native and adventive flora of Illinois (figure 4) shows that most taxa, including native and adventive, are (obligate) upland species; only about 91 adventive taxa are wetland species (~10% of all wetland species). Figure 5 shows the distribution of wetness categories.

The need for weighting species, rather than merely counting them, has been recognized (Diamond 1976). However, efforts to explain patterns of plant species survival and diversity in habitats have lacked any clear models that consider taxa modal to natural areas. It is understood in Grime's triangle that no vascular plant species can survive with high levels of stress and disturbance. However, the C-S-R model does not accommodate species intolerant of stress and disturbance that also are lacking in competitive abilities. About 50% of the native species of vascular plants in the Illinois flora were assigned coefficients (0-6) that more or less correspond to Grime's ruderals (16.8%) or competitors (33.8%). Some taxa in this broad guild demonstrate tolerance to environmental stress (e.g., *Opuntia humifusa*, *Quercus marilandica*, and *Vaccinium arboreum*). The remaining flora—the species modal to relatively stable natural areas—may only loosely fit the stress-tolerator guild. Despite a long history of habitat loss and degradation in Illinois, there are remnant plant communities in localized little-disturbed areas on both nutrient-poor and nutrient-rich sites. These remnants typically are rich in species and include many taxa that lack ruderal characteristics, strong competitive abilities, or tolerance to high stress levels (e.g., *Asclepias perennis*, *Caulophyllum thalictroides*, *Cypripedium reginae*, *Dalea candida*, *Lilium philadephicum*, *Trillium grandiflorum*, and *Viburnum acerifolium*).

Any assessment of ecosystem integrity based on a single index is likely to be insufficient to account for all relevant aspects. For example, the FQI or $\overline{\mathrm{C}}$ when reported alone can be misleading (figure 1). Also, species richness alone can be an insensitive indicator of habitat quality, since it is possible for a degraded site to support a similar or greater number of taxa than an undegraded site. Six measures of biological integrity for wetlands have been suggested by Keddy et al. (1993): species diversity, indicator guilds, exotic species, rare species, plant biomass, and amphibian biomass. Diversity is viewed as an essential indicator of integrity (Keddy et al. 1993). However, instead of only measuring species richness, Keddy et al. (1993) also recommend assessing guild diversity. FQA readily addresses the first four recommended measures, provides an index of wetness characteristics, and can be applied to wetland and upland vegetation; moreover, it can be expanded to include other community traits or particular interests such as INAI grades.

Examples of Floristic Quality Assessment

The following three examples of Floristic Quality assessment application are not intended as proof or strenuous testing of the method, but rather as illustrations of cases where FQA and analytic methods are used in an attempt to differentiate vegetation quality.

Example 1: Four Herbaceous Communities. Sites 1, 2, and 3 are prairie remnants. Site 1 is a high-quality Natural Area; Sites 2 and 3 have been damaged by past disturbances but are dominated by native prairie species. Site 4 is an old field with a history of cultivation. All sites are similar in area (~2 to 4 ha) and were surveyed with similar inventory efforts. Parameters of floristic quality from all sites are compared in table 1. Comparisons of all sites are shown for the cumulative proportion of species by conservatism ranks (figure 6) and distribution pattern of coefficients for each site using box plots (figure 7).

Data Analysis. Frequency of the coefficient of conservatism for each taxon present at each site are normally distributed and meet the equal variance assumptions, although data from the old field (Site 4, n = 51) are extremely skewed to the right (normality test p = 0.084). Results are compared first using parametric techniques and then (as a precaution against possible nonnormal distributions and unequal group size) compared using results from nonparametric methods. For parametric tests, qualitative differences in composition among all four sites were examined with analysis of variance (ANOVA); multiple comparisons were examined with Tukey's HSD mean-separation technique (table 2). ANOVA indicates that a significant difference (p<0.000001) exists in floristic quality among the sites examined, as measured by the frequency distribution of the C values. Tukey's HSD test indicates the Natural Area (Site 1) is distinct from all other sites. The old field (Site 4), which contains a few prairie species, is distinct from one degraded prairie remnant (Site 3) but not the other (Site 2). The two degraded prairie remnants (Sites 2 and 3) are qualitatively similar (table 2).

The Kruskall-Wallis test is a one-way ANOVA on ranked data (a nonparametric test) and is suitable when the assumptions of parametric tests can not be met. The results of the Kruskal-Wallis test agree with the ANOVA, showing that a significant difference exists among sites (test statistic is 44.4, 3 df, p < 0.000001). Multiple comparisons can be made by performing Tukey's HSD mean-separation technique on ranked data (Zar 1984). Multiple (planned) comparisons also can be made with t-tests, Mann-Whitney U tests (the nonparametric equivalent to the t-test), or the Kolmogorov-Smirnov (K-S) goodness-of-fit two-sample test. However, with these two-sample tests, the probability levels must be adjusted (e.g., Bonferroni correction) to avoid inflating the Type I error rate. When comparisons are numerous, these can become too conservative (less statistical power), and the probability of Type II errors (probability of accepting the null hypothesis when it is false) is increased (Zolman 1993).

The results of these multiple comparisons are shown in table 3. The K-S test is based on the maximum difference between cumulative frequency distribution patterns among C values (for this example); it tests differences in the respective cumulative proportion curves (figure 6). The K-S test is more conservative (has less statistical power) when applied to rank data (Zar 1984) and generally yields the most conservative probability estimates among the tests compared here (table 3).

As with analysis of cumulative proportion curves among C values, membership differences for other guilds among sites or time sequences also can be examined. With time-series or comparative ecological management studies, changes in guilds (e.g., physiographic classes or wetness ranks) may be of specific interest and could be explored with the K-S test or contingency table analysis.

Example 2: Two Mesic Upland Forest Communities. Parameters of floristic integrity are compared in table 4. Woodland 1 (Grade C) had been grazed by livestock for an extended period, while Woodland 2 (Grade B) did not appear to have a damaging grazing history. Woodland 1 is larger and topographically more diverse with dissected ravines, different aspects (primarily N, W, and S), and localized dolomite outcrops. Woodland 2 is on a step east-facing slope with local exposures of dolomite. Though many more species were recorded from Woodland 1, Woodland 2 is rated with a similar FQI and a higher $\overline{C}$ (table 4). A comparison of the cumulative proportion of species by conservatism ranks at the two sites is shown in figure 8, and the distribution shape of coefficients for each site is given in figure 9.

Data Analysis. A test of the difference (using nonparametric methods) between $\overline{C}$ values indicates significant differences between sites (Mann-Whitney U statistic = 1939.0, p = 0.005). However, the K-S goodness-of-fit comparison (figure 8) yields nonsignificant differences (Dmax = 0.2111, p = 0.088). The two tests, however, provide answers to two different questions and may not be contradictory. When the interest is in comparing mean coefficients of conservatism of the sites, the Mann-Whitney U statistic (or the parametric equivalent t-test) is the appropriate approach. When the interest is in a measure of differences in guild diversity, comparison and analysis of cumulative proportion profiles with the K-S test is suggested, but caution is warranted because of increased Type II errors with this conservative test. Although these floristic data indicate that no differences exist in guild profiles, quantitative data on ground cover species (not available with these data) may reveal important differences in the guild profiles.

Example 3: Two Southern Flatwoods Communities. Parameters of floristic integrity are compared in table 5. Both sites are recognized by the INAI as high-quality Natural Areas. Lake Sara Flatwoods (Grade B) had been managed with prescribed fire for 20 years prior to study. Williams Creek Flatwoods (Grades A and B) had not been managed prior to study. Both sites were among locations selected as part of an ecological study of flatwoods on the Illinoian till plain that examined quantitative aspects of vegetation and soils (Taft et al. 1995). Guild diversity among coefficients of conservatism is compared for both sites (figure 10); comparisons are shown for the cumulative proportion of species and cumulative proportion of Importance Value (IV 200 = sum of relative frequency and relative cover).

Data Analysis. Several measures of diversity, including species richness, species density, dominance concentration, and Shannon-Weiner Equitability Index, indicate that significant differences exist between Lake Sara Flatwoods and the other sites studied, including Williams Creek Flatwoods (Taft et al. 1995). The fire management history at Lake Sara appears to have contributed to the greater measures of diversity there. However, a two-sample means test (t-test) on presence-absence floristic data from the Lake Sara and Williams Creek flatwoods indicates that no significant differences exist between C values. Guild diversity analysis based on cumulative proportion of species among C values (K-S test) also indicates that no differences exist (figure 10). In contrast, quantitative data for the ground cover vegetation (using IVs) reveal that significant differences exist ($p < 0.001$) in the pattern of abundance among C values (figure 10).

Judging from the first two examples above, significance tests on FQA data have promise as aids in qualitatively differentiating vegetation as measured by floristic presence-absence data alone when the sites are characterized by distinctly different disturbance histories. However, the third example suggests that statistical tests based on floristic data alone may be relatively insensitive for differentiating among similar habitats with important differences in diversity and/or abundance patterns, particularly where only slight differences exist in levels of habitat degradation. These illustrations suggest that examining differences in FQI, $\overline{C}$, guild profiles, and quantitative data may contribute to greater sensitivity in interpretation, when needed, in the assessment of floristic integrity.

Keddy et al. (1993) recommended establishing limits that reflect tolerable and desirable levels for indicator traits. We find that sites with a FQI of less than 20, based on “complete” inventory data, are usually severely degraded or derelict plant communities, or are very small habitat remnants. Sites with an FQI greater than 20 may be degraded but generally have potential for some level of recovery. Sites with indices greater than 35 are at least regionally noteworthy and often are sharply distinct from the predominant heavily degraded matrix areas in the landscape. Sites with indices greater than 45 are often also statewide-significant Natural Areas. Wetland or prairie reconstructions seldom exceed an FQI of 35, at least in the short term, and only do so with intensive efforts. The long-term potential or stability of many reconstructions has not been determined. Many reconstructions in early developmental stages appear to be prone to rapid fluctuations in composition, diversity, and community structure. Limits and goals for other traits in FQA are variable according to the specific goals of ecosystem management. While goals for richness of exotic species may be 0, this may not be achievable in certain regions of Illinois, particularly where aggressive, adventive species are abundant.

Testable Paradigm

A goal of many biological indices is to make predictions about responses to perturbations. FQA appears to meet this general goal. We predict that intact natural communities exposed to damage will show a reduction of floristic integrity to which FQI, $\overline{C}$, and ultimately the cumulative proportion curves (among C values) are sensitive. For example, in a mesic tallgrass prairie remnant exposed to a regime of soil disturbances or sustained heavy grazing, populations of typical “conservative” species such as *Amorpha canescens*, *Asclepias viridiflora*, *Baptisia leucophaea*, *Cacalia tuberosa*, *Polytaenia nuttalii*, and *Sporobolus heterolepis* (C guild 7-10) will decline to extirpation. Other species such as *Andropogon gerardii*, *Sorghastrum nutans*, and *Panicum virgatum* (C guild 4-6: Grime’s competitors) temporarily may increase under certain circumstances in cover if not in frequency. If the disturbance is continued, species such as *Solidago rigida*, *S. canadensis*, *Helianthus rigidus*, *Ratibida pinnata*, and *Asclepias verticillata* (C guild 1-4: species that are intermediate between Grime’s ruderals and competitors) become predominant, and adventive species often become common. If the frequency and duration of the disturbance are increased, species with regeneration intervals shorter than the disturbance frequencies (C guild 0-2[3]: Grime’s ruderals) become dominant, including many adventive species.

The reverse of this paradigm is the recovery of a degraded system. Restoration seeks to return damaged habitats or communities to their qualitative, compositional, and structural states prior to degradation. We predict that both the FQI and C will increase at a site with the introduction of appropriate vegetation management. In the

Midwest, many studies have been conducted, or are ongoing, that track the recovery of plant communities with the reintroduction of fire (Tester 1989; DeSelm and Clebsch 1991; Apfelbaum and Haney 1991; Wilhelm and Masters 1994; Taft, unpublished data). FQA offers a method to track changes in floristic composition that may be helpful in goal development and assessment (Masters 1997). Again, quantitative data provide the most accurate account of the relative abundance of species at a site. Species at low population levels sometimes are at greater risk of extinction (May 1973). If, by chance, most of the taxa with high C values are at low population levels, the species pool may be unstable and susceptible to rapid changes in the FQI and $\overline{C}$. As always, the cost in time needed to collect and analyze quantitative data has to be contrasted with the ease, rapidity, and qualitatively thorough nature of floristic presence-absence data collection. Inventory goals will determine the approach to be taken.

CONCLUSIONS

We offer Floristic Quality Assessment (FQA) for the Illinois flora as a versatile, relatively rapid, dispassionate, and repeatable method for making qualitative assessments of plant communities and for assessing effectiveness of ecological restoration activities. Using floristic inventory data, FQA summarizes several parameters of plant communities, including a weighted measure of species richness (FQI), a mean coefficient of conservatism ($\overline{C}$), guild diversity, proportion of adventive taxa, wetness characteristics, relative importance of native species, physiognomic characteristics, and rare species. The FQI is calculated from coefficients of conservatism (on a scale of 0-10) assigned to each taxon in the Illinois flora. The philosophy underlying the assignment of the coefficients is a recognition that plant species are unequal contributors to habitat quality. Factors that influence diversity and composition also influence the FQI (e.g., habitat size, heterogeneity, disturbance history, and level of degradation). The mean coefficient of conservatism (and quadrat-based sampling methods) provides an area-independent means of making qualitative comparisons among sites. FQA can accommodate measures of species abundance and accompany other measures of natural community quality such as Illinois Natural Areas Inventory grades. We suggest testing the method by comparing floristic composition among sites and time intervals with known levels of disturbances and restoration activities using mean-separation techniques and analysis of guild diversity. Although similar results may be achieved with parametric statistics, nonparametric tests may be preferred for small sample sizes when all assumptions of parametric methods may not be met.

GLOSSARY

Adventive – Not native to Illinois. Adventive is synonymous with the terms exotic and alien. Species that have limited natural ranges in Illinois, but that are widely planted or escaped, such as *Pinus strobus* and *Robinia pseudoacacia*, should be treated as adventive when encountered outside their natural Illinois distributions, and assigned a C value of 0 in the calculation of the floristic quality index and mean coefficient of conservatism.

Coefficient of conservatism (C) – An integer from O to 10 assigned to each taxon in the Illinois flora and used in calculating the floristic quality index. Each value reflects an estimate of a plant's tendency to be restricted to "natural areas" (see detailed description in methods section). The mean coefficient of conservatism (C) is calculated by summing all coefficients in an inventory unit and dividing by number of species (N), or $\overline{C} = \sum C/N$.

Conservatism – The tendency of a taxon to be restricted to natural areas. Similar to remnant dependency (Panzer et al. 1995).

Floristic Quality Index (FQI) – An index derived from floristic inventory data and calculated by the following formula from Swink and Wilhelm (1979, 1994):

$I = \overline{C}(\sqrt{N})$, in which:

C = coefficient of conservatism

$\overline{C} = \sum C/N$

N = number of taxa.

Guild Diversity – Guild diversity is measured from frequency distributions for species among traits such as physiognomic classes, wetness ranks (see Wetness), or conservatism ranks. These frequency data allow for graphical depictions of these guilds for comparison among sites and time periods (see Data Analysis in results section).

Illinois Natural Areas Inventory Grades – Definitions taken from White (1978, p. 31):

Grade A = Relatively stable or undisturbed communities. *Example:* old growth, ungrazed forest.

Grade B = Late successional or lightly disturbed communities. *Example:* old growth forest that was selectively logged 5 years ago.

Grade C = Mid-successional or moderately to heavily disturbed communities. *Example:* young to mature second-growth forest.

Grade D = Early successional or severely disturbed communities. *Example:* severely grazed forest of any age.

Grade E = Very early successional or very severely disturbed communities. *Example:* cropland.

Integrity, Ecological and Community – Integrity implies an unimpaired, complete condition. Ecological or community integrity refers to the degree to which self-correcting properties in an ecosystem or community exert themselves when that community is exposed to disturbance.

Natural Area – In a broad sense, a natural area is considered to be a natural community that is (presumably) representative of the presettlement vegetation for the site. This general definition includes all Natural Areas (INAI sites graded A and B), but also areas that presently do not meet the standards for the INAI but that, with management and time, have potential for restoration to a community with floristic composition and diversity similar to the presettlement condition.

Physiognomy – Broadly defined, physiognomy includes plant habit (architectural characteristics), life history, and certain taxonomic classes. Physiognomic classes assigned to each taxon in the Illinois flora are Fern (including fern allies), Annual Forb, Biennial Forb, Perennial Forb, Annual Grass, Perennial Grass, Annual Sedge, Perennial Sedge, Herbaceous Vine, Woody Vine, Shrub, and Tree. Tracking physiognomic classes can be an important component of FQA, since it is theoretically possible for dramatic changes in community structure to occur without changes in the FQI or $\overline{C}$.

Rare Species – Plant species listed as threatened or endangered by the Illinois Endangered Species Protection Board (Herkert 1991, 1994).

Species richness – Total number of native and adventive species.

Wetness – Wetness classification is based on the National Wetland Category for Region 3 of the United States Fish and Wildlife Service (Reed 1988). Plants are designated as *Obligate Wetland*, *Facultative Wetland*, *Facultative*, *Facultative Upland*, and *Upland*. These classes are further ranked by “+” and “-“ values for the three facultative classes, thereby providing greater resolution. These nominal classes have been sorted into ordinate values:

-5 = Obligate Wetland	(OBL)
-4 = Facultative Wetland+	(FacW+)
-3 = Facultative Wetland	(FACW)

-2 = Facultative Wetland-	(FACW-)
-1 = Facultative+	(FAC+)
0 = Facultative	(FAC)
+1 = Facultative-	(FAC-)
+2 = Facultative Upland+	(FACU+)
+3 = Facultative Upland	(FACU)
+4 = Facultative Upland-	(FACU-)
+5 = Upland	(UPL).

Mean wetness is an average derived from all wetness (ordinate) values in a floristic inventory unit; it provides an index that characterizes the plant community in terms of hydrological characteristics.

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FIGURES

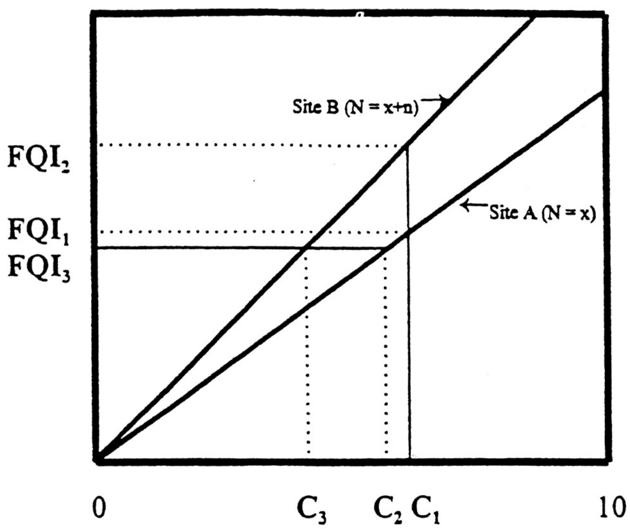

Figure 1. Baseline model comparing floristic quality index (FQI) and mean coefficients of conservatism (C) from two sites with differing total species richness. Site A has N (species richness) = x, and Site B has N = x + n. The examples illustrate where two sites with different total species richness but similar mean coefficient of conservatism (C_1) will differ in floristic quality indices (FQI_1 and FQI_2), and where two sites with similar floristic quality indices (FQI_3) will differ in mean C values (C_2 and C_3).

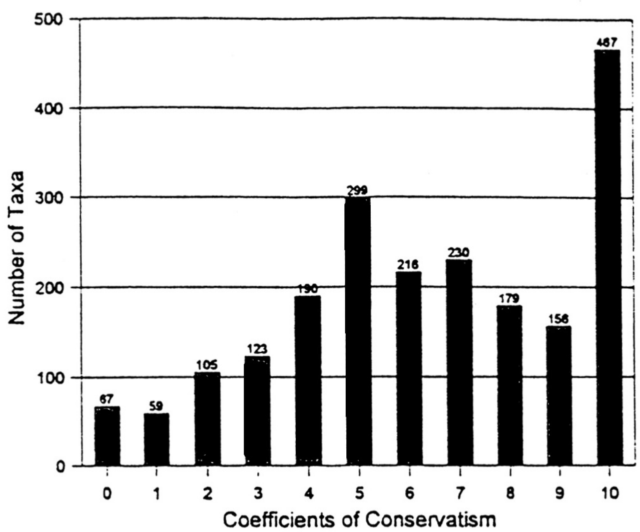

Figure 2. Distribution of vascular plant species occurring in Illinois by coefficient of conservatism ranks. In addition to the native taxa, there are 957 adventive or non-native taxa ranked at coefficient 0 (not shown). See text for definitions of conservatism and ranks.

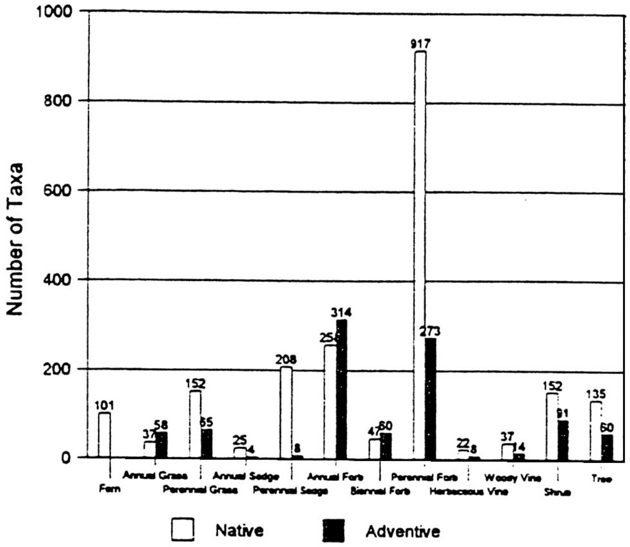

Figure 3. Distribution of native and adventive (non-native) taxa in the Illinois vascular flora by physiognomic classes.

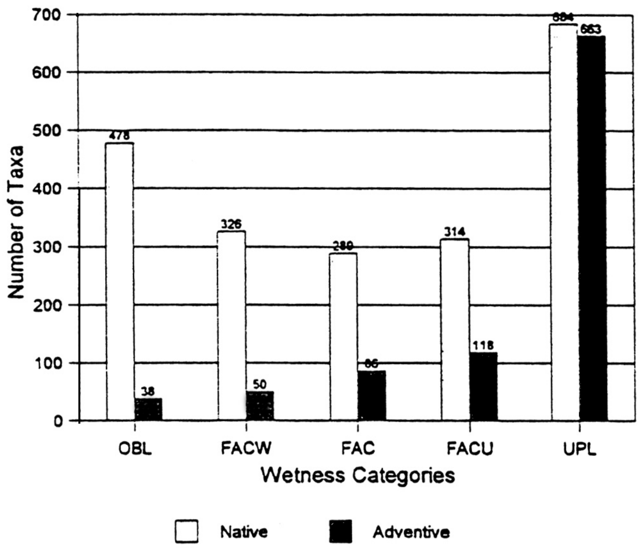

Figure 4. Distribution of native and adventive (non-native) taxa in the Illinois vascular flora by indicator wetness categories. Wetness categories are OBL (obligate wetland species), FACW (facultative wetland species), FAC (facultative species – equally likely to occur in wetland and upland habitats), FACU (facultative upland species), and UPL (obligate upland species).

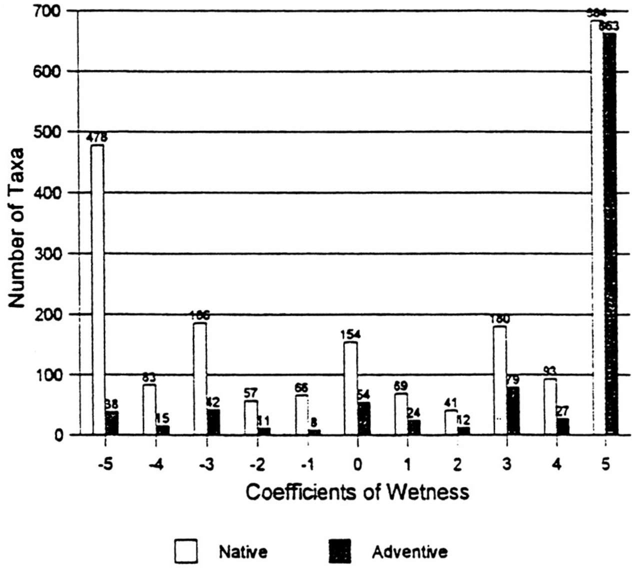

Figure 5. Distribution of native and adventive (non-native) taxa in the Illinois vascular flora by numerical wetness ranks.
-5 = OBL, -4 = FACW+, -3 = FACW, -2 = FACW-, -1 = FAC+, 0 = FAC, 1 = FAC-, 2 = FACU+, 3 = FACU, 4 = FACU-, 5 = UPL.

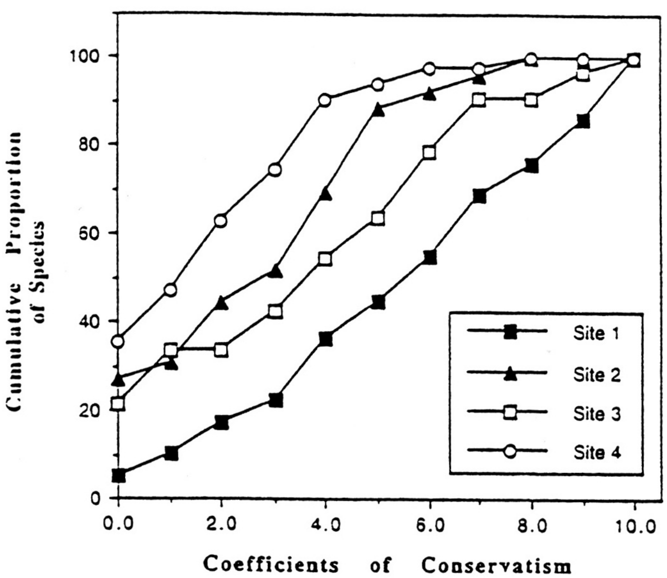

Figure 6. Cumulative proportion of species by coefficients of conservatism comparing curves among four herbaceous communities. See text for site descriptions. Significant differences in these profiles exist between Site 1 (high quality prairie) and all other sites, and between Site 3 (degraded prairie) and Site 4 (old field). No significant differences exist between sites 2 (degraded prairie) and 4 and Sites 2 and 3. See Table 3 for significance levels in paired comparisons.

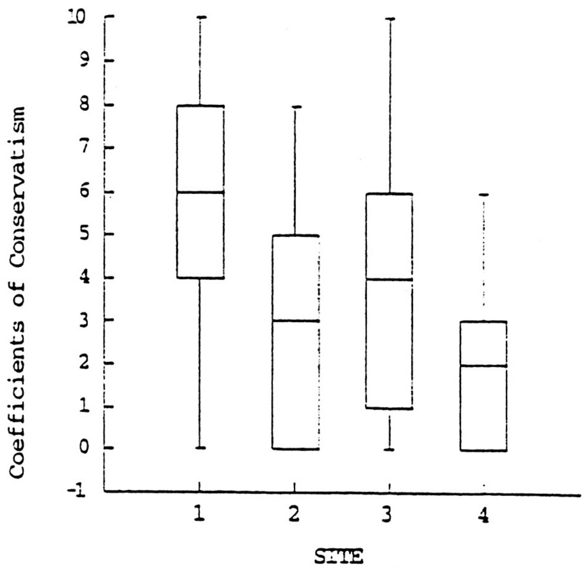

Figure 7. Box plot of four grasslands (Sites 1-4) showing medians, quartiles, and spread of the coefficients of conservatism among the floristic data. Horizontal bar in box is median; boundaries of the box represent 25^{th} and 75^{th} percentiles and describe the range of the middle half of the distribution; vertical lines extending from the box represent the range of observed values within 1.5 times the value of the interquartile range. See text for site descriptions.

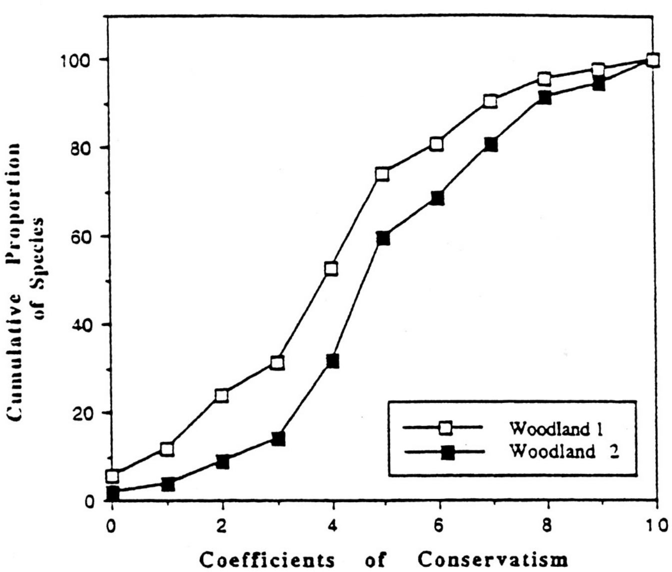

Figure 8. Cumulative proportion of species by coefficients of conservatism comparing curves among two woodland communities. Woodland 1 (Grade C) is a larger site with a damaging grazing history, Woodland 2 (Grade B) is on a steep slope and apparently lacks a damaging grazing history. The maximum difference between the profiles, tested with the Kolmogorov-Smirnov two-sample goodness-of-fit test, is Dmax 0.2111 (n1=93, n2=57; p=0.088). See text for additional site descriptions.

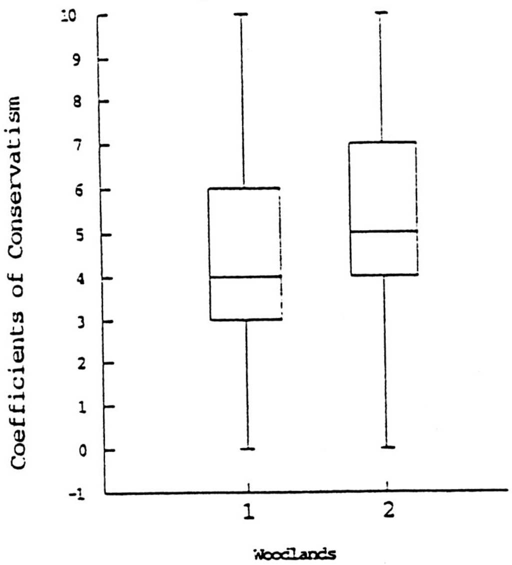

Figure 9. Box plot for Woodland 1 (Grade C) and Woodland 2 (Grade B) showing medians, quartiles, and spread of the data. Horizontal bar in box is median; boundaries of the box represent 25th and 75th percentiles and describe the range of the middle half of the distribution; vertical lines extending from the box represent the range of observed values within 1.5 times the value of the interquartile range. See text for site descriptions.

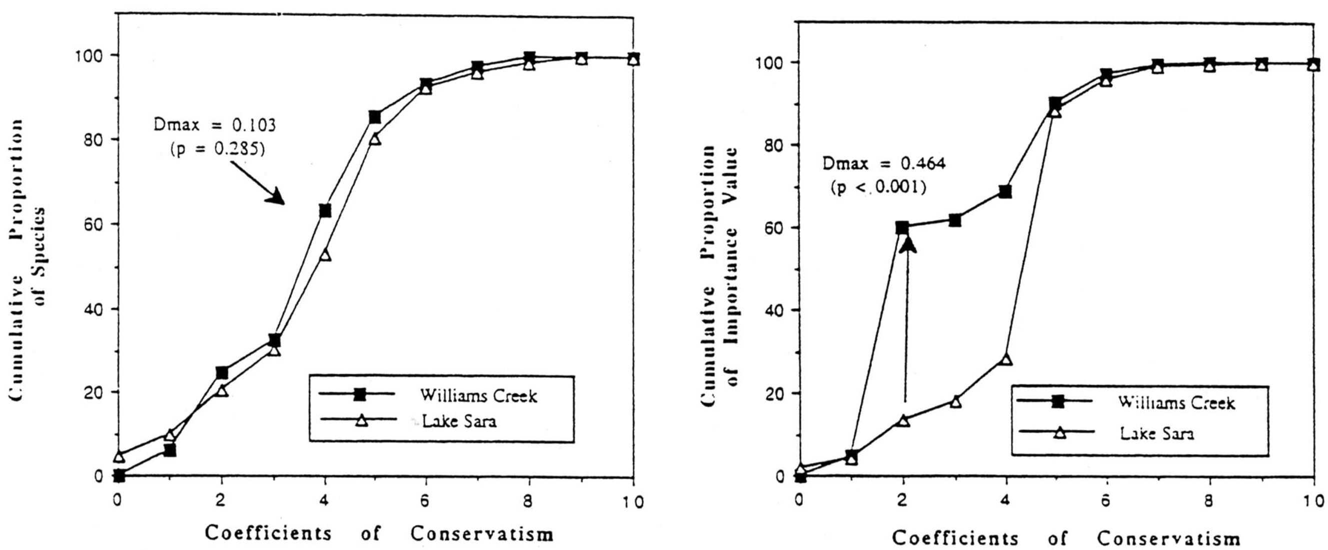

Figure 10. Cumulative proportion of species (top figure – no significant difference) and cumulative proportion of importance value (bottom figure – significant difference) by coefficients of conservatism (C) comparing curves among the ground cover vegetation of two high quality (Grades A and B) flatwoods remnants. Distribution patterns of importance values indicates that at Lake Sara a greater proportion of the species importance values are in the upper range of the C values. Lake Sara had a prior history of prescribed-fire management; Williams Creek Flatwoods had no prior vegetation management. See text for additional details.

TABLES

TABLE 1. Floristic integrity assessment summary data comparing four herbaceous communities (Sites 1-4).

Parameter	Site 1	Site 2	Site 3	Site 4
INAI Community Classification	Dolomite Prairie	Dry-Mesic Prairie	Dolomite Prairie	Old Field
INAI Grade	B	C	C	na (E)
Total Species Richness	58	52	33	51
Native Species Richness	56	42	27	37
% Adventive	3.4	19.2	18.2	27.5
Floristic Quality Index (FQI)	44.0	21.6	22.6	14.3
FQI (natives only)	44.8	24.1	25.0	16.8
Mean Conservatism	5.8	3.0	3.9	2.0
Mean Conservatism (natives only)	6.0	3.7	4.8	2.8
Mean Wetness	3.8	2.9	4.0	1.6
Mean Wetness (natives only)	3.8	2.9	3.9	1.1
# Rare Species (T&E)	1	0	0	0
Guild Diversity – Coef. Conserv.	Figure 6	Figure 6	Figure 6	Figure 6

TABLE 2. Analysis of variance and Tukey Honestly Significant Difference multiple comparison test of probabilities for Floristic Quality Assessment of four grasslands.

ANALYSIS OF VARIANCE

Source	Sum-of Squares	DF	Mean Square	F-Ratio	P
Site	424.556	3	141.519	20.652	0.000
Error	1301.965	190	6.852		

LEAST SQUARES MEANS

Site	LS Mean	SE	N
1	5.776	0.344	58
2	3.000	3.363	52
3	3.939	0.456	33
4	2.000	0.367	51

TUKEY HSD MULTIPLE COMPARISONS

Matrix of Pairwise Comparison Probabilities

Site	1	2	3	4
1	1.0000			
2	0.0000	1.0000		
3	0.0070	0.3720	1.0000	
4	0.0000	0.2120	0.0050	1.0000

TABLE 3. Floristic quality comparisons among four herbaceous communities. Probability levels shown compare results from two parametric tests and two nonparametric tests. See text for site descriptions. The adjusted critical values for the two-sample tests are shown for these multiple comparisons (e.g., $p<0.0083$).

Parametric Tests

Tukey HSD Test, alpha = 0.05

Site	1	2	3	4
1	1.000			
2	0.000	1.000		
3	0.007	0.372	1.000	
4	0.000	0.212	0.005	1.000

Student's t-test, adjusted alpha = 0.0083

Site	1	2	3	4
1	1.000			
2	0.000	1.000		
3	0.007	0.138	1.000	
4	0.000	0.023	0.002	1.000

Nonparametric Tests, adjusted alpha = 0.0083

Site	1	2	3	4
1	1.000			
2	0.000	1.000		
3	0.008	0.139	1.000	
4	0.000	0.029	0.003	1.00

Kolmogorov-Smirnov Test, adjusted alpha = 0.0083

Site	1	2	3	4
1	1.000			
2	0.00	1.000		
3	0.049	0.143	1.000	
4	0.000	0.124	0.009	1.000

TABLE 4. Floristic integrity assessment summary data comparing two mesic upland forests. Woodland 1 has been grazed while Woodland 2, a smaller forest, apparently has not.

Parameter	Woods 1	Woods 2
INAI Community Classification	Mesic Upland Forest	Mesic Upland Forest
INAI Grade	C	B
Total Species Richness	93	57
Native Species Richness	91	57
% Adventive	2.2	0
Floristic Quality Index (FQI)	42.1	41.2
FQI (natives only)	42.6	41.2
Mean Conservatism	4.4	5.5
Mean Conservatism (natives only)	4.5	5.5
Mean Wetness	2.2	2.3
Mean Wetness (natives only)	2.3	2.3
# Rare Species (T&E)	1	0
Guild Diversity – Coef. Conserv.	Figure 8	Figure 8

TABLE 5. Floristic integrity assessment summary data comparing quadrat sampling data from the ground cover in two high-quality flatwoods. Lake Sara had a 20-year history of prescribed fire prior to sampling.

Parameter	Lake Sara	Williams Creek
INAI Community Classification	Southern Flatwoods	Southern Flatwoods
INAI Grade	B	A and B
Total Species Richness	83	49
Native Species Richness	82	49
% Adventive	1.2	0
Floristic quality Index (FQI)	37.6	27.7
FQI (natives only)	37.9	27.7
Mean Conservatism	4.1	4.0
Mean Conservatism (natives only)	4.2	4.0
Mean Wetness	2.7	1.8
Mean Wetness (natives only)	2.7	1.8
# Rare Species (T&E)	1	0
Guild Diversity – Coef. Conserv.	Figure 10	Figure 10