Ecological Monographs, 79(2), 2009, pp. 173–199

Standards for associations and alliances of the U.S. National Vegetation Classification

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Abstract. This article provides guidelines for the description, documentation, and review of proposals for new or revised plant associations and alliances to be recognized as units of vegetation within the U.S. National Vegetation Classification (NVC). By setting forth standards for field records, analysis, description, peer review, and archiving, the Ecological Society of America's Vegetation Classification Panel, in collaboration with the U.S. Federal Geographic Data Committee, NatureServe, and others, seeks to advance our common understanding of vegetation and improve our capability to sustain and restore natural systems. We provide definitions for the two floristic levels of the NVC hierarchy: associations and alliances. This is followed by a description of standards for field plot records and the identification and classification of vegetation types. Procedures for review and evaluation of proposed additions and revisions of types are provided, as is a structure for data archiving and dissemination. These procedures provide a dynamic and practical way to publish new or revised descriptions of vegetation types while maintaining a current, authoritative list of types for multiple users to access and apply.

Key words: floristic types; national standards; plot data; U.S. National Vegetation Classification; vegetation alliance; vegetation association; vegetation classification.

Introduction

Vegetation documentation and classification are central to biological conservation, from planning and inventory to direct resource management. They are also important to basic scientific research as a tool for organizing and interpreting ecological information and placing ecological research in an appropriate biophysical context. All of these activities require that plant species assemblages be defined within a consistent typological framework and that their distribution on the landscape be known and understood. Vegetation documentation and classification contribute considerably to the basic understanding of ecological patterns as well as to analysis of problems that vary in scale from the persistence of tiny populations of rare species to global projections of human impacts on the biosphere. Technological advances in fields such as remote sensing and geographic information systems have made it practical to assess and synthesize biological and ecological conditions over large spatial extents, yet at fine spatial grain sizes. These capabilities offer entirely new insights into the behavior of natural systems. Such assessments can cover multiple administrative jurisdictions and physical regions. They typically address applied ecological issues as diverse as regional climate change, ecosystem management, and conservation planning. However, all such efforts depend on having available a common set of well-documented and broadly accepted vegetation classification units.

Considering the magnitude and rate of change in vegetation worldwide that is expected over this century (Hansen et al. 2001, Walther et al. 2002, Rehfeldt et al. 2006, Scholze et al. 2006), adequate standardized description of vegetation units is imperative. With the wide-ranging and rapid shifts in species distributions resulting from ongoing global environmental change, it is probable that some plant communities will disappear while entirely novel communities will appear, perhaps in a matter of decades. In the past several decades, remnants of natural vegetation have become increasingly rare, with some types now imperiled without ever having been studied or documented well (Grossman et al. 1994). The loss of vegetation types due to habitat conversion, changes in climate, continued atmospheric pollution, and invasions by exotic organisms can lead to

Manuscript received 29 October 2007; accepted 10 March 2008; final version received 11 June 2008. Corresponding Editor (ad hoc): N. L. Christensen.

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Table 1. Examples of the questions to be answered by a standardized National Vegetation Classification (NVC) at a range of scales.

Application	Scale†
How should the vegetation community attributes of a forest stand be quantified?	single patch, alpha
How should the vegetation types and diversity expected over a land management unit such as a National Forest be documented?	>10 000 ha, beta
How intact is the vegetation of a particular region when compared with other regions?	100–100 000 ha, epsilon
What is the relationship between biodiversity and productivity in temperate deserts, grasslands, or forests?	>1 000 000 km^2, gamma

† See Whittaker (1977).

species being placed in danger of extinction (Overpeck et al. 1991, Vitousek et al. 1997, Wilcove et al. 1998) and to significant changes in ecosystem functions (Mooney et al. 1995). A standardized classification of vegetation can contribute to our understanding of plant ecology and perhaps may advance general ecology by providing comparable units of species composition and abundance during a period of rapid change in species assemblages. A formal classification can provide an important context for basic ecological and biodiversity studies as well as conservation assessments. It can help to guide research, ecosystem management, and the planning of restoration work. Examples of the kinds of questions that a national classification can help to answer, across multiple scales, are in Table 1.

In February 2008, the U.S. Federal Geographic Data Committee (FGDC) formally approved Version 2 of the National Vegetation Classification Standard (FGDC 2008). The floristic levels of that standard were developed by the Ecological Society of America's Vegetation Classification Panel (here referred to as the "Vegetation Panel") over a 10-year period, from 1997 to 2006 (see Jennings et al. 2008). Here we present the rationale, along with the detailed conceptual and technical basis, for those standards. In particular, we address standards for data collection, analysis, classification, review, and archiving needed to meet the needs of the U.S. National Vegetation Classification (NVC) as well as the needs of floristic vegetation research and biological conservation at multiple scales. These standards will be useful to federal and state land management agencies, university researchers and educators, and private conservation practitioners.

Background and Principles

For well over a century, vegetation scientists have studied plant communities to identify their compositional variation, distribution, dynamics, and environmental relationships. Classification has been a major activity in Europe throughout the 20th century, with vegetation scientists largely using the methods of the Braun-Blanquet school. Moreover, vegetation classification gained new impetus in many European countries during the 1970s and 1980s (Rodwell et al. 1995). However, for a variety of reasons, no consensus on standards for sampling or analysis has been developed in the United States. Instead, a wide range of sampling approaches and analytical methods has been used to reveal and interpret patterns of vegetation, including two fundamentally different approaches. One form of vegetation classification uses physiognomic characteristics, which requires data on the external appearance of vegetation, using growth form of the dominant plants (gross morphology; Poore 1962). Floristic characterization, on the other hand, uses the assemblage of taxa and their abundances to describe stands of similar vegetation.

Establishment of the interagency Federal Geographic Data Committee (FGDC) in 1990 provided the impetus for federal standards in the classification of all mappable natural resources, including vegetation (Loucks 1996). During the 1980s and 1990s, some resource managers and conservationists began developing classifications (e.g., Driscoll et al. 1984, Grossman et al. 1998) as federal agencies launched mapping programs that required standardized vegetation classifications (e.g., the National Gap Analysis Program and the USGS-NPS Vegetation Mapping Program). In 1997 the FGDC approved a vegetation classification standard in the form of a physiognomic–floristic hierarchy, in collaboration with The Nature Conservancy and the Ecological Society of America (FGDC 1997). That hierarchy was composed of five higher-level physiognomic units and two lower-level floristic units. However, it failed to effectively integrate both physiognomic and floristic criteria and was later revised (Faber-Langendoen et al. 2009, FGDC 2008) to better combine the strengths of the two traditional schools of vegetation classification. The restructured hierarchy contains eight levels, emphasizing physiognomy at the highest levels, both physiognomy and floristics at the middle levels, and floristics at the lower levels (Table 2). However, regardless of the hierarchy's conceptual developments, a robust and detailed classification of floristic types was lacking. The Vegetation Panel therefore undertook the task of consolidating the disparate concepts, methods, and practices in American vegetation classification to develop unified criteria for floristic classification (Jennings et al. 2008). This monograph describes the scientific and technical criteria that underpin the federal standard

Table 2. Categories and examples of the National Vegetation Classification, showing the hierarchy from Class to Association (FGDC 2008).

Hierarchy	Example: Scientific name	Example: English name
Upper levels		
1) Formation Class	Mesomorphic Shrub and Herb Vegetation	Shrublands and Grasslands
2) Formation Subclass	Temperate and Boreal Shrub and Herb Vegetation	Temperate and Boreal Shrubland and Grassland
3) Formation	Temperate Shrub and Herb Vegetation	Temperate Shrubland and Grassland
Mid levels		
4) Division	*Andropogon–Stipa–Bouteloua* Grassland and Shrubland Division	North American Great Plains Grassland and Shrubland
5) Macrogroup	*Andropogon gerardii–Schizachyrium scoparium–Sorghastrum nutans* Grassland and Shrubland Macrogroup	Great Plains Tall Grassland and Shrubland
6) Group	*Andropogon gerardii–Sporobolus heterolepis* Grassland Group	Great Plains Mesic Tallgrass Prairie
Lower levels		
7) Alliance	*Andropogon gerardii–(Calamagrostis canadensis–Panicum virgatum)* Herbaceous Alliance	Wet-mesic Tallgrass Prairie
8) Association	*Andropogon gerardii–Panicum virgatum–Helianthus grosseserratus* Herbaceous Vegetation	Central Wet-mesic Tallgrass Prairie

Notes: Among the taxa that are chosen to name a type, those occurring in the same strata (tree, shrub, field, ground, floating, submerged) are separated by a dash (–), and those occurring in different strata are separated by a slash (/). Species that may occur with low constancy are in parentheses. Taxa occurring in the dominant stratum are listed first, followed successively by those in other strata. Within one stratum, the order of species names generally reflects decreasing levels of dominance, constancy, or diagnostic value of the taxa.

(FGDC 2008) as well as the standard used by NatureServe and the Vegetation Panel.

The earlier version of the FGDC (1997) standard did provide preliminary definitions for the floristically based *association* and *alliance* levels. These definitions begin with the premise that a vegetation type can be represented as a group of sampled stands having similar plant species composition and physiognomy, and that type descriptions can be derived from quantitative field data. However, the 1997 FGDC standard provided no list of recognized types, no details about nomenclature, no methods for defining and describing alliances and associations, and no basis for evaluating proposed types, publishing findings, or archiving underlying data. Instead, the FGDC adopted the list of alliances and associations published by The Nature Conservancy (now represented by NatureServe; see Anderson et al. 1998). Each association and alliance was described from a compilation of literature that includes varying combinations of plot data and field observations. This compendium, maintained and updated by NatureServe (2008), constitutes a summary of our knowledge of the plant communities of the United States. Most of the type descriptions, however, lack either accessible field plot data or standardized analyses and summary tables.

Principles in vegetation classification

The processes and standards presented in this paper are intended to formalize the ongoing development and revision of the NVC's floristic levels. Our work began with the FGDC (1997) "Guiding Principles" (Box 1), which we later helped to revise (FGDC 2008). We intend that the classification of associations and alliances be based on standardized field plot observations, standardized type descriptions, peer review of proposed changes to the accepted types and their descriptions, and publication and permanent archiving of accepted types, revisions to the classification, and underlying data and analyses. These principles, developed fully in later sections, can be stated briefly as follows:

1) *Standardized field observations.*—Vegetation associations and alliances should be documented through analysis of standardized field plot data collected across the potential range of a vegetation type and closely related types, irrespective of political borders.

2) *Type descriptions.*—Proposals for new, revised, or deleted floristic units should include sufficient information to determine the distinctive features of the types and their relationship to similar accepted types. A proposal for new or revised types should include comparison of the focal type with related types, showing the differentiating characteristics.

3) *Peer review.*—Proposals for new or revised types need to be evaluated through a credible, open, peer review process.

4) *Permanent archiving.*—Plot data used to define vegetation types must be permanently archived in a publicly accessible repository. Similarly, the rationale behind each change in the classification units must be permanently archived. This archived information must also: (a) include the rationale for classification decisions, (b) allow for quantitative revision of the descriptions

Box 1. Guiding Principles of the FGDC Vegetation Classification Standard (FGDC 1997).

- The classification is applicable over extensive areas.
- The vegetation classification standard is compatible, wherever possible, with other Earth cover/land cover classification standards.
- The classification will avoid developing conflicting concepts and methods through cooperative development with the widest possible range of individuals and institutions.
- Application of the classification must be repeatable and consistent.
- When possible, the classification standard will use common terminology (i.e., terms should be understandable and jargon should be avoided).
- For classification and mapping purposes, the classification categories were designed to be mutually exclusive and additive to 100% of an area when mapped within any of the classification's hierarchical levels (Division, Order, Class, Subclass, Subgroup, Formation, Alliance, or Association). Guidelines have been developed for those instances where placement of a floristic unit into a single physiognomic classification category is not clear. Additional guidelines will be developed as other such instances occur.
- The classification standard will be dynamic, allowing for refinement as additional information becomes available.
- The NVCS is of existing, not potential, vegetation and is based upon vegetation condition at the optimal time during the growing season. Vegetation types are defined on the basis of inherent attributes and characteristics of the vegetation structure, growth form, and cover.
- The NVCS is hierarchical (i.e., aggregatable) to contain a small number of generalized categories at the higher level and an increasingly large number of more detailed categories at the lower levels. The categories are intended to be useful at a range of scales (UNEP/FAO 1995, Di Gregorio and Jansen 1996).
- Upper levels of the NVCS are based primarily on physiognomy (life form, cover, structure, leaf type) of the vegetation (not individual species). Life forms (e.g., herb, shrub, or tree) in the dominant or uppermost stratum will predominate in classification of the vegetation type. Climate and other environmental variables are used to help organize the standard, but physiognomy is the driving factor.
- Lower levels of the NVCS are based on actual floristic (vegetation) composition. The data used to describe Alliance and Association types must be collected in the field using standard and documented sampling methods. The Alliance and Association units are derived from these field data. These floristically based classes will be nested under the physiognomic classes of the hierarchy.

based on original data and new data, and (c) provide the basis for new or revised type descriptions. Accordingly, plot data must conform to a standard format so as to readily allow reevaluation. Accepted proposals for addition or modification of vegetation types, as well as all supporting documentation, need to be deposited in a public NVC digital archive. All plant taxa referenced in plot data or community type descriptions must be defined unambiguously by reference to public databases or publications.

These principles relate primarily to the original observations ("plots") or their systematic analysis and use for describing vegetation types. Additional principles associated with recognition of vegetation types that are incorporated in NVC standards are: (1) given similar habitat conditions, similar combinations of species and subspecies recur from stand to stand, although similarity declines with geographic distance; (2) no two stands (or sampling units) are exactly alike, owing to unpredictable events of dispersal, disturbance, extinction, and history; (3) taxon assemblages change more or less continuously with geographic or environmental distance; and (4) stand composition varies with the spatial and temporal scale of analysis (Mueller-Dombois and Ellenberg 1974:153).

Caveats to classification

The scope of these standards necessarily includes the full range of variation in existing natural and seminatural vegetation, from old-growth forest to abandoned agricultural lands undergoing natural succession, to new community types formed by recent expansions and contractions of species ranges. We define natural and seminatural vegetation as "a system of largely spontaneously growing plant populations, growing in coherence with their sites and forming an ecosystem with these sites and all other forms of life occurring in these sites" (Westhoff and van der Maarel 1978:249). Planted or cultivated vegetation ("cultural vegetation"), such as row crops, orchards, and some forms of forest plantations, are excluded from consideration here, although this vegetation is treated in the revised FGDC (2008) standard.

Our approach to defining floristic units begins with the premise that a vegetation type can be represented by a broad sampling of stands that show similar plant composition and physiognomy, and that the types will have diagnostic features that enable their consistent recognition. At the same time, we accept that vegetation is a continuously varying phenomenon due to complex biophysical factors and natural and cultural disturbances as well as chance. Plant species are, to some extent, stochastic in their distribution and abundance. Thus, floristic vegetation units are not readily defined by a few specific criteria. Some vegetation can be understood unambiguously as belonging to a particular type. Other vegetation can be understood as intermediate between types, such that its assignment should be defined in terms of relative affinities with alternative types.

The standards presented here do not directly provide criteria for vegetation mapping; that is a separate and well-treated science (e.g., Küchler and Zonneveld 1988, Alexander and Millington 2000). Nonetheless, the types defined by this classification can indeed be mapped and can be used as the basis for mapping patterns of land cover, subject to limitations of scale, resolution, and inferential mapping technology. With this classification, species that have a known relationship with an association or an alliance can be tied to thematically coarser vegetation map units that follow the FGDC (2008) hierarchy.

We accept that alternative vegetation classification approaches are appropriate for certain uses, particularly those that recognize units on the basis of physiognomy (e.g., UNESCO 1973) or floristics (e.g., the Braun-Blanquet method described by Westhoff and Van der Maarel 1978). Other hierarchical classifications include vegetation as one of several criteria, including biotic, abiotic, and geographic ecosystem processes (Bailey 1996), or potential natural vegetation as an expression of site potential (Daubenmire 1968, Küchler and Zonneveld 1988). The floristic units defined using the standards and guidelines presented here can nest to varying degrees under these and other hierarchies.

The Association and Alliance Concepts

The most basic units of the NVC hierarchy are associations and alliances. The association is the primary unit of vegetation, reflecting patterns of plant species occurrence and frequency. The alliance is the next broader unit of vegetation and is composed of one to many associations. Both need to be defined by characteristics that can be derived from standard field plots and accepted analytical methods. It is through associations and alliances that more general classes of vegetation can be related to species and their composition as habitat.

Association

The first widely accepted definition of the association was "a plant community of definite floristic composition, uniform habitat conditions, and uniform physiognomy" (Flahault and Schröter 1910*a*, *b*). Importantly, that proposal focused on vegetation types as a conceptual abstraction rather than particular stands of vegetation. Gabriel and Talbot (1984) reviewed numerous definitions for the association, one of which was "a recurring plant community of characteristic composition and structure." Curtis (1959:51, 53) defined plant community types as segments of a continuum, "more or less similar groups of species recurring from place to place . . . their lack of an inherent discreteness, however, does not prohibit their orderly arrangement into groups for purposes of study and discussion." The individual stand is defined simply as a "studiable grouping of organisms which grow together in the same general place and have mutual interactions" (Curtis 1959). Most definitions of the plant association include four central ideas: (1) uniform physiognomy and structure, (2) uniform habitat, (3) definite floristic composition, and (4) recurring distribution across a landscape or region.

Mueller-Dombois and Ellenberg (1974) recognized that "species assemblages change more or less continuously, if one samples a geographically widespread community throughout its range." Their phrasing highlights an important element in understanding natural patterns of vegetation, which is the variability within an association that occurs across its geographic distribution. This variability, expressed as the range of species composition, physiognomy, and habitat found among the set of field plot data, is used to define the association. In this context "habitat" refers to the combination of environmental or site conditions and disturbances that influence community composition. Temporal variation in floristic composition due to unusual weather events, seasonal variation in phenology, or moderate disturbances (fire, insects, disease, grazing) must be accepted, provided it does not fundamentally change species presence and community physiognomy. In addition, characteristic physiognomy and species composition subsume fine-scale, within-community patterns (e.g., shrub/herb structure in semidesert steppe, or hummock/hollow microtopography in bogs). Finally, plant associations have limited distributions that are usually specific to a biogeographically defined area.

In a synthesis and as the basic unit of vegetation in the NVC, we define the association as: *a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy*.

The association is based on overall species composition (the "characteristic range of species composition") along with the particular composition of diagnostic species. Despite a characteristic range of species composition and diagnostic species, results vary continuously due to historical and environmental stochasticity. For these reasons, vegetation classification relies on representative (or modal) plots to define the central concept of the type. For type definition, numerical multivariate analysis of the species composition is typically used to arrange plots that span the compositional and geographic range of interest into discrete types, as well as to show their relation to other types. After types are established, numerical methods are used to identify the composition of diagnostic species. (See *Analysis and interpretation for classification of associations* and Appendix A for a glossary of terms, such as the various kinds of diagnostic species.) The standard for assigning a plot to an association is determined by a composition consistent with a characteristic range of species occurrences in combination with the presence of diagnostic species and the biogeographic context. Intermediate plots can be assigned to associations based on measures of similarity, relative occurrence or abundance of overall composition, or diagnostic species.

"Diagnostic species" here refers to any plant taxon or group of taxa whose relative constancy or abundance can be used to differentiate one vegetation type from another. (We typically use "species" as shorthand for "taxa," with respect to the taxonomic classes of species, subspecies, and varieties, and occasionally genera.) Depending on the analytic methods used, a greater or lesser number of species having the necessary constancy and fidelity may be identified. Diagnostic species can be: (1) character or strong differential species, i.e., species limited to a particular type, (2) a combination of species sharing similar behavior (ecological or sociological species groups), or (3) dominant species (Moravec 1993).

Because of the inherently large variability in patterns of composition among vegetation types, which range from deserts to temperate rain forests, for example, there is no absolute limit of acceptable variation within an association or alliance. For overall composition, Mueller-Dombois and Ellenberg (1974) suggest, as a rule of thumb, that stands with a Jaccard presence–absence index (of similarity to the most typical plot) between 25% and 50% could be part of the same association, and that stands with greater levels of similarity may better define sub-associations. With respect to diagnostic species, Schaminée et al. (1993) recommends that at least one constant and one differential species are needed to define an association. Willner (2006) recommends that the differential and character species should have cover value indices between 2 (weak diagnostic) and 10 (strong diagnostic) times the value they have in other types in which they are found. Still, the nature of the particular vegetation itself should strongly influence the range of variability in compositional similarity, diagnostic species, and dominance used to define any given type. Important related considerations may include species richness, amount of variation among stands, degree of anthropogenic alteration, and within-stand homogeneity of the vegetation.

Alliance

The vegetation alliance is a unit of vegetation determined by broader compositional and physiognomic patterns than the association. It includes the floristic characteristics shared among its constituent associations while being constrained by the physiognomic characteristics of the higher levels of classification. We define the alliance as: *a vegetation classification unit containing one or more associations, and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation.*

Alliances are more compositionally and structurally variable, more geographically widespread, and occupy a broader range of habitat conditions than associations. Thus, alliances should be well separated floristically, either by many moderately differential species or one or more strong differential (character) species. As with the association, the pattern of vegetation correlates with ecological factors, although these are often regional in scale. Alliance concepts that are narrowly defined or based on specialized local habitats, locally distinctive species, or that differ only in the relative dominance of their major species, should be avoided. The vegetation alliance concept used here is similar to that of the floristically based Braun-Blanquet (1964) work (e.g., Westhoff and van der Maarel 1978), although a greater degree of structural and physiognomic uniformity is expected. For example, using the Braun-Blanquet criteria, the Dicrano–Pinion alliance, which typically includes evergreen tree physiognomy, also includes common juniper (*Juniperus communis*) shrubland associations of a quite different physiognomy (Rodwell 1991). Under the NVC approach, those associations would be placed in a boreal *Juneripus communis* Shrubland Alliance. The emphasis of having at least one diagnostic species in the dominant stratum provides a link to the higher-level physiognomic classification units. Still, alliances of the Braun-Blanquet system typically contain broadly uniform physiognomic and habitat characteristics comparable to the concepts and standards put forth here (Rodwell et al. 2002). Specht et al. (1974) uses an approach for defining alliances in Australia similar to that described here for the NVC.

Tree-dominated alliances sometimes may be roughly equivalent to the "cover types" developed by the Society of American Foresters, SAF (Eyre 1980). Where the cover type is based solely on differences in the codominance of major species (e.g., the Bald Cypress cover type, and the Bald Cypress–Water Tupelo cover type), the corresponding alliance may be broader than the SAF type. In cases where the dominant tree species extend over large geographic areas with varied environmental or floristic conditions, the alliance may represent a finer level of classification than the SAF cover type. Jack Pine forest cover type (Eyre 1980: No. 1) may include at least two alliances, a rather closed, mesic jack pine alliance and a more xeric, bedrock-determined woodland alliance.

The alliance also is somewhat similar in concept to the "series," widely used in the western United States for groupings of similar late-successional associations following the habitat–type approach of Daubenmire (1952, see also Pfister and Arno 1980). The series concept (for groups of associations) emphasizes the diagnostic potential of climax-dominant species based on age and/or size–structure and autecological competitiveness. The presumed final stage of seral development is used to assign a stand (or sample) to a series, regardless of its composition at the time of observation. For stands of a NVC association where the potential climax species have attained a dominant position, the series may be identical to the alliance concept, but, for those stands where the potential climax species is subordinate to a seral species, there would be a difference between the identified series and the alliance.

Vegetation Field Plots

An explicit requirement of the NVC standard is that units of vegetation are sampled and described through the use of plot data (Box 1, last paragraph). The premise is that adherence to common standards for recording field data is central to advancing our knowledge of vegetation as well continuously improving the classification itself. Although the kinds of information needed from the field are discussed here and listed in detail in Appendix B, this section is not a definitive guide to recording and describing vegetation. Such information can be found in other sources (e.g., Mueller-Dombois and Ellenberg 1974, Kent and Coker 1992, Jongman et al. 1995, Peet et al. 1998, Mucina et al. 2000).

The standards presented here recognize that many investigators may have objectives other than classification when recording field plots. They may be focused on documenting large-scale patterns, assessing long-term change and human impacts, or collecting ground-truth point data for remote-sensing applications. Although these objectives may require methods different from those needed to characterize a vegetation type, all observations can complement one another and can be valuable for ongoing improvements to the classification, as well as providing a better understanding of association and alliance biogeography. Because field-data collection is the most expensive and scarce information required for vegetation science, using as many opportunities as possible to extend sampling into related field-based studies will help to maximize the utility of all the data being collected. Basic field forms for collecting plot data that conform to these standards are available at the VegBank website (see Ecological Society of America, Vegetation Classification Panel 2008).

Stand selection and plot design

Stand selection.—The selection of areas of vegetation for sampling that are reasonably uniform in physiognomy, floristic composition, and environment can be made by either preferential (subjective) or representative (objective) means, or some combination of both (sensu Podani 2000). With preferential methods, stands are selected based on the investigator's previous experience, and stands that are degraded, atypical, or redundant may be rejected. A stand selected for a plot record is considered typical of the vegetation of which it is a part, and each plot recorded is expected to yield a more-or-less typical description for both floristic composition and physiognomy (Werger 1973). With a representative selection of stands, plots are also expected to be statistically typical of the vegetation. The selection of representative stands may be via a simple-random, stratified-random, systematic, or semi-systematic method (Podani 2000). Either preferential or representative methods can yield plots suitable for the NVC, but representative sampling usually leads to a less biased set of plots. However, the representative method may under-sample rare and unusual types; consequently, this method often requires supplementary sampling with a few plots selected a priori. In highly modified landscapes, preferential selection is often the only way to assure that the elements of natural vegetation are sufficiently observed to allow comparison with other vegetation present. The criteria used to select stands need to be documented in metadata (Appendix B: Section B2).

Plot location.—Following reconnaissance and sample stand selection, a plot or series of plots, is located within all or some subset of stands. Each plot should represent only a single entity of vegetation in the field; that is, a plot should be relatively homogeneous in both vegetation and habitat. It should be large enough to represent the stand's floristic composition, and homogeneous enough that the relative importance of the dominant species observed within the plot is comparable to that of the surrounding stand. Some within-plot pattern is inevitable; for example, small gaps or "tip-up" mounds occur within forests due to the death of individual dominants. Bryophyte and herb distributions form their own fine-scale pattern and often reflect substrate heterogeneity. For the purposes of the NVC, the field sampling should not seek homogeneity at the scale of either the mosses on bare soil or the forests across a landscape. Rather, field plots should be taken from homogeneous stands at an intermediate scale, usually between 10 and 10 000 square meters (m^2), reflecting the size of patterns at which local plant species are co-occurring. (As used here, "m^2" denotes the area in square meters, e.g., 1000 m^2 is the area within a 50×20 m plot; see Taylor [1995].)

The location of plots in time (i.e., during a season) also influences the floristic composition and structure record. Some forest types (e.g., mixed mesophytic forests of the Tennessee and Cumberland regions) may have a diverse, but ephemeral, spring flora. Some deserts have striking assemblages of annuals that appear only once in several decades. Although plot data for the NVC will be based on the vegetation existing at the time of observation, plots that are known or expected to be missing a portion of the likely flora should be annotated to enable future analysts to interpret the data quality. Repeated inventories may be made over the course of a season to fully document the species in a plot. Practically speaking, these repeat visits (which should be documented as such) can be treated as multiple visits to the same plot and recorded as one plot observation record with the start and end date noted (Poore 1962).

Longer-term nonseasonal variation in species composition caused by, for example, a decadal oscillation of climate resulting in annuals populating an exposed river bank or a rare abundance of desert annuals, are not typical of the vegetation otherwise on a site. Such vegetation should be recorded using separate plots that may be used to establish separate vegetation types.

Plot size and design.—Two fundamentally different approaches are commonly used for recording vegetation: (a) a plot where the record is taken from a single entire plot, and (b) subplots, where the information recorded is taken from a set of smaller plots distributed within the stand. Both types of plot designs provide adequate data for vegetation classification, but each method has its own requirements and advantages.

1. *Data from a single large plot*.—This is an efficient, rapid method for collecting floristic and physiognomic data. The plot size is chosen to ensure that it is small enough to remain relatively uniform in habitat and vegetation, yet is large enough to include most of the species that occur within the stand. This approach permits statistical assessment of variation among stands but not within stands. Recommended plot size varies depending on the structure of vegetation (such as the size of individual plants, their spacing, and the number of canopy layers). Plot sizes have also been based on the need for the size to be such that an increase in plot area yields few new species within the stand. Plots that are too small to capture fully the stand's entire species composition and structure will not serve adequately for quantitative vegetation classification. In most temperate hardwood or coniferous forests, plots of between 200 and 1000 m^2 are adequate for characterizing both the herb and the tree strata, whereas in many tropical forests, plots between 1000 and 10 000 m^2 are required. Grassland and shrubland vegetation may require plots between 100 and 400 m^2, whereas vegetation containing very sparse vascular vegetation (sometimes dominated by nonvascular vegetation), such as open cliff, talus, or desert vegetation, may require plots between 1000 and 2500 m^2 (McAuliffe [1990]; see Chytrý and Otýpková [2003] for plot sizes used by European phytosociologists). We do not recommend any particular plot shape; indeed shape may have to vary depending on the local environment (e.g., riparian stands tend to be linear).

2. *Data from a set of subplots*.—Multiple subplots within a stand is an alternative to the single-large-plot sampling method. This approach yields data that can assess the internal variability within a stand and can more precisely estimate the average abundance of each species across the stand. It is often used to measure responses to experimental manipulations of vegetation. The approach also may be useful for characterizing average vegetation composition in topographically complex terrain where boundaries between stands may be unclear. This approach, however, is inappropriate for measures of species number per unit area larger than the subplot.

Investigators using the multiple-subplot methods may locate subplots randomly or systematically within the stand. The observation unit can be a quadrat, line transect, or point transect, and can be of various sizes, lengths, and shapes. Quadrats for ground-layer vegetation typically range from 0.25 to 5.0 m^2, and anywhere from 10 to 50 quadrats may be placed in the stand. Although subplots may be distributed through a large portion of the stand, the total area from which data are recorded may be smaller than that from a single large plot.

Finally, the choice between a single large plot and multiple subplots must consider the trade-off between a better ability to estimate the precision of species abundance values obtained from small, distributed subplots compared to the more complete species list and more realistic assessment of intimate co-occurrence obtained using the single large plot. A disadvantage of relying on subplots to characterize the stand is that a large number of small sample units may be needed to characterize the full floristic composition of the stand. Yorks and Dabydeen (1998) describe how reliance on subplots can result in a failure to assess the importance of many of the less abundant species in a plot. Consequently, whenever subplots or transects are used, a list of "additional species present" within a larger part of the stand, such as some fixed area around the subsamples, should be included. For example, the California Native Plant Society protocol uses 50-m point transects supplemented with a list of all the additional species in a surrounding 5 $\times$ 50 m area (Sawyer and Keeler-Wolf 1995).

3. *Hybrid approaches*.—A hybrid sampling method combines advantages from the above approaches. Sometimes several somewhat large subplots (e.g., >200 m^2 in a forest) are established to capture internal stand variability. The plots are sufficiently large that, should variability between plots be high, the plots could be classified separately as individual plots. An alternative has plots of differing sizes nested and used for progressively lower vegetation strata, from the tree layer to the shrub and herb strata. Although efficient with respect to measures of abundance for the common

species, this method risks underrepresenting the floristic richness of the lower strata, which are often more diverse than the upper strata and where diagnostic species tend to be concentrated. This problem can be ameliorated by listing all species found within the largest plot used to sample the upper stratum.

Because vegetation pattern and its correlation with environmental factors can vary with plot size (see Reed et al. 1993), no one plot size is correct a priori. The widely applied 1000-m^2 Whittaker (1960) plots and the 375-m^2 Daubenmire (1968) plots both contain a series of subplots for herbaceous vegetation. A number of investigators have proposed protocols in which multiple plot sizes are nested within a single large plot (e.g., Naveh and Whittaker 1979, Stohlgren et al. 1995, Peet et al. 1998). With adequate documentation, this approach can yield data compatible with many other types of sampling while providing data on compositional variation as a function of the scale of observation.

Plot data

Three types of plot data are needed for effective vegetation classification: vegetation data, site data, and metadata. Of these, vegetation data on floristics and physiognomy are the primary focus of these guidelines. Site, or habitat data, such as soil attributes, topographic position, and disturbance history, are also important, but because environmental variables that are significant in one region may be insignificant in another region, the selection of such variables is less amenable to standardization. Floristic composition and cover estimation require direct estimation of the canopy cover for each plant species. It is preferable to estimate the cover of each species in each vertical canopy stratum. To assess vegetation structure, the total canopy cover should also be determined for each stratum of vegetation (i.e., tree, shrub, herb layer). These measurements of species and stratum cover, detailed in the sections that follow, allow for a three-dimensional representation of the vegetation in a plot in order to characterize associations and alliances. To ensure as much field-based information as possible for developing the NVC, the tables in Appendix B distinguish between data fields that are minimally *required* for classification and data fields that fully reflect the best practice. This latter set of data fields is *optimal* and will provide the most useful information.

Floristic composition.—The complete vascular species composition of each classification plot must be recorded. A record of nonvascular species is needed in vegetation where such species are dominant. Plot records should be made only when the vegetation is developed phenologically and the prevailing cover of each species can be observed. However, some ephemeral species may not be visible in certain seasons or may be unreachable (i.e., canopy epiphytes or cliff species) and not identifiable. Vegetation exhibiting strong seasonal changes in species composition should be noted (e.g., young grasses, which may be underestimated in late spring). Where phenological changes are pronounced (especially among dominants), repeat visits are necessary. If a repeat visit reveals a higher cover value for some species, those values should be used in analyses, but repeated measures should not span more than the typical seasonal variation.

All plant taxa should be identified to the finest taxonomic resolution possible. For example, variety- and subspecies-level determinations should be made when feasible. Plant names have different meanings in different references, and it is imperative that the meaning of each name be conveyed by referring to a standard authoritative source (as discussed in the botanical nomenclature section). In lieu of an authoritative source, an investigator may specify an authoritative listing such as PLANTS (USDA NRCS 2006) or Kartesz (1994). The version and date of access to electronic listings should be recorded.

Species by strata or growth form.—Individuals of a species in a plot should also be recorded by the stratum or strata in which they are found. Alternatively, they may be recorded by growth form (see Appendix B; also see Appendix F: Table F2 for summary table example). Although not all plant species fit unambiguously into particular stratum or growth form categories, the purpose of categorizing species by strata is to document the vegetation structure and to describe the composition by strata (also see the section on *Vertical structure and physiognomy*). Although a species may occur in more than one stratum because of differences in size among individuals, an individual plant should be assigned only to the single stratum in which the majority of its leaf area occurs. Thus, in a single plot one tree species might occur in the herb stratum as a seedling, the shrub stratum as a sapling, and the tree stratum as a mature tree.

Species importance.—Cover is a meaningful measure of importance and abundance for nearly all plant life. Percent cover can be defined generically as the vertical projection to the ground surface of the crown or shoot area, expressed as a percentage of plot area. The use of canopy as opposed to shoot area results in two definitions of cover as follows:

1. *Canopy vs. foliar cover*.—Canopy cover is the percentage of the ground covered by a vertical projection downward of the outermost perimeter of the natural spread of foliage of plants (Society for Range Management 1989). Foliar cover is the percentage of ground covered by the vertical portion of plants, excluding small openings in a canopy or intraspecific overlap (Society for Range Management 1989). Foliar cover is the vertical projection of the shoots, stems, and leaves.

Canopy cover is the preferred method of recording cover because it better estimates the area that is directly influenced by the individuals of each species (Daubenmire 1968). Canopy cover is easier to estimate from aerial photos than foliar cover. It is more likely to

TABLE 3. Comparison of commonly used cover–abundance scales in the United States.

Cover–abundance	BB	NC	K	DAUB	FS(Db)	PA	NZ	BDS	D	FS(eco)
Present but not in plot	( )†					+				
Single individual	r	1	+	1	T	T	1		+	1
Sporadic or few	+	1	1	1	T	T	1		1	1
0–1%	1‡	2	2	1	T	T	1	0	2	1
1–2%	1	3	3	1	1	1	2	0	3	3
2–3%	1	4	3	1	1	1	2	0	3	3
3–5%	1	4	3	1	1	1	2	0	4	3
5–6.25%	2	5	4	2	2	2	3	1	4	10
6.25–10%	2	5	4	2	2	2	3	1	4	10
10–12.5%	2	6	5	2	2	2	3	1	5	10
12.5–15%	2	6	5	2	2	2	3	1	5	10
15–25%	2	6	5	2	2	2	3	2	5	20
25–30%	3	7	6	3	3	3	4	3	6	30
30–33%	3	7	6	3	3	3	4	3	6	30
33–35%	3	7	7	3	3	3	4	3	7	30
35–45%	3	7	7	3	3	3	4	4	7	40
45–50%	3	7	7	3	3	3	4	5	7	50
50–55%	4	8	8	4	4	4	5	5	8	50
55–65%	4	8	8	4	4	4	5	6	8	60
65–75%	4	8	8	4	4	4	5	7	8	70
75–85%	5	9	9	5	5	5	6	8	9	80
85–90%	5	9	9	5	5	5	6	9	9	90
90–95%	5	9	9	5	5	5	6	9	10	90
95–100%	5	10	10	6	6	6	6	10	10	98

Notes: Abbreviation "r" means rare or solitary; "T" means trace, or <1%. Where row classes are not used in a method, cells are blank (not applicable). Agencies and authors are abbreviated as: BB, Braun-Blanquet (1928); NC, North Carolina Vegetation Survey (Peet et al. 1998); K, Domin sensu Krajina (1933); DAUB, Daubenmire (1959); FS(Db), Forest Service, modified Daubenmire (1959) scale; PA, Pfister and Arno (1980); NZ, New Zealand LandCare (Allen 1992, Hall 1992); BDS, Barkman et al. (1964); D, Domin (1928); FS(eco), Hann et al. (1988) and Keane et al. (1990) for the U.S. Forest Service ECODATA software. Break points shown in the cover–abundance column reflect the major break points of the Braun-Blanquet scale, which is considered the minimum standard for cover classes. Among the available cover class systems, NC and K can be unambiguously collapsed to the BB standard, and the D, DAUB, FS, PA, and NZ scales are for all practical purposes collapsible into the BB scale without damage to data integrity. The BDS is somewhat discordant with the BB standard and should be avoided except when required for incorporation of legacy data.

† Species present in the stand but not in the plot are indicated in parentheses on the species list.

‡ This is a cover–abundance scale; if numerous individuals of a taxon collectively contribute less than 5% cover, then the taxon can be assigned a value of 1 or, if very sparse, a "+."

correlate with spectral analysis of remotely sensed images and is better suited for mapping vegetation.

An overall measure of cover must be recorded for each species found in the plot. Additionally, recording species cover values by each stratum is recommended. Recording species canopy cover by strata provides a three-dimensional representation of the vegetation and facilitates interpretation of physiognomic and floristic relationships within the NVC hierarchy. Cover for all of the species in any single stratum (or overall) may be greater than 100%, because the foliage of one species within a layer may overlap with that of another.

2. *Cover scales*.—The use of cover classes instead of continuous percent cover values can speed up fieldwork. A practical cover scale should be logarithmic, in part because humans discern doublings more readily than linear units (it is easier to tell the difference between 1% and 2% cover than between 51% and 52%). In addition, many species are sparsely distributed across stands and small differences in sparse cover can be important for classification. Generally, if cover class estimations are repeatable to within one unit when used by trained field workers, the precision being required is in balance with the accuracy that can be achieved. One widely used cover scale has class boundaries of "few" (between 0% and 1%), 5%, 25%, 50%, and 75% (van der Maarel [1979], derived from Braun Blanquet [1932]). Any scale used for collecting species cover data should be convertible to this common scale (Table 3). For example, the Krajina (1933) and North Carolina (Peet et al. 1998) cover class systems can be unambiguously collapsed to the Braun-Blanquet (1932) standard. Any species noted as being present in the stand but not found in the plot should be assigned a unique occurrence code, so that these species can be identified as not part of the plot itself.

3. *Other measures of species importance*.—In addition to canopy cover, species importance also can be measured as density (number of individuals), frequency (percentage of quadrats or points having a species present), biomass, basal area, or some weighted average of two or more importance measures. Such supplemental measures of importance may add to the value of a plot record, but are not required. For data sets having measures of species importance other than cover, but which are otherwise acceptable for classification, calculation of a normalized estimate of cover may be possible.

FIG. 1. An illustration of strata showing growth forms of individual plants as may be found in a plot (the ground stratum is not delineated). The field stratum is 0–0.5 m; the shrub stratum is 0.5–3.5 m; and the tree stratum is 3.5–12 m. Assignment of individual plants to a stratum (circled letters) is based on height and growth form as follows. (A) A plant having an herbaceous growth form. Although projecting vertically into the shrub stratum, it is excluded from being recorded as part of the shrub stratum canopy cover because its stems die and regrow each year. (B) A plant having a dwarf-shrub growth form is recorded as part of the field stratum. If desired, a separate dwarf-shrub substratum can be recognized. (C) A moss, recorded as part of the ground stratum. (D) A plant having a tree growth form but at a sapling stage of life. This individual is recorded as part of the shrub stratum canopy. (E) A plant having a tree growth form but at a seedling stage of life. This plant is recorded as part of the field stratum canopy. (F) Mature trees, recorded as part of the tree stratum. (G) A sapling, as in (D). (H) A plant having a shrub growth form, recorded as part of the shrub stratum canopy cover. (I) A plant having an herb growth form and projecting into the shrub stratum; excluded from being recorded as part of the shrub stratum canopy (as in A).

Vertical structure and physiognomy of vegetation

Data on vegetation structure and physiognomy are needed to relate associations and alliances to the higher-order physiognomic and structural categories of the FGDC (2008) hierarchy. Physiognomy is the external or overall appearance of vegetation (Fosberg 1961, Barbour and Billings 2000). It is the product of the growth forms of dominant plants, along with vegetation structure. Vegetation structure, on the other hand, relates to the spacing and height of plants. Structure is the product of plant height, canopy layer stratification, and the horizontal spacing of plants (Mueller-Dombois and Ellenberg 1974).

1. *Growth form, size class, and stratum.*—The related concepts of growth form, size class, and stratum need to be distinguished in characterizing vegetation structure. *Growth form* is a statement about the morphology of mature individuals of a species. The tree growth form may be defined as a woody plant with a single dominant stem, generally taller than 5 m at maturity, whereas a needle-leaved tree is a specific tree growth form based on leaf type (see Appendix A). *Size class* refers to the size of individual organisms, not the size of the mature individuals of that species. The tree growth form may have "seedling," "sapling," and "mature" size classes.

A *stratum* is a layer of vegetation defined by the height of the plants. Each stratum is named for the typical growth form that occupies that layer of vegetation. For example, the *tree stratum* is the zone of woody vegetation usually above 5 m in height, but tree saplings generally occupy the *shrub stratum*. Individual plants are assigned to a stratum based on their predominant position or height in the stand, and, secondarily, on their growth form. Herbaceous growth forms are always placed in the *field stratum* unless they are epiphytic or aquatic. Ground-level nonvascular species are placed in their own *ground stratum*. The purpose in describing the vegetation structure of a plot is to record the essential features of often complex stand conditions rather than to describe the layers of vegetation in great detail.

Fig. 1 shows the four vegetation strata that can be recognized in terrestrial environments: tree, shrub, field (or herb), and ground (or moss stratum, sensu Fosberg 1961). In aquatic environments, floating and submerged strata should be recorded where present. These six strata are needed to convey both the vertical distribution of overall cover and the predominant growth forms

TABLE 4. A cross-tabulation of strata categories with common growth form and size class categories (e.g., Tart et al. 2005).

	Growth form							
	Tree, by size classes			Shrub, by size classes				
	Regeneration							
Stratum	Seedling	Sapling	Overstory	Tall shrub	Medium shrub	Low shrub	Herb	Non-vascular
Tree			x	(x)				
Shrub	x	x		x	x			
Field (Herb)	x					x	x	
Ground (Moss)								x
Floating							x	
Submerged							x	

making up the vegetation. They help to place a plot within the NVC hierarchy. The six strata are defined as follows:

1) *Tree stratum*.—The layer of vegetation where woody plants are typically more than 5 m in height, including mature trees, shrubs over 5 m tall, and lianas. Epiphytes growing on these woody plants are also included in this stratum.

2) *Shrub stratum*.—The layer of vegetation where woody plants are typically more than 0.5 m tall but less than 5 m in height, such as shrubs, tree saplings, and lianas. Epiphytes may also be present in this stratum. Rooted herbs are excluded even if they are over 0.5 m in height, as their stems usually die back annually and do not provide a consistent structure.

3) *Field (or Herb) stratum*.—The layer of vegetation consisting primarily of herbs, regardless of height, as well as woody plants less than 0.5 m in height.

4) *Ground (or Moss) stratum*.—The layer of vegetation consisting of nonvascular plants growing on soil or rock surfaces. Included are mosses, liverworts, hornworts, lichens, and algae. This stratum is sometimes termed the "nonvascular stratum."

5) *Floating aquatic stratum*.—The layer of vegetation consisting of rooted or drifting plants that float on the water surface (e.g., duckweed, water-lily).

6) *Submerged aquatic stratum*.—The layer of vegetation consisting of rooted or drifting plants that, by and large, remain submerged in the water column or on the bottom (e.g., sea grass). In aquatic environments the focus is on the overall strata arrangement of these aquatic plants. Emergent plant growth forms in a wetland should be placed in appropriate strata from this list.

Epiphytes, vines, and lianas are not normally treated as separate strata; rather, they are treated within the strata just defined, but can be distinguished from other growth forms within a stratum using the growth form data field (see Appendix B, Table B1.2).

Strata may be further divided into substrata. For example, the tree stratum can be divided into canopy trees and subcanopy trees; the shrub stratum can be divided into tall shrub and short shrub; and the field stratum may be divided into dwarf-shrub and herb layer, or further into forb and graminoid. Such subdivisions illustrate how records of the layers of vegetation are based on both vertical position and the growth form of the vegetation.

For each stratum, the total percent cover and the prevailing height of the top and base of the stratum should be recorded (see Appendix F: Table F1 for a summary table example, and Table 4 for growth forms by stratum). The cover of the stratum is the total vertical projection on the ground of the canopy cover of all the species in that stratum collectively, not the sum of each species' cover. The total cover of a stratum will, therefore, never exceed 100% (this is in contrast with estimating the cover of individual species, where adding up the cover of each species within the stratum could exceed 100% because, in this case, species may overlap in their leaf cover). The best practice for recording overall canopy cover of strata is to record percent cover as a continuous value; however, it may be estimated using ordinal values of, for example, 5–10% intervals, or another recognized cover scale.

The percent cover of the three most abundant growth forms in the dominant or uppermost strata should also be estimated from field observation. When this is not possible, it can be estimated by assigning each species to a particular growth form (see Appendix C: Table C6 for a list of growth form types). For example, in addition to total cover estimates for all trees in a stand dominated by the tree stratum, separate cover estimates should be made of the dominant growth forms (e.g., deciduous broadleaf trees, needleleaf evergreen trees). These data will help to place the plot within the physiognomic hierarchy of the NVC.

2. *Data conversion between growth form × strata and growth form × size class*.—Previously collected plots may record structure according to growth forms, either by strata or, alternatively, by size class. For classification plots (see Appendix B for criteria), vegetation structure can be provided using either of the approaches described in the previous section by converting growth form cover values to stratum cover values. This can be accomplished by using the basic size classes in conjunction with the standard growth forms by size class. Table

4 shows a cross tabulation among the common growth form categories and the common strata categories.

In cases in which species or growth form cover values must be composited to provide a single cover estimate for a given stratum, the percent cover of stratum *i* can be estimated as follows:

$$C_i = \left[1 - \prod_{j=1}^{n}\left(1 - \frac{\%\mathrm{cov}\ j}{100}\right)\right] \times 100$$

where C_i is the percent cover of stratum *i* for species or growth form *j* in stratum *i*.

Physical and geographic site characteristics.—Physical data provide important measures of abiotic factors that may influence the structure and composition of vegetation at the site. For classification purposes, a selected set of basic and readily obtainable measures is important. Primary physical features include elevation, slope aspect, slope gradient, topographic position, landform, and geological substrate. Desirable soil and water features include soil drainage, depth of water, and soil or water pH or salinity where appropriate. The soil surface should be characterized in terms of percent litter cover (including dead stems $<$ 10 cm diameter), bare ground, rock, woody debris (dead stems $>$ 10 cm diameter), nonvascular plants, and surface water (see Appendix B: Table B1.4). Values of soil surface cover estimates should always add to 100%. Habitat conditions should be described, including landscape context, homogeneity of the vegetation, phenological expression, stand maturity, successional status, and evidence of disturbance (such as even-aged demographics). Constrained vocabularies have been developed for these data fields (see Appendix C) and plot data should conform to these vocabularies to facilitate data exchange.

All plot records must include geocoordinates in the form of latitude and longitude in decimal degrees, per the WGS 84 datum (also known as NAD83; see EUROCONTROL and IfEN 1998). If data were originally collected following some other system (e.g., UTM coordinates with the NAD27 datum), the original records should also be included. These data should include *x* and *y* coordinates, the datum or spheroid size used with the coordinates, and the projection used, if any. Geographic data also should include a description of the method used to determine the plot location (e.g., estimated from a USGS 7.5-minute quadrangle, or from a global positioning system). Plot location accuracy should be given in the form of an estimate that the plot origin has a 95% or greater probability of being within a given number of meters of the reported location.

Metadata.—Metadata are needed to explain how the plot data were gathered and as a high-level directory for specific measurements (see Appendix B: Tables B2.1–2.6). All field-plot metadata must include a project name, date, and project description. The approach used to locate the plot should be recorded as narrative text. Metadata on plot layout should include the total plot area in square meters and the size of the homogeneous stand in which the plot was located. If the plot is made up of subplot observations, the total area of the subplots, and the spacing between the subplots, should be specified. The canopy cover approach and strata methods used must be recorded in metadata, as should the name and contact information of the lead field investigators. Metadata can be generated readily if the records are archived in the VegBank (Ecological Society of America, Vegetation Classification Panel 2008) XML schema discussed in *Plot data archives and data exchange* and Appendix E of this paper.

Legacy data.—Legacy data are historical plot data that may or may not conform to the standards presented here. Given that vegetation data collection has been going on in the United States for over a century, legacy data will contribute substantially to future development of the NVC. Some plots may represent stands or even types that no longer exist. Other plots may contain valuable information on the historic distribution and ecology of a plant community, or may contain important structural data (such as on old-growth features) that may be difficult to obtain today. Some legacy data can be used for classification. In such cases, the known limitations of legacy data should be documented in new metadata. Limitations include: (1) uncertainty about plot location (a common problem in data that exist only in published form rather than field records); (2) inadequate metadata on stand selection, plot placement, and sampling method; (3) uncertainty about species identity because of changes in nomenclature and lack of voucher specimens; (4) uncertainty about completeness of the floristic record; (5) uncertainty about sampling season; and (6) incompatibility of the cover or abundance measures used.

Classification and Description of Floristic Units

The classification of associations and alliances is based on the assumption that an abstracted type is an integrative summary of the field data and their analysis as well as its relationships to similar types. The process flows from planning to analysis and data interpretation, then to documenting, reporting, and archiving.

From planning to data interpretation

This part of the classification process can be conceptualized in three stages: (1) scope and planning of the plot observation (sampling design), (2) data preparation, and (3) analysis and interpretation.

Scope and planning of plot observation.—For a classification to be effective, plots should be taken from across the expected geographic distribution of the types of interest, using the standards previously described for plot design, location, and observation. Although only a few plots may ultimately be needed to determine that a distinct type is warranted, a set of records covering the full geographic and environmental range is needed for describing the type in relation to similar types. However, many field studies cannot be geographically comprehensive, and therefore those engaged in classification must often use field plots collected by multiple investigators. For this reason, practitioners and scholars interested in contributing classification plots as well as type descriptions are encouraged to use these standards so that their data and analyses can be integrated with the work of others.

Data preparation.—Vegetation data from all available, high-quality data sets should be combined with data from any new field plots and various supplemental environmental data to provide the basic information for comprehensive documentation of new or revised types. Where the data used do not meet minimum guidelines for quality, consistency, and geographic completeness, these limitations should be noted explicitly.

To meet the needs of combining field-plot data sets from multiple sources, the Vegetation Panel and others established VegBank (Ecological Society of America, Vegetation Classification Panel 2008), a public database of vegetation plots. The purpose of VegBank is to facilitate reanalysis of plot data, ease the burden of data preparation, and promote mining of existing data from multiple of sources. Those preparing to collect data from field plots should become familiar with the tools and standards that VegBank offers.

An important step in plot data preparation is taxonomic standardization. A consistent taxonomic standard must be used and organisms should be resolved at a consistent taxonomic level for analytical procedures. Rules to follow when standardizing taxonomic nomenclature are: (1) procedures for taxonomic resolution within a data set must be clearly documented; (2) dominant taxa must be resolved to at least the species level; (3) plots having genus-only entities with a combined total cover of more than 20% generally will be too floristically incomplete; (4) plots having >10% of their entities resolved at the genus level or coarser should to be excluded; and (5) aggregation of subspecies and varieties to the species level, when necessary, should be carefully documented.

In preparing the data, univariate outlier analysis should be applied to environmental variables such as elevation and mean annual precipitation. Multivariate outlier analysis should be used to identify plots having floristic compositions outside the central tendency of the plots being considered. In both univariate and multivariate data, plot values with more than two standard deviations from the mean value should be questioned and accepted only under unusual, clearly articulated circumstances (see Tabachnik and Fidell 1989, McCune et al. 2002).

Analysis and interpretation for classification of associations.—Two criteria need to be met for a robust determination of any particular association or alliance. First, the plot records used must represent the expected compositional, physiognomic, and environmental variation of the possible vegetation type or group of closely related types. Second, sufficient redundancy must be present in plot species composition to allow clear explanation of the patterns in compositional variation.

Because of the enormous range in the nature of vegetation and the multiple interacting factors and chance events that drive its pattern, no crisp set of criteria suffice for defining all types. It is the role of the type author to provide evidence showing numerical disjunction between one type and other types based on both compositional similarity and diagnostic species.

Various quantitative methods are available to identify floristic patterns (see Mueller-Dombois and Ellenberg 1974, Gauch 1982, Ludwig and Reynolds 1988, Kent and Coker 1992, Jongman et al. 1995, McCune and Mefford 1999, Podani 2000, McCune et al. 2002). The approaches most commonly used are ordination, clustering (including tabular analysis), and direct gradient analysis. These may be used either alone or in combination. Ordination methods order plot data strictly in terms of their similarity in floristic composition. Clustering methods aggregate plot data into discrete groups based on floristic composition. Direct gradient analysis is the representation of floristic change along specific environmental or geographic gradients. In both gradient analysis and ordination, the discontinuities in floristic composition can be recognized or continuous variation can be partitioned into type-like segments. For each of these, a wide range of analytical procedures and reporting tools is available (for examples, see McCune et al. 2002). The specific tool employed must be documented and justified. If analysis of the floristic composition with respect to environmental factors is undertaken, the environmental data employed must be available either in appendices or by placement in a publicly accessible digital archive such as VegBank (Ecological Society of America, Vegetation Classification Panel 2008).

The standard for assigning a plot to an association is determined by it having a composition consistent with a characteristic range of species present in combination with the diagnostic species occurrence or abundance. Intermediate plots can be assigned to associations based on: (1) measures of similarity, such as those used by ordination or cluster methods; (2) occurrence, abundance, or composition of diagnostic species; or (3) considerations of habitat and physiognomy. Westhoff and van der Maarel (1973), Mueller-Dombois and Ellenberg (1974), and Kent and Coker (1992) summarize methods for identifying diagnostic species (constant, differential, character, and dominant species; see Appendix A for a glossary of terms).

Acceptable association concepts will specify a range of compositional similarity, diagnostic species, and correlations with ecological factors. Other methods can be used to provide further evidence for type concepts, such as the use of indicator species analysis of Dufrêne and Legendre (1997), in which the total information content of all indicator species is used to define an optimal level of clustering. This approach may help to integrate the two criteria of diagnostic species and overall compositional similarity. The distinctiveness of the type concepts will vary, depending on methods used and the nature of the vegetation of interest.

Care is needed to assure that the analysis incorporates appropriate geographic variation and that the resulting type summary tables are not distorted by spatially clumped plot records due to a localized focus of field investigators. This is a problem when field data are scarce across a region, but locally abundant where intensive surveys have been conducted. When attempting to classify types that typically occur as spatially isolated instances, such as in glades or on rock outcrops, researchers should strive to factor out similarity patterns driven simply by spatial proximity.

Across the variety of analytical methods and techniques available to identify and describe associations, the goal remains the same: categorizing the variability of vegetation into types having a defined floristic composition, physiognomy, and habitat. Acceptance of a NVC type depends on the investigator making an acceptable case via peer review.

1. *Documentation of analytical methods*.—The rationale and methods for data reduction and analysis must be described in detail. Documentation should include any data transformations or similarity measures employed. Where appropriate, more than one analytical method should be used, and converging lines of evidence presented. Tabular and graphical presentation of such evidence as biplots of compositional and environmental variation, dendrograms illustrating relationships among clusters, and synoptic tables summarizing community composition should be provided. Criteria used to identify diagnostic species, such as level of constancy or fidelity, should be described.

Possible sources of uncertainty in the data or from the methods, such as removal of outliers, must be reported. For example, noise in the data may be caused by several or many species occurring in plots only a very few times, especially species that seldom occur, but have a relatively large canopy cover.

The basis for identifying geographic and environmental bounds of the type should be clearly documented. This should include a description of the density of plots across spatial and environmental gradients.

2. *Considerations for the classification of alliances*.—Descriptions (and revisions) of alliances are based on data and analysis similar to those used to define associations. Alliances are more generalized vegetation types that share some of the diagnostic species found in their associations. Compared to associations, definitions of alliance types rely more on the species composition of the dominant stratum or growth forms. Because alliances are often wide ranging, analyses usually require geographically more extensive data to distinguish them. At the same time, the broader pattern should encompass a greater number of diagnostic species. For example, a number of swamp associations may have *Thuja occidentalis* as a common dominant diagnostic, along with other diagnostic shrub and herb species, where the associations are based on the differential species responding to degrees of saturation and flooding. The *Thuja occidentalis* swamp alliance will be analytically based on a larger set of stands where this species (and preferably a suite of other species) is found more strongly than in any other alliance. This is in keeping with the overall concept of the alliance, that it be well separated floristically, either by many moderately differential species or by one or more strong differential (character) species correlated with a recognizable regional ecological habitat.

The methods for classifying alliances may depend to a certain degree on whether associations making up a potential alliance have already been described and classified. Under data-rich conditions, alliances can be defined by aggregating associations via comparisons of species abundances. If several associations have species in common in the dominant or uppermost canopy layer, and those same species are absent or infrequent in other nearby associations, then the associations with those shared dominants can be joined as an alliance. Similarity in ecological factors and structural features also should be considered. A range-wide perspective should be maintained when considering how best to aggregate associations under alliances. Where no truly diagnostic species exist in the upper layer, species that occur in a secondary layer may be used, especially if the canopy consists of taxa having broad geographic ranges and occupying a heterogeneous set of ecological habitats.

It is tempting to suggest that alliance development should only proceed from associations in an agglomerative manner. However, two considerations suggest the value of a flexible approach. First, diagnostic criteria for associations are often improved and insights gained by understanding to which alliances they are related (a divisive approach; see Willner 2006). Second, in the United States it has not yet been possible to develop a consistent set of described associations, first because of a lack of data or incomplete data, the expense of developing and analyzing large data sets, and more broadly, the lack of unified standards and authoritative review—all of which are motivations for a standardized National Vegetation Classification and VegBank. Alliances should be based as much as possible on associations, but the lack of definitive association descriptions should not hinder efforts to describe alliances. The completeness of association information on which an alliance description is based will be reflected in the type's assigned level of classification confidence (high, moderate, low, proposed, provisional; see section on *Classification confidence*). Development of alliances (or higher units), whether initial approximations or definitive works, is an important way of directing future development and analysis of finer-scale associations. Coordination of their development through a structured peer review process (see section on *Peer review*) will ensure an orderly development of both levels.

Under data-poor conditions, new alliances may be identified provisionally by analyzing species data from the dominant stratum, combined with information on the habitat or ecology of the stands sampled by the plots. Alliances also may be provisionally identified by showing an alliance-like relationship among associations, including those defined by many localized studies. However, alliance types developed through such incomplete data may fail to meet high standards for defining floristic units. These type concepts can be refined subsequently through analysis of new field plot data used to characterize the associations that ultimately may be included in the provisional alliance(s). Thus development of NVC floristic units will often proceed as an iterative process.

Documentation and description of the types

To meet the objective of an improved understanding of patterns in vegetation, the NVC process requires systematic documentation of how and why a particular vegetation type has been recognized and described, along with a standardized, formal description of each named type. Although vegetation types may be defined and published through many venues, this approach often lacks the consistency needed for a unified synthetic classification. For NVC classification purposes, the description of associations and alliances need to: (1) document the vegetation characteristics that define the type, including variation present across geographic or environmental gradients; (2) summarize the relationships of the type to habitat, ecological factors and community dynamics; (3) identify the typical plots upon which the type is based; (4) describe the analyses of the field data that led to recognition of the type; and (5) provide a synonymy to previously described similar types and document the relationships to closely related NVC types (see Box 2 for requirements and Appendix D for examples).

Systematic documentation for a set of related types includes the following eight elements:

1) *Overview*.—This section summarizes the main features of a type or types. The names of the types should be listed following the nomenclatural rules provided below. A common name for the type may be provided. An association's placement within an alliance should be described, and if a new alliance is being proposed, a separate description for that alliance should be provided. For alliance(s), placement within a group or macrogroup should be indicated. The overview should briefly describe floristics, physiognomy and structure, diagnostic features, environment, and geographic range of the type(s).

2) *Vegetation*.—Because the associations and alliances are defined using floristics and physiognomy, supplemented by environmental data, to assess ecological relationships and dynamics among the species and types, details are needed on each of these as follows:

a) *Floristics*.—This section should summarize the species composition and average cover observed in the plots as well as, preferably, by strata. The floristic variability in the type should be reported as discussed in *Analysis and interpretation for classification of associations*. Data tables are needed in the following sequence:

i) A stand table of floristic composition, preferably also for each stratum, showing constancy, mean, and range of percent cover (Appendix F: Table F3). All species with more than 20% constancy should be included to facilitate comparisons among types. Constant species (Table 5), typically defined as those occurring in more than 60% of the plots (i.e., the top two Braun-Blanquet (1932) constancy classes), should be identified.

ii) Diagnostic species should be identified in a synoptic table, graph, or by other means.

iii) The compositional variability of the type across the range of its plot samples should be either presented as a table or discussed. Discussion of possible sub-associations or variants may be useful, especially for future refinements of the type(s).

b) *Physiognomy*.—This section should present the physiognomy of the type as documented in the data, particularly of the dominant species. The variability in physiognomy across the range of plots being used should be included. A summary should be included for each of the main strata (tree, shrub, field (or herb), ground (or moss), floating, or submerged), including their height and percent cover.

c) *Dynamics*.—This section summarizes evidence of successional and disturbance processes that influence the stability and within-stand species composition. Where possible, the important natural or anthropogenic disturbance regimes should be summarized so as to understand successional trends (if any), and the temporal dynamics of the type. Information on population structure of dominant or characteristic species with respect to the dynamics of the type should be provided. Changes in the disturbance regime that could affect the type's dynamics should be described, as appropriate. For example, in parts of the United States the fire regime has been altered by fire suppression, causing fire-adapted types to decline and leading to large-scale changes in forest and grassland composition (Baker 1993).

3) *Environmental summary*.—An overview is needed of the general landscape position (elevation or topographic position usually occupied by the type, landforms, and geology), followed by more specific information on soils, parent material, drainage, and any physical or chemical properties that affect the composition and structure of the vegetation. Preferably, these data should be provided as summary tables.

Box 2. Required Topical Sections for Monographic Description of Alliances and Associations.

Overview

1) Proposed names of the type (Latin, translated, common).
2) Floristic unit (alliance or association).
3) Placement in hierarchy.
3) Brief description of the overall type concept.
5) Classification comments.
6) Rationale for nominal species.

Vegetation

7) Physiognomy and structure.
8) Floristics.
9) Dynamics.

Environment

10) Environment description.

Distribution

11) Description of the geographic distribution.
12) List of U.S. and Mexican states and Canadian provinces where the type occurs or may occur.
13) List of nations outside the U.S., Mexico, and Canada where the type occurs or may occur.

Plot sampling and analysis

13) Plots used to define the type.
15) Location of archived plot data.
16) Factors affecting data consistency.
17) The number and size of plots.
18) Methods used to analyze field data and identify the type.
  a) Details of the methods used to analyze field data.
  b) Criteria for defining the type.

Confidence level

19) Overall confidence level for the type (see section on classification confidence).

Citations

20) Synonymy.
21) Full citations for any sources.
22) Author of description.

Discussion

23) Possible sub-association or sub-alliance types or variants, if appropriate, should be discussed here along with other narrative information.

Note: See Appendix D for a completed example.

4) *Geographic distribution*.—This section should include a brief narrative description of the geographic range of the type as shown from the plots. It should include observations on historic distribution if possible. A list of states and provinces where the type occurs, or may occur, can help to describe the geographic range of the type(s). The text should distinguish between those regions where the type is known to occur and those where the type potentially occurs.

5) *Plot records and analysis*.—This section should describe the plots and the analytical methods used to define the type(s). The plots used must have met the

TABLE 5. Constancy classes for the percentage of plots in a given data set in which a taxon occurs.

Constancy class	Relative constancy (%)
I	1–20
II	>20–40
III	>40–60
IV	>60–80
V	>80–100

criteria for classification plots (Appendix B). Information should be provided on considerations that affect data consistency (such as taxonomic resolution), completeness of physiognomic–structural descriptions, or environmental information. Range-wide completeness and variability in the geographic or spatial distribution of plot locations should be discussed. Above all, the methods used to prepare, analyze, and interpret the data should be reported fully, including outlier analyses, distance measures, numerical and tabular techniques, and other interpretation tools. Occurrence maps that may have been used to estimate the geographic range of a type or some other characteristic should be identified. Finally, the publicly accessible archive where the plot data have been deposited should be provided.

6) *Relationships among types and synonymies*.—A section on synonymies should list other previously or provisionally described types that the author considers to be closely related or synonymous. The general relationships with closely related types should be described here.

7) *Discussion*.—Problematic issues should be discussed briefly, including possible sub-association or sub-alliance types or variants, if appropriate, along with other narrative information about distribution, rarity, current threats to the type, and limitations to be overcome with additional data and analyses.

8) *Citations*.—References used in the descriptive sections should be provided in this section, including references to previous descriptions or other synoptic tables comparing the type(s) to related work.

Nomenclature of associations and alliances.—The primary purpose of naming the units in a classification is to create a standard label that is unambiguous and facilitates communication about the type. A secondary goal is to create a name that is meaningful. These purposes, however, are sometimes in conflict. For instance, the primary purpose of an unambiguous label can be met by a number (e.g., "Association 2546"), but such a label is not meaningful or easy to remember. A long descriptive name is meaningful, but difficult to remember and use. To meet these varying requirements, the guidelines set forth here strike a compromise among these needs, including the use of alternative names for a type.

Two contrasting approaches to naming associations and alliances are recognized: (1) a more descriptive approach, such as is practiced through the habitat typing in the western United States (e.g., Daubenmire 1968, Pfister and Arno 1980) as well as the current NVC (Grossman et al. [1998]; see also similar approaches used by the Canadian Forest Ecosystem Classification manuals in Sims et al. [1989]); and (2) the more formal syntaxonomic code of Weber et al. (2000). The descriptive approach uses a combination of dominant and characteristic species to name the type, but no formal process for amendment or adoption of names need be followed. By contrast, the syntaxonomic approach follows a formalized code that allows individual investigators to assign a legitimate name that sets a precedent for subsequent use in the literature, much like species taxonomic rules. In this approach only two species can be used in an association or alliance name. Hybrid approaches have also been suggested (e.g., Rejmanek 1997; see also Klinka et al. 1996, Česka 1999). Here we adopt the descriptive approach, but with formal establishment of names through a peer review process and publication.

Because the names of associations and alliances are based on plant names and species concepts that are constantly changing, the names of communities may change without peer review, provided that they are unambiguously linked to the original name through the globally unique identifier assigned to them upon acceptance as a type, following nomenclatural rules.

Nomenclatural rules.—Each association and each alliance is assigned a scientific name based on the scientific names of plant species that occur in the type. The scientific name will also have a standard translated English name from the vernacular plant names listed in the PLANTS database (USDA NRCS 2006). Translated names should also be provided in French and Spanish where possible. Finally, each association and alliance is assigned a globally unique identifier.

Dominant and diagnostic taxa are used in naming a type and are derived from the tabular summaries of the type. Names of associations and alliances should include one or more species names from the dominant stratum of the type. For alliances, taxa from secondary strata should be used sparingly. Among the taxa that are chosen to name a type, those occurring in the same strata (tree, shrub, field, ground, floating, submerged) are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/). Species that may occur with low constancy can be placed in parentheses. Taxa occurring in the dominant stratum are listed first, followed successively by those in other strata. Within one stratum, the order of species names generally reflects decreasing levels of dominance, constancy, or diagnostic value of the taxa. Where a dominant herbaceous stratum is present with a scattered woody stratum, names can be based on species found in the herbaceous stratum and/or the woody stratum, whichever is more characteristic of the type. Association or alliance names include the term association or alliance as part of the name to indicate the level of the

Box 3. Examples of Association and Alliance Names.

Examples of association names

- *Schizachyrium scoparium*–(*Aristida* spp.) Herbaceous Vegetation
- *Abies lasiocarpa*/*Vaccinium scoparium* Forest
- *Metopium toxiferum*–*Eugenia foetida*–*Krugiodendron ferreum*–*Swietenia mahagoni*/*Capparis flexuosa* Forest
- *Rhododendron carolinianum* Shrubland
- *Quercus macrocarpa*–(*Quercus alba*–*Quercus velutina*)/*Andropogon gerardii* Wooded Herbaceous Vegetation

Examples of alliance names

- *Pseudotsuga menziesii* Forest Alliance
- *Fagus grandifolia*–*Magnolia grandiflora* Forest Alliance
- *Pinus virginiana*–*Quercus* (*coccinea*, *prinus*) Forest Alliance
- *Juniperus virginiana*–(*Fraxinus americana*, *Ostrya virginiana*) Woodland Alliance
- *Pinus palustris*/*Quercus* spp. Woodland Alliance
- *Artemisia tridentata* ssp. *wyomingensis* Shrubland Alliance
- *Andropogon gerardii*–(*Calamagrostis canadensis*, *Panicum virgatum*) Herbaceous Alliance

type in the hierarchy, as well as a descriptive physiognomic term, e.g., forest or grassland (see Box 3).

In cases where diagnostic species are unknown or in question, a more general term is permitted in parentheses as a "**placeholder**" (e.g., *Pinus banksiana*–(*Quercus ellipsoidalis*)/*Schizachyrium scoparium*–**Prairie Forbs** Savanna association). However, this should be used only for types of low confidence (see section on *Classification confidence*). An environmental or geographic term, or one that is descriptive of the height of the vegetation, also can be used as a modifier when such a term is necessary to characterize the association. For reasons of standardization and brevity, however, such usage is kept to a minimum. Typical examples include (1) *Quercus alba*/*Carex pennsylvanica*–*Carex ouachitana* **Dwarf** Forest association, and (2) *Thuja occidentalis* Carbonate **Talus** Woodland association. The smallest possible number of species should be used in forming a name. The use of up to five species may be necessary to define and name certain associations, recognizing that some regions contain very diverse vegetation, with relatively even dominance and variable composition. For alliances, no more than three species may be used. Nomenclature for vascular plant species used in type names should follow the current version of PLANTS (USDA NRCS 2006) or ITIS (2007). The version of the database and the date(s) when the database was consulted should be included in the metadata.

If desired, an English or regionally common name also can be designated. The common name may be used to facilitate understanding and recognition of the community type for a more general audience, much like the common names of species (see Plate 1).

Peer review

The NVC must be open to change by peer consensus, and any person must be free to submit proposals for changes to the classification. The rules, standards, and opportunities have to be the same for all potential contributors. A key component of the classification is a formal and impartial peer review of proposed floristic units.

Several options are available to manage and maintain a standardized set of association and alliance types for the NVC. One is the model used in plant taxonomy in which scientists apply credible methods to define the taxa, follow generally accepted rules for describing and naming the taxa, and publish the results, after which the taxon can be accepted or rejected by individual practitioners. Sometimes an expert source (a person or organization) maintains an authoritative list of taxa that it chooses to recognize as valid.

A second model is for a professional body to administer a formal peer review process, whereby individuals, who seek to publish their results as they choose, also submit their proposed results to a professional review body. That body ensures that consistent standards are followed to maintain an up-to-date rigorous list of types and their descriptions. This approach is used by the American Ornithological Union (AOU) for North American bird lists. Members of the AOU's Committee on Classification and Nomenclature keep track of published literature for any systematic, nomenclatural, or distributional information that suggests something contrary to the information in the current checklist or latest supplement, e.g., part of a revision to a taxonomic group or a species new to the area covered by the AOU. A member then prepares a proposal for the rest of the committee, summarizing and evaluating the new information, and recommends whether a change should be made. Proposals are sent and discussion takes place by e-mail, and a vote is taken. Proposals that are adopted are gathered together and published every two years in *The Auk* as a Supplement to the AOU Checklist (R. Banks, *personal communication*).

A third model is provided by the Natural Resource Conservation Service, which maintains the USDA soil taxonomy (USDA NRCS 2001) as one of its official functions as a government agency.

The peer review process that we outline here is a hybrid of the second and third models, in that changes and additions to the classification must be made within the context of current classification standards, such that the resulting units continue to form a comprehensive and authoritative list. The peer review is an open process conducted by professional organizations in collaboration with other interested parties. It is to be administered by a peer review board under the aegis of an institution capable of providing independent reviewers of appropriate experience in plant community classification.

Classification confidence.—As a practical matter, it is necessary to recognize that some type descriptions may not comply with all the standards. As part of the NVC peer review process, each proposed type description will be assigned one of the following levels of confidence based on the rigor of the data and analysis used to define the type.

1. *High*.—The type description is based on quantitative analysis of verifiable, high-quality plot data that are published in full or are archived in a publicly accessible database. These classification-quality plots meet the minimum requirements specified in Appendix B. The geographic distribution and habitat range of the type are known and are well represented by plots. In addition, comparisons have been made with plots that form the basis for closely related types.

2. *Moderate*.—Documentation for classification at this level may be lacking in either geographic scope of sampling or degree of quantitative characterization and subsequent comparison with related types, or the plot data are published only as a floristic summary table, but otherwise meet the requirements for high confidence.

3. *Low*.—Here the type is based on plot data that are incomplete or not readily accessible. These types are based on a combination of qualitative analysis, anecdotal information, or community descriptions that are not accompanied by plot data, or if so, in an incomplete summary table, such as reporting only dominant or characteristic species of a type. Local experts may have identified these types on the basis of experience and a few plots. Although there may be reasonable confidence that these are significant vegetation entities that should be recognized in the NVC, one cannot know whether a future analysis would meet the standard for floristic types.

Status categories for types not formally recognized.—In addition to the three levels of classification confidence, two categories can be used to identify vegetation types that have been described to some extent, but have no level of confidence and have not been accepted as a unit of the NVC. These categories are:

1. *Proposed*.—Types that have been formally described and are in some stage of the NVC peer review, but the process is still incomplete. This term is used when investigators need to refer to a potential type in publications or reports prior to the completion of the peer review process.

2. *Provisional*.—These types are not yet formally described, but are expected to be additions or revisions to the existing list of NVC types. The term should be used when certain vegetation has not been sampled sufficiently to validate it as a floristic unit. For example, authors of a report may need to submit a list of known NVC types as well as possible types that are not yet recognized by the NVC.

Peer review process.—The process for submitting proposals for types and evaluating changes to the classification must be systematic, impartial, open, and scientifically rigorous, yet it must be simple, clear, and timely. To facilitate timely review and efficient use of human resources, forms containing the components required for compliance with the guidelines are available for use with submission of proposed changes to the NVC. The NVC Peer Review Board, in conjunction with the NVC partners, will be responsible for ensuring that the criteria specified in the current FGDC standard are followed. The current standards found in the most up-to-date version of "Description, Documentation, and Evaluation of Associations and Alliances within the U.S. National Vegetation Classification" (Jennings et al. 2008) will be used to interpret and implement the standard. The objectives of the peer review process are to (1) verify compliance with classification, nomenclature, and documentation standards; (2) ensure robust analyses and interpretation of results; (3) maintain reliability of the floristic data and other supporting documentation; and (4) referee conflicts with established and potential NVC floristic types.

Investigators wishing to contribute to the NVC by proposing changes to the classification should submit their proposals to the Peer Review Board using the forms available through the Vegetation Panel web site (www.esa.org/vegweb) so they can be readily reviewed, incorporated into the NVC database system, and published and archived in the *Proceedings of the U.S. National Vegetation Classification* (the "*Proceedings*";

see the section *Proposal submission and the Proceedings of the U.S. NVC*).

Data access and management

Routine access to data is critical for meeting the goal of an improved understanding of the vegetation of the United States. The three constituent databases that underpin the NVC are: (1) standard botanical nomenclature, (2) field plot data, and (3) classified associations and alliances. Information flow among these databases, as shown in Fig. 2, ultimately defines and holds together all parts of the NVC.

Botanical nomenclature database.—All stages of NVC association and alliance type development refer to specific plant taxa. These taxa need to be recorded unambiguously, especially in plot databases and type nomenclature. However, a plant name may represent more than one species concept and a species concept may be represented by more than one name. When plot data are collected by various investigators and combined into a single database, divergent taxonomic nomenclatures may have to be reconciled. Traditionally, the solution has been to agree on a standard list and to map the various names to that list. For example, within the U.S. the several standard lists of plant taxa include PLANTS (USDA NRCS 2006), ITIS (2007), Kartesz (1994) and the yet incomplete Flora of North America (1993–). Each is intended to cover the full range of taxa in the United States at their time of publication, and each lists synonyms for the recognized taxa.

However, these lists do not permit effective integration of data sets for several reasons. (1) Online lists are updated periodically but have not always been archived consistently, with the result that a user cannot necessarily reconstruct the database as it was when used by another person sometime in the past (although we stress the need to cite the date on which a database was observed, previous versions are not consistently accessible). (2) It is not unusual for a single name to be used for multiple taxonomic concepts, which leads to irresolvable ambiguities. The standard lists do not define the intended taxonomic concepts behind the names. (3) Different parties have different perspectives on acceptable names and the meanings associated with them. When one worker uses the Kartesz (1994) list as a standard, many of the taxa recognized can overlap ambiguously with taxa having either the same or different names in a data set collected by a different worker who used the PLANTS (USDA NRCS 2006) list as a standard.

Importantly, much ambiguity arises from the nomenclature requirement that when a taxon is redefined, as when a taxon is split into two or lumped with another, its name continues to be applied to the taxon that corresponds to the type specimen for the original name. Moreover, different authors can interpret taxa in different ways. Thus, names can refer to multiple definitions of plant taxa, and a plant taxon can have multiple names. To limit the ambiguity, plant taxa associated with the NVC must be documented by reference to both a specific name and a particular use of that name, typically in a published work. All databases used to support the NVC must track plant taxa by documenting such name–reference couplets. Here, we follow the ideas of Berendsohn (1995; citing a "potential taxon"), Pyle (2004; an "assertion"), and Franz et al. (2008; a "taxon concept") with respect to name–reference couplets. For the purposes of the NVC, we adopt name–reference couplets for a "taxon concept." Organism identifications (whether occurrences in plots, labels on museum specimens, or treatments in authoritative works), should be by reference to a taxon concept so as to allow unambiguous identification of the intended taxonomic object. Identification of the appropriate concept to attach to an organism does not immediately dictate what name should be used for that concept. Different parties may have different name usages for a particular species concept.

An example illustrating the need for this approach is the species name *Abies lasiocarpa* (Hooker) Nuttall. The concept intended for this name by the 2006 version of the PLANTS database (USDA NRCS 2006) is quite different from the concept intended for the same name by the Flora of North America (1993–). The taxon concept *Abies lasiocarpa* (Hooker) Nuttall sec Flora of North Am. 1993+, Volume 2, refers to a subset (occurring in the Northwest USA and western British

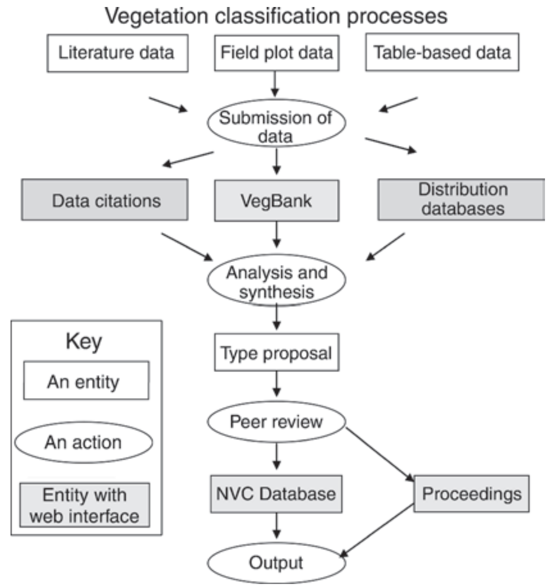

Fig. 2. Flow of information through the process for formal recognition of an association or alliance. Beginning at the top, field plot data are collected, plot data are submitted to the plots database (VegBank), data are analyzed, and a proposal describing a type is submitted for review. If accepted by reviewers, the type description is classified under the NVC (U.S. National Vegetation Classification), the monograph is published, and the description is made available.

Columbia) of the broader taxon concept *Abies lasiocarpa* (Hooker) Nuttall sec PLANTS (USDA NRCS 2006). (We follow Berendsohn [1995] in using the term "sec," which means "in the sense of.") The PLANTS (USDA NRCS 2006) taxon concept includes the taxon concepts of: (1) *Abies lasiocarpa* (Hooker) Nuttall sec Flora of North America, Volume 2, as well as (2) *Abies bifolia* A. Murray sec Flora of North America, Volume 2. Use of the name *Abies lasiocarpa* (Hooker) Nuttall without reference to which concept is intended means that it is not possible to know if the name applies to the more general or the more narrow concept. When using a genus or species name that could refer to more than one concept, the particular intended taxonomic concept should be indicated by using the term "sec" in front of the reference for the intended concept.

Unknown or irregular taxa (such as composite morphotypes representing several similar taxa) should be reported with the name of the taxon for the first level at which identification is certain. The best practice is to provide additional information in a note and provide a name to follow the given taxon in parentheses (e.g., *Potentilla* (*simplex* + *canadensis*) sec USDA PLANTS; Poaceae (aff. *Festuca*) sec USDA PLANTS). In addition, inclusion of logical relationships to other concepts, such as "includes," "included in," or "overlaps," can add clarity (see Franz et al. 2008).

Plot data archives and data exchange.—Plot database archives are needed to hold the data that form the basis for documenting and refining the associations and alliances. Data used in development or revision of the NVC must be retained in a permanent, publicly accessible database system so that they can be examined and reinterpreted in the course of future research. In addition, plot data used to support description of a vegetation type must be linked by accession number to the description of the type in the NVC database. Having plot data in a form consistent with a standard data exchange schema (see Appendix E) will facilitate data exchange and analysis. The Vegetation Panel maintains VegBank (Ecological Society of America, Vegetation Classification Panel 2008) as a repository to facilitate archiving, discovering, viewing, citing, and disseminating plot data. There is, however, no requirement that classification plot data be deposited in VegBank as long as the data meet archival requirements for public accessibility.

Collection of plot data is a distributed activity external to the NVC, driven by the needs and interests of numerous organizations and individuals. All such individuals and organizations are encouraged to submit their plot data to a public plot database as a component of proposals for changes in the NVC or as a separate submission of basic data documenting of the occurrence of a vegetation types. All uses of plot data with respect to the NVC must cite the original author of the plot record and link directly to the plot archive through a globally unique identifier.

Classified associations and alliances database.—The National Vegetation Classification Database must be viewable and searchable over the Internet and be regularly updated. A single primary access point for viewing the classification is maintained by the NVC management team. Although some or all of this information may be duplicated at other Internet sites, the primary access point should be seen as definitive. Currently, this access point is the NatureServe (2008) Explorer web site. When citing an association or alliance, users of the NVC should cite the website and the explicit version or date on which the information was obtained so as to facilitate exact reconstruction of the community concept of interest.

Proposal submission and the Proceedings of the U.S. NVC

The *Proceedings* constitutes the primary literature underpinning the classification and is used to document and archive changes to the NVC database of types. The Peer Review Board maintains records of all NVC transactions in the *Proceedings*, such as proposals for new or modified types, their status, and changes to the list of NVC associations and alliances, along with supporting information and type descriptions. The *Proceedings* can be accessed through websites of the Vegetation Panel (esa.org/vegweb), VegBank (vegbank.org), or NatureServe (natureserve.org).

Looking Ahead

The NVC must be seen as a long-term enterprise, one that learns even as it leads to new knowledge. Other than original plot data, few components of it will remain static. For now, we can only sketch some of the ways these standards will be implemented and where they are likely to change our understanding of U.S. vegetation and its trends.

Building the classification consortium for the future

Implementation of the NVC as a continuing scientific activity depends on the support and participation of scientists and their institutions, federal and state, public and private. A consortium for the advancement of the NVC has already been formalized by a memorandum of understanding among several national players represented on the Vegetation Panel. Other partners are likely to join this consortium. The future activities of these partners will include more widespread sampling, more systematic use of the databases for classification studies, revisions to these guidelines, and full implementation of a review process for changes to the units of classification. Within this framework, the FGDC represents the needs of U.S. federal agencies and will coordinate continued testing and evaluation of the classification by these agencies. NatureServe, representing the network of natural heritage programs and conservation data centers throughout the Americas, will use its experience with the national classification to ensure

PLATE 1. A stand of *Taxodium distichum–Nyssa aquatica/Fraxinus caroliniana* Forest association at Francis Marion National Forest in South Carolina, USA. The plant community's English name is Bald-cypress–Water Tupelo/Carolina Ash Forest, and it is also known as a Cypress–Tupelo Semipermanently Flooded Brownwater Swamp. It is found along brownwater rivers of the outer Atlantic Coastal Plain and the East Gulf Coastal Plain of the United States. The association is characterized by a dense canopy of *Taxodium distichum* and *Nyssa aquatica* with a sparse to moderate subcanopy, which often includes *Fraxinus caroliniana*, and depauperate shrub and herb layers. A formal description under the National Vegetation Classification can be found through NatureServe Explorer at ⟨www.natureserve.org/explorer⟩. Photo credit: R. K. Peet.

continuity in applications to conservation. ESA's participation represents engagement of the professional scientific community. Its experience with publication and independent peer review ensures the credibility of the classification. The Vegetation Panel provides an objective, neutral arena for all interested parties in the evaluation of proposed changes to these guidelines as well as to the recognized classification units.

Prospects for scientific advancement

Knowledge about the vegetation of the United States will be advanced in the coming years through a combination of analyses of new data, use of new methods, and through new applications to natural resource management problems. Some of these will concern necessary adjustments to regional or national inventory and management as resource systems respond dynamically to invasive species, pollutants, and climate change.

New data.—The implementation of standards, broad application of the NVC, and the development of open and electronic plot archives will catalyze the collecting and reporting of new field data as well as increase access to legacy data. Under the guidelines presented here, the new data will meet the need for consistency in describing and documenting vegetation types that, in turn, will lead to advances in our understanding of vegetation as a whole.

New analytic methods.—A goal of the NVC has been to create a framework for characterizing vegetation communities across a continent-sized area. With a common approach, an increase in data, and consequent greater statistical power, the potential for developing new analytic methods will improve substantially.

Discovery and description of vegetation types.—A truly comprehensive classification of vegetation consistent with the guidelines presented here will emerge as the databases become widely used and the process of analysis and monographing becomes established. A significant part of this work is the continuing reassessment of names and type concepts already published (e.g., Anderson et al. 1998). The needed review, analysis, and documentation are expected to be undertaken, in large part, by the community of scientists working in conservation, resource management agencies, universities, and related institutions.

New applications of existing knowledge.—The primary reason for establishing standards for vegetation classification is to ensure compatibility of vegetation types and related ecological information across society: citizens, governments, universities, and private organizations. Although some applications may require map units unique to a project, the use of an underlying standard vegetation classification as the basis for those map units will allow them to be compared across states and regions as well as across time. With advances in mapping and inventory, these applications are likely to expand in breadth. Some important applications follow.

1. *Resource inventory, conservation, and management*.—Government and private organizations need to know which vegetation types are rare or threatened, which are exemplary in quality, and where they occur. These needs have initiated a new genre of vegetation inventory applications. Recognition that many rare species are found in uncommon vegetation types has led to biodiversity conservation through maintenance and restoration measures focused on those types.

2. *Resource mapping*.—Established guidelines for vegetation classification will lead to improved consistency and reliability of vegetation mapping, e.g., in the U.S. Geological Survey–National Park Service Vegetation Mapping Program (Faber-Langendoen et al. 2007*a*, *b*), the U.S. National Gap Analysis Program (Jennings 2000), or Landfire (Karau and Keane 2007). Land development activities that include land use planning techniques such as Habitat Conservation Plans (Kareiva et al. 1999) will use a new standard of fine-grained vegetation classification and mapping in developing future conservation management plans.

3. *Resource monitoring*.—Throughout North America, studies have been initiated to monitor changes in vegetation resulting from overgrazing, invasive species, and climate change. State and federal agencies are often mandated to monitor specific resources, such as forests or grasslands, or to assess ecosystem health. However, results from many of these initiatives are too coarse in spatial or thematic resolution to resolve fully the problems that land managers face. Previously, there has been no consistent method for defining the assemblages of species to be monitored as a unit, or the deviation of a community occurrence from the normal expression of that community. A rigorous classification of associations and alliances allows community and species information to be linked to more generalized floristic and physiognomic information. This capability requires clear definition and documentation of vegetation types along with repeated measurements and comparisons over longer periods of time.

4. *Ecological integrity*.—Vegetation provides one of the most fundamental contexts with which to understand the complexity and integrity of ecosystems. Vegetation is habitat for millions of species. Because vegetation can be mapped with remotely sensed information, it can be used as a surrogate for understanding, tracking, and forecasting a wide range of changes in ecosystem integrity.

International collaboration

Vegetation is present globally, and does not recognize political boundaries. Thus, classification of vegetation is most effective for improving knowledge if it is undertaken as an international collaboration. The NVC emerged as a national component of a larger multinational initiative, the International Vegetation Classification (IVC; Grossman et al. 1998, Faber-Langendoen et al. 2009). The guidelines presented in this document are designed with the expectation that they will be consistent with the IVC vision for a unified set of standards for the broader community of vegetation practitioners and scientists.

For example, the Canadian National Vegetation Classification, like the US-NVC, uses the general approach of the IVC (Ponomarenko and Alvo 2000). In particular, the Canadian Forest Service is working with provincial governments, Conservation Data Centers, other agencies, and nongovernmental organizations to define forest and woodland types consistent with the association concept used in these guidelines. The individual provinces have conducted extensive surveys using standardized plots, and either have well-established vegetation classifications or are in the process of describing them. Some have already developed association and alliance units using the same standards, nomenclature, and codes for types as are described here, and are developing additional names and codes for new types. This approach ensures that associations developed in the United States and in Canada have the potential to be integrated as part of an IVC that is global in scope.

The extension of these guidelines toward improvement of the IVC must be understood as a continuing process. Five critical elements of this process are: (1) standardized collection and incorporation of new data; (2) evaluation and integration of new methods for analysis and synthesis; (3) publication of new and revised vegetation types in many countries; (4) new practical applications of present knowledge about vegetation; and (5) integration of national classification activities into a consistent IVC. Collaboration with European and other partners to develop mechanisms for integrating plot data, as well as vegetation types developed following various standards, into global databases that complement and enhance each other will be critical. The Vegetation Panel is facilitating a U.S. role in international collaboration for further development of classification standards.

The approach to, and framework for, international classification of vegetation described in this paper create a basis for long-term progress in resource conservation, environmental management, and basic vegetation science. Undoubtedly, new applications of vegetation classification will emerge and lead to further improvements.

Acknowledgments

Ton Damman (1932–2000) worked tirelessly toward the creation of a unified vegetation classification for the United States, and toward this end he shared his wealth of experience from around the world. These guidelines reflect his shared desire for a rigorous, plot-based approach to vegetation description and analysis. In recognition of his many contributions to vegetation science and these standards in particular, we dedicate this work to his memory.

Many individuals have contributed in one way or another to the development of these guidelines. David Glenn-Lewin, Robert Pfister, Dennis Grossman, David Tart, Marilyn Walker, Stephen Talbot, Joan Walker, Gary Hartshorn, Gary Waggoner, Marc Abrams, Alison Hill, and Marcel Rejmanek served on the Vegetation Panel and helped to develop the initial guidelines. Mark Anderson, David Brown, Rex Crawford, Kathy Goodin, David Graber, John Harris, Miles Hemstrom, Bruce Kahn, Kat Maybury, Ken Metzler, William Michener, Ladislav Mucina, J. Scott Peterson, Thomas Philippi, Milo Pyne, Marion Reid, Rebecca Sharitz, Denice Shaw, Marie Loise Smith, Lesley Sneddon, Miklos Udvardy, Jan van Wagtendonk, Alan Weakley, Neil West, and Peter White provided input and review. Jim MacMahon, Jerry Franklin, Jane Lubchenco, Mary Barber, and Julie Denslow, as ESA officers, fostered the establishment of the Vegetation Panel. Ralph Crawford played a vital role as liaison to the FGDC Vegetation Subcommittee. Elisabeth Brackney edited several versions of the manuscript. Lori Hidinger of ESA provided unflagging staff support over the many years of deliberation in developing these guidelines. Thanks to Frank Davis for his guidance and insight.

The work of the Vegetation Panel was made possible in part by support from the U.S. Geological Survey's Gap Analysis Program, the Federal Geographic Data Committee, the National Science Foundation, the National Center for Ecological Analysis and Synthesis, the Environmental Protection Agency, the Bureau of Land Management, the Army Environmental Policy Institute, and the Ecological Society of America's Sustainable Biosphere Initiative.

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APPENDIX A

Glossary of terms (*Ecological Archives* M079-006-A1).

APPENDIX B

Required and optimal attributes for classification and occurrence plot records (*Ecological Archives* M079-006-A2).

APPENDIX C

Constrained vocabularies (*Ecological Archives* M079-006-A3).

APPENDIX D

An example of the description of a floristic association (*Ecological Archives* M079-006-A4).

APPENDIX E

Field plot data exchange schema (*Ecological Archives* M079-006-A5).

APPENDIX F

Physiognomic and floristic data tables (*Ecological Archives* M079-006-A6).