STANDARDS FOR ASSOCIATIONS AND ALLIANCES

OF THE

U.S. NATIONAL VEGETATION CLASSIFICATION

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Dedicated to Antoni Damman
1932-2000

He worked hard to help create a unified vegetation classification in the United States, based on his wealth of experience from around the world. These standards have been shaped by his desire for a rigorous, plot-based approach to vegetation description and analysis.

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SUMMARY

The purpose of this document is to provide both a technical and a general basis for describing and classifying the plant associations and alliances that are to be formally recognized as units of vegetation under the U.S. National Vegetation Classification (NVC). It should be useful to practitioners, researchers, and students of vegetation ecology. The standards presented here are to be used by anybody proposing additions, deletions, or other changes to the named units of the NVC. By implementing standards for field sampling, analysis, description, peer review, archiving, and dissemination, the Ecological Society of America's Vegetation Classification Panel—in collaboration with the Federal Geographic Data Committee, NatureServe, the U.S. Geological Survey, and others—intends to advance our common understanding of vegetation and improve our capability to sustain this resource by formal, science-based processes.

We begin with the rationale for developing these standards. Then the history and development of vegetation classification in the United States is briefly reviewed. Standards for establishing and revising the floristic units of vegetation include the definition of association and alliance concepts, requirements for vegetation field plots, and classification and description of associations and alliances. A standard framework for peer review of types that are proposed for inclusion in the National Vegetation Classification is provided, as is a structure for data access and management. Finally, we conclude with a discussion of future prospects of and new directions in vegetation classification.

Because new knowledge will inevitably lead to the need for improvements to the standards described here, this document is written with the intention that it will be revised, with new versions produced as needed. Recommendations for revisions should be addressed to the Panel Chair, Vegetation Classification Panel, Ecological Society of America, Suite 400, 735 H St, NW, Washington, DC. Email contact information can be found at www.esa.org/vegwebpg.htm or contact the Ecological Society of America's Science Program Office, 1707 H St, NW, Suite 400, Washington, DC 20006, Telephone: (202) 833-8773.

Table Of Contents

INTRODUCTION

1. RATIONALE

A standardized, widely accepted vegetation classification for the United States is required for effective assessment, management, and inventory of the nation's ecosystems. These needs are increasingly apparent as individuals, private organizations, and governments grapple with the escalating rate and magnitude of alteration to natural vegetation (see Klopatek et al. 1979, Mack 1986, LaRoe et al. 1995, Mac 1999). Remnants of many natural vegetation types have become increasingly rare (Noss et al. 1995, Noss and Peters 1995, Barbour and Billings 1999). Some are now imperiled because of habitat loss or degradation, and others have disappeared entirely from the landscape without ever being formally documented (Grossman et al. 1994). Fifty-eight percent of the plant associations described by NatureServe—the most comprehensive set of such records known for the U.S.—are either presumed extinct or are in some danger of becoming extinct (NatureServe Explorer 2002). Losses of vegetation types represent losses in habitat diversity, leading directly to more species being in danger of extinction (Ehrlich 1997, Wilcove et al. 1998, Naeem et al. 1999). Predicted changes in climate, continued atmospheric pollution, ongoing species invasions, and land use changes are likely to cause further unprecedented and rapid alterations in vegetation (Overpeck et al. 1991, Vitousek et al. 1997, Morse et al. 1995). Widespread changes in land use have led to increased social and economic conflicts, resulting in an increasing demand for more robust and timely information about remaining natural and seminatural environments. In addition to these environmental issues, a standardized classification is needed in order to make progress with basic issues in vegetation science, such as ecological processes, biomass productivity, or succession. We expect a standardized classification system to play a prominent role in guiding research, resource conservation, and ecosystem management, as well as in planning, restoration activities, and in predicting ecosystem responses to environmental change.

Vegetation ecologists have made significant progress toward a consistent vegetation classification that will meet the need for conservation and resource management (Loucks 1996, FGDC 1997, Grossman et al. 1998). The coordinated activities of the major institutions involved in vegetation classification and mapping in the United States has created the possibility for a fully functional, widely applied system of vegetation classification. Still lacking, however, are important components, such as widely accepted standards for terminology, documentation of vegetation types, field data acquisition, and data management tools. To help meet the need for a credible, broadly accepted vegetation classification, the Ecological Society of America (ESA: the professional organization for ecologists in the United States) formed a Panel on Vegetation Classification, composed of vegetation scientists, and joined with cooperating organizations such as the U.S. Geological Survey, U.S. Federal Geographic Data Committee, and NatureServe[1]. To formalize this partnership, the four participating organizations signed a formal Memorandum of Understanding (MOU)[2] in August 1998. This MOU defines the working relationship among the signers for the purpose of advancing the National Vegetation Classification.

The objectives of the ESA Vegetation Classification Panel are to (1) facilitate and support the development, implementation, and use of a standardized vegetation classification for the United States; (2) guide professional ecologists in defining and adopting standards for vegetation sampling and analysis in support of the classification; (3) maintain scientific credibility of the classification through peer review; and (4) promote and facilitate international collaboration in development of vegetation classifications and associated standards. In this document the Panel articulates and explains a set of standards aimed at achieving the first three of these objectives.

[1]In July of 2000 The Nature Conservancy's science staff that helped to develop the U.S. National Vegetation Classification transferred to a new organization, NatureServe, which now represents the interests of the Conservancy in the ongoing development of the NVC.

[2] Forming a partnership to further develop and implement the national vegetation classification standards. Memorandum of Understanding among ESA, TNC (NatureServe), USGS, and FGDC. 1999. Ecological Society of America, Washington, D.C., USA. 6pp. (http://esa.sdsc.edu/mou.htm)

2. THE EMERGING FLORISTIC CLASSIFICATION

The ESA Panel on Vegetation Classification recognizes the Federal Geographic Data Committee's (FGDC's) "National Vegetation Classification Standard," published in 1997, as the starting point for developing a national vegetation classification. The FGDC classification standard contains a physiognomic-floristic hierarchy with higher-level physiognomic units and lower-level floristic units (Figure 1). The standard introduced the classification hierarchy, documented the component elements of all except the floristic levels, and provided the context for defining those floristic levels. Between 1995 and 1996 the Panel concentrated on assisting the FGDC by reviewing proposed standards for the physiognomic categories (class, subclass, group, subgroup, and formation; Loucks 1996), as well as the specific physiognomic types within these categories.

The guiding principles established by the FGDC for the overall development of the NVC are shown below in Box 1 (FGDC 1997, Section 5.3). These principles, particularly the final one, are the basic criteria that the FGDC intended the floristic units be based on. The 1997 FGDC document also provided definitions for the floristic units of the classification: the alliance and association (Box 2). These definitions begin with the premise that a vegetation type represents a group of stands that have similar plant composition and physiognomic structure. Furthermore, that the types must have clear diagnostic criteria to enable their recognition.

Although the 1997 FGDC standard includes the two floristic categories of the NVC hierarchy, Alliance and Association, it provides no list of recognized types, no details about nomenclature, nor methods for defining and describing alliances and associations. With respect to these categories, the document states "The current list of Alliances and Associations for the conterminous United States will be published by The Nature Conservancy in the spring of 1997 . . ." (FGDC 1997, Section 6.0). The list was published in 1998, in cooperation with the Natural Heritage Network (Anderson et al. 1998). Importantly, each alliance and association on the list is described in detail in a standardized format (see Grossman et al. 1998, page 48). Each description is an exhaustive compilation of literature and field observations of each type, and is the most complete summary of our knowledge about individual plant communities to date. The Panel accepts this set of records, which is maintained by NatureServe and widely used by many federal and state agencies, as a first approximation of alliance and association types. However, this initial set of type descriptions is accepted with the expectation that the descriptions be enhanced and revised in accordance with the FGDC requirement that the data used to describe alliance and association types must be collected from the field with standard and documented sampling methods (FGDC 1997, Sections 5.3 and 7.1). In addition, although the FGDC established alliances and associations as the standard units of vegetation characterized by floristic composition—with the association being the most fundamental unit of vegetation in the classification hierarchy—it was only able to provide the conceptual framework for the very large amount of detailed work that would be needed to establish a robustly described set of alliances and associations. The standards presented here are intended to help meet that need.

We use the FGDC "Guiding Principles" (Box 1) as well as the definitions for association and alliance (Box 2) to guide the development of standards for defining, naming, and describing floristic units. In the future, alliances and associations accepted into the list of NVC floristic units are expected to meet these standards for sampling, definition, and description, based on a quantitative and peer-reviewed approach. Specifically, after a brief historical overview of vegetation classification concepts and development, we provide standards in four main areas: (1) field plot records, (2) type description, (3) peer review, and (4) data management. The underlying principles for setting the standards in these four areas is presented in Box 3. Each of these four areas is briefly discussed below.

<u>Field plot records</u>. Vegetation associations and alliances should be identified and described through numerical analysis of standardized plot data that are collected from across the range of the vegetation type of interest and closely related types (irrespective of political and jurisdictional borders). Thus, a critical need is to identify standards for collecting the plot data. There is also a vital need to bring together as much previously collected field plot data as possible. *We outline standards for plot data in Chapter 5*.

<u>Type description</u>. Proposals for new or revised floristic units must adhere to standards for defining and describing types. Each type description should include sufficient information to determine the diagnostic vegetation features of the type and its relation to other types recognized in the classification. *We outline standards for type description in Chapter 6.*

<u>Peer review.</u> Types need to be reviewed through a credible, scientific peer-review process. The peer-review process must include comparison of any proposed types with existing related alliances and associations to ensure that proposed types do not duplicate or significantly overlap existing ones, rather enhance, replace, or add to them. Because a representation of the full diversity of U.S. vegetation must rely on applying all existing expertise and available qualitative and quantitative information, the initial set of NVC type descriptions developed and maintained by NatureServe (2002) prior to adoption of these standards will be reviewed and upgraded or replaced as plot data and analyses become available. *Standards for the peer-review process are outlined in Chapter 7.*

<u>Data management.</u> Plot data used to define and describe an association or alliance must be permanently archived in a publicly accessible data archive for future analysis and revision of the NVC, as well as for other uses and applications. Accepted proposals for addition or modification of vegetation types and all supporting documentation must be deposited in a digital public archive. All plant taxa referenced in plot data or community type descriptions must be unambiguously defined through reference to a public archive of recognized taxa. All three types

of data archives must be truly archival in the sense that the data will be able to be extracted in their original form and context at some indefinite future time by any reasonably diligent investigator. *Data management standards are outlined in Chapter 8.*

Unresolved issues and disclaimers.

The NVC is a classification of the full range of existing vegetation, from natural types that include old-growth forest stands and seminatural vegetation (including grazed rangelands, old agricultural lands undergoing natural succession, and stands dominated by naturalized exotics) to planted or cultivated vegetation, such as row crops, orchards, and forest plantations. Various uses and applications may require distinctions with respect to naturalness (see Grossman et al. 1998, Appendix E). Descriptions of types should aid users of the classification in differentiating among natural, seminatural, and planted types. However, at this time, no standards for defining naturalness are proposed.

Consistent with the FGDC principles, the standards described here for floristic units relate to vegetation classification and are not standards for the identification of mapping units. Nevertheless, types defined using these standards can be mapped and can be used to design useful map units subject to limitations of scale and mapping technology. The criteria used to aggregate or differentiate within these vegetation types and to form mapping units will depend upon the purpose of and resources devoted to any particular mapping project (e.g., Damman 1979, Pearlstine et al. 1998). Mapping projects can be more consistent from place to place and over time if map units are developed from a standardized classification.

Finally, it is important to remember that, while vegetation varies continuously in time and space, classification partitions that continuum into discrete units, primarily for *practical* reasons. Alternative classification approaches, particularly those that aggregate alliances and associations differently than the NVC (which uses vegetation physiognomy as criteria for aggregates of alliances) are available and may be more practical for some particular uses. For example, in using the NVC Alliance class as a target for vegetation mapping by the Gap Analysis Program, not all alliance types can be resolved. In such cases alliance types are aggregated into map units of "compositional groups" or "ecological complexes" (see Pearlstine et al. 1998). Although not part of the NVC standard, such alternative approaches would result in units of vegetation that are just as "legitimate." Hierarchical levels of vegetation classifications have been defined based purely on floristic criteria (Westhoff and van der Maarel 1973), on ecosystem processes (Bailey 1996), or on potential natural vegetation (Daubenmire 1968). Each of these approaches meet different needs.

In providing standards for implementation of the floristic levels of the U.S. National Vegetation Classification, we in no way mean to imply that this is the only valid classification approach. The alliance and association concepts may be unworkable in some kinds of vegetation, particularly floristically complex vegetation as found in some tropical forests (see Pignatti et al. 1994). In these systems, vegetation classifications based on physiognomy (i.e., Adam 1994) or climate and landform (i.e., Holdridge 1967) have been the norm. Pillar and Orlóci (1993) point out that others have questioned the use of species as the fundamental unit of plant communities (e.g., Salisbury 1940, Constance 1953, Ehlich and Holm 1962, McMillan 1969, Snaydon 1973, Grime 1979, Harper 1982, Orloci 1991). There are many alternative taxonomies based on life forms and character-based community description and analysis. For example: (a) life form (phanerophytres, chamaephytes, hemicryptophytes, geophytes, therophytes); (b) overall growth form (solitary, rosette, caespitose, prostrate, erect, stoloniferous, rhizomatous); (c) stem type (herbaceous, woody); (d) leaf type (straight, folded, rolled, glabrous, glaucous, hairy, tomentose, leafless, width); and (e) plant height (<2.5 cm, 2.5-5.0, 5.0-10.0, 10-20, 20-50, 50-100, >100 cm). We hope that the NVC can be implemented in concert with other classifications.

3. A BRIEF HISTORICAL BACKGROUND

> *"Vegetation classification attempts to identify discrete, repeatable classes of relatively homogeneous vegetation communities or associations about which reliable statements can be made. Classification assumes either that natural vegetation groupings (communities) do occur, or that it is reasonable to separate a continuum of variation in vegetation composition and/or structure into a series of arbitrary classes." (Kimmins 1997).*

As we reflected on the history of vegetation classification in the United States and elsewhere and on the opportunities that now lie before us, we became convinced that a clear set of standards for defining floristic units would advance the discipline of vegetation ecology and make a strong contribution to conservation and resource management. Because our goal is to develop standards informed by the rich historical debate surrounding vegetation classification, we begin this document where the Panel began its work: by reviewing the historical basis for some of the fundamental concepts that shaped the floristic levels of the NVC.

3.1. DESCRIBING AND CLASSIFYING VEGETATION

For more than a century vegetation scientists have studied plant communities to identify their compositional variation, distribution, dynamics, and environmental relationships. They have used a multiplicity of methods including intuition, knowledge of physiological and population ecology (autecology), synthetic tables, and mathematical analyses to organize and interpret these patterns and relationships. Perhaps Shimwell (1971) expressed the situation best when, after reviewing the large and diverse literature on vegetation classification, he prefaced his book on the subject with the Latin maxim *quot homines tot sententiae*, "so many men, so many opinions." What follows is not a comprehensive review of vegetation classification; that has been done elsewhere (e.g., Whittaker 1962, 1973, Shimwell 1971, Mueller-Dombois and Ellenberg 1974). Instead, we focus on those elements most significant to the National Vegetation Classification enterprise and particularly those most relevant to the floristic levels.

Vegetation classification is a powerful tool employed for several purposes, including: (1) efficient communication, (2) data reduction and synthesis, (3) interpretation, and (4) land management and planning. Classifications provide one way of summarizing our knowledge of vegetation patterns. Although different individuals conceptualize vegetation patterns differently, all classifications require the identification of a set of discrete vegetation classes. Several ideas are central to the conceptual basis for classification (following Mueller-Dombois and Ellenberg 1974, p. 153):

1. Similar combinations of species recur from stand to stand under similar habitat conditions, though similarity declines with geographic distance.
2. No two stands (or sampling units) are exactly alike, owing to chance events of dispersal, disturbance, extinction, and history.
3. Species assemblages change more or less continuously if one samples a geographically widespread community throughout its range.
4. Stand similarity depends on the spatial and temporal scale of analysis.

These fundamental concepts are widely shared, and articulating them helps us understand the inherent limitations of any classification scheme. With these fundamentals in mind, we can better review the primary ways in which vegetation scientists and resource managers have characterized vegetation pattern to meet their needs.

Physiognomic characterization

Physiognomy, broadly refers to structure (height, spacing, and shape), growth form (gross morphology and growth aspect), and external appearance (leaf seasonality, phenology, duration, size, shape, and texture) of the dominant or characteristic plants. The basic unit of many physiognomic classifications is the formation a "community type defined by dominance of a given growth form in the uppermost stratum of the community, or by a combination of dominant growth forms" (Whittaker 1962).

Physiognomic patterns often apply across broad scales as they typically correlate with or are driven by climatic factors, whereas floristic similarities are more regionally constrained as they often reflect geographic discontinuities and idiosyncratic historical factors. Consequently, physiognomic classifications are often developed for coarse-scale mapping applications. A variety of classifications based on physiognomy or structure (e.g., Fosberg 1961) preceded the development of the widely recognized international classification published by the United Nations Educational, Scientific, and Cultural Organization (UNESCO 1973, Mueller-Dombois and Ellenberg 1974). The UNESCO classification was intended to provide a framework for preparing vegetation maps at a scale of about 1:1 million or coarser, permitting worldwide comparison of ecological habitats indicated by equivalent categories of plant growth forms.

Physiognomic classifications have been used for natural resource inventory, management, and planning. Such classifications are based on measurement of vegetation attributes that may change during stand development and disturbance and which have management implications for wildlife habitat, watershed integrity, and range utilization. Criteria for physiognomic classification commonly include (1) plant growth forms that dominate the vegetation (e.g., forb, grass, shrub, tree), (2) plant density or cover, (3) size of the dominant plants, and (4) vertical layering (e.g., single stratum, multistrata). Stand structure types have been used in numerous regional wildlife habitat studies and forest secondary succession studies (e.g., Thomas 1979, Arno et al. 1985, Barbour et al. 1998, Barbour et al. 2000), and they have been widely used in conjunction with age to assess old-growth conditions (Tyrrell et al. 1998).

Physiognomic classifications alone typically provide a coarse-level generalization of vegetation patterns. However, because they lack specificity at local or regional scales they are often used in conjunction with, or integrated into, other classification approaches that rely on floristics. An exception can be found in certain kinds of floristically complex or poorly understood vegetation, such as tropical rain forests, where they remain the most common approach to vegetation classification (Adam 1994, Pignatti et al. 1994).

Floristic characterization

Floristic characterization uses species composition to describe stands. Methods range from describing only the dominant species to listing and recording the abundance of all species present in the stand (total floristic composition). These characterizations have usually been based on field vegetation plots, which are fundamental to the definition, identification, and description of vegetation types. The differences in methods have an important bearing on the definition and description of the types.

<u>Dominance</u>

Under the dominance approach, vegetation types are classified on the basis of dominant plant species found in the uppermost stratum. Determining dominance is relatively easy, requiring only a modest floristic knowledge. However, because dominant species often have a geographically and ecologically broad range, there can be substantial floristic and ecologic variation within any one dominance type. The dominance approach has been used widely in aerial photo interpretation and mapping inventories because of its ease of interpretation and application. With the advent of remotely sensed imaging (space borne and airborne) of the earth's surface (such as AVHRR, AVIRIS, Landsat and others; see Table 1) a significant level of effort is now applied to classifying and mapping dominant vegetation types across large areas (e.g., Scott and Jennings 1998, Belward et al. 1999, Lins and Kleckner 1996). A variety of different criteria are used to define dominance types, including “cover types,” “dominance types,” and “community-layer dominance types.” Each of these is defined next.

“Cover types” are typically based on the dominant species in the uppermost stratum of existing vegetation. Forest cover types are based on the tree species which may by one or more species) having a plurality of basal area as measured from ground plots (Eyre 1980) or on leaf area cover in the canopy. For rangelands, recently developed cover types are based on the plurality of canopy cover by dominant species (Shiftlet 1994). Although their limitations have been clearly articulated (e.g., Whittaker 1973), dominance types and cover types remain broadly used because they provide a simple, efficient approach for inventory, mapping, and modeling purposes.

"Dominance types" provide a simple method of classification based on the floristic dominant (or group of closely related dominants) as assessed by some measure of importance such as biomass, density, height, or leaf-area cover (Kimmins 1997). They represent one of the lowest levels in several published classification hierarchies (e.g., Cowardin et al. 1979, Brown et al. 1980).

"Community-layer dominance types" (sometimes referred to as unions, synusia, or strata; see Whittaker 1973) have been used to classify existing vegetation on the basis of dominant species in each major vegetation layer. This classification approach, with a long history in northern Europe (Fennoscandia), is based on the uniformity of the dominant species in each layer (Whittaker 1962, Brown et al. 1980). In this context, they can be a convenient and ecologically meaningful way to subdivide cover types or dominance types, classifying them more finely based on the dominant species in lower, conspicuous layers of vegetation.

<u>Total floristic composition</u>

Characterizations of vegetation that emphasize total community floristic composition have been widely used for systematic community classification. Two of the major approaches used are those of the Braun-Blanquet (1928) approach, also referred to as the "Zürich-Montpellier School" (Westhoff and van der Maarel 1973, Kent and Coker 1992), and the Daubenmire (1952) approach (see Kimmins 1997). Both approaches use an "association" concept. The Braun-Blanquet association derives from the definition of Flahault and Schröter (1910), which states that an association is "a plant community type of definite floristic composition, uniform habitat conditions, and uniform physiognomy (Flahault and Schröter 1910; see Moravec 1993). In contrast, the Daubenmire association is more of a potential site type classification, based on the assemblage of species expected to occupy a site after succession has been allowed to proceed to its presumed endpoint.

Braun-Blanquet (1928), working in western Europe, defined the association as "a plant community characterized by definite floristic and sociological (organizational) features" which shows, by the presence of diagnostic species "a certain independence." Diagnostic species are those whose patterns of abundance or constancy help to distinguish one association from another (Whittaker 1962). Identification of character species, those species that are particularly restricted to a single type, was considered essential to the definition of an association, whereas differential species, those species that are more constant in one type but also common in others, defined even lower taxa, such as subassociations (Moravec 1993). Patterns of diagnostic species are assessed using relevés. A relevé is a record of vegetation composition that requires a comprehensive list of plants in a relatively small, environmentally uniform habitat (Mueller-Dombois and Ellenberg 1974). The Braun-Blanquet approach groups plant associations with common diagnostic species into a hierarchical classification with progressively broader floristic units called alliances, orders, and classes (see Pignatti et al. 1994). The association concept has been progressively narrowed as more associations have been defined, each with fewer diagnostic or character species (Mueller-Dombois and Ellenberg 1974). Today many associations are defined using only differential species (Weber et al. 2000). Classifications based on the Braun-Blanquet approach continue to be widely employed in Europe (see Mucina et al. 1993, Mucina 1997, 2001), and is occasionally applied in the U.S. (e.g., Komarkova 1980, Cooper 1986, Peinado et al. 1994 Nakamura and Grandtner 1994, Nakamura et al. 1994, Walker et al. 1994, Peinado et al. 1998,Rivas-Martinez et al. 1999). Daubenmire (1952), working in the western United States, substantially modified the association concept to a "type of climax phytocoenosis" (Daubenmire 1968). His forest associations were based almost exclusively on stands of "near-climax" vegetation (>300 years old). Stands were grouped by traditional synecological synthesis tables for study of community floristics and evaluation of diagnostic species. Because Daubenmire's use of the term "association" was restricted to the "near-climax and projected climax" vegetation, he used the word "associes" to indicate plant communities in earlier recognizable stages of secondary succession (Daubenmire 1968). Later, many authors preferred to use a different term—"community type"—for seral and disclimax plant communities to avoid confusion between climax and seral types. The term "sere" has also been used for successional types that are defined based on diagnostic tree species.

There are underlying similarities between the Daubenmire and Braun-Blanquet methods (see Layser 1974). However, the original approach of Daubenmire (1952) was to define climax associations as floristically stable reference points for interpreting vegetation dynamics. Conversely, the Braun-Blanquet association was intended as a *systematic* unit of classification, irrespective of successional status. Thus, under the Braun-Blanquet approach, old fields, pastures, and forests were all to be described using the association concept, with no preconceptions as to how such types relate to a climax association . A fundamental difference between the Braun-Blanquet approach and that of Daubenmire is apparent in forest vegetation, where the latter assigns primary weighting to diagnostic members of the predominant growth form (tree species), particularly those expected to dominate in late-successional states, and only secondary weighting to diagnostic members of the undergrowth vegetation. Another difference is that the Daubenmire approach makes an explicit effort to use the late-successional natural vegetation to predict the climax vegetation. Because the two methodologies rely on similar vegetation data and analysis, the units defined for late-successional vegetation under these two methods are often similar (but see Spribille et al. 2001). Daubenmire's "habitat types" represent parts of the land surface capable of supporting the same kind of climax plant association (Daubenmire 1978). During the 1960s, with an emerging emphasis on natural resource management, his approach of using climax associations as a conceptual framework for a site classification gained preeminence in the western United States. Financial support became available for developing plant association and habitat type taxonomies on a systematic basis over large areas of the West. With millions of hectares to cover, methods were revised for efficiency (Franklin et al. 1971). In addition, sampling was no longer restricted to "climax" or "near-climax" stands; rather, vegetation was sampled with relevés from "late-successional" (maturing) stands across the full range of environmental conditions (Pfister and Arno 1980). The term "series" was coined to define a forest type based on diagnostic tree species. Associations, nested within series, were defined by diagnostic species (identified from a synthesis of field samples) in the forest understory. By the 1980s, more than 100 monographs had been published on habitat types of forestlands and rangelands in the western United States (Wellner 1989), and many keys were available to identify all stages of secondary succession on a habitat type and to infer its potential climax association (also called potential natural vegetation type).

Physiognomic-floristic characterizations

Descriptions of vegetation need not rely solely on either floristics *or* physiognomy. A classification that combines physiognomic and floristic criteria allows flexibility for characterizing a given area by both its structure and composition. Driscoll et al. (1984) proposed a multi-agency ecological land classification system for the United States that consists of a combination of the physiognomic units of UNESCO (1973) and the floristic "late-successional" associations or habitat types. Subsequently, The Nature Conservancy developed a combined physiognomic-floristic classification of existing vegetation titled the International Classification of Ecological Communities (Grossman et al. 1998) using modified physiognomic units of UNESCO for the upper levels and alliance and association units for the lower levels (see Figure 1). Units at all levels of the classification were developed across the United States, based on a synthesis of existing information and ecological expertise (Anderson et al. 1998). The Conservancy's definition of the association was based on Flahault and Schröter's (1910) association concept of an existing vegetation type with uniform floristic composition, habitat conditions, and physiognomy. Both the Driscoll et al. (1984) and the TNC classifications use a formation concept that incorporates some elements of climate and geography into the physiognomic units, and integrates them with floristic units based on variations of the association concept.

Floristic classifications and community concepts

Continuum concepts and vegetation classification

The work of Curtis (1959) and Whittaker (1956), and especially Mcintosh (1967), explicitly recognized that vegetation varies continuously along environmental, successional, and geographic gradients. In addition, these workers embraced the observation of Gleason (1926) that species respond individualistically to these gradients and that chance plays an important role in the composition of vegetation (however, see Nicolson and McIntosh [2002] for an important clarification of Gleason's individualistic concept). The necessary consequence is that in most cases there are no clear and unambiguous boundaries between vegetation types, and that vegetation is not entirely predictable. Any decision as to how to divide the continuously varying and somewhat unpredictable phenomenon of vegetation into community types must be somewhat arbitrary with multiple acceptable solutions.

A common approach to capturing vegetation pattern across landscapes is to measure the directional (with respect to geography or environmental factors such as climate and soils) change in floristic composition and represent it as a gradient. The set of techniques used to relate vegetation to known physical gradients is referred to as direct gradient analysis. In contrast, techniques for ordering vegetation along compositional gradients deduced from stand similarity and independently of knowledge of the physical environment (e.g., ordination methods) are referred to as indirect gradient analysis (Gauch 1982, Kent and Coker 1992). Gradients observed using indirect methods can be divided to form a classification, or these gradients can be used to identify key variables driving compositional variation, and these in turn can be used to create an optimal direct gradient representation. Gradient analysis need not lead to classification, yet many researchers have "classified" or summarized vegetation into types based on gradient patterns (e.g., Whittaker 1956, Curtis 1959, Peet 1981, Faber-Langendoen and Maycock 1987, Smith 1995).

Many natural resource professionals and conservationists have used gradient analysis to develop classifications. Practitioners have also used a "natural community type" concept to develop state-level classifications, defining units by a combination of criteria, including vegetation physiognomy, current species composition, soil moisture, substrate, soil chemistry, or topographic position, depending on the local situation (e.g., Nelson 1985, Reschke 1990, Schafale and Weakley 1990, Minnesota NHP 1993). This approach has been used with great success for conservation and inventory at the local and state level, but its lack of uniform rules for defining "natural community" concepts has limited its applicability at larger scales.

Ecological land classifications

There are a number of classification systems that include vegetation as one of several criteria for classifying ecological systems, ecological types (e.g., McNab and Avers 1994, Avers et al. 1994). Vegetation physiognomy is often used at broad scales to help delineate biogeographic or bioclimatic regions (e.g., Loveland et al. 1999), while floristic information is often used at finer scales to define ecological types and delineate ecological land units (e.g. Bailey et al. 1994, Cleland et al. 1994). The habitat-type approach (see above) relies primarily on species occurrence criteria and potential vegetation to define habitat types. Ecological land classification approaches typically use potential natural vegetation as one of several key elements to define ecosystem or ecological land units (Lapin and Barnes 1995, Bailey 1996).

Beginning as early as the Life Zone classifications of Merriam (1898), site classifications using physiographic or environmental characteristics (i.e., climate, soil, land form) along with vegetation have emerged in several forms. These classifications have often been used to guide forest management.

The site classification approach does not provide direct information on existing, or actual, vegetation, and care must be taken not to confuse this distinct goal with the study of existing vegetation. Instead, once the ecological unit is defined, existing vegetation information may be used to characterize the current condition of the unit (Bailey 1996). As Cleland et al. (1997:182) state, “Ecological unit maps may be coupled with inventories of existing vegetation, air quality, aquatic systems, wildlife, and human elements to characterize...ecosystems.” Thus, vegetation classifications can play an important role in other classification approaches, even those that are quite dissimilar.

Existing vegetation and potential natural vegetation

Ecologists have developed classifications of both existing vegetation and potential natural vegetation. These should always be kept distinct in considerations of vegetation classifications as they support quite different objectives and applications. By **existing vegetation** we simply mean the vegetation structure and composition that can be observed at a site at the present time. By **potential natural vegetation** we mean “the vegetation structure that would become established if all successional sequences were completed without interference by man under the present climatic and edaphic conditions (including those created by man)” (Tüxen 1956, in Mueller-Dombois and Ellenberg 1974).

Classifying existing vegetation requires fewer assumptions about vegetation dynamics than classifying potential natural vegetation. Emphasis is placed on the current conditions of the stand. Classifications that emphasize potential natural vegetation require the classifier to predict the composition of mature stages of vegetation based on knowledge of the existing vegetation, species autecologies and habitat relationships, and disturbance regimes. For this reason, sampling is often directed at stands thought to represent mature or late seral vegetation.

The 1997 FGDC vegetation standard pertains to existing vegetation and does not address issues related to the study of potential natural vegetation. This document has been written specifically in support of the FGDC standard and is intended solely to support study of existing vegetation.

3.1. A NATIONAL VEGETATION CLASSIFICATION IN THE UNITED STATES

Agency and scientific consensus on classification

Vegetation classification, especially a unified nationwide classification, received little support in the U.S. academic community prior to the 1990s, in part because classification was viewed as having little to contribute towards a general conceptual synthesis of broad applicability; rather it was of more local or regional interest and applicability. This view stemmed in part from different approaches to interpreting and understanding the nature of vegetation patterns, reviewed in the previous section (Nicolson and McIntosh 2002). Consequently, little attention was paid to creating a unified national vegetation classification.[3]

Individual federal and state agencies in the U.S. charged with resource inventory or land management often required vegetation classifications and maps of public lands. Most of these projects were generally limited in scope and geography and tended to use divergent methods and categories (see Ellis et al. 1977), such that their various products did not fit together as components of a larger scheme. Instead, the disparate, disconnected activities resulted in development of incompatible sets of information and duplication of effort (National Science and Technology Council 1997). Nevertheless, during the 1970s and 80s some useful and geographically broad classifications were produced, including the habitat type (or potential natural vegetation) classification of western forests by the U.S. Forest Service (Wellner 1989) and a classification of U.S. wetlands (Cowardin et al. 1979). The Society of American Foresters produced a practical dominance-based approach for classifying forest types in North America (Eyre 1980). In addition, in the early 1980s, five federal agencies developed an ecological land classification framework integrating vegetation, soils, water, and landform (Driscoll et al. 1984).

In the late 1970s, The Nature Conservancy (TNC) initiated a network of state natural heritage programs (NHPs), many of which are now part of state government agencies. The general goal of these programs was the inventory and protection of the full range of natural communities and rare species. Because inventory requires a list of the communities being inventoried, the various programs proceeded to develop their own state-specific community classification systems. As TNC started to draw on the work of the NHPs to develop national-level priorities for community preservation and protection, it quickly recognized the need to integrate the state-level vegetation classifications into a consistent national classification.

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[3] In contrast, classification has been a major activity in Europe throughout the twentieth 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).

In the late 1980s, the U.S. Fish and Wildlife Service initiated a research project to identify gaps in biodiversity conservation (Scott et al. 1993), which evolved into what is today the U.S. Geological Survey's National Gap Analysis Program (GAP, www.gap.uidaho.edu; Jennings 2000). This program classifies and maps existing natural and seminatural vegetation types of the United States on a state and regional basis as a means of assessing the conservation status of species and their habitats. Because a common, widely used, floristically-based classification, particularly at the alliance level, was judged to be critical to this work, in 1990 GAP began supporting TNC's effort to develop a nationwide classification (Jennings 1993). Collaboration between GAP and TNC led to a systematic compilation of alliance-level information from state natural heritage programs and from the existing literature on vegetation (e.g., Bourgeron and Engelking 1994, Sneddon et al. 1994, Drake and Faber-Langendoen 1997, Weakley et al. 1997, Reid et al. 1999). With support from TNC and an array of federal programs, Grossman and others (1998) and Anderson and others (1998) produced the first draft of what became the U.S. National Vegetation Classification (USNVC, or NVC). The NVC was initially populated with a compilation of described natural vegetation types taken from as many credible sources as could be found, drawing from the experience of hundreds of vegetation ecologists having regional expertise. Although the majority of the types initially described were not tied to specific plot data, they were often based upon studies that used plot data, or were based on extensive field knowledge of regional and state ecologists (Weakley et al. 1998, Faber-Langendoen 2001).

The Federal Geographic Data Committee and the ESA Vegetation Panel

The federal government in general also recognized the need for a standard nationwide vegetation classification. In 1990, the government published the revised Office of Management and Budget Circular No. A-16 (Darman1990)[4], which introduced spatial information standards. This circular described the development of a National Spatial Data Infrastructure (NSDI) to reduce duplication of information, reduce the expense of developing new geographically based data, and make more data available through coordination and standardization of federal geographic data. The circular established the Federal Geographic Data Committee (FGDC) to promote development of database systems, information standards, exchange formats, and guidelines, and to encourage broad public access.

Interagency commitment to coordination under Circular A-16 was strengthened and urgency was mandated in 1994 under Executive Order 12906 (Federal Register 1994), which

[4] The circular was originally issued in 1953 to insure surveying and mapping activities be directed toward meeting the needs of federal and state agencies and the general public, and that they be performed expeditiously, without duplication of effort. Its 1967 revision included a new section, "Responsibility for Coordination." It was revised and expanded again in 1990 to include not just surveying and mapping, but also the related spatial data activities.

instructed the FGDC to involve state, local, and tribal governments in standards development and to use the expertise of academia, the private sector, and professional societies in implementing the order. Under these mandates, the FGDC established a Vegetation Subcommittee to develop standards for classifying and describing vegetation. The subcommittee included representatives from federal agencies and other organizations, including TNC. After reviewing various classification options, FGDC proposed to adopt a slightly modified version of the TNC classification. During this period, ecologists from the National Biological Survey,[5] TNC, and academia discussed the need to involve the Ecological Society of America (ESA) to provide peer review as well as a forum for discussion and debate among professional ecologists with respect to the evolving NVC (Barbour 1994, Barbour et al. 2000, Peet 1994, Loucks 1995). The FGDC Vegetation Subcommittee invited ESA to participate in the review of the physiognomic standards and in the development of the standards for the floristic levels. The further developments of ESA and its interactions with FGDC are discussed in Chapter 2.

The following chapters constitute standards recommended by the Ecological Society of America and its partner organizations for use by those seeking to formally describe associations and alliances, and for the further development of the NVC. We hope these standards will provide the necessary impetus for continued rapid development, wide acceptance, and scientific maturation of the NVC.

[5] Now the U.S. Geological Survey's Biological Resources Division.

STANDARDS FOR ESTABLISHMENT AND REVISION OF FLORISTIC UNITS OF VEGETATION

4. THE ASSOCIATION AND ALLIANCE CONCEPTS

The historical record of vegetation classification in the United States and recent developments in classification standards show a continuing evolution toward the basic concepts that make up the standards of the National Vegetation Classification (NVC). Definitions of associations and alliances that were developed early in the 1900's were later modified in the U.S. for use with climax or late seral forests. At the same time, plant and animal ecologists emphasized research on interactions within biotic communities, which led to frequent use of "community types" as a unit of vegetation. Vegetation types were also understood by some as segments along gradients of vegetation, with increasing attention paid to the more-or-less continuous variation that occurred within and among types along gradients. Despite the range of analytical tools and concepts that are now used to assess vegetation patterns, the basic and practical needs for classifying those patterns have led to a convergence in how to conceptualize the types for classification purposes. This section briefly recapitulates the fusion of concepts that has taken place as a basis for standard definitions of association and alliance in the NVC.

4.1. ASSOCIATION

The association is the most basic unit of vegetation in the NVC. Several definitions of this term are listed in the Glossary, and even more are shown in Gabriel and Talbot (1984). The earliest definition (Flahault and Schröter 1910) is "a plant community of definite floristic composition, uniform habitat conditions, and uniform physiognomy". Gabriel and Talbot (1984) also include a definition of association as "a recurring plant community of characteristic composition and structure." Curtis (1959) defined the plant community, a segment along a continuum, as a "studiable grouping of organisms which grow together in the same general place and have mutual interactions." Some commonalities are evident in the words used in the three definitions including the four central ideas: characteristic composition, physiognomy and structure, habitat, and a recurring distribution geographically across a landscape or region.

As these association terms emerged into common use, our conceptualization of vegetation also shifted so as to accept more or less continuous variation in the field. As noted earlier in Section 3, 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, the variability within an association that occurs across its range. Many classifications, including this one, have been framed around some characteristic range in composition, structure (physiognomy), and habitat rather than the "definite" composition and habitat of the original association definition of Flahault and Schröter (1910).

Three other points should be considered:

(1) "Habitat" refers to the combination of environmental or site conditions and ecological processes (such as disturbances) that influence the community. Temporal variation (e.g., from recurrent fire in temperate grasslands and extreme weather influences on populations of annual species) is subsumed into a characteristic habitat, as long as fundamental species presence is not materially changed.

(2) Characteristic physiognomy and habitat conditions may include fine-scale patterned heterogeneity (e.g., hummock/hollow microtopography in bogs, shrub/herb structure in semidesert steppe).

(3) Unlike strictly floristic applications of the association (and alliance) concept, the definition for the NVC standard retains an emphasis on both floristic and physiognomic criteria, particularly in light of the integrated physiognomic-floristic hierarchy. However, primary emphasis is given to floristic criteria.

Accordingly, classification into a plant association imposes a standard set of methods for describing a complex ecological reality, yet a practical, meaningful classification must accept a degree of variation within the association.

As a synthesis of the above considerations, we adopt the following definition of association as the basic unit of vegetation:

> A recurring plant community with a characteristic range in species composition, specific diagnostic species, and a defined range in habitat conditions and physiognomy or structure.

By diagnostic we mean any species or group of species whose relative constancy or abundance clearly differentiate(s) one type from another. This definition acknowledges the advances in studies of vegetation patterns and incorporates the key elements of the various traditions contributing to recent classification studies in U.S. vegetation. As is evident in the sections that follow, the drawing together of these diverse traditions requires adoption of common minimum standards for plot sampling, data analysis, type description, and peer review. Further work is needed to improve and standardize the concept of diagnostic species (or taxa), including terms such as dominant, differential, and character (see Glossary).

Having stated that a range of variability is expected for any given association, there is no consensus as to an overall range of variability for all types. Mueller-Dombois and Ellenberg (1974) suggest, as a rule of thumb, that stands with an presence/absence index of similarity of between 25% and 50% could be part of the same association and that stands with greater levels of similarity may define subassociations. Others have developed guidelines for the minimum number of diagnostic species required to define an association, such as “at least one constant and one absolute or local character taxon, or…an equivalent unit distinguished from all other vegetation units by differential taxa.” (Schaminée et al. 1993). Obviously, the more character or differential taxa that are used to define an association, the stronger the case for recognizing the unit. Moravec (1993) stated that associations may be differentiated by (1) character species, i.e., species that are limited to a particular type, (2) a combination of species sharing similar behavior (ecological or sociological species groups), (3) dominant species, or(4) the absence of species (groups) characterizing a very similar type. No simple rule can be applied to all vegetation types, but guidance is needed to achieve a level of standardization. The subject of “stopping rules” in classification is a complex one, and a variety of criteria are often applied, including physiognomic and habitat considerations. In addition, the nature of the vegetation itself strongly influences decisions about where to draw conceptual boundaries between vegetation types. Important considerations may include species richness, variability, degree of anthropogenic alteration, and the homogeneity of the vegetation.

4.2 ALLIANCE

The vegetation alliance is an abstract unit of vegetation determined both by floristic characteristics shared among the associations present and the physiognomic-ecological characteristics of the higher levels of classification within which the alliance is included. It is broader in concept (i.e., more floristically and structurally variable) than the association, yet it has discernable and specifiable floristic characteristics. Thus, the alliance is defined as follows: A grouping of associations with a characteristic physiognomy and habitat and which share one or more diagnostic species that, as a rule, are found in the uppermost or dominant stratum of the vegetation. This definition includes both floristic and physiognomic criteria, in keeping with the integrated physiognomic-floristic hierarchy of the NVC. It also builds directly from the association concept.

The concept of vegetation alliance presented here differs somewhat from applications of the concept in the more floristically-based Braun-Blanquet approach (Braun-Blanquet 1964, Westhoff and van der Maarel 1973). For example, using the Braun-Blanquet criteria, the Dicrano-Pinion alliance, which typically contains evergreen tree physiognomy, can include common juniper (*Juniperus communis*) shrublands (Rodwell 1991). The Vaccinio-Piceion (or

Piceion excelsae) alliance, with typically evergreen physiognomy, can include deciduous broadleaf birch (*Betula pubescens*) woodlands (Ellenberg 1988, Rodwell 1991). Nonetheless, alliances of the Braun-Blanquet system typically contain broadly uniform physiognomic and habitat characteristics comparable to the concepts and standards put forth here. In Australia, Specht et al. (1974) used a similar approach to define alliances for the entire country.

In comparison to the association then, the alliance is more compositionally and structurally variable, more geographically widespread, and occupies a broader set of habitat conditions. Because it is a more inclusive concept, it may be expected to contain a greater set of diagnostic species than the association. Indeed, although the need for character species (i.e. species with high fidelity to a type) is not critical for associations, it remains important to do so for alliances. That is, alliances should contain diagnostic or character species "that appear almost exclusively, or at least preferentially, in a particular unit." (Ellenberg 1988). Alliances that are defined narrowly based on specialized local habitats, locally distinctive species, or differ primarily in the relative dominance of major species, are to be avoided.

Many forest alliances are roughly equivalent to the "cover types" developed by the Society of American Foresters (SAF) to describe North American forests (Mueller-Dombois and Ellenberg 1974, Eyre 1980). In cases where the cover type is based solely on differences in the co-dominance of major species (e.g. Bald Cypress cover type, Water Tupelo cover type, and Bald Cypress-Water Tupelo cover type), the alliance may be broader than the cover types. However, in cases where the dominant tree species extend over large geographic areas and varied environmental, floristic or physiognomic conditions, the alliance may represent a finer level of classification than the SAF cover type. In these situations, multiple dominant or co-dominant tree species as well as habitat may be needed to meet the required diagnostic level of physiognomic, floristic, and environmental specificity for identification of an alliance type. Jack pine (*Pinus banksiana*) forests and woodlands, for example, may be placed in one or more different alliances (see Anderson et al. 1998); those with a pure evergreen woodland structure belong to the Jack Pine-Red Pine Woodland Alliance, others with a pure evergreen- forest physiognomy to the Jack Pine Forest Alliance. Such alliance distinctions are best made when supported by additional floristic information across all vegetation layers and from habitat information, in particular the need for clear diagnostic species. For example, distinguishing mixed Jack Pine-Aspen forests from pure evergreen Jack Pine forests based on physiognomic grounds may not be supported by floristic and habitat criteria.

The alliance also is similar in concept to the "series," a group of habitat types that share the same dominant species under apparent climax conditions (Pfister and Arno 1980). Alliances differ from the series concept in that alliances, like associations, are based on existing vegetation,
regardless of successional status. For example, a shrub type that dominates after a fire would be

classified as distinct from both the forest type that was burned and the possible forest type that may eventually reestablish on the site. The series concept emphasize the composition of the tree regeneration layer more than tree overstory composition in order to reveal the *potential* homogeneity of late-seral or climax canopy conditions based on the current tree population structure.

4.3. LIMITATIONS OF FLORISTIC CONCEPTS

A review of how the association and alliance concepts have been applied reveals that they have not been applied to cropland or other kinds of cultivated vegetation, although they are applied to abandoned agricultural land, road verges, trampled vegetation, permanent pastures, and other kinds of seminatural and anthropogenic vegetation. Since we are unaware of any experience with which to develop standards for floristic classification of artificial assemblages such as crop monocultures or orchards, at this time we recommend that the terms association and alliance be applied to natural and seminatural vegetation. Additional standards must be developed before vegetation consisting primarily of planted species can be recognized at the association or alliance level.

4.4. STANDARDS FOR FLORISTIC UNITS

1. The standard definitions for the floristic units of vegetation are:

    a. Association: A recurring plant community with a characteristic range in species composition, specific diagnostic species, and a defined range in habitat conditions and physiognomy or structure.

    b. Alliance: a grouping of associations with a characteristic physiognomy, and sharing one or more diagnostic species, which, as a rule, are found in the uppermost or dominant stratum of the vegetation.

2. Diagnostic species exhibit patterns of relative fidelity, constancy or abundance that clearly differentiate one type from another.

3. Diagnostic criteria used to define the association and alliance should be clearly stated, and the range of variability in composition, habitat, and physiognomy and structure should be clearly described. Alliances, in particular, require clear evidence of diagnostic species that are exclusively, or preferentially, found in a given alliance.

4. Associations and alliances are categories of existing vegetation, namely, the plant species present and the vegetation structure found at a given location at the time of observation.

5. Associations and alliances recognized within the NVC must be defined so as to nest within categories of the recognized physiognomic hierarchy (e.g. in FGDC 1997, Association, Alliance, Formation, Subgroup, Group, Subclass, Class; see Figure 1).

5. VEGETATION FIELD PLOTS

A basic premise underlying our standards for defining alliance and association units is that they are best described and analyzed from plot data collected in the field using standard methods. Agreement on common data standards for plot sampling is of prime consideration for developing a scientifically credible NVC. Without such agreement, efforts to accurately recognize, describe, and compare units of vegetation will be very difficult.

5.1. MAJOR TYPES OF REQUIRED DATA

The focus of plot sampling is on the vegetation and its habitat or environment. The interpretation of the information collected in the plot itself requires metadata. Consequently, data collected during plot sampling for the NVC fall into three main categories:

1. Vegetation data: floristic composition and structure of the vegetation that can be used to classify vegetation. This, in turn, can be divided into floristic data (plant species or taxon-specific data) and physiognomic and structural data (the outward appearance and vertical layering of the vegetation).
2. Environmental data: the habitat, geographic location, and stand history, including:
   a) assessment of the abiotic factors (soils, parent material, elevation, slope, aspect, topographic position, climate etc.),
   b) stand history and disturbances,
   c) geographic location and landscape position of the stand.
3. Metadata: data that describe the vegetation and environmental data and the methods used to collect them. Examples of required metadata are the method and precision used to determine plot location, the field methods , the nomenclatural (taxonomic) source for identifying/naming plant species, the field personnel (including names and contact information or institutional affiliation) and the sampling date.

Not all vegetation studies that use field plot data are focused on classification. Investigators may have a variety of objectives when collecting plot data (e.g., fire history, old growth structure, nutrient cycling). However, if these plot data are used to support NVC types, these investigators need to collect the data described below.

This chapter is not a definitive guide to vegetation sampling and description. Discussion of these issues can be found in other references (e.g., Mueller-Dombois and Ellenberg 1974, Gauch 1982, Kent and Coker 1992, Jongman et al. 1995). Rather, we want to alert investigators to the kinds of issues that must be considered when collecting vegetation plot data for the purpose of developing or supporting a vegetation classification. The standards here emphasize the minimum information needed to support the development of a scientifically credible, floristically based NVC.

5.2. STAND SELECTION AND PLOT DESIGN

Sample selection

Vegetation classification surveys are typically focused on detecting the full range of vegetation pattern in a region or on a rangewide assessment of one or more vegetation types. To achieve adequate representation of all vegetation in the focal area or type under study, sampling is usually preceded by reconnaissance (ground or aerial) to assess the major patterns of variation in vegetation (or its underlying environmental gradients) and by some method of sample selection. For example, the major environmental factors may be used to create a type of "abiotic grid" within which to select points for field sampling (e.g., the gradsect technique; Austin and Heyligers 1991). Sample (or stand) selection is a critical step because it determines how well the plots will represent the area under study. By *stand* we mean a contiguous area of vegetation that is reasonably uniform in physiognomy, floristic composition, and environment.

Selection of samples or stands can be done either using *preferential* sampling or *representative* sampling (Podani 2000). With preferential sampling, stands are selected based on the sampler's previous experience, and stands that are "degraded" or "atypical" may be rejected. Stands selected for sampling are considered typical of the vegetation of which it is a part, and each plot sampled therein is expected to yield a more or less typical description in terms of both floristic composition and structure (Werger 1973). By contrast, representative sampling involves a means of selecting stands (or even points) with some degree of random element to represent the "universe" of vegetation within which the study is being conducted. The selection of stands may vary from simple random, stratified random (including the environmental grid or gradsect approach noted above), systematic, or semisystematic (Podani 2000). After the points are selected, stands may be delineated around the points to assist with sampling. Either preferential or representative sampling will yield plots suitable for inclusion in analyses of the NVC, but representative sampling will typically lead to a less biased set of plots.

For a variety of reasons, sample or stand selection may be limited to only part of the vegetation present in an area. Many studies focus only on natural vegetation, including naturally disturbed, and various successional stages of vegetation. Others may be most interested in late-successional or mature natural vegetation. However, in principle, the NVC applies to existing vegetation, regardless of successional status or cultural influence. Criteria used to select stands should be thoroughly documented in the metadata.

Plot location

Following reconnaissance and stand or point selection, a plot or series of plots are then located within a stand. Plots, typically a fixed area in which vegetation data are recorded, may be located subjectively or objectively. Each plot should represent one entity of vegetation in the field; that is, a plot should be relatively homogeneous in both vegetation and habitat and large enough to represent the stand's floristic composition. In open tree or shrub vegetation, for example, plots should be large enough and homogeneous enough that the relative importance of the tree or shrub component within the plot is comparable to that of the surrounding stand. Homogeneity in vegetation refers to the homogeneity of plant cover. Dahl and Hadac (1949) gave this definition of homogeneity: "A plant community is said to be homogeneous if the individuals of the plant species which we use for the characterization of the plant community are homogeneously distributed." They point out that communities are never fully homogeneous, and that an investigator should be satisfied with more or less homogeneous communities. Indeed, the main requirements for homogeneity can be met as long as obvious boundaries and unrepresentative floristic or structural features present in the stand are avoided (Rodwell 1991). Decisions about plot placement and homogeneity must be included in the plot metadata. These initial decisions are important, as both stand selection and plot placement within stands affect data quality.

The floristic composition and structure of a plant community will differ in space and time. Seasonal changes, even during the growing season, can be dramatic in some types of vegetation. Large shifts in floristic composition over one to several years can occur in response to unusually dry or wet weather conditions or to fire. Some forest types (e.g., mixed mesophytic forests) may have a diverse and prominent, but ephemeral, spring flora. Some deserts have striking assemblages of annuals that appear only once every decade or two. Although plot records for the NVC are based on the existing vegetation at the time of sampling, plots that are known or expected to be missing a substantive portion of the likely flora must be so annotated to enable future analysts to properly interpret their data quality. Repeated inventories may be made over the course of a season to fully document the species in the 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. Conversely, multiple visits over different years should be treated as separate plot observations (Poore 1962).

Plot design

Two fundamentally different approaches are commonly used for sampling vegetation: a single large plot or a plot consisting of multiple small subsamples. Both can provide adequate data for vegetation classification, but each method has its own requirements and utility.

<u>Data from a single, large sampling unit (plot)</u>

This is an efficient, rapid method for collecting floristic and physiognomic data for classification. The plot size is chosen to ensure that the plot is small enough to remain relatively uniform in habitat and vegetation, yet is large enough to include most or a majority of the species that occur within the stand. Proponents of this method explain that (1) sampling must be concentrated in a modestly sized area to ensure that the environment is not too heterogeneous, and (2) the overall plot should be contiguous so that it is clear that the composition reflects the interactions among the component species and not some generalized average. The data permit statistical assessments between stands but not within a stand.

Recommended plot size varies within wide limits, depending on vegetation formation and layer. Plot sizes have also been based on the need for the plot to meet or exceed a critical "minimal area" of the community; that is, an increase in plot area should be expected to yield few or no new species and none of major significance for vegetation structure or physiognomy (Mueller-Dombois and Ellenberg 1974). Plots larger than this are acceptable, but smaller plots provide inadequate floristic data for developing a vegetation classification. Recommended sizes vary with the vegetation being sampled. For instance, in most temperate hardwood or coniferous forests, plots of between 10x20 m and 20x50 m are adequate for characterizing both the herb and the tree layers, whereas in many tropical forests, plots between 20x50 m and 100x100 m may be required. Grasslands and shrublands may require plots between 10x10 m and 20x20 m, moss and lichen-dominated communities may require plots between 1x1 m and 10x10 m, and deserts and other arid-zone vegetation may require very large plots between 20x50 m and 50x50 m in size, because the vegetation cover is sparse and species may be widely scattered. These recommended plot sizes typically satisfy minimum area calculations (McAuliffe 1990).

Rather than vary plot size by vegetation type, Whittaker developed a 0.1 ha diversity plot method that would be applicable to a wide range of vegetation types, thereby facilitating comparisons of species diversity among types (Naveh and Whittaker 1979, Whittaker et al. 1979, Shmida 1984). Data are collected in a series of nested plots that can be used to calculate a species-area curve. This method is discussed further below (see Hybrid approaches).

We do not specify or recommend any particular plot shape; in fact, plot shape may need to vary, depending on whether the stand is linear (e.g., riparian stands), broad (e.g., floodplain stands), or some other shape.

Data from multiple small sampling units

This sampling approach yields data that can be used to assess internal variability within a stand and to more precisely estimate the average abundance of each species within the stand. It is often used to measure treatment responses or other experimental manipulations of the vegetation. This approach may be useful for sampling vegetation in topographically gentle terrain where boundaries between stands may be diffuse. This method is inferior for measures of species number per unit area (but see below), but superior for estimates of statistical variation both within and among stands.

Investigators using the multiple small plot methods may locate their sample units randomly or systematically within the stand. The sample unit can be a quadrat, line-belt or point-transect of various sizes, lengths, and shapes. Quadrats for ground layer vegetation typically range from 0.5x0.5 m to 1x5 m, and anywhere from 10 to 50 quadrats may be placed in the stand, again, either randomly or systematically. Quadrats for trees, where measured separately, typically run on the order of 10x10 m or more. Even though samples may be taken throughout a large portion of the stand using this method, the total area on which data are recorded may be smaller than if the investigator used a single large plot (e.g., 50 1x1 m quadrats dispersed in a temperate forest stand will cover a 50 square meter area, whereas a single large plot may cover 200 to 500 square meters).

When using smaller sampling units, it is important to consider the tradeoff between the greater precision of species abundance obtained with smaller, distributed units versus the greater accuracy of a more complete species list and generalized abundance measure obtained using the single large plot. A major disadvantage of relying solely on subsamples to characterize the stand is that it requires a larger number of small sample units to adequately characterize the full floristic composition of the stand. Yorks and Dabydeen (1998) showed that relying on subsamples alone would miss between 32 and 54% of the species found in a single large plot. Thus, whenever quadrats or transects are used, we highly recommend that a list of "additional species present" within a larger part of the stand, such as some fixed area around the subsamples, be included. For example, the California Native Plant Society uses a 50 m point transect method within a 50 x 5 m area and augments the transect species record by listing all the additional species in the full 250 m^2 area (Sawyer and Keeler-Wolf 1995).

Hybrid approaches

Hybrid methods can combine some of the advantages of the two approaches. Sometimes, several somewhat large plots (e.g., > 200 square meters in a forest) are established in the stand to gain some sense of internal stand variability. The plots are sufficiently large that, should variability between plots be high, the plots could be classified separately. A different strategy is for plots of differing sizes to be nested and used for progressively lower vegetation layers, such that plot size decreases as one moves from the tree layer to the shrub and herb layers. The presumption is that variability in composition or abundance decreases for lower layers. Although efficient with respect to quantitative measures of abundance, especially for common species, this method also risks under representing the floristic richness of the lower layers, which are often more diverse than the upper layer. This problem can be ameliorated by listing all additional species found outside the nested plots within the largest plot used for the upper layer. Again, the fundamental concern is that the plot method provide an adequate measure of the species diversity and structural patterns of the vegetation for the purposes of classification.

Finally, a hybrid approach was developed by Whittaker using a 0.1 ha (1,000 square meters) plot (Naveh and Whittaker 1979, Whittaker et al. 1979, Shmida 1984). In this method, where the emphasis is on being able to compare vegetation of different types using the same technique, the herb layer is recorded in a series of subplots nested within the single large 0.1 ha plot, thereby generating diversity estimates at multiple spatial scales and permitting the calculation of a species-area curve (see Stohlgren et al. 1995, Peet et al. 1998, Yorks and Dabydeen 1998). Trees are generally recorded for the entire plot, as are any species that did not occur in the subplots, thereby producing standard estimates of diversity up to the 0.1 ha level. This plot approach has the added advantage in that it documents all vegetation types at several consistent scales of resolution.

5.3. VEGETATION PLOT DATA

There are three types of data needed for effective vegetation classification—vegetation data, environmental data, and metadata. Of these, data on the structure and floristic composition of the vegetation must meet especially strict criteria. Environmental, or habitat, data, such as edaphic conditions, topographic position, and disturbance history, are also critical, but their requirements are not as demanding. It is the quality of the vegetation data that largely determines whether a plot qualifies for use in the NVC.

We have developed different standards for two different types of plot data depending on whether (a) the plots can be used to develop types for the NVC classification (*classification plots*), or (b) they provide important information relevant to existing NVC types but are incomplete in some manner that prevents their use for primary classification analysis (*observation plots*). The minimum set of plot attributes that should be collected for each field plot for both kinds of plot records (classification and observation) are listed in Appendix 2. Additionally, to ensure that as many kinds of classification plot sampling data as possible are available to develop the NVC, Appendix 2 also distinguish between those fields that are minimally required for classification (category 1) from others that are optimal (category 2). For classification plots, the minimal requirements include a select set of record and location fields, species (taxon) cover, elevation, slope gradient and aspect, plot area, the sampling method used, and the persons who collected the plot. Nonetheless, plots that meet only these minimal requirements are much less valuable for classification than those that contain the optimal set of fields that are part of the standard. Observation plots have essentially the same minimum requirements as classification plots, but they do not require slope gradient, aspect, or plot area, and they have fewer metadata requirements. In what follows we discuss the main features of the plot sampling standards for *classification* purposes.

Vertical structure and physiognomy of vegetation

Select data on vegetation structure and physiognomy are needed to relate associations and alliances to the physiognomic and structural categories of the FGDC (1997) hierarchy.

Physiognomy and structure have overlapping but different meanings. Fosberg (1961) defined vegetation physiognomy as the external appearance of vegetation. Physiognomy in this sense is the result in part of biomass structure, functional phenomena (such as leaf fall in forests), and gross compositional characteristics (such as luxuriance or relative xeromorphy). Structure relates to the spacing and height of plants forming the matrix of the vegetation cover. Similarly, Küchler (1967) defined physiognomy as the overall appearance of a plant community, while its structure is made up of the different life form types, such as trees, shrubs, and herbs, in the community. To be of value as a classification tool for the NVC, the description of vegetation structure by layers (or strata) must be standardized to permit consistent comparisons among data sets.

In terrestrial vegetation, four basic vegetation layers should be recognized whenever they are present: **tree**, **shrub**, **herb,** and **nonvascular** (moss, lichen, algae). For aquatic vegetation, **floating**, and **submerged** layers should be recognized when present. These layers represent a compromise between emphasizing height classification or growth form.[6] They help to convey both the distribution of species by layers and the abundance of each species in each layer. In describing the vegetation structure of a plot, the purpose is to capture the essential (matrix) features of the often-complex stand conditions, rather than to describe the layering in the greatest possible detail.[7]

For each of the layers, their total percent cover and predominant height should be recorded. Total percent cover can be estimated using 5-10% intervals or, if desired, a standard cover scale (see below). The percent cover of the three most abundant growth forms in the dominant or uppermost strata should also be estimated (see Table 2 for a list of growth forms). For example, in addition to total cover estimates for all trees in a stand dominated by the tree layer, separate cover estimates of the dominant growth forms (e.g., deciduous broadleaf trees, needleleaf evergreen trees) should be made. These estimates will help place the plot within the physiognomic hierarchy of the NVC. If desired, an approximate cover for all growth forms in

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[6] The terms growth form and life form are often used interchangeably to refer to the characteristic appearance of a plant under a particular set of environmental conditions (Lincoln et al. 1982, Kuchler and Zonneveld 1988). Growth form as used here simply refers to the overall growth and appearance of a plant. The two terms are sometimes distinguished as follows, "Growth form is a 'plan'," life form is the result of the interplay between the plan and the environment. For example, the environment can shape the growth form tree into the life form shrub (Rauh 1978, Körner 1999). Formal life form types have been created, such as by Raunkiaer (1937, also see Kent and Coker 1992) but they require some knowledge of the plants' life history in a region and are not as practical for field description. Since our list of forms in Table 2 is taken from a list of growth forms by Whittaker (1975, Table 3.1), we retain that term here.

[7] Other kinds of structural data can be important to assess successional trends, such as size class structure of the woody species. These types of data are not required to classify vegetation and therefore are not included in the minimum NVC standards.

the dominant layer (or all layers) could be calculated by assigning each species to a growth form and adding up their cover[8].

In describing vegetation structure, the following rules should be followed:

1. Always recognize the standard layers (tree, shrub, herb, nonvascular, floating, submerged), whenever present. Sublayers (e.g., canopy tree and subcanopy tree, tall shrub and short shrub) can be used, but these should always be used in conjunction with the main layers.
2. The height of a layer is its prevailing upper height, not the average canopy height.
3. The cover of the layer is the total vertical projection of the layer on the ground, not the sum of the covers of all species in the layer. The total cover of the layer will therefore never exceed 100% (whereas, adding up the individual cover of species within a layer could well exceed 100% since species may overlap in their cover).
4. Rambling woody vines can be included in the shrub layer.
5. Epiphytes and lianas are a special case of plant species that are best treated as a growth form independent of the layers mentioned above. For example, epiphytes growing in the tree layer and shrub layer of a stand should not be treated as part of that layer per se in terms of cover and species, but can be listed as an epiphyte category and divided by these layers. Lianas, however, are distinguished as woody vines rooted in the ground and climbing on trees in the tree layer. They should also be treated as a separate category and may also be divided by their occurrence in the different layers. Lianas, though, are not to be confused with rambling woody vines, such as *Smilax*. Moss or lichen species within 0.5 m of the ground are treated as part of the nonvascular layer. Those above 0.5 m can be treated as epiphytes.
6. Plants are assigned to layers based on their predominant position or height in the stand, not by their taxonomy or mature growth form. Consequently, a tree species that has both seedlings and saplings in a plot could be listed in several layers.
7. The herb layer includes all woody or semiwoody plants or creeping vines where these overlap in height. This is a compromise between layers based strictly on height versus growth form. More specific measures of growth form (forbs, grasses, dwarf-shrubs) within this layer can be estimated by assigning species within a layer to a growth form category and calculating an approximate percent cover of the growth form (see footnote 8).
8. The nonvascular layer (sometimes called ground layer) is reserved strictly for cryptogams (mosses, lichens, liverworts, algae and bacteria) even where herbs or woody plants may be reduced to very short heights.

Floristic composition

Species list

For field plots used to classify vegetation, sampling should be designed to detect and record the complete species assemblage of the plot. Only one field visit is required as a

[8] This approach will not be completely accurate, since individual species of a given growth form may overlap in cover, so that one cannot simply add up the individual covers to get a total. Some type of algorithm will be needed. But for most purposes, it may be adequate to use such an algorithm to approximate the total cover of these growth forms.

minimum standard. Generally, plots should be described when the vegetation is adequately developed phenologically. However, some plant species may not be visible in certain seasons (e.g., spring ephemerals) or may be unreachable (e.g., epiphytes, cliff species), and thus not identifiable. All reasonable efforts should be made to ensure that such species are recorded, and their occurrence at least noted. The phenological aspects of vegetation exhibiting clear seasonal changes in floristic composition must also be noted (e.g., young grasses, whose abundances may be underestimated in late spring). In cases where phenological changes are pronounced (especially among dominants), repeat visits are highly recommended.

At a minimum, data must include a comprehensive list of all vascular plant species visible in the plot at the time of sampling. A conscientious effort should be made to thoroughly traverse the plot to compile a complete species list. Nonvascular plants (e.g. bryophytes and lichens) should be listed where they play an important role (e.g., peatlands, rocky talus). We recommend, but do not require, that a list of additional species found in the stand (but not the plot) also be compiled. However, it is important that species within the plot(s) be distinguished from those outside the plot, in order that diversity estimates on a plot (or area) basis are not inflated.

<u>Species by layer</u>

Each species listed in a plot should also be assigned to the main layers (tree, shrub, herb, nonvascular, floating, submerged) in which it is found. Not all plants will fit clearly into the layers recognized, but the purpose of listing species by vegetation structure is to document the composition of the most visible layers of the stand (see the above section "Vertical structure and physiognomy of vegetation").

<u>Cover</u>

For each species found in the plot, whether listed by the main layers or not, some measure of its abundance or performance should be recorded. Abundance can be measured as mere presence or absence, percent cover, 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 abundance measures. The standard measure for vegetation classification purposes is percent cover, which has been widely accepted as a useful measure that can be applied to all species, whether tree, shrub, herb, or other species. Cover is the vertical projection of all the aboveground parts of a species on the substrate surface. Cover values are relatively rapid, reliable, and, for the purposes of vegetation survey and classification, they accurately reflect the abundance of a species from stand to stand (Mueller-Dombois and Ellenberg 1974).

Cover should be recorded for all species in each vegetation layer. For example, separate cover estimates should be provided for *Acer saccharum* (sugar maple) if it is found in the herb layer, shrub layer, and tree layer. Recording abundance of species cover by strata provides a three-dimensional view of the vegetation and facilitates the interpretation of physiognomic and floristic relationships within the FGDC hierarchy. Where species have not been recorded by layer, the total cover of a species within the plot should be recorded. Cover values should be absolute rather than a relative portion of a layer (e.g., if a species forms a monospecific layer with a cover of 50%, the cover for the species is recorded as 50%, not as 100% of the layer). The cover for all species in any single layer (or overall) may be greater than 100%, as the foliage of one species within a layer may overlap with that of another. Cover can easily be converted from absolute to relative cover at a later stage, if that fits the needs of the investigation.

Cover scales

Use of cover classes instead of actual percent cover can speed up fieldwork considerably. Cover class estimates are acceptable because percent cover for a species varies over the course of the growing season (especially for herbs). A practical cover scale needs to be most detailed at its low end, as many species are relatively sparse across all stands and small differences in their cover may be particularly important for classification. Table 3 is a comparison of widely used cover-abundance scales. Among these, the Braun-Blanquet scale, which has been extensively and successfully used for vegetation classification purposes (Mueller-Dombois and Ellenberg 1974, Kent and Coker 1992), has a set of class boundaries at 1%, 5%, 25%, 50%, and 75%. It provides a common minimal set of cover classes acceptable for classification. Any scale used for collecting species cover data needs to be convertible to this common scale by having boundaries at or near 1%, 5%, 25%, 50%, and 75%. By this criterion, all of the scales shown in Table 3 are acceptable.

When recording species cover in a plot, any species noted as being present in the stand, but not found in the plot, should be assigned a unique cover code, so that these species can be identified as not part of the plot itself.

Tree abundance measures

In North America, tree species abundance has often been assessed using basal area or density rather than by using cover. Nonetheless, cover is a requirement for trees because, by using cover for tree species as well as for all other species, it is possible to look at the abundance of all species across all layers and to assess relationships between and among the layers. However, it can be difficult to accurately estimate cover of individual tree species in large plots (e.g., > 500 m^2). In such cases, basal area and stem density measures can be used to augment the cover data. In addition, these data will allow comparisons with a wide variety of other forest plot data. For these reasons, collection of basal area and density (stem area and stem counts) for tree species is encouraged. For those data sets where cover was not collected for the tree layer, but which are otherwise acceptable for classification, it may be possible to calculate an estimate of tree cover derived from basal area and density. The method used to do this, however, must be thoroughly documented.

Environmental data

Environmental data provide important measures of the abiotic factors that influence the structure and composition of vegetation (see Appendix 2). For classification purposes, a select set of basic and readily obtainable measures is highly desirable. Physical features of the stand include elevation, slope aspect and gradient, topographic position, landform, and geology. Soil and water features include soil moisture, drainage, hydrology, depth of water, and water salinity (where appropriate). The soil surface should also be characterized in terms of the percent cover of litter, rock, bare ground, wood, and surface water. Habitat conditions should also be described, including landscape context, homogeneity of the vegetation, phenology, stand maturity, successional status, and evidence of disturbance.

Geographic Data

All plot records must include latitude and longitude coordinates, the datum or spheroid size used with the coordinates, and the projection used, if any. The geographic data must specify whether the spatial units are meters or feet. If a projection is used, include the following information:

1. Longitude of center of projection
2. Latitude of center of projection
3. False easting
4. False northing
5. X axis shift
6. Y axis shift

Geographic data should include a description of the method used to determine the plot location (e.g., estimated from a USGS 7.5 minute quadrangle, used a geographic positioning system (GSP) in the field). An estimate of the accuracy of the plot's location information should also be included. For example, provide an estimate that the plot origin has a 95% or greater probability of being within a given number of meters of the reported location. Additionally, it may be useful to provide narrative information for plot relocation.

Metadata

Metadata are needed to understand how the plot data were gathered (Appendix 2). All field plots must have a project name and project description associated with them, the methodology used to select and lay out the plots, cover scale and strata types used, and the name and contact information of the lead field investigators.

5.4. LEGACY DATA

Legacy data are data collected prior to the publication of these standards. Given that collection of vegetation plot data has been going on in the United States for over a century, with extensive sampling of some parts of the country, these data may contribute substantially to the improvement of the NVC.[9] Some plots may represent stands (or even types) that no longer exist. Others may contain valuable information on the historic distribution and ecology of a plant community or may contain important structural data (such as old growth features) that may be difficult to obtain today.

In using legacy data, however, there are some difficult issues. Problems include: (1) uncertainty about plot location, which is especially common for 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 floristic data; (5) uncertainty about sampling season; and (6) incompatibility of the abundance measures used. The floristic composition of plots in the same plant community may have changed over time due to succession, introduction of exotics, physical disturbance, or other causes. On one hand, being able to measure such changes by comparing the legacy data to data obtained by resampling the plot locations would be invaluable in describing and fundamentally understanding the causes of such changes. On the other hand, if such legacy data were used to train remotely sensed imagery of a significantly different date, the results may be invalid.

For purposes of numeric classification, legacy records can be a legitimate and important source of data, providing that the records are valid, and potential problems such as discussed above are known and dealt with. To include plot records that may be of value to the NVC requires special consideration for missing data, and their special status must be documented in the metadata of the plot database records. Depending on the quality of the data, legacy plots may be either “classification plots” or “observation plots” (see section 5.3 “Vegetation Plot Data,” and Appendix 2).

5.5. STANDARDS FOR VEGETATION PLOTS

1. *Sampling methods*: Methods used to initially entitate the vegetation cover (select stands), selection of plot locations, choice of plot sampling technique, and comprehensiveness of vegetation description must be described in metadata.
2. *Plot methods*: Any plot method used must ensure that the plot is large enough to represent the stand in terms of total species composition and abundance that is adequate for the purposes of classification. We set no standards per se as to the kind of plot method to use.
3. *Plot data:* Plot data fundamentally consist of vegetation information, environmental information, and metadata. Vegetation data should contain information on both vegetation structure (physiognomy) and species composition. Environmental data,

[9] A great deal of the vegetation in the country has actually been field sampled by the USDA Forest Service’s Forest Inventory and Analysis program and the USDA National Resources Inventory program. However, these plot data are by policy not available and therefore do not pertain to the discussion on legacy data.

though not the primary basis for classifying types, are very important for assessing the ecological relationships within and between stands and types.

4. *Physiognomy (structure):* The following layers should be recognized whenever they are present: **tree**, **shrub**, **herb, nonvascular** (moss, lichen, liverwort, alga), and in aquatic habitats, **floating**, **submerged.** For each of the layers, their total percent cover and predominant height should be recorded. The percent cover of the three most abundant growth forms in the dominant or uppermost layer should also be estimated (see Table 2 for a list of growth forms).

5. *Species composition*:

    a. For vegetation classification plots, sampling should be designed to detect and record the complete species assemblage of the stand. Only one field visit at an optimal time of year is required as a minimum standard.

    b. Cover is the required measure of species abundance. Cover scales should be at least as detailed as the Braun-Blanquet cover-abundance scale (<1%, 1-5%, 5-25%, 25-50%, 50-75%, and 75-100%).

    c. Each species listed in a plot should be assigned to the main layers (tree, shrub, herb, nonvascular, floating, submerged) in which it is found, and a separate cover estimate be made for its abundance in each of these layers. At a minimum, total cover of a species in the plot is required. Epiphytes and lianas are a special case and should be listed separately from these layers, though the layer they are found in should also be recorded.

    d. When recording species, any species noted as being present in the stand, but not found in the plot, should be assigned a unique cover code, so that these species can be identified as not part of the plot itself.

    e. The minimum requirements for species composition are:

        i. A comprehensive list of vascular plant species in a plot, recorded at an optimal time of year.

        ii. Total cover of each vascular species in a plot, assigned using percent cover, or a cover scale that can be accurately converted to the Braun-Blanquet scale (<1%, 1-5%, 5-25%, 25-50%, 50-75%, and 75-100%).

6. *Environmental data*:

    a. Physical features of the stand should be described, including elevation, slope aspect and gradient, topographic position, landform, and geology.

    b. Soil and water features include soil moisture, drainage, hydrology, depth of water, and water salinity (where appropriate).

    c. The soil surface should also be characterized in terms of the percent cover of litter, rock, bare ground, wood, and surface water.

    d. Habitat conditions should also be described, including landscape context, homogeneity of the vegetation, phenology, stand maturity, successional status, and evidence of disturbance.

e. The minimum requirement for environmental information is:
    i. elevation
    ii. slope aspect
    iii. slope gradient

7. *Geographic Data:*
    a. Latitude and longitude coordinates,
    b. The datum or spheroid size used with the coordinates,
    c. The projection used, if any
    d. Whether the spatial units are meters or feet
    e. If a projection is used, include the following information:
        i. Longitude of center of projection
        ii. Latitude of center of projection
        iii. False easting
        iv. False northing
        v. X axis shift
        vi. Y axis shift
    f. A description of the method used to determine the plot location (e.g., estimated from a USGS 7.5 minute quadrangle, used a geographic positioning system (GSP) in the field).
    g. An estimate of the accuracy of the plot's location information
    h. Narrative information useful for plot relocation
8. *Metadata:* All plots should have a project name and description associated with them, the methodology used to select and lay out the plots, effort expended in gathering floristic data, cover scale and strata types used, and the name and contact information of the lead field investigators. The minimum requirements are:
    a. Author plot code
    b. Author observation code
    c. Observation date
    d. Field investigator's name, role, and address
    e. Plot area: size of the plot, in meters
    f. Taxon observation area (if subplots are used): size of subplots
    g. Taxon inference area: size of the stand from which the plot is taken
    h. Cover dispersion (if subplots are used, how are they distributed?)
    i. Stratum methods
    j. Description of cover scale

k. Coordinate system

6. CLASSIFICATION AND DESCRIPTION OF FLORISTIC UNITS

Quantitative plot data constitute the primary descriptor of the floristic units. The standards for describing alliances and associations are based on the assumption that their descriptions summarize the results of field-based plot sampling (see Chapter 5). Over time these quantitative descriptions will replace the existing qualitative information on alliance and association types in the NVC (NatureServe 2001). The process by which that is to take place is described further in Chapter 7, the review and acceptance of type descriptions.

6.1. FROM PLANNING TO DATA INTERPRETATION

An association represents a statistical and conceptual synthesis of floristic patterns (Westhoff and van der Maarel 1973, Mueller-Dombois and Ellenberg 1974, Kent and Coker 1992). It is an abstraction, representing a defined range of floristic, structural, and environmental variability. Alliances represent a similar kind of abstraction, but at a more general level. The definition of associations and alliances as individual types of vegetation is the result of a set of classification decisions based on field sampling and data analysis. The process can be conceptualized in three stages: (1) scope and planning of sampling, (2) data collection and preparation, and (3) data analysis and interpretation.

Scope and planning of sampling

For a classification effort to be effective, samples of types should be collected from as wide an area as possible. Although only a few plots may be sufficient to determine that a distinct type is warranted, more widespread sampling—ideally covering the full geographic and environmental range expected—will ensure that the type is adequately characterized and understood in comparison to others that may be conceptually similar. Not all field sampling can be done this comprehensively, however, and we recognize that much of the work will be accomplished in smaller stages and by different investigators. For this reason, those interested in contributing to the classification, even if they are not conducting extensive fieldwork, should use these standards so that their data can at least be integrated with the data of others to contribute to a larger classification data set.

Data collection and preparation

Useful information from existing data sets, other classifications, environmental data such as soils and climate, and maps can be brought together with additional new field data. Criteria for plot sampling methods and for the use of existing (legacy) data sets are specified above in the section on standards for vegetation plot data (Chapter 5). Standards for plot placement and data collection are particularly important to ensure that the standards for uniform habitat conditions and floristic and physiognomic homogeneity are followed.

Data preparation requires coding the species to a standard nomenclature and entering the data into a database. The standard organismal nomenclature for the NVC follows that of Kartesz (1999), USDA PLANTS (http://plants.usda.gov/), and ITIS (http://www.itis.usda.gov/index.html), which is discussed at length in Chapter 8. The Panel is developing a standardized vegetation plot database, known as VegBank (www.vegbank.org), that will ease the burden of data preparation and facilitate mining of existing data from different sources (see Chapter 8). When the data do not meet minimum standards for quality, consistency, and geographic completeness, their limits must be understood and explicitly described.

Data analysis and interpretation

Two criteria must be met in order for any analysis to be robust. First, the samples must represent a wide range of the compositional and structural variation of the proposed vegetation type or group of closely related types. Second, there must be a sufficient level of redundancy in the samples to statistically identify mutually exclusive clusters in the data.

Various methods are available for examining a data matrix of species occurrences (or environmental variables) by field plot samples in order to group the samples into classes based on their floristic and environmental similarities. The substantial menu of available analytical methods allows individual researchers to select those methods that provide the most robust analyses of the available data (for examples, see Braun-Blanquet 1932, Mueller-Dombois and Ellenberg 1974, Jongman et al. 1987, Ludwig and Reynolds 1988, Gauch 1982, Kent and Coker 1992, McCune and Mefford 1999, Podani 2000). A variety of methods may be used to identify and describe a consistent set of vegetation types, and technical improvements will result in changes to specific methods over time.

The four most common approaches used in the identification of vegetation patterns are gradient analysis, ordination, clustering, and tabular analysis. Tabular analysis, a technique widely used in the Braun-Blanquet approach, involves sorting a matrix of species and plots into groups based on their sharing of diagnostic species (Mueller-Dombois and Ellenberg 1974, Kent and Coker 1992). It relies less on multivariate methods than do the others, though any combination of these methods can be used. While gradient analysis is usually a straightforward regression between species and one or more environmental gradients, ordination and clustering encompass a rich array of different numerical methods. Each of these, however, requires particular mathematical processes that should be included in the description of methods used to identify an association. For example, a matrix of samples by species is the first arrangement of sample data, and this matrix should be included in any definitive description. If an analysis of the samples with respect to environmental factors such as soil depth, soil moisture, or land form, is undertaken, a matrix of samples by such factors is also required. Any or all of these techniques form part of the tools that are helpful for defining associations and alliances.

The preparation of data requires that possible sources of noise or identification of outliers in the data be described. The narrative for a type description should include any assumptions or known limitations of the data being used, such as taxonomic issues or uneven environmental data. The methods used and rationale for rejecting some plots based on outlier analyses should be documented (examples of outlier analysis for gradient analysis are provided in Belsey 1980, and for ordination and clustering in Tabachnik and Fidell 1989; also see the outlier analysis function in PC-ORD [McCune and Mefford 1999]). If novel methods are used, they should be described in detail.

When engaging in numerical analysis, an important issue involves the taxonomic level at which the organisms are resolved. As mentioned above and discussed in depth in Chapter 8, all the entities in a set of plots must conform to a single taxonomic standard. However, it is usual in any data set of plots to find entities resolved at various levels, whether genus, species, subspecies, variety, or some other level. Some of the causes for multiple levels of taxonomic resolution in a field plot data set are: (a) the observer was unable to determine a finer taxonomic level of some of the organisms observed in the field, commonly resulting in the field notation "(genus) ssp"; (b) a group of species intergrade, have significant morphological variability, or are not well described or understood; and (c) a species is well described with a number of varieties and subspecies that are recognizable and well known, resulting in some entities in the data set being resolved at a very fine taxonomic level. Because of the variety of reasons for resolving individual taxa differently for any given plot, very few standards for dealing with this important problem can be established at this time. Dominant entities must be resolved to at least the species level. Rarely would an alliance type be described by subspecific entities. Additionally, some general practices are recommended. The rules and reasons used by an investigator in standardizing the thematic resolution of a data set's entities must be carefully documented and explained. For example, the data set may be stratified initially by increments of the average relative cover of each taxonomic entity, then by those entities that are resolved only to the genus level. Those plots having genus level entities with a combined total cover of >20% cover may be judged too floristically incomplete. Or perhaps those plots having >10% of their entities resolved at the genus level or coarser may be excluded. Ecologists are encouraged to strive for resolving and documenting plot entities at the finest level possible in the field. Aggregation of subspecies and varieties to the species level should be carefully documented. Narratives about vegetation types that discuss the subspecies and varieties that were aggregated to the species level for the numerical analysis can be quite useful, especially for future work. This general issue—taxonomic level of resolution with respect to numerical classification of a supposed set of equivalent units of vegetation (alliances and associations)—is one deserving of substantial further investigation.

Methods of data reduction and a rationale for using a given method over others should be described in detail. The similarity or dissimilarity among the field samples should be calculated, and the methods, including distance measures, should be provided. A detailed interpretation of results from all transformations is critical to a convincing argument for formal recognition of an association. More than one analytical method should be used, and converging lines of evidence should be clearly presented. Tabular and graphical presentation of such evidence, such as biplots, dendrograms, and synoptic tables, is important and should be used. Where tabular methods are used, the criteria to identify diagnostic species (such as level of constancy, fidelity, etc.) should be clearly specified. The interpretation of the data is strongly influenced by these summary statistics and the visual products from these data analyses, such as results from ordination and partitioning, multiple-factor direct-gradient analysis, cluster analysis, and tabular analysis. These results by themselves do not identify the associations, but they provide the quantitative basis for their identification.

Finally, any classification analysis of stands across a region should be aware of the issue of locally intensive sampling that can lead to some skewing of the results. It is possible that a set of plots may look very distinctive using conventional numerical methods simply because the samples are positively autocorrelated in space. This may be a particular problem when field data are generally scarce across a region but locally abundant in portions of the range where an intensive survey has been done. Comprehensive methods for evaluating spatial autocorrelation of communities have yet to be developed (Mistral et al. 2000). Measures of spatial autocorrelation is one vital area for which standards are needed, yet are lacking. We recommend that researchers focus on this issue.

There are a wide variety of methods and techniques that can be used to identify and describe an association, but the goal remains the same: to produce types with a defined floristic composition and characteristic physiognomy, occurring in similar habitats. We do not prescribe any one technique or approach to arrive at this definition (see also Chapter 4). Investigators are free to explore any number of techniques and competing type definitions will be handled through dialog and a peer review process (see Chapter 7).

Special consideration in the description of alliances

The recognition of alliances is typically based on the same kind of data used to develop associations. Alliances can be defined as more generalized types that share some of the diagnostic species found in the associations, especially in the dominant layer. However, because the definition of alliances relies more strongly on the species composition of the dominant layer, and because alliances are often wide ranging, it may take more comprehensive analyses to resolve alliances based on a quantitative approach as compared to associations. Thus, we include here some discussion of both qualitative and quantitative approaches to their definition.

The methods for classifying alliances depend on the degree to which associations that make up a given alliance have already been described and classified. Under data-rich conditions, alliances are defined by aggregating associations based on quantitative comparisons of species abundances. If a number of associations have species in common in the dominant or uppermost layer, and those same species are absent or infrequent in other associations, then the associations with those shared dominants can be placed together to form an alliance. Similarity in ecological factors and structural features should also be considered. Care is needed to ensure that a rangewide perspective is maintained when considering how best to aggregate associations. In cases where no truly diagnostic species exist in the upper layer, species that occur in a secondary layer can be used, especially where the canopy is of broad geographic distribution or occupies a diverse range of ecological settings (Grossman et al. 1998).

Under data-poor conditions, alliances may be provisionally identified by a more qualitative recognition of the dominant species in the uppermost vegetation layers, or through data that only consist of quantitative information on species in the dominant strata. In these cases, stands may first be grouped by broadly shared structural characteristics and habitat features, then qualitatively divided into types based on dominant species in the uppermost layer and shared ecological factors. Alliances identified using these methods tend to be most robust when they are part of relatively simple vegetation regions with low floristic diversity, and are dominated by one or a few species. In places with high floristic diversity, nondominant species become more important as potential diagnostic species for vegetation types, and the development of alliances in these regions will take more careful analysis of shared species, genera, or even family patterns. In any case, all alliances developed through such methods do not meet the highest standards for defining floristic units described in Chapter 7. To improve the confidence in these units, they should be refined through data that contain more complete species and ecological information.

6.2. DOCUMENTATION AND DESCRIPTION OF TYPES

The classification process requires accurate documentation of how a particular vegetation type has been recognized and described, as well as a standardized, formal description, or monograph, of each named type. Currently, vegetation types may be defined and published through any means, including the scientific literature. But these may vary widely in methodology and approach, and lack the consistency needed for an accessible, standardized classification. Here we outline a process for describing types based on the standards for field sampling and analysis.

Type Description

Descriptions of alliances and associations need to: (a) emphasize the core vegetation characteristics that define the type; (b) summarize relationships among ecological factors and dynamics; (c) define the overall concept of the type, including key classification issues; (d) identify the field plots and describe the plot sampling methods; (e) describe analyses of the field data and other information; (f) assess the confidence level of the type; and (g) provide a synonymy to other known types (see Box 4).

The rationale for using each of these criteria is explained in more detail below, and an example description is provided in Appendix 1. Throughout the description, the organismal nomenclature should follow that of either Kartesz (1999), USDA PLANTS (http://plants.usda.gov/), or ITIS (http://www.itis.usda.gov/index.html), and should indicate which is used. If PLANTS or ITIS is used, the date(s) the web site was consulted should be included, as these web sites are constantly updated.

Overview

The overview section provides a summary of the main features of the type. First, the names of the type are listed following the nomenclatural rules in Section 6.4 (including Latin names, their translated names (i.e., species common names), and a colloquial or common name for the type). Second, for associations, placement within alliances is indicated (if a new alliance is required, a separate description should be provided); for alliances, placement within formations should be indicated. Next, a summary of classification issues is provided, including the type's placement in the NVC hierarchy, followed by the reasons for choosing the species to name the type. Finally, a summary is provided that describes the type concept, including the geographic range, environment, physiognomy and structure, floristics, and key diagnostic features of the type. Ultimately a unique code will be assigned to the type. This code contains a start date, and serves as the key database tool to track the concept of the type (see Chapter 8).

Vegetation

The association and alliance concepts are defined primarily using physiognomy and floristics, supplemented with environmental data to assess ecological relationships among the species and types.

1. Physiognomy and structure: This section describes the physiognomy and dominant species of the types, including physiognomic variability across the range of the plots being used. Summary information is provided as applicable for each of the main layers (tree, shrub, herb, nonvascular, floating, submerged), including their height and percent cover. Dominant growth forms are also noted.
2. Floristics: This section summarizes the species composition and average cover in the plots for all species by layer. Issues relating to the floristic variability of the type are highlighted. Tables are provided in the following form:

a) A stand table of floristic composition for each layer, showing constancy, mean, and range of percent cover. Criteria for inclusion in the table should be specified. It is recommended that all species with greater than 20% constancy be included to facilitate comparisons of species patterns with that of other types.

b) A summary of diagnostic species, through a tabular arrangement, synoptic table, or other means of identifying and displaying diagnostic species.

3. Dynamics: This section provides a summary of the successional and disturbance factors that influence the type. Where possible, a summary of the important natural disturbance regimes, successional trends, and temporal dynamics should be provided for the type. Information on population structure of dominant or characteristic species may be appropriate along with information on, for example, old growth or other significant characteristics.

Environmental Summary

A general overview is provided of the landscape position (elevation, topographic position, landforms, and geology), followed by more specific information on soils, parent material, and any physical or chemical properties that affect the composition and structure of the vegetation. Preferably, these data are also provided as summary tables of the available categorical and quantitative environmental variables.

Geographic Distribution

This section includes a brief textual description (not a list of places) of the total range (present and historic) of the type. A list of the U.S. and Mexican states, Canadian provinces, and other countries where the type occurs, or may occur, helps to describe the geographic scope of the type concept. The description should distinguish between those jurisdictions where the type is known to occur and those where the type probably or potentially occurs. Also, jurisdictions where the type is estimated to have occurred historically but has been extirpated should also be provided if possible.

Plot Sampling and Analysis

This section describes the plots and the analytical methods used to define a type, as well as where the plot data are archived. The plots used must have met the criteria for *classification plots* (see Section 5.3 and Appendix 2). The plot data must be deposited in a publicly accessible archive that itself meets the standards set forth in Chapter 8. Information should be provided on factors that affect data consistency, such as taxonomic issues or completeness of physiognomic-structural or environmental information. Rangewide completeness and variability in the geographic or spatial distribution of plot locations should also be described (also, see discussion of problems with spatial autocorrelation in Section 6.2). Finally, the methods used to prepare, analyze, and interpret the data should be described, including outlier analyses, distance measures, numerical and tabular techniques, and other interpretation tools.

Confidence

This section summarizes the overall confidence level for the type, whether Strong, Moderate, or Weak (see Chapter 7). These levels reflect the relative degree to which quantitative methods have been successfully used to describe and define a type. Data gaps should be identified where appropriate and suggestions made for further analysis or research. Confidence level is an important tool for maintaining clear standards for the relative quality of the types that are included in the NVC.

Citations

A set of citations used in the descriptive fields above is provided in this section, including references to the literature or other synoptic tables comparing this type to similar types. Finally, a section on synonymies is provided that lists other previously defined types that the author considers synonymous with the type they are describing.

Discussion

Possible subassociation or suballiance types or variants, if appropriate, should be discussed in greater detail here along with other narrative information.

Diagnostic Key to the Type

A dichotomous key to the type is vital to its recognition by others. While detailed standards for such keys have not yet been developed, authors should attempt to provide some type of a key to the type. Guidelines for construction of diagnostic keys will be developed by the Panel in future versions of these standards.

6.3. NOMENCLATURE OF VEGETATION TYPES

Rationale

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 ecologically meaningful. Finally, a name must not be so cumbersome that it is difficult to remember or use. These purposes, though, are sometimes in conflict. For instance, the primary purpose of an unambiguous label is met by "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 standards set forth here strikes a compromise between these needs, including the use of some alternative names for a type (see also Grossman et al. 1998, page 23).

There are two very different nomenclatural approaches to naming associations and alliances: (a) that based on a more descriptive approach, such as practiced by the habitat type approach 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 Canadian Forest Ecosystem Classification manuals in Sims et al. 1989), and (b) the more formal syntaxonomic code of the Braun-Blanquet approach (Westhoff and van der Maarel 1973, Weber et al. 2000).

The descriptive approach uses a combination of dominant and characteristic species to name the type. No formal process of amendments or adoptions of names are followed. By contrast, the Braun-Blanquet approach is a substantially formalized code that, by first using the Braun-Blanquet methodology to identify types, allows individual investigators to assign a legitimate name that sets a precedent for subsequent use in the literature, much like species taxonomic rules. Only two species are allowed in the name, and their name follows Latin grammatical requirements. Hybrid approaches have also been suggested, for example, by Rejmanek (1997, see also Klinka et al. 1996, Ceska 1999). Here we adopt the descriptive approach and, as explained in Chapter 7, rely on a peer-review process to maintain appropriate nomenclature. However, as tracking the ever changing usages of names and concepts of organisms—which forms the basis for the names of associations and alliances—is a challenging task, we also rely on a technical implementation of concept-based taxonomy through the development of VegBank and as described in greater detail in Chapter 8 (also see Berendsohn 1995).

Nomenclatural Rules

Each association is assigned two basic kinds of names: a) the scientific name (see details below) and b) the colloquial or common name—a unique common name used to facilitate understanding and recognition of the community type for a more general audience, much like the common name of species. The scientific name also has a standard translated name; that is, the Latin names of the nominal species used in the scientific name are translated to common names based on Kartesz (1994, 1999) for English-speaking countries (translated names could be developed for other languages). Finally, each association and alliance is assigned a database code. The following nomenclatural rules focus on the scientific name.

The names of dominant and diagnostic taxa are the foundation of the association and alliance names. The relevant dominant and diagnostic taxa that are useful in naming a type are available from the tabular summaries of the types. Names of associations and alliances should include at least one or more species names from the dominant layer of the type. For alliances, taxa from secondary layers should be used sparingly. Among the taxa that are chosen to name the type, those occurring in the same layer (tree, shrub, herb, or nonvascular, floating, submerged) are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/) (Table 4). Taxa occurring in the uppermost layer are listed first, followed successively by those in lower layers. Within the same layer, the order of names generally reflects decreasing levels of dominance, constancy, or other measures of diagnostic value of the taxa. Where there is a dominant herbaceous layer with a scattered woody layer, names can be based on species found in the herbaceous layer and/or the woody layer, whichever is more characteristic of the type. Taxa less consistently found in all occurrences of the association or alliance (less than 60% constancy) are placed in parentheses. In cases where a particular genus is dominant or diagnostic, but individual taxa of the genus may vary among occurrences, only the specific epithets are placed in parentheses.

Association or alliance names include the FGDC (1997) class in which they are placed (e.g., closed tree canopy, shrubland, herbaceous vegetation, etc; see Figure 1). For alliances, the term alliance is included in the name to distinguish these units from association units (Table 4).

In cases where diagnostic species are unknown or in question, a more general term is currently allowed as a "placeholder" (e.g., *Pinus banksiana* - (*Quercus ellipsoidalis*) / *Schizachyrium scoparium* - **Prairie Forbs** Wooded Herbaceous Vegetation). An environmental or geographic term, or one that is descriptive of the height of the vegetation, can also be used as a modifier when such a term is necessary to adequately characterize the association. For reasons of standardization and brevity, however, this is kept to a minimum. Examples are: *Quercus alba / Carex pennsylvanica - Carex ouachitana* **Dwarf** Forest, *Cephalanthus occidentalis / Carex* spp. **Northern** Shrubland.

The lowest possible number of species is used in a name. The use of up to five species may be necessary to define associations, recognizing that some regions contain very diverse vegetation, with relatively even dominance, and variable total composition. For alliances, no more than three species may be used.

Nomenclature for vascular plant species should follow that of Kartesz (1999), USDA PLANTS (http://plants.usda.gov/), or ITIS (http://www.itis.usda.gov/index.html). If PLANTS or ITIS is used, the date(s) the web site was consulted should be included, as these web sites are constantly updated. Nomenclature for nonvascular plants follows Anderson (1990), Anderson et al. (1998), Egan (1987, 1989, 1990), Esslinger and Egan (1995), and Stotler and Crandall-Stotler (1977).

Cultivated Vegetation

At this time, the nomenclature rules apply to natural (near-natural and seminatural) vegetation (see Grossman et al. 1998). This is partly because association and alliance concepts were developed for natural and seminatural vegetation (Chapter 4). However, the NVC is intended to be comprehensive for all vegetation. As an interim measure, we recommend that the nomenclature for planted and cultivated types be as follows: The name will contain the common name of the dominant species, with the scientific name in parentheses, followed by a descriptor of the kind of cultivated vegetation, e.g., Ponderosa Pine (*Pinus ponderosa*) Plantation, Corn (*Zea mays*) Field. These names will be placed directly below the formation unit of the FGDC (1997), equivalent to the alliance level.

6.4. STANDARDS FOR DESCRIPTION OF FLORISTIC UNITS OF VEGETATION

The description of a vegetation type must include the following:

1. Name of natural and seminatural types.

   a. Community nomenclature should contain both scientific and English names, e.g., *Pinus taeda - Quercus* (*alba, falcata, stellata*) Forest Alliance as well as Loblolly Pine - (White Oak, Southern Red Oak, Post Oak) Forest Alliance. For associations, it should also include a colloquial or common name, e.g., Ozark Dolomite Glade. The relevant dominant and diagnostic species that are useful in naming a type are available from the tabular summaries of the types. Dominant and diagnostic species should include at least one, and typically more, from the dominant layer of the type.

   b. For alliances, taxa from secondary layers should be used more sparingly.

   c. Among the taxa that are chosen to name the type, those occurring in the same layer (tree, shrub, herb, nonvascular, floating, submerged) are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/). Taxa occurring in the uppermost layer are listed first, followed successively by those in lower layers.

   d. Within the same layer, the order of taxon names generally reflects decreasing levels of dominance, constancy, or other measures of diagnostic value based on character or differential value.

   e. Taxa less consistently found in all occurrences of the association or alliance (less than 60% constancy) are placed in parentheses.

   f. In cases where a particular genus is dominant or diagnostic, but individual taxa of the genus may vary among occurrences, only the specific epithets are placed in parentheses.

   g. Association or alliance names include the FGDC (1997) class in which they are placed. The word “vegetation” follows “herbaceous” and “nonvascular” for types in those classes. For alliances, the term “alliance” is included in the name to distinguish these units from association units, e.g., *Pinus ponderosa* Forest Alliance.

   h. In cases where diagnostic taxa are unknown or in question, a more general term is currently allowed as a “placeholder,” e.g., *Cephalanthus occidentalis / Carex* spp. Northern Shrubland. For reasons of standardization and brevity, however, this is kept to a minimum.

   i. The lowest possible number of taxa is used in a name. The use of up to five species may be necessary to define associations, recognizing that some regions contain very diverse vegetation with relatively even dominance and variable total composition. For alliances, no more than three species may be used.

j. Nomenclature for vascular plant taxa follows the nationally standardized list of Kartesz (1994, 1999). Nomenclature for nonvascular plants follows Anderson (1990), Anderson et al. (1990), Egan (1987, 1989, 1990), Esslinger and Egan (1995), and Stotler and Crandall-Stotler (1977).

k. The nomenclature for planted and cultivated types should be as follows: The name will contain the common name of the diagnostic species, with the scientific name in parentheses, followed by a descriptor of the kind of cultivated vegetation (e.g., Ponderosa Pine (*Pinus ponderosa*) Plantation, Corn (*Zea mays*) Field). We do not define any hierarchy of nomenclature for cultivated vegetation below the formation.

2. Floristic unit. A description should note what floristic unit is being described, whether "Association" or "Alliance." For planted or cultivated types indicate "Planted/Cultivated."

3. Placement in the hierarchy. Indicate the full name and database code, if possible, of the alliance or formation under which the types should be placed. The list of accepted alliances and formations will be accessible from the NatureServe Explorer web site (www.natureserveexplorer.org) or through the ESA Vegetation Panel web site (www.esa.org/vegwebpg.htm).

4. Classification comments. Describe any classification issues relating to the definition or concept of the type. Any assessment of the proposed type's natural or seminatural status should be clearly identified. Characteristics affecting its naturalness should be noted if known, for example, dependence on seasonal flooding, periodic fire, etc.

5. Rationale for choosing the nominal taxa (the species by which the type is named). Explain the choice of nominal species, for example, whether or not they are dominant, or if they are indicative of distinctive conditions such as alkaline soils, elevation, geographic region, etc.

6. Brief description. Provide a brief (1-2 paragraph) summary of the structure, composition, environmental setting, and geographic range of the community. The summary should start with a sentence or two that provide an overall concept of the type (e.g., This is a dense, often giant conifer forest dominated by *Chamaecyparis lawsoniana* and *Pseudotsuga menziesii*. It is found on serpentine, gneiss, or peridotite soils in the Klamath Mountains of southwestern Oregon and northwestern California). The summary should also include a brief description of a)

environmental setting in which the type occurs; b) structure/physiognomy; c) species by strata; d) key diagnostic characters.

7. Physiognomy. Provide the following summary information for the plots:
    a. Briefly describe the physiognomy, structure, and dominant species, including any issues of variability across the range of the plots taken. Possible subassociation or variants can be discussed.
    b. Complete the following summary table (Table 5) for each layer present (tree, shrub, herb, nonvascular, floating, submerged).

8. Floristics. Species composition and average cover in the plots for all species by layer should be provided in the following summary form:
    a. At minimum, a stand table of floristic composition for each layer, showing constancy and percent cover category, mean, and range. All species should be listed that have 21% or more constancy (Table 6, 7).
    b. Floristic synthesis table derived from the stand table by layer could also be provided, showing the selection of diagnostic species, for example see Kent and Coker (1992, Tables 7.6, 7.7) or Wells (1996, Tables 1-11).
    c. A list of constant, dominant, and diagnostic species that summarizes the above tables. The same species can be listed more than once for different layers and growth forms. Constant species are those occurring in > 60% (i.e. Table 6 constancy classes IV, V) of the field plots used to define a type.

9. Dynamics. Provide a summary of the successional and disturbance factors that influence the type by summarizing information on the important natural disturbance regimes, successional status, and temporal dynamics for this community. Describe the extent to which this information is known and the limitations and assumptions of the assessment. Cite relevant information sources.

10. Environmental description. Provide a detailed description of important factors such as elevation (in meters), landscape context, slope aspect, slope gradient, geology, soils, hydrology, and any other important environmental determinants of the biological composition or structure of the type. The flow of information should generally be from the broad to the specific.

11. Description of the range. Provide a brief textual description (not a list of places) of the total range (present and historic) of the type.

12. List national and subnational (states or provinces) jurisdictions of occurrence in North America. Distinguish between those states and provinces where the type definitely occurs and those where the type probably/potentially occurs. Also note the states/provinces where the type is believed to have historically occurred, but has now been extirpated.

13. List nations outside North America where the type occurs or may occur. Distinguish between those nations where the type is known to occur and those where it is assumed to occur, potentially occurs, or may have occurred historically.

14. Plots used to define the types. List the plots and plot codes that were used to define the type.

15. Location of plot records. Specify where the plots records are stored. All plot records used must conform to the minimum standards described in Chapter 5 and be deposited in a publicly accessible archive that itself meets the standards described in Chapter 8.

16. Factors that affect plot data consistency. Describe all issues that affect plot data consistency (incomplete sampling throughout the range, poor floristic quality of plots, etc.).

17. The number and size of plots. Justify the amount and sizes of plots used in terms of the floristic variability and geographic distribution.

18. Methods used to analyze field data. Discuss the analytical methods used to define the types. Include software citations.

19. Overall confidence level for the type. Assign a level of confidence to the type, whether Strong, Moderate, or Weak (see Chapter 7). The peer-review process ultimately will result in an assignment of a confidence level (see Chapter 7).

20. Citations. Provide complete citations for all references used in the above section.

21. Synonymy. List any relevant type names that already describe this type, either in whole or in part. Include comments or explanations where possible.

22. Additional discussion.

7. PEER REVIEW

While we describe a uniform set of standards for sampling, recognizing, naming, and describing types, these same standards allow for a variety of approaches to defining associations and alliances because the concepts themselves are somewhat general (see Chapter 4). A key part to a credible and continuously improving classification of vegetation is a process by which standardized information can be peer-reviewed. This process will ultimately determine whether a proposed type is recognized as a unit of vegetation in the NVC.

There are a variety of different ways to maintain a standardized set of alliance and association types for the NVC. One model is that used in plant taxonomy whereby individual workers, using credible scientific methods to define a taxa and some generally accepted rules for describing and naming the taxa, publish their results in a journal. To organize the list of types, a committee, or author, then attempts to collect the publications and review and reconcile differences among them in order to provide an up-to-date list of taxon and their descriptions. A second model is for a professional body to administer its own peer-review process, whereby individuals, who publish their results as they choose, also submit their results to a professional body. That body ensures that consistent standards are followed to maintain an up-to-date list of types and their descriptions. Such an approach is used by the American Ornithological Union[10] for bird lists and by the Natural Resource Conservation Service for soil taxonomy (NRCS 2001). The peer-review process we outline here is based on the second model.

7.1. CLASSIFICATION CONFIDENCE

As part of the peer-review process, each type will be assigned a "confidence level" based on the relative rigor of description and analysis used to define it. These confidence levels are needed for several reasons. First, the initial NVC list consists of provisional types adopted, developed, and maintained by TNC and NatureServe (NatureServe 2002). These types include initial descriptions of more than 4,000 associations and 1,500 alliances, most described using the more qualitative process outlined in Grossman et al. (1998). These types represent a wealth of accumulated information on vegetation in the United States and adjacent areas, but many lack some of the rigor required by the floristic standards outlined here. They are already in

[10]Members of the American Ornithological Union's (AOU) 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. This could be, for example, on a revision to a taxonomic group or on 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 email 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 Check-list (R. Banks pers. comm. 2000).

widespread use by state and federal agencies, and although they may, on review, not be sufficient to become high-confidence types, they may be sufficiently documented to be useful and generally recognized. The peer-review process is designed to upgrade and improve on this provisional list. A second reason for confidence levels is that new submissions may document legitimate new types in a less than comprehensive manner required for highest confidence in a type, yet these types also may be useful and be needed for immediate applications. The peer-review process requires some means of reviewing, categorizing, and incorporating these types into the NVC whenever they are clearly distinctive types, while still recognizing their more provisional nature compared to other types.

Classification confidence levels for associations

Level 1 - Strong: Classification is based on quantitative analysis of verifiable, high-quality classification plots from plots that are published in full or are archived in a publicly accessible database. Classification plots meet the minimum requirements for identifying plot location, taxon, taxon cover, elevation, gradient slope, gradient aspect, plot area, sampling method, and collectors, as specified in Chapter 5 and Appendix 1. A sufficient number of high-quality classification plots covering the vegetation type's expected geographic distribution and habitat range, as well as plots from related types across the region, have been used in the analysis.

Level 2 - Moderate: Classification is based either on quantitative analysis of a limited data set of high quality, published, and accessible classification plots and geographic range or on a more qualitative assessment of published and accessible field data of sufficient quantity and quality, but with incomplete quantitative analysis.

Level 3 - Weak: Classification is based on limited or unpublished, or inaccessible plot data, insufficient analysis, anecdotal information, or community descriptions that are not accompanied by plot data. Local experts have often identified these types. Although there is a high level of confidence that they represent recognized vegetation entities, it is not known whether they would meet national standards for floristic types in concept or in classification approach if data were available.

Classification confidence levels for alliances

Level 1- Strong: Classification is based on a quantitative analysis of verifiable high quality classification plots that are published in full and are archived in a publicly accessible database (a classification plot record meets the minimum standards for information on location, taxon, elevation, slope gradient, slope aspect, plot area, sampling method, and collectors, as specified in Appendix 1). A sufficient number of high-quality classification plots covering the expected geographic distribution and habitat range of the vegetation type, as well as plots from related types across the region, have been used in the analysis, and the majority of associations within the alliance have a Strong to Moderate level of classification.

Level 2 - Moderate: Classification is based either on quantitative analysis of a limited data set of high-quality, published and accessible classification plots or on a more qualitative assessment of published and accessible field data of sufficient quantity and quality. Many associations within the type have a Moderate to Weak level of classification confidence.

Level 3 - Weak: Alliances are defined primarily from incomplete or unpublished and inaccessible plot data (e.g., plots may only contain information about species in the dominant layer), from use of imagery, or other information that relies primarily on the dominant species in the dominant canopy layer. The majority of associations have a Weak to Moderate level of classification confidence.

Strong types are well documented based on a set of plots that are available in digital form to anyone wishing to review the primary sources that were used to define them. Moderate types have fairly comprehensive documentation, with many well documented associations , but they may lack one or two attributes required for Strong confidence, such as formal linkage to plots that define the type, or lack of information on the variation in the type across its range. Moderate types will also have been assessed through peer review. Weak types have been described incompletely or in a manner not consistent with the proposed standards.

7.2. PEER-REVIEW TEAMS

An effective peer-review process requires that the review team be broadly based, professional, and represents the interests of the various users and stakeholders. Several teams with regional expertise will consult with each other in cases of overlapping jurisdiction. It is the peer-review team's job to: (a) ensure compliance with classification, nomenclature, and documentation standards, (b) maintain reliability of the floristic data and other supporting documentation, and (c) referee conflicts with established NVC elements.

In order to establish effective peer-review teams, reviewers should have sufficient regional expertise to understand how a given proposed change to the NVC (i.e., additions, mergers, or splits of associations or alliances) would affect related associations and alliances. Our approach is to use a set of geographically based review teams. The process could build on the regional review process that NatureServe has successfully used to build the first approximation of types that are now part of the NVC. Review methods used internally by these regional teams would need to be compatible to those used by others, and changes to types that could potentially occur in more than one region would need to be evaluated by all the appropriate teams.

The process of submitting and evaluating changes to the classification must be simple, clear, and timely. By using a defined template to describe types, descriptions can be readily reviewed and, if accepted, easily uploaded into the database system. The ESA Vegetation Panel will seek to establish and maintain peer-review teams.

7.3. PEER-REVIEW PROCESS

First steps

The standards for confidence levels of NVC types are new, so those types on the current NVC list cannot *a priori* be expected to meet them. However, many current NVC types would qualify as Moderate types given the level of documentation maintained by NatureServe. Thus, the first step in the process requires that NatureServe evaluate the current NVC list and recommend those types that qualify as either Moderate or Weak, based on these standards. By definition, no types currently maintained by NatureServe qualify as Strong, as NatureServe has not been storing primary plot data, except for local projects. Once this initial screening process is complete, the NVC list will consist of a first set of Moderate and Weak types. This list of NVC types and their descriptions will be publicly accessible through the NatureServe Explorer web site (www.natureserve.org/explorer) and will set the stage for the formal peer-review process.

Peer Review

Investigators who plan to describe association or alliance types will start from the NVC list (as created by the steps listed above) to determine whether their type is distinct, or whether their data will instead refine or upgrade the definition of a type already on the list. Two kinds of peer review are available. If an investigator proposes to describe a type at the Strong or Moderate level, a *full peer-review process* is required. If the investigator does not have sufficient information to do that, but is convinced that the type is new to the NVC, he or she can submit the type as a Weak type and an *expedited peer-review process* will be used (Figure 3).

<u>Full Peer Review</u>

The full peer-review process includes the following:

1. An investigator electronically submits a type description following procedures, templates, and required data fields, outlined in Chapter 6, to a managing coordinator of the peer-review teams.

2. The coordinator evaluates the submission to determine if it meets the criteria for full peer-review. If rejected, the submission is returned to the investigator with an explanation.
3. If approved for full peer review, the coordinator sends the submission to a lead team member of a regional review team, who then handles the review by sending the submission to three reviewers in the region. Regional leads may inform other regional leads of the submission, depending on whether the type has a broad or narrow distribution.
4. Reviewers assess the proposal, including a review of the implications for existing NVC types, assess confidence level of the proposed type, and return their review to the regional lead.
5. Reviews are returned to the lead regional reviewer and
    a. The lead reviewer makes a decision to
        i. accept as either a Strong or Moderate type,
        ii. accept with modifications,
        iii. reject, but recommend as a Weak type, or
        iv. reject.

        All comments are sent to the managing coordinator.
    b. If the submission is accepted, the lead reviewer indicates what effect (if any) this submission may have on other types in the NVC not addressed by the submission. If an effect to other types is determined to be significant, the lead reviewer then sends this review to other regional leads for their comment and proposes other updates to related NVC types. Additional input from the investigator may be required.
    c. If rejected, the type description may still be either accepted as a Weak type, if the managing coordinator judges that the type may be new to the NVC list, or, if undecided, the managing coordinator may use an expedited peer-review process to further assess its potential as a Weak type.
6. The managing coordinator informs the investigator of the results of the peer review.
7. If submission is accepted, the managing coordinator ensures that the NVC list and database are updated.
    a. The managing coordinator sends the accepted submission to the database manager of the NVC to upload the new changes.
    b. The managing coordinator ensures that NVC information for any related types in the NVC that are affected by the submission are also updated.
8. Updates to the NVC are posted in the NVC electronic journal.

Expedited Peer Review – Weak Types

1. An investigator(s) electronically submits a description following the outlined procedures, templates, and required data fields, presented in Chapter 6, to a managing coordinator of the peer-review teams.
2. The coordinator would first evaluate the submission to determine if it meets the criteria for expedited peer-review of a Weak type. If rejected, the submission is returned to the investigator.
3. If approved for expedited peer review, the coordinator sends the submission to a lead team member of a regional review team. The regional leads may work with any experts in the region to help assess the validity of the type, and makes a decision about the type.
4. Results from step 3 are sent to the coordinator
   a. The coordinator informs the investigator of the team's finding.
   b. If the submission is accepted, the managing coordinator ensures that the NVC list and database are updated.
   c. The managing coordinator sends the accepted submission to the database manager of the NVC to upload the changes.
   d. The managing coordinator also ensures that NVC information for any related types in the NVC that are affected by the submission are also updated.
5. Updates to the NVC are posted in the NVC electronic journal.

Outcomes

One outcome of a peer-review process is that an existing Moderate or Weak type on the current NVC list may be substantially revised and become a Strong type, or it may be deleted and completely replaced by a Strong or Moderate type. Types submitted for peer-review that are not already on the NVC list would not be added to the NVC list until peer review had been completed. Submissions of Weak types, i.e. types with insufficient documentation to warrant full peer review, but for which there is enough credible documentation to warrant its use in a particular project or application, will be handled by an expedited peer review, much as the NatureServe ecology team does now with the NVC list to ensure that a proposed type does not overlap or confound existing types in the NVC.

7.4. PUBLICATION

Currently, all descriptions of associations and alliances in the NVC are maintained in the NatureServe classification database (NatureServe 2001), with key components available on the NatureServe web site (www.natureserve.org/explorer). These descriptions include references to primary and secondary literature. However, a conspicuous problem with the NVC as it currently exists is that there is no publicly accessible primary literature that the general user can refer to when researching the basis for, or the attributes of, a particular vegetation type. The NatureServe web site must be augmented to provide not only an actively maintained NVC list of associations and alliances, but links to a plot database and to digital tables whenever such data exist.

In addition to these linked, online databases, we envision an electronic journal to serve as a home for primary literature. This journal, potentially called "Proceedings" or "Annals," would publish official changes to the list of NVC associations and alliances. The Annals would also include the required supporting information for all changes made to the list, and it would be directly linked to the relevant plot data, housed in a plot database (see Chapter 8). This journal is essential for the success of a publicly accessible NVC and could be part of the NatureServe web site.

Other means of publishing vegetation descriptions are also available. A number of current journals and agency reports are available in which to publish original vegetation descriptions, using whatever classification system desired by the authors. There may also be a need for a journal that emphasizes monographs of North American vegetation. In any case, this primary literature can be consulted, as it has always been, for information that may contribute to the definition of types in the NVC.

7.5. STANDARDS FOR PEER REVIEW

1. The peer-review process is to be based on the model where a professional body administers the process. Investigators participating in the NVC must submit their methods and results to a panel of peers who will ensure that specified and consistent standards are followed for the maintenance of a robust, continuously improving classification.
2. The objectives of the peer review team are to: (a) ensure compliance with classification, nomenclature and documentation standards, (b) maintain reliability of the floristic data and other supporting documentation, and (c) referee conflicts with established NVC elements.
3. Reviewers should have sufficient regional expertise to understand how a given proposed change to the NVC would affect related associations and alliances.
4. Each type will be assigned a confidence level (Strong, Moderate, Weak) based on the relative rigor of the data and the analysis used to identify, define, and describe the type.

5. Investigators participating in NVC will use a defined template for type descriptions that can be readily reviewed and, if accepted, easily uploaded into the database system.
6. Investigators who plan to describe association or alliance types must start from the list of existing NVC types to determine whether the type under consideration is distinct, or whether their data will instead refine or upgrade the definition of a type already on the list.
7. Two kinds of peer review are available. If an investigator proposes to describe a type at the Strong or Moderate level, a full peer-review process is required. If the investigator does not have sufficient information to do that but is convinced that the type is new to the NVC, he or she can submit the type as a Weak type, and an expedited peer-review process will be used.
8. Full descriptions of types will constitute the NVC primary literature and will be published in an electronic journal. This journal will publish official changes to the list of NVC associations and alliances. It will include the required supporting information for all changes made to the list, and it will be directly linked to the relevant plot data.

8. DATA ACCESS AND MANAGEMENT

8.1. INFORMATION FLOW AND THE USER COMMUNITY

Data availability and management are central to the organization and implementation of the National Vegetation Classification. Most issues regarding the organization of the NVC can be clarified by careful consideration of information flow into, through, and out of the NVC. In effect, information flow defines and holds together the many parts of the NVC. The information flow we anticipate is presented graphically in Figure 2 and is summarized in the following paragraphs.

The fundamental unit of vegetation observation is the plot (Chapter 5). Vegetation scientists use plots to observe and record vegetation in the field. At a minimum, a plot contains information on location, spatial extent, species present, their cover values, select environmental data and metadata. Collection of plot data is a distributed activity external to the NVC itself, driven by the needs and interests of numerous organizations and individuals. All should be encouraged to submit plot data to a publicly accessible plots database, either as components of proposals for changes in the NVC or as separate submissions of basic data. Receipt and quality control of incoming plot data, as well as management and maintenance of the plots database, will be one role of an NVC management team.

A *Vegetation Plots Database* is needed to store, preserve, and distribute plot data that meet recognized minimum standards. Although a public vegetation plots database with Internet access tools is required, so too is a desktop version for local data preparation, manipulation analysis, and submission. The ESA Vegetation Classification Panel is currently developing the VegBank plot database to meet this need (www.vegbank.org).

Plots are used to develop vegetation classifications. Investigators will be expected to include plot data and summaries in their descriptions (see Chapter 6). Eventually, plot data that relate to descriptions of each vegetation type will be documented in a *Vegetation Classification Database*, which will refer to the individual plots used to develop the types. All of these plots will be referenced to types in the Vegetation Classification Database and will be publicly available. We anticipate that NatureServe will maintain the classification database in its Heritage Data Management System (HDMS).

The Vegetation Classification Database will be viewable and searchable over the web, and it will be regularly updated. All updates will be date-stamped to allow reconstruction of the information for any given past date, facilitating citation in literature and legal documents. In addition, the primary literature, composed of the successful proposals for additions and changes, must be permanently and publicly available as a form of digital journal.

All stages in this information flow contain references to plant names, but using different taxonomic standards for different plots weakens our ability to compare and synthesize plot data. A concept-based *Taxon Database* (following some of the principles described by Berendsohn 1995) is needed to avoid these problems.

Participation by the user community could be increased by building appropriate rewards into the NVC database system. If the classification database is designed to accommodate modification for other uses, and if the plot database has user-defined fields so as to be more flexible in the kinds of data archived, more users and more uses will be likely. If all interested parties are given opportunities to propose changes in the classification and are given proper credit, a steady stream of proposals for improvement can be anticipated. If a linkage between the classification system and some form of electronic publication is established, much higher participation can be expected on the part of academics and those government researchers who depend on journal publications for professional advancement.

8.2. BASIC DATABASE REQUIREMENTS

Data management is central to the NVC as a dynamic body of information. The NVC will be a work in progress for many years, and we can anticipate rapid change as more data become available and more associations and alliances are documented. In order for users to make the best use of the classification, the NVC needs to be continuously accessible and updated as information and improvements become available. It is essential that the classification be archived in such a way that it can be reconstructed for any particular date in the past. If the NVC is to serve as a national standard, the exact content of the classification at any specified time, as well as a complete documentation of the changes made, will need to be recoverable by users. Otherwise, it would be impossible to know what standards and criteria were employed by any particular project or how to reconcile or align the definitions employed by related projects.

Computer and telecommunications technologies evolve rapidly; database systems that are optimized to best exploit the attributes of a particular software product and operating system are notoriously difficult or expensive to migrate into new software. Specific user groups can be expected to have institutional reasons for using software products or operating systems different from those used by the majority of participating institutions. Consequently, it is important to design the NVC and its associated databases to maximize transportability between different computer database software and operating systems, and to be based on ANSI/ISO standards when available and appropriate.

The NVC floristic units are linked to the FGDC (1997) physiognomic hierarchy and the utility of the NVC will be maximized if its associated databases allow transfer of the data on floristic types from the FGDC-approved classification hierarchy to alternative hierarchical classification systems. While the NVC itself must be FGDC-compliant in following the established FGDC vegetation classification hierarchy, no one hierarchy is ideal for all uses. The database needs to be structured in such a way that floristic-level information can be provided to those who would use it as part of other classification systems.

Easy-to-use software tools are key to broad acceptance and participation. Development, widespread distribution, and ease of use of a set of software tools that are operating system-independent can be critical in achieving widespread participation by the various constituencies, including government agencies, academics, and sophisticated amateurs. Tools for data preparation, entry, query, access, manipulation, display, and export are critically needed. Because we will not be able to anticipate all the tools needed, or their optimal design, VegBank will accommodate second-party plug-in tools.

8.3. COMPONENT DATABASE ARCHITECTURE

The NVC will require several different component databases: (1) a vegetation plots database containing specific plot records, (2) a taxon database, which maintains the plant species nomenclature, and (3) the NVC classification database containing type descriptions. An overview of the architecture of each follows. Decisions on specific design details, such as file structure and standard data fields, will require collaboration among stakeholders and involvement of a professional database design team.

Plot data

Field plot data and plot databases are to vegetation types what plant specimens and herbaria are to plant species types. The fundamental unit of vegetation information is the vegetation plot; without plot data there would be no tangible basis for classification. A nationwide plots database is needed to hold the plot data that form the basis for documenting, defining, and refining the associations and alliances that constitute the floristic levels of the NVC. Proposals for changes in the NVC must refer either to plots already in the database or new plots proposed to be added to the database. At present, there is no nationwide plots database available to form this fundamental basis of the NVC. Consequently, a necessary step in developing the NVC is establishment of a vegetation plot database linked to the NVC with internally consistent plot data recorded according to the standards laid out in Chapter 5.

Plot data and associated metadata should be publicly available through Internet access tools (although some component data, such as sensitive locations and endangered species occurrences, need to be controlled). These data could be used alone, or in conjunction with new data, by anyone wanting to prepare proposals for changes in the NVC. The requirements for submission of proposals for changes in the list of associations and alliances or their supporting information include digital submission in a form that can be automatically uploaded upon approval of the management team (see Chapter 7, Peer Review).

The plots database should include at least the following functionality:

1. Plots should aggregate into "Projects" that have common attributes (such as author, purpose, and start date).
2. Each plot must have at least one observation but may have multiple observations. Transient site data and metadata should be associated with individual observations rather than the site.
3. Site data that do not change between observations of the same site should be included in each plot record.
4. The database structure and functions must accommodate subplot sampling methods and subsequent retrieval and manipulation of subplots.
5. All field observations, whether as subplots or otherwise, must be collected in a manner that permits them to be aggregated or extrapolated to meet plot-level requirements for classification purposes.
6. Taxon identification is to be linked to a standard list of taxa, but capability should exist for the user to add new or special taxa.
7. The user should be able to define cover class systems for reporting covers, and should be able to define vertical structural classes (layers) for reporting species cover by layer.
8. Reinterpretation of plant taxa identifications by subsequent workers should be recorded permanently as is done with annotation of herbarium specimens.
9. Assignment of a plot observation to a vegetation type by a particular party should be recorded together with methods and rationale. In addition, subsequent reinterpretations of the observation by the same party or a different party should also be recorded.
10. Authors should be able to define new fields not engineered into the database and should be able to tag these as to category for data query purposes.
11. Capability should exist for annotation of any field by either a database manager or a database user.
12. Changes in the database should be logged so that it is possible to reconstruct the content of the database for any time in the past.

Botanical nomenclature

Plant taxa need to be clearly and unambiguously recorded in the plots database and in the classification database. Use of a plant name does not necessarily convey accurate information on the taxonomic concept employed by the user of that name. Vegetation plots are intended to represent records of taxa present at some time and place as observed by some investigator. Data management is made complex by the fact that taxonomic standards vary with time, place, and investigator. When we combine data collected at various times and places by various investigators into a single database, we need to somehow reconcile the different standards applied. The traditional solution has been to agree on a standard list and to map all the various applications onto that list. For example, within the U.S., there are several related standard lists of plant taxa including Kartesz (1999), USDA PLANTS (http://plants.usda.gov/), and ITIS (http://www.itis.usda.gov/index.html). Each of these intends to cover the full range of taxa in the U.S. and lists the synonyms for the taxa recognized. However, these lists fail to allow effective integration of data sets for several reasons. (1) The online lists are periodically updated but are not simultaneously archived, with the consequence that the user cannot reconstruct the database as it was viewed at an arbitrary time in the past. For this reason users should at a minimum cite the date on which the database was observed. (2) One name can be used for multiple taxonomic concepts, which leads to irresolvable ambiguities. The standard lists are simply lists and do not define the taxonomic concepts employed, or how they have changed as the list has been modified. (3) Different parties have different perspectives on acceptable names and the meaning associated with them. If one worker uses the Kartesz 1999 list as a standard, that does not necessarily allow others to merge his data with those of a worker who used USDA PLANTS as a standard.

Much ambiguity arises from the requirement of biological nomenclature that when a taxon is split, the name continues to be applied to the taxon that corresponds to the type specimen for the original name. Consider the case of shagbark hickory, which some authors think of as a single entity and others think should be divided into two entities: northern and southern shagbark. If one encounters the name "*Carya ovata* (Miller) K. Koch" in a database, they cannot be sure of the meaning. The name could mean all shagbark hickories (the meaning applied by Gleason and Cronquist 1952), or it could mean just northern shagbark (the meaning applied by Radford et al. 1968). Trees that Radford et al. recognize as *Carya carolinae-septentrionalis* would be lumped within *Carya ovata* by a worker who followed Gleason and Cronquist. An additional ambiguity is added by the fact that those who think there are two types of shagbark differ in their opinion as to whether they are distinct species or simply varieties. Most botanical workers do not identify to variety individuals that belong to the nominal variety. Thus, even if a worker follows Stone's (1997) treatment of *Carya* in Flora North America, in which the two entities are treated as varieties, they cannot be sure whether plants identified as *Carya ovata* include just *Carya ovata* var. *ovata* (= *C. ovata* sensu Radford et al.), or also include *Carya ovata* var. *australis* (= *Carya carolinae-septentrionalis*) (= *C. ovata* sensu Gleason and Cronquist 1952).

We follow Pyle (2000) in referring to the name-reference couplet as an "assertion" (this is very similar in meaning to the term "potential taxon" used by Berendsohn [1995]). A number of important points emerge from the *Carya ovata* example. (1) A name-reference combination constitutes an assertion of a taxonomic concept, though that assertion might be synonymous with, or otherwise relate to, one or more other assertions. (2) Organism identifications (be they occurrences in plots, labels on museum specimens, or treatments in authoritative works), should be by reference to an assertion so as to allow unambiguous identification of the taxonomic concept intended. (3) A party might choose to recognize a certain set of assertions as accepted concepts, and simultaneously recognize other assertions as nonstandard and bearing some defined or undefined relationship to one or more of the accepted assertions. (4) Identification of the appropriate assertion to attach to an organism does not immediately dictate what names should be used for that assertion. Different parties will have different name usages for a particular accepted assertion. For example, one might choose to label a plant as representing *Carya ovata* var. *australis* as used in Stone 1997, but still choose to use the name *Carya carolinae-septentrionalis* for that name.

Vegetation classification

A database is required to manage the vast amount of information on every Strong, Moderate, and Weak association and alliance in the NVC. All of the required fields for a description of the type (physiognomic, floristic, environmental, etc.) will be stored in the classification database. The descriptions will be linked to the vegetation plots database through the plot numbers that form the basis for the definition of the type.

Each type will be assigned a unique code or identifier to facilitate tracking the concept of the vegetation type. Information will be contained in numbered records with multiple fields. Each record will have a start date and stop date for each unique identifier (element number). At any one time only one record will be effective for any given element (vegetation type). To reconstruct the database on any given date, the user need only employ public software tools to search for those records in effect on the date of interest. Records will never be changed or discarded from the database but will frequently be superseded by new records. The reasons for, and changes associated with, the start/stop of any given record will be permanently recorded in a transaction file.

Currently, much of the information on the provisional list of associations and alliances is stored in the NatureServe database (and is available on the web at www.NatureServe.org). The Panel intends to work with NatureServe to make this database fully serviceable for the needs of the NVC.

8.4. DATA MANAGEMENT

Maintenance of NVC data files should be the responsibility of an NVC management team. Individuals assigned to this function will be able to modify appropriate NVC files. Minor changes based on new information, such as an increase in the range of a species, should be inserted without review, though rules for this have not yet been developed. However, definition, redefinition, or change in the confidence level of an element would require approval of a peer-review team that would coordinate the data management (see Chapter 7).

8.5. STANDARDS FOR DATA MANAGEMENT

1. The NVC database will consist of three components: (a) a vegetation plots database, (b) a taxon database, and (c) a database of alliance and association types.
2. The NVC database will be accessible from the web.
3. The NVC database will be compliant with appropriate standards of the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI).
4. The NVC database will store and maintain all data fields that are recommended as optimal fields for classification plots (Appendix 2).
5. The NVC database will be structured so that floristic-level information can be used under various classifications.
6. Proposals for changes to the NVC must refer to plot records already in the database or new plots proposed to be added to the database.
7. The plots database will accommodate subplot as well as multitemporal sampling methods.
8. The NVC database will provide for user-defined fields.
9. Records will not be changed or discarded from the database but will be superseded by new records. Reinterpretations of vegetation types, the assignment of plots to a type, or of taxa will be archived.
10. Only one record will be effective for any given NVC vegetation type at any one time.
11. Definition of a vegetation type or changes to its confidence level requires a peer-review process.
12. Each taxon must be reported as a name and publication couplet. For example, if the plot author based all the taxa on Fernald (1950), then the names would each be linked to Fernald (1950). If USDA PLANTS or ITIS was used, then an observation date must be provided.

13. 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 with certain identification and must be associated with a note field in the database that provides additional information (e.g., Peet, R.K., plot #4-401, third "unknown grass", aff. Festuca, NCU 777777). For best practice provide a name field to follow the given taxon in parentheses (e.g., *Potentilla* (*simplex* + *canadensis*), Poaceae (aff. *Festuca*)).

14. At the time of a plot's submission to the plots database, each taxon must be mapped to a taxon recognized in USDA PLANTS, ITIS or Kartesz (1999). For example, *Carya ovata* var. *australis* sensu FNA 1997 should be mapped onto *Carya carolinae-sepentrionalis* sec. PLANTS (+date) or ITIS (+ date) or Kartesz (1999). Details should be reported in appropriate database fields where mapping is imperfect or uncertain.

14. All taxa should be reported to the species level. Best practice is that all species be reported to the finest taxonomic level possible in the plots database.

PROSPECTS AND NEW DIRECTIONS

9. LOOKING AHEAD

9.1. DIRECTIONS IN THE UNITED STATES

The United States has great floristic diversity in its vegetation cover, yet the pattern of plant communities making up this cover in space and time are still poorly known. Similar situations exist elsewhere in North America, and a need exists for full collaboration with related work in Canada and Mexico. While standards for sampling and documenting units of vegetation may be agreed to in all three countries, description and scientific acceptance of specific units of vegetation at the alliance and association levels may be years away for many vegetation types. Nonetheless, mapping and inventory of vegetation types at multiple levels of resolution is under way now and will continue under the auspices of state, federal, and private agencies and organizations.

Accordingly, proposals for ongoing use of, and continued improvement in vegetation classification standards, must be understood as a continuing process within a complex context. Five critical elements of this context include the prospects for: new data, new methods for analysis and synthesis, publication of new types of vegetation, new applications of present knowledge about vegetation, and a major new direction, the integration of classification approaches with adjacent countries. The standards described in the previous sections are to set the course for further development in each of these five elements.

Building the classification consortium for the future

The development and implementation of the U.S. National Vegetation Classification in the United States as a viable scientific initiative and practical application will depend on support from a variety of partners. Under the MOU among the FGDC, TNC (NatureServe), ESA, and the USGS, a consortium for vegetation classification is emerging. Future activities of the partners in this consortium will include refining the standards described here, providing open access to databases containing all the supporting information for full classification, and establishing a review process for proposed changes in the floristic units of the classification. The FGDC represents the needs of federal agencies, and it will coordinate testing and evaluation of the classification by these agencies. NatureServe will use its long-term experience with the development and management of the national classification system to ensure a practical continuity in classification applications, as well as continued interaction among applied vegetation scientists. The ESA will represent the needs of, and facilitate interaction with, the professional scientific community. Its long experience with publication and peer review will be a guide to the professional critique needed to ensure credibility of the classification. The USGS will provide information technology to assure broad access to the NVC and its associated products.

Prospects for new data

Relatively few agencies or organizations, if any, are likely to have a database sufficient for immediate and publicly accessible plot-based documentation of vegetation types. Much of the United States still remains to be adequately sampled. General descriptions of vegetation exist, but not with sufficient data to meet the criteria for differentiating associations or alliances at a common level of resolution across the country. Furthermore, many data sets are available in agency or institutional research files that have not yet been made available for analysis.

The establishment of standards, and the development of the NVC, is expected to catalyze the collection of significant amounts of new field data. A reasonable projection can now be made that there will be an increased availability of new data over the next 20 years, through state and federal programs, through the work of NatureServe and its member programs in the Natural Heritage Network, and through university-based studies of vegetation. Using the standards and processes presented here, these new data would meet the need for consistency in identifying, describing, and documenting vegetation types in the incompletely sampled areas of the United States, scaling up to achieve the statistical power necessary for a task of this magnitude. It will eventually advance our understanding of vegetation in the country as a whole.

Prospects for new analytic methods

One goal of the NVC is to create a framework for standards of data analysis and statistical tests for characterizing alliances and associations, and ensuring that these are somewhat flexible. The methods used to achieve the clustering, or grouping, of samples into types, or to determine diagnostic species, are improving continually. The standards outlined in this report will guide the scientific community toward improvement in the analytical tools that will foster consensus on recognized units of vegetation.

Discovery and monographing of new types of vegetation

The nationwide classification of U.S. vegetation will emerge only as the sample database becomes more complete, and the process of comprehensive analysis and monographing becomes established. Such work will be ongoing for many years to come. A significant part of this work will be the reassessment of names and type concepts already published and proposed for consideration at the alliance and association level. The needed careful analysis and documentation is expected to be done by the community of scientists working in many agencies and institutions, and published in short papers or major monographs.

Establishment of peer-review teams will, at the same time, ensure that proposals for changes in nomenclature will take place within a systematic, credible and consensual peer-review process. Researchers will be encouraged to submit proposals for both original findings of new vegetation types and for revisions of types already described, both having to meet reviewer criteria to be included in the NVC. Researchers will, undoubtedly, want to define types in ways that meet their own objectives, but where they also desire to improve the NVC, formal documentation will need to be submitted and subjected to peer-review.

Another area of new work will concern changes in described units of vegetation resulting from the effects of invasive species, climate change, edaphic change, and other broad-scale biophysical dynamics. For example, the potential for enduring change due to invasive species is not well understood, and the effect of the current episode of rapid global mixing of species on vegetation types with respect to stability, distribution, dynamics, functioning, has not been evaluated. The effects of climate change on species distributions is only beginning to be considered. All such factors need to be understood as potentially part of the national classification of vegetation as it develops. However, the operational details await additional sampling, analysis, and monographing.

New applications of present knowledge

A major reason for establishing standards of vegetation classification has been to ensure compatibility of applications across federal agencies, state agencies, universities, and private organizations. With recent advances in mapping and inventory, these applications are likely to expand in breadth. Important applications include the following:

<u>Resource inventory, conservation, and management</u>: Government and private agencies 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 application. Recognition that many rare species are found in uncommon vegetation types also has led to biodiversity conservation through maintenance and restoration measures focused on those types. Further recognition of the services provided by natural vegetation, from flood control to carbon sequestration, has also increased attention on maintaining these systems. Conversely the increasing threat of nonindigenous species to these functions is a research area of growing importance. The scope of these applications will almost certainly expand.

<u>Resource mapping</u>: With standards established for vegetation classification, improved consistency and reliability can be expected of vegetation mapping. Major land development projects, including those associated with Habitat Conservation Plans (see Endangered Species Act 1982, Kareiva et al. 1999), also will use fine-grained vegetation classification as part of the

needed progress toward compatible conservation management. There is also a growing need to establish mapping guideline applications for various resource applications, so that mapping efforts can be coordinated.

Resource monitoring: Throughout the United States, studies have been initiated with a view to monitoring changes in vegetation. Agencies are often mandated to monitor specific resources, such as forests or grasslands, or to assess ecosystem health. However, results from many of these efforts are too coarse in spatial or thematic resolution to be readily useful to land managers, and until now there has been no consistent method used to define species assemblages to monitor. The monitoring may become broad-based, such as assessment of the effects of change in climate or long-term fire suppression, both of which may have induced landscape-scale effects. Such research requires clear definition and documentation of vegetation types as a baseline condition, followed by repeated measurements and comparisons over decades.

Ecological integrity: Vegetation provides a fundamental framework for understanding the complexity and integrity of ecosystems. Vegetation is habitat for hundreds of thousands of species. As it changes over space and time, a ripple effect can be expressed throughout the nation's ecosystems, and because vegetation can be mapped through remote-sensing technologies, it can be used as a surrogate for tracking and understanding many changes in ecosystems.

9.2. POTENTIAL COLLABORATION WITH OTHER COUNTRIES

Exchange of information on sampling and analysis, on databases, and on classification applications among the three largest countries in North America is both an opportunity and an urgent need. With an emerging consensus on the US-NVC under the broad physiognomic-floristic classification framework called the International Classification of Ecological Communities (ICEC; Grossman et al. 1998), significant progress can be expected during the coming years on long-delayed collaborations with the adjacent Nearctic nations of Mexico and Canada, as well as other nations, especially those of the Neotropical realm (Takhtajan 1969).

Canada

A movement is building for a Canadian National Vegetation Classification (C-NVC), using the ICEC approach that complements work already done with the US-NVC (Ponomarenko and Alvo 2000). The Canadian Forest Service is working closely with provincial governments, Conservation Data Centres (CDCS, which are also member programs within the Natural Heritage Network supported by NatureServe), and other federal agencies and organizations to define forest and woodland types similar to the association concept used in this report. The Canadian agencies are developing a number of pilot studies to bring together large data sets (Ken Baldwin, pers. comm. 2001). In addition, individual provinces have conducted extensive surveys using standardized plots, and they either have well-established vegetation classifications or are in the process of building them. Some have already utilized the ICEC framework to develop alliance and associations units, using the same nomenclature and codes for types shared with the U.S. and developing additional names and codes for new types (Greenall 1996). This information is stored in the NatureServe databases, and will ensure that associations developed in the U.S. and in Canada have the potential to be comparable and global in scope.

Mexico and other parts of Latin America

In Mexico, conservation planning is under way through the CDC programs. These include ProNatura Noreste (the CDC in northeastern Mexico), and the CDC in Sonora, Mexico. The planning process brings together experts in vegetation science and has the potential to become a review of floristic types found in the northern states of Mexico. Other more systematic collaborations between vegetation scientists in the U.S. and Mexico are needed.

Elsewhere in Latin America, much interest is being expressed in the upper or physiognomic levels of the ICEC classification (C. Josse pers. comm. 2001). Various national institutions and organizations may begin a formal review of the upper levels as early as 2002. This input will further test the overall framework within which the U.S. National standards have been developed. Floristic units in Latin America have yet to be explored over any but local areas.

9.3. CONCLUSION

The approach to developing a classification of the vegetation of the United States described in this report is a framework for many long-term developments in resource conservation and management, environmental management, and basic vegetation science. The classification only can develop as new data become available and are evaluated. Undoubtedly, new applications of the national classification will emerge and lead to further improvements. The standards described here are to provide a point of departure to those ends.

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GLOSSARY

Words in italics in a definition have their own definition in this glossary.

Alliance—(1) a physiognomically uniform group of Associations (q.v.) sharing one or more diagnostic (dominant, differential, indicator, or character) species which, as a rule, are found in the uppermost stratum of the vegetation (Grossman et al. 1998, FGDC 1997). (2) A ranked category in the classification (q.v.) of vegetation, comprising one or more closely related associations (Lincoln et al. 1982). (3) A grouping of associations (q.v.) with a characteristic physiognomy and habitat and which share one or more diagnostic species that, as a rule, are found in the uppermost or dominant stratum of the vegetation (this document).

Association— (1) a plant community type of definite floristic composition, uniform habitat conditions, and uniform physiognomy (Flahault and Schröter 1910 (2) a plant community characterized by definite floristic and sociological (organizational) features" which shows, by the presence of diagnostic species "a certain independence" (Braun-Blanquet 1928), (3) a type of climax phytocoenosis (Daubenmire 1968), (4) a physiognomically uniform group of vegetation stands that share one or more diagnostic (dominant, differential, indicator, or character) overstory and understory species. These elements occur as repeatable patterns of assemblages across the landscape, and are generally found under similar habitat conditions (Grossman et al. 1998, FGDC 1997). (5) A recurring plant community with a characteristic range in species composition, specific diagnostic species, and a defined range in habitat conditions and physiognomy or structure (this document).

Associes—a type of vegetation in the Western US tradition, to avoid confusion with association (q.v.) as used in the Western US tradition to refer to the latest successional or climax (q.v.) stage species; suggested for use to classify plant communities in earlier recognizable stages of secondary succession (Daubenmire 1968).

Basal Area—the surface of a woody stem (or stems) if cut off at a specific height (usually 1.37 m = 4.5')

Character species—(1) key species by which individual communities in the field can be identified as members of a particular community. Recognition of key species is often sensitive to geographical extent of study (Mueller-Dombois and Ellenberg 1974, pg. 25), (2) a species that shows a distinct maximum concentration (quantitatively and by presence) in a well-definable vegetation types, sometimes recognized at local, regional, and absolute geographic scales

(Mueller-Dombois and Ellenberg 1974, p. 178, 208). (2) species that are found in only one single vegetation unit. (Bruelheide 2000) c.f. differential species.

Class—the first level in the NVC hierarchy (see Figure 1) based on the structure of the vegetation and determined by the relative percentage of cover and the height of the dominant, uppermost life forms (Grossman et al. 1998).

Classification—the grouping of similar types (in this case - vegetation) according to criteria (in this case - physiognomic and floristic) that are considered significant for this purpose. The rules for classification must be clarified prior to identification of the types within the classification standard. The classification methods should be clear, precise, and based upon objective criteria, so that the outcome would be the same regardless of who identifies the location within the classification. (UNEP/FAO 1995, FGDC 1997).

Classification Plot Records—plot records which contain the data necessary to be used to classify vegetation (e.g., high-quality data on floristic composition and structure, with sufficient location, environmental and meta data; see Section 5.3).

Climax Vegetation (1) the stabilized plant community of a particular site where the plant cover reproduces itself and does not change as long as the environment remains the same; (2) the final, stable community of ecological succession that is able to reproduce itself indefinitely under existing environmental conditions (Gabriel and Talbot 1984).

Community (1) a study-able group of organisms which grow together in the same general place and have mutual interactions (Curtis 1959), (2) a system of organisms living together and linked together by their effects on one another and their responses to the environment they share (Whittaker 1975), (3) any group of organisms interacting among themselves (Daubenmire 1978). c.f. plant community

Community Ecology—(1) a subdivision of ecology that examines the qualitative and quantitative changes in community membership in response to environmental factors and species interactions, (2) a study of the manner in which groupings of species are distributed in nature and the ways in which these groupings can be influenced, or caused, by interactions between species and the physical forces of their environment (Begon et al. 1986).

Constant (species)—in vegetation classification, often defined as a species that occurs in more than 60% of the stands of a type (Rodwell 1991).

Cover Estimate—an estimate of the percentage of the surface of the earth (within a specified area) covered by biomass of plants of a specified group (from one species to all species, from one horizontal layer to all growth.). This can be viewed as the percentage of the sky that would be obscured by the biomass. In contrast to leaf area index, the total cover cannot exceed 100%.

Cover Type—a type of community type defined on the basis of the plant species forming a plurality of composition and abundance (FGDC 1997; see this document Section 3.1, also see Eyre 1980).

Crosswalk—organizational and definitional property of a classification standard which provides that all its categories either share a common definition with an FGDC vegetation standard category at some level of the hierarchy, or represent a subset of one and only one category at a given level of the FGDC Vegetation Classification Standard. When a standard crosswalks with the FGDC Vegetation Classification, it means that all categories of the standard have one and only one place with in the FGDC Standard where they logically exist. It does not mean that all categories of the standard must crosswalk to the same level of the FGDC Standard (FGDC 1997).

Diagnostic Species—(1) any species or group of species whose relative constancy or abundance clearly differentiates one type from another (this document, see Section 4.2); (2) an indicator species or phytometer used to evaluate an area, or site, for some characteristic (FGDC 1997), (3) a plant of high fidelity to a particular community and one whose presence serves as a criterion of recognition of that community (Curtis 1959). In the Braun-Blanquet system, diagnostic species comprises the character and differential species (q.v.) used to delimit associations (Bruelheide 2000).

Differential Species—(1) a plant species that, because of its greater fidelity (q.v.) in one kind of community than in others, can be used to distinguish vegetation units (Gabriel and Talbot 1984), (2) A plant which is distinctly more widespread or successful in one of a pair of plant communities than in the other. It may be still more successful in other communities not under discussion (Curtis 1959), (3) a species that shows a distinct accumulation of occurrences in one or more vegetation units (Bruelheide 2000) c.f. character species

Division—level in the FGDC physiognomic classification standard separating Earth cover into either vegetated or nonvegetated categories (FGDC 1997).

Dominance—the extent to which a given species or growth form (or life form; see also predominates in a community because of its size, abundance, or cover.. Dominance is interpreted in two different ways for vegetation classification purposes:

(1) where one or more vegetation layers covers greater than 25% of the area, the growth form within that layer greater than 25% is referred to as the dominant growth form, and (2) where no vegetation life form covers greater than 25%, the growth form with the highest percent canopy cover is referred to as the dominant growth form. In the case of a 'tie', the upper canopy will be referred to as the dominant growth form. (FGDC 1997). (3)Other definitions may refer to (a)

most common taxon of the upper-most stratum, (b) the taxa with the greatest relative basal area (q.v), or (c) more successful taxon in a competitive interaction.

Dominance Type—a class of communities defined by the dominance (q.v.) of one or more species, which are usually the most important ones in the uppermost or dominant layer of the community, but sometimes of a lower layer of higher coverage (Gabriel and Talbot 1984).

Dominant Species—(1) species with the highest percent of cover, usually in the uppermost dominant layer; (2) floristic dominant in terms of biomass, density, height, coverage, etc., (Kimmins 1997; see Section 2.1.3).

Edaphic Conditions—conditions determined by the physical characteristics of the soil or water environment without reference to climate.

Entitation—(see Mueller-Dombois and Ellenberg 1974). The act of dividing something (often a continuously varying) into a set of discreet entities. In vegetation ecology, the act of segmenting the vegetation into entities, within which samples (plots) can be placed. Segments can be defined broadly by canopy physiognomy and dominants sometimes in combination with environmental categories, or more narrowly by both canopy and ground layer characteristics.

Existing Vegetation—the plant species and vegetation structure found at a given location at the time of observation c.f. potential vegetation

Fidelity—the degree to which a species is concentrated in a given vegetation unit. The fidelity of a species determines whether it can be considered a differential or character species, or just a companion or accidental species (Bruelheide 2000)

Floristics—the kinds of plant species in particular areas and their distribution.

Formation—(1) a level in the classification hierarchy below subgroup (see Figure 1) which represents vegetation types that share a definite physiognomy or structure within broadly defined environmental factors, relative landscape positions, or hydrologic regimes (Grossman et al. 1998); (2) a level in the classification based on ecological groupings of vegetation units with broadly defined environmental and additional physiognomic factors in common. (FGDC 1997), (3) A major kind of community on a given continent, as recognized by physiognomy. In practice, formations are often defined by combinations of physiognomy and environment (Whittaker 1975), (4) A group of plants which bears a definite physiognomic character…characterized by a single social species, by a complex of dominant species, or, finally, by an aggregate of species, which though of various taxonomic character, have a common (physiognomic) peculiarity. These form edaphic or climatic vegetation types in certain geographic regions (Grisebach 1938, in Shimwell 1971) (5) Plant communities that are dominated by one particular life form (q.v.), and which recur on similar habitats (Mueller-

Dombois and Ellenberg 1974). **Frequency**—percentage of observations within which a taxon occurs.

Growth form—the characteristic appearance of a plant under a particular set of environmental conditions (Lincoln et al. 1982). Sometimes used interchangeably with life form (q.v), sometimes distinct (see section 5.3).

Group—the level in the classification hierarchy below subclass (see Figure 1) based on leaf characters and identified and named in conjunction with broadly defined macroclimatic types to provide a structural-geographic orientation (Grossman et al. 1998).

Habitat—(1) the combination of environmental or site conditions and ecological processes influencing a plant community.

Habitat Type—(1) a collective term for all parts of the land surface supporting, or capable of supporting, a particular kind of climax plant association (Daubenmire 1978); (2) an aggregation of land areas having a narrow range of environmental variation and capable of supporting a given plant association (Gabriel and Talbot 1984).

Indicator Species—(1) a species whose presence, abundance, or vigor is considered to indicate certain site conditions (Gabriel and Talbot 1984). (2) In this document, used synonymously with diagnostic species (q.v.).

Layer (vegetation)—(1) a structural component of a community consisting of plants of approximately the same height stature (e.g., tree, shrub, and field layer); (2) the aggregate of plants of a given, limited range of heights in a plant community, usually set off by a relative discontinuity from layers above and below it (Gabriel and Talbot 1984), c.f. strata

Life form—the characteristic structural features and method of perennation of a plant species; the result of the interaction of all life processes, both genetic and environmental (Lincoln et al. 1982) c.f. growth form

Metadata—information about data. This describes the content, quality, condition, and other characteristics of a given set of data. Its purpose is to provide information about a data set or some larger data holdings to data catalogues, clearinghouses, and users. Metadata is intended to provide a capability for organizing and maintaining an institution's investment in data as well as to provide information for the application and interpretation of data received through a transfer from an external source (FGDC 1997).

Observation Plot Records—plot records that contain data that are valuable for ecological and geographical characterization of a vegetation type, and contain sufficient vegetation information to be placed in an already established classification, but which contain insufficient vegetation data to help produce original classifications (see Section 5.3).

Order—the level in the NVC hierarchy under division, generally defined by dominant growth form(tree, shrub, herbaceous); FGDC 1997).

Physiognomy—the structure or outward appearance of a plant community as expressed by the dominant growth forms, such as their leaf appearance or deciduousness (Fosberg 1961), c.f. structure

Physiographic—the physical, geomorphologic, and geographic conditions of an area.

Phytocoenosis—(1) the entire plant community (q.v.) or totality of plants in a stand of vegetation (Gabriel and Talbot 1984). (2) An aggregation of taxa which are capable of successfully competing with one another within the confines of a particular combination of environmental features they can tolerate (Küchler 1988).

Phytosociology—the division of ecology concerned particularly with the origin, composition, classification, and distribution, etc., of plant communities.

Plant Community——(1) a combination of plants that are dependent on their environment and influence one another and modify their environment (Mueller-Dombois and Ellenberg (1974), (2) a collection of plant species growing together in a particular location that show a definite association or affinity with each other (Kent and Coker 1992) c.f. community

Plot—in the context of vegetation classification, a sampling area of defined size and shape that is intended for characterizing the vegetation of a stand, c.f. relevé, sampling unit.

Potential Natural Vegetation—the vegetation structure that would become established if all successional sequences were completed without interference by man under the present climatic and edaphic conditions (Tüxen 1956).

Relevé—a sampling area of defined size and shape that is intended for characterizing the vegetation of a stand, large enough to contain all species belonging to the plant community, with uniform habitat and relatively homogeneous plant cover (Mueller-Dombois and Ellenberg 1974) c.f. plot, sampling unit.

Sampling Method—the means used to select the locations that will be sampled using sampling units (q.v.) or plots (q.v).

Sampling Unit—the entities that are measured in the field based on selection from a broader set of samples (Podani 2000). In vegetation classification, the sampling units are typically plots (q.v.) or relevés.

Seral—nonclimax, i.e., a species or community demonstrably susceptible to replacement by another species or community (Daubenmire 1978).

Sere—a particular community type in a successional sequence prior to reaching the climax type.

Series—(1) a set of vegetation types based on the diagnostic tree species; (2) Daubenmire's term for a group of habitat types having the same tree species dominant at climax (Gabriel and Talbot 1984).

Site Type—a qualitative grouping or classification of sites by climate, soil, and vegetation (Gabriel and Talbot 1984). An area defined by combinations of soil moisture and temperature within a given region (Bailey 1996).

Stand—(1) a unit of vegetation with uniform conditions; (2) an uninterrupted unit of vegetation, homogeneous in composition and of the same age (Daubenmire 1978) (3) a particular example of a plant community (q.v.; Curtis 1959).

Strata—In this document used synonymously with layer (q.v.).

Structure (vegetation)—the spatial pattern of growth forms (or life forms) in a plant community, especially with regard to their height, abundance, or coverage within the individual layers (Gabriel and Talbot 1984), c.f. physiognomy

Subclass—the level in the NVC classification hierarchy under class (see Figure 1) based on growth form characteristics (Grossman et al. 1998).

Subclimax—the seral stage in the succession of plant communities immediately preceding the climax stage in that habitat (Gabriel and Talbot 1984).

Subgroup—the level in the NVC classification hierarchy below group (see Figure 1) that divides each group into either "natural or seminatural" or "cultural" (planted or cultivated; Grossman et al. 1998).

Succession—(1) partial or complete replacement of one community by another (Daubenmire 1978). (2) Often separated into (a) cyclic succession – the cyclic replacement of vegetation components which usually are recognized as separate communities, (b) secondary succession – the recovery of a mature community from a major disturbance, (c) primary succession – establishment and development of vegetation components on newly exposed substrates, and (d) secular succession – changes in plant communities as a result of long-term environmental changes, often climatic changes (Glenn-Lewin and van der Maarel 1992).

Synusia—c.f. layer.

Vegetation—(1) the collective plant cover over an area (FGDC 1997), (2) the total of the plant communities of a region (Curtis 1959), (3) the mosaic of plant communities in the landscape (Küchler 1988).

APPENDIX 1

Example of the description of a floristic association.

OVERVIEW:

Names:
Name: Sporobolus heterolepis - Schizachyrium scoparium - (Carex scirpoidea) / (Juniperus horizontalis) Herbaceous Vegetation

Name.translated: Prairie Dropseed - Little Bluestem - (Scirpus-like Sedge) / (Creeping Juniper) Herbaceous Vegetation
Common Name: Little Bluestem Alvar Grassland

Identifier: CEGL005234
Unit: ASSOCIATION
Placement in Hierarchy:

CLASS:	V.	Herbaceous
FORMATION:	V.A.5.N.c.	Medium-tall sod temperate or subpolar grassland
ALLIACNE:	V.A.5.N.c.41	SPOROBOLUS HETEROLEPIS - (DESCHAMPSIA CAESPITOSA, SCHIZACHYRIUM SCOPARIUM) HERBACEOUS ALLIANCE

Summary: The little bluestem alvar grassland type is found primarily in the upper Great Lakes region of the United States and Canada, in northern Michigan and in Ontario. These grasslands occur on very shallow, patchy soils (usually less than 20 cm deep, average is about 6 cm deep) on flat limestone and dolostone outcrops (pavements). Soils are loams high in organic matter. This community often has a characteristic soil moisture regime of alternating wet and dry periods; they can have wet, saturated soils in spring and fall, combined with summer drought in most years (except unusually wet years). In large patches over 50 acres (20 ha) this grassland often occurs as a small-scale matrix, with smaller patches of other alvar communities occurring within the larger patch of little bluestem alvar grassland, forming a landscape mosaic. The most commonly associated alvar communities are creeping juniper - shrubby cinquefoil alvar pavement, tufted hairgrass wet alvar grassland, alvar nonvascular pavement, and white cedar - jack pine / shrubby cinquefoil alvar savanna. The vegetation is dominated by grasses and sedges, which usually have at least 50% cover. Characteristic species of the grassland are *Sporobolus heterolepis, Schizachyrium scoparium, Juniperus horizontalis, Carex scirpoidea, Deschampsia caespitosa, Packera paupercula (= Senecio pauperculus)*, and *Carex crawei*. There is usually less than 10% cover of shrubs over 0.5 m tall; however there may be as much as 50% cover of dwarf-shrubs (under 0.5 m tall) especially *Juniperus horizontalis*. This dwarf-shrub is shorter than the dominant grasses, and usually is found under the canopy of grasses, so the physiognomic type is here considered a grassland (in spite of relatively high cover of dwarf-shrubs). Less than 50% of the ground surface is exposed bedrock (including bedrock covered with nonvascular plants: lichens, mosses, algae).

Classification Comments: The most commonly associated alvar communities that occur with this community in a landscape mosaic are Creeping Juniper - Shrubby-cinquefoil Alvar Pavement Shrubland, *Juniperus horizontalis - Dasiphora fruticosa ssp. floribunda / Schizachyrium scoparium - Carex richardsonii* Dwarf-shrubland (CEGL005236); Tufted Hairgrass Wet Alvar Grassland, *Deschampsia caespitosa - (Sporobolus heterolepis, Schizachyrium scoparium) - Carex crawei - Packera paupercula* Herbaceous Vegetation (CEGL005110); Alvar Nonvascular Pavement, *Tortella tortuosa - Cladonia pocillum - Placynthium* spp. Sparse Vegetation (CEGL005192); and White-cedar - Jack Pine / Shrubby-cinquefoil Alvar Savanna, *Thuja occidentalis - Pinus banksiana / Dasiphora fruticosa ssp. floribunda / Clinopodium arkansanum* Wooded Herbaceous Vegetation (CEGL005132) (Reschke et al. 1998).

Rational for nominal species: *Sporobolus heterolepis* and *Schizachyrium scoparium* are dominants and constants (>60% constancy) in the type. *Carex scirpoidea* is less constant, but is an important differential compared to other alvar types. *Juniperus horizontalis* is less constant, but when present, may be dominant.

VEGETATION:

Physiognomy and structure: The vegetation is dominated by grasses and sedges, which usually have at least 50% cover. There is usually less than 10% cover of shrubs over 0.5 m tall; however there may be as much as 50% cover of dwarf-shrubs (under 0.5 m tall) especially *Juniperus horizontalis*. This dwarf-shrub is shorter than the dominant grasses, and usually is found under the canopy of grasses, so the physiognomic type here is considered a grassland (in spite of relatively high cover of dwarf-shrubs). Less than 50% of the ground surface is exposed bedrock (including bedrock covered with nonvascular plants: lichens, mosses, algae).

Floristics: Characteristic species of the grassland are *Sporobolus heterolepis, Schizachyrium scoparium, Juniperus horizontalis, Carex scirpoidea, Deschampsia caespitosa, Packera paupercula (= Senecio pauperculus)*, and *Carex crawei*. *Juniperus horizontalis* may co-dominate in some stands.

Dynamics:

Environment: These grasslands occur on very shallow, patchy soils (usually less than 20 cm deep, average is about 6 cm deep) on flat limestone and dolostone outcrops (pavements). Soils are loams high in organic matter. This community often has a characteristic soil moisture regime of alternating wet and dry periods; they can have wet, saturated soils in spring and fall, combined with summer drought in most years (except unusually wet years). In large patches over 50 acres (20 ha) this grassland often occurs as a small-scale matrix, with smaller patches of other alvar communities occurring within the larger patch of little bluestem alvar grassland, forming a landscape mosaic (Reschke et al. 1998).

DISTRIBUTION:

Range: The little bluestem alvar grassland type is found primarily in the upper Great Lakes region of the United States and Canada, in northern Michigan, and in Ontario on Manitoulin Island and vicinity, on the Bruce Peninsula, and at a few sites further east in the Carden Plain and Burnt Lands.
Nations: CA US
States/Provinces: MI:S?, ON:S?

USFS Ecoregions: 212H:CC, 212Pc:CCC

PLOT SAMPLING AND ANALYSIS:

Plots: [*To be provided*]

Location of archived plot data: Spreadsheet files with compiled vegetation data from plots and structural types will be available from The Nature Conservancy's Great Lakes Program Office or from the state or provincial Heritage Programs. Original field forms are already filed at state/provincial Heritage Programs.

Factors affecting data consistency: [*See methods below*]

The number and size of plot: Vegetation data were collected using 10 x 10 m square relevé plots placed within subjectively defined stands.

Methods used to analyze field data and identify type:
From Reschke et al. (1998): Field data collected by collaborators in Michigan, Ontario, and New York were compiled by the Heritage program staff in each jurisdiction, and provided to Carol Reschke (inventory and research coordinator for the Alvar Initiative). With assistance from a contractor (Karen Dietz), field data on vegetation, environment, and evidence of ecological processes from alvar sites were entered into spreadsheets using Lotus 123 and Excel software. Spreadsheets were edited to combine a few ambiguous taxa (e.g. *Sporobolus neglectus* and *S. vaginiflorus*, which look similar and can only be positively distinguished when they are flowering in early fall), incorporate consistent nomenclature (Kartesz 1994), delete duplicates, and delete species that occurred in only one or a few samples. Corresponding data on the environment and evidence of ecological processes were compiled in two additional spreadsheets. The plot data set consisted of data from 85 sample plots; there were 240 taxa of vascular and nonvascular taxa included in the initial data set.

The plot data set included a great deal of structural detail. If a tree species was present in different vegetation layers, then it was recorded as a separate taxon for each layer in which it occurred; for example, *Thuja occidentalis* might be recorded as a tree (over 5 m tall), a tall shrub (2 to 5 m tall), and a short shrub (05 to 2 m tall). The full data set of 85 samples by 240 taxa was analyzed using PC-ORD software (McCune and Mefford 1995). Vegetation data on percent cover were relativized for each sample and then transformed with an arcsine - square root transformation. This standardization is recommended for percentage data (McCune and Mefford 1995).

Two kinds of classification and two kinds of ordination procedures were run on the full data set. Classification procedures used were: 1) cluster analysis with group average (or UPGMA) group linkage method and Sorenson's distance measure, and 2) TWINSPAN with the default settings. The two ordination procedures used were 1) Bray-Curtis ordination with Sorenson's distance and variance-regression endpoint selection, and 2) non-metric multidimensional scaling (NMS) using Sorenson's distance and the coordinates from the Bray-Curtis ordination as a starting configuration.

Environmental data recorded for each plot and data on evidence of ecological processes were used as overlays in ordination graphs to interpret ordination patterns and relationships between samples.

The classification dendrograms and ordination graphs were presented to a core group of ecologists to discuss the results. Participants in the data analysis discussions were: Wasyl Bakowsky, Don Faber-Langendoen, Judith Jones, Pat Comer, Don Cuddy, Bruce Gilman, Dennis Albert, and Carol Reschke. The two classifications were compared to see how they grouped plots, and ordinations were consulted to check and confirm groupings of plots suggested by the classification program. At the end of the first meeting to discuss the data analysis, collaborating ecologists agreed on eight alvar community types, and suggested another four or five that had been observed in field surveys but were not represented in the plot data set. The group also recommended some refinements to the data analysis.

Following the recommendations of the ecology group, the plot data were modified in two ways. For nonvascular plants, the first data set included data on individual species or genera, as well as taxa representing simple growth forms. Since only a few collaborators could identify nonvascular plants in the field, we had agreed to describe the nonvascular plants in plots by their growth form and collect a specimen if the species had at least 5% cover in the plot. If nonvascular species were identified by the surveyor, or from the collected specimen, the species were included in the data set. This may have biased the results, because the plots sampled by folks who knew the nonvascular plants had a greater potential diversity than plots in which only a few growth forms were identified. Therefore, all data on nonvascular taxa were lumped into nine growth form categories: foliose algae (e.g. *Nostoc*), rock surface algae, microbial crusts, turf or cushion mosses, weft mosses, thalloid bryophytes, crustose lichens, foliose lichens, and fruticose lichens. The second modification involved lumping the different structural growth forms of woody taxa into a single taxon; for example, trees, tall shrubs and short shrubs forms of *Thuja occidentalis* were lumped into a single taxon.

These modifications reduced the dimensions of the plot data set to 85 plots by 199 taxa with the nonvascular taxa lumped, and even fewer taxa with the woody growth forms lumped. The analyses were run again using the procedures described above with the modified data sets. It turned out that lumping the nonvascular plants improved the classification and ordination results (yielding more clearly defined groups), but lumping the growth forms of tree species was actually detrimental to the results. The final classification that we used was produced from an analysis of the data set with nonvascular plants lumped into nine growth forms, and multiple growth forms of tree species kept separated.

Within each community type, species composition was then summarized by calculating average percent cover for each species and then sorting the species in order of average percent cover across all the samples from the community type.

CONFIDENCE LEVEL:

Confidence Rank: STRONG.

CITATIONS:

Synonymy:
Dry – Fresh Little Bluestem Open Alvar Meadow Type = (Lee et al. 1998).

References:
Kartesz, J. T. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Second edition. Volume 1--Checklist. Timber Press, Portland, OR. 622 pp.

Lee, H., W. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and S. McMurray. 1998. Ecological land classification for southern Ontario: First approximation and its application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02.

McCune, B., and M.J.Mefford. 1995. Multivariate analysis of ecological data, PC-ORD version 3.0. MjM Sofware, Gleneden Beach, Oregon, USA.

Reschke, C., R. Reid, J. Jones, T. Feeney, and H. Potter, on behalf of the Alvar Working Group. 1998. Conserving Great Lakes Alvars. Final Technical Report of the International Alvar Conservation Initiative. December 1998. The Nature Conservancy, Great Lakes Program, Chicago, IL. 119 pp. plus 4 appendices.

Author of Description: C. Reschke

APPENDIX 2

Required and optimal attributes for classification and observation plot records. *Classification plots* provide data needed to develop and define a classified vegetation types (associations and alliances). *Observationr plots* contain sufficient information to accurately assign the plot to an association or alliance. Required fields, indicated with a number 1, are those minimally needed to serve as either classification (C) or observation (O) plots. Optimal fields, indicated with a number 2, are those fields that, while not required, reflect best practices when conducting plot sampling.

Table Index

For access to an ASCII file of each table as well as more detailed information, see VegBank on the web, www.vegbank.org.

1. Information that should be included on the form used to record plot data in the field.

1.1. Field form information about the plot record.

Attribute Name	Attribute Definition	C	O
Author_Plot_Code	Author's plot number/code, or the original plot number if taken from literature.	1	1
Author_Observation__Code	Code or name that the author uses to identify this plot observation. Where a plot has only one observation, code will often equal Author Plot Code.	1	2
Placement_Method	Description of the method used to determine the placement of a plot.	2	2
Observation_Start_Date	The date of the observation, or the first day if the observation spanned more than one day.	1	1

Obervation_Stop_Date	The last day of the observation if the observation spanned more than one day.	2	2

1.2. Field form information about the plot location (some can be determined after a return to office, for example, with coordinate conversions).

Attribute Name	Attribute Definition	C	O
Latitude	Latitude of the plot origin in degrees and decimals	1	1
Longitude	Longitude of the plot origin in degrees and decimals	1	1
Datum	Datum used (e.g., World Geodetic System 1984)	1	1
Projection	Geographic projection, if used. This must also include: Units: specify meters or feet Longitude of center of projection Latitude of center of projection False easting False northing X axis shift Y axix shift	1	1
Location_Accuracy	Estimated accuracy of the location of the plot. Plot origin has a 95% or greater probability of being within this many meters of the reported location.	2	2
Location_Narrative	Text description that provides information useful for plot relocation.	2	2
Area	Total area of the plot in square meters. If many subplots, this area includes the subplots and the interstitial space	1	1
Stand_Size	Estimated size of the stand of vegetation in which the plot occurs	2	2
USGS_quad	U.S. Geological Survey 7.5 minute quadrangle name.	2	2
Ecoregion	Bailey (1995) Ecoregion Section .	2	2

1.3. Field form information about the plot vegetation.

Attribute Name	Attribute Definition	C	O
Tree_Height	Height of the tree layer in m.	2	2
Shrub_Height	Height of the shrub layer in m.	2	2
Herb_Height	Height of the herb layer in m.	2	2
Nonvascular_Height	Height of the nonvascular layer in m.	2	2
Submerged_Height	Height of the submerged layer in m.	2	2
Total_Vegetation_Cover	Total cover of all vegetation	2	2
Tree_Cover	Total cover of the tree layer in percent.	2	2
Shrub_Cover	Total cover of the shrub layer in percent.	2	2
Field_Cover	Total cover of the field layer in percent.	2	2
Nonvascular_Cover	Total cover of the nonvascular layer in percent.	2	2

Floating_Cover	Total cover of the floating layer in percent.	2	2
Submerged_Cover	Total cover of the submerged layer in percent.	2	2
Dominant_Stratum	Identify the dominant stratum (of (of the six standard strata)	2	2
Growth-Form_1	The predominant growth form.	2	2
Growth-Form_2	The second-most predominant growth-form.	2	2
Growth-Form_3_Type	The third-most predominant growth-form	2	2
Growth-Form1_Cover	Total cover of the predominant growth-form.	2	2
Growth-Form_2_Cover	Total cover of the second-most predominant growth-form.	2	2
Growth-Form_3_Cover	Total cover of the third-most predominant growth-form.	2	2
Stratum_Height	Average height to the top of the stratum in meters.	2	2
Stratum_Base	Average height of the bottom of the stratum in meters.	2	2
Stratum_Cover	Cover of the vegetation within the given stratum in percent.	2	2
Taxon_Stratum_Cover	Percent cover of taxon in stratum.	2	2
Taxon_Cover	Overall cover of the taxon across all strata.	1	2

1.4. Field form information about the plot environment.

Attribute Name	Attribute Definition	C	O
Elevation	The elevation of the plot origin in meters above sea level.	1	2
Elevation_Accuracy	The accuracy of the elevation in percentage of the elevation reported.	2	2
Slope_Aspect	Representative azimuth of slope gradient (0-360 degrees); if too flat to determine = -1; if too irregular to determine = -2.	1	2
Slope_Gradient	Representative inclination of slope in degrees; if too irregular to determine, = -1.	1	2
Topographic_Position	Position of the plot on land surface (e.g., summit, shoulder, upper slope, middle slope, lower slope, toeslope, no slope, channel bed, dune swale, pond).	2	2
Landform	Landform type.	2	2
Geology	Surface geology type.	2	2
Hydrologic_Regime	Hydrologic regime based on , frequency and duration of flooding) (Cowardin et al. 1979).	2	2
Soil_Moisture_Regime	Moisture of soil at the time of sampling event. (picklist)	2	2
Soil_Drainage	Drainage of the site (generally consistent with USDA classes). (picklist)	2	2
Water_Salinity	How saline is the water, if a flooded community. (picklist)	2	2

Water_Depth	For aquatic or marine vegetation, the water depth in m	2	2
Shore_Distance	For aquatic or marine vegetation, the closest distance to shore in m	2	2
Soil_Depth	Median depth to bedrock or permafrost in m (usually from averaging multiple probe readings).	2	2
Organic_Depth	Depth of the surficial organic layer, where present, in centimeters.	2	2
Percent_Bed_Rock	Percent of surface that is exposed bedrock.	2	2
Percent_Rock_&_Gravel	Percent of surface that is exposed rock and gravel.	2	2
Percent_Wood	Percent of surface that is wood.	2	2
Percent_Litter	Percent of surface that is litter.	2	2
Percent_Bare_Soil	Percent of surface that is bare soil.	2	2
Percent_Water	Percent of surface that is water.	2	2
Soil_Taxon	Name of soil type.	2	2
Soil_Taxon_Source	Source of soil type.	2	2

1.5. Field form information about the plot habitat.

Attribute Name	Attribute Definition	C	O
Observation_Narrative	Additional unstructured observations useful for understanding the ecological attributes and significance of the plot observations.	2	2
Landscape_Narrative	Unstructured observations on the landscape context of the observed plot.	2	2
Homogeneity	Homogeneity of the community (e.g., homogeneous, compositional trend across plot, conspicuous inclusions, irregular mosaic or pattern)?	2	2
Phonologic_Aspect	Season expression of the community (e.g., typical growing season, vernal, aestival, wet, autumnal, winter, dry, irregular ephemerals present).	2	2
Representativeness	How representative was the plot of the stand.	2	2
Stand_Maturity	Assess maturity of stand (e.g., young, mature but even-aged, old-growth, etc.)	2	2
Successional_Status	Description of the assumed successional status of the plot.	2	2
Disturbance_Type_1 . . .*n*	The type of disturbance being reported. Repeat this field as many times as necessary where there is more than one type of disturbance	2	2
Disturbance_Comment_1 . . .*n*	Text description of details of the disturbance and its impact on the vegetation. Repeat this field as many times as necessary where there is more than one type of disturbance	2	2

2. Information that should be included as metadata.

2.1. Metadata about the original field project for which the plot record was collected.

Attribute Name	Attribute Definition	C	O
Project_Name	Project name as defined by the principal investigator.	2	2
Project_Description	Short description of the project including the original purpose for conducting the project. This can be viewed as the project abstract plus supporting metadata.	2	2
Start_Date	Project start date.	2	2
Stop_Date	Project stop date.	2	2
PI_Role	Name of the field plot inventory project's principal investigator.	2	2

2.2. Metadata about the plot and the plot observation.

Attribute Name	Attribute Definition	C	O
Layout_Narrative	Text description of and the rationale for the layout of the plot.	2	2
Method_Narrative	Additional metadata helpful for understanding how the data were collected during the observation event.	2	2
Taxon_Observation_Area	The total surface area (in m2) used for cover estimates and for which a complete species list is provided. If subplots were used, this would be the total area of the subplots without interstitial space.	1	2
Cover_Dispersion	Were cover values for the total taxon list collected from one contiguous area or dispersed subplots (e.g., continguous, dispersed-regular, dispersed-random).	1	2
Original_Data	Location where the hard data reside and any access instructions.	2	2
Effort_Level	Effort spent making the observations as estimated by the party that submitted the data (picklist).	2	2
Floristic_Quality	Subjective assessment of floristic quality by the party that submitted the plot (picklist)	2	2
Bryophyte_Quality	see Floristic Quality	2	2
Lichen_Quality	see Floristic Quality	2	2
Submitter	Name of the person submitting the analysis.	1	1
Primary_Field_Observer	Name of the person who made the field observation (e.g., PI, technician, volunteer, etc.).	1	1
Author	Name of the author of the plot record.	1	1

2.3. Metadata about the methods used to collect the field data. Vertical strata used for recording taxon cover must be defined in terms of their upper and lower limits. Cover class scales must be defined in terms of their minimum, maximum, and representative cover in percent.

Attribute Name	Attribute Definition	C	O

Stratum_Method_Name	Name of the stratum method (e.g., Braun-Blanquet, NatureServe, , North Carolina Vegetation Survey #1,etc..).	1	2
Stratum_Method_Description	This field describes the general methods used for strata.	1	2
Cover_Code	The name or label used in the cover class scale for this specific cover class.	1	2
Upper_Limit	Upper limit, in percent, associated with the specific cover code.	1	2
Lower_Limit	This is the lower limit, in percent, associated with a specific Cover Code.	1	2
Cover_Percent	A middle value (usually mean or geometric mean) between the Upper Limit and Lower Limit stored by the database for each taxon observation and used for all cover class conversions and interpretations. This is assigned by the author of the cover class schema.	1	2
Index_Description	Description of the specific cover class. This is particularly helpful in the case that there is no numeric value that can be applied.	2	2
Cover_Type	Name of the cover class method (e.g., Braun-Blanquet, Barkman, Domin, Daubenmire, North Carolina Vegetation Survey, etc.).	1	2
Taxon_Inference_Area	This is the area in m^2 used to infer the cover of a given taxon. Generally this should be equal to Taxon Observation Area, but at times this area may be larger or smaller for a specific taxon.	1	2

2.4. Metadata about the human sources of the field data.

Attribute Name	Attribute Definition	C	O
Given_Name	One's first name.	1	1
Middle_Name	One's middle name or initial, if any.	2	2
Surname	Name shared in common to identify the members of a family, as distinguished from each member's given name.	1	1
Organization_Name	Name of an organization.	2	2
Current_Name	Recursive foreign key to current name of this party.	2	2
Email	email address	2	2
Address_Start_Date	The first date on which the address/organization information was applied.	1	1
Delivery_Point	Address line for the location (street name, box number, suite).	2	2
City	City of the location.	2	2
Administrative_Area	State, province of the location.	2	2
Postal_Code	Zip code or other postal code.	2	2
Country	Country of the physical address.	2	2

Authors	Name of authors if plot record is taken from published work.	1	1
Title	Title of publication, if plot record is taken from published work.	1	1
Publication_Date	Date of publication, if plot record is taken from published work.	1	1
Edition	Edition of publication if applicable, and if plot record is taken from published work.	1	1
Series_Name	Name of publication series, if applicable, and if plot record is taken from published work.	1	1
Page	Page number of publication, if plot record is taken from published work.	1	1
Table_Cited	Table number or code, if applicable and if plot record is taken from published work.	1	1
Plot_Cited	Original plot name, if plot record is taken from published work.	1	1
ISBN	International Standard Book Number (ISBN), if applicable, and if plot record is taken from published book.	2	2
ISSN	International Standard Serial Number, if applicable.	2	2

2.5. Metadata about plot record confidentiality, accuracy of the date of collection, and links to publications and sources.

Attribute Name	Attribute Definition	C	O
Confidentiality_Status	Are the data to be considered confidential? 0=no, 1= 1km radius, 2=10km radius, 3=100km radius, 4=location embargo, 5=public embargo on all plot data, 6=full embargo on all plot data. This applies also to region.	2	2
Confidentiality_Reason	The reason for confidentiality. This field should not be open to public view. Reasons might include specific rare species, ownership, prepublication embargo, or many other reasons.	2	2
Date_Accuracy	Estimated accuracy of the observation date.	2	2
Classification_Publication_ID	Link to a publication wherein the observation was classified.	2	2
Community_Authority_ID	Link to the reference from which information on the community concept was obtained during the classification event.	2	2

3. Information that should be included about analyses of the field plot data.

Attribute Name	Attribute Definition	C	O
Classification_Start_D	Start date for the application of a vegetation class to a	1	1

ate	plot observation by one or more parties.		
Inspection	Was the classification informed by simple inspection of data?	2	2
Table_Analysis	Was the classification informed by inspection of floristic composition tables?	2	2
Multivariate_Analysis	Was the classification informed by use of multivariate numerical tools?	2	2
Expert_System	Was the classification informed by use of automated expert system?	2	2
Classifier	Name of person who classified the plot.	1	1
Classification_Fit	Indicates the degree of fit with the community concept being assigned (e.g., fits concept well, fits but not typal, possible fit, just outside concept).	2	2
Classification_Confidence	Indicates the degree of confidence of the interpretor (s) in the interpretation made. This can reflect the level of familiarity with the classification or the sufficiency of information about the plot (e.g., High, Moderate, Low).	2	2
Interpretation_Date	The date that the interpretation was made.	1	1
Interpretation_Type	Categories for the interpretation (e.g., author, computer-generated, simplified for comparative analysis, correction, finer resolution).	1	1
Original_Interpretation	Does this interpretation corresponds to the original interpretation of the plot author, as best as can be determined. There is no requirement that the authority match the authority of the author; only that the concepts are synonymous.	1	1
Current_Interpretation	This interpretation is the most accurate and precise interpretation currently available.	1	1

TABLES

Table 1. Some Earth imaging systems.

Acronym	Name	Altitude, km	Ground Resolution, m
AVHRR	Advanced Very High Resolution Radiometer satellite	833	1,100
AVIRIS	Airborne Visible Infrared Imaging Spectrometer	multiple	altitude dependent
Landsat	Landsat satellite	705	15-60
MODIS	Moderate-Resolution Imaging Spectroradiometer	705	250-1,000
NAPP	National Aerial Photography Program	6	represented at a scale of 1:40,000
SPOT	Systeme Pour l'Observation de la Terre	832	10-20

Table 2. Recommended growth forms (or life forms) to be used when describing vegetation structure (see also Whittaker 1975, Table 3.1)

Needle-leaved tree
Broad-leaved deciduous tree
Broad-leaved evergreen tree
Thorn tree
Evergreen sclerophyllous tree
Succulent tree
Palm tree
Tree fern
Bamboo

Needle-leaved shrub
Broad-leaved deciduous shrub
Broad-leaved evergreen shrub
Thorn shrub
Evergreen sclerophyllous shrub
Palm shrub
Dwarf-shrub
Semi-shrub
Succulent shrub

Forb
Fern
Graminoid
Succulent forb
Aquatic herb

Bryophyte
Lichen
Alga

Epiphyte
Vine/Liana (woody climbers or vines)

Table 3. Comparison of commonly used cover-abundance scales in the United States. Agencies and authors are abbreviated as: WHTF=Western Heritage Task Force, The Nature Conservancy (Bourgeron et al. 1991); FS=Forest Service, modified Daubenmire (1959) scale; BB=Braun-Blanquet (1928); D=Domin (1928); BDS=Barkman et al. (1964); PA=Pfister and Arno (1980); DAUB=Daubenmire (1959); NC=North Carolina Vegetation Survey (Peet et al. 1998). 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. All other cover classes shown can be collapsed to this standard.

	Cover scale used by:							
Cover-abundance	WHTF	FS	BB	D	BDS	PA	DAUB	NC
Present, but not in plot			( )[11]			+		
Single individual	1	T	R	+	-	T	1	1
Sporadic	1	T	+	1	-	T	1	1
0 - 1%	1	T	+	2	-	T	1	2
1 - 2%	3	1	1[12]	3	-	1	1	3
2 - 3%	3	1	1	3	0	1	1	4
3 - 5%	3	1	1	4	0	1	1	4
5 - 6.25%	10	2	2[2]	4	1	2	2	5
6.25 – 10%	10	2	2	4	1	2	2	5
10 – 12.5%	10	2	2	5	1	2	2	6
12.5 – 15%	10	2	2	5	1	2	2	6
15 – 25%	20	2	2	5	2	2	2	6
25 – 30%	30	3	3	6	3	3	3	7
30 – 33%	30	3	3	6	3	3	3	7
33 – 35%	30	3	3	7	3	3	3	7
35 – 45%	40	3	3	7	4	3	3	7
45 – 50%	50	3	3	7	5	3	3	7
50 – 55%	50	4	4	8	5	4	4	8
55 – 65%	60	4	4	8	6	4	4	8
65 – 75%	70	4	4	8	7	4	4	8
75 – 85%	80	5	5	9	8	5	5	9
85 – 90%	90	5	5	9	9	5	5	9
90 – 95%	90	5	5	10	9	5	5	9
95 – 100%	98	6	5	10	10	6	6	10

[11] Species present in the stand but not in the plot are usually added in parentheses to the species list.

[12] 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 "+."

Table 4. 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

Table 5. Summary of layer data from field plots for a given type.

Layer	Height Class	Average % Cover	Minimum % Cover	Maximum % Cover
Tree				
Shrub				
Herb				
Nonvascular				
Floating Aquatic				
Submerged Aquatic				

Table 6. A stand table of floristic composition for each layer. Layers are defined in Table 5).

Species Name	Layer	1, Dominant 2, Characteristic 3, Constant	Constancy Class	Av. % Cover	Min. % Cover	Max. % Cover
Species 1						
Species 2						
Species 3						
Species *n*						

Table 7. Constancy classes.

Constancy Classes	Relative (%) Constancy
I	1-20
II	21-40
III	41-60
IV	61-80
V	81-100

FIGURES

Figure 1. Categories and examples of the National Vegetation Classification, showing the levels from class to association. The FGDC (1997) standard also includes two higher levels above class - Division and Order.

Physiognomic Categories

Category Example

Class . . . . .Open Tree Canopy

Subclass . . . . Evergreen Open Tree Canopy

Group . . . . Temperate or Subpolar Needle-leaved Evergreen Open Tree Canopy

Subgroup . . . . . . Natural/Seminatural

Formation . . . . . Rounded-crowned temperate or subpolar needle-leaved evergreen open tree canopy.

Floristic Categories

Alliance . . . .*Juniperus occidentalis* Woodland Alliance

Association . . .*Juniperus occidentalis /Artemesia tridentata* Association

Figure 2. Flow of information through the process for formal recognition of an association or alliance. Beginning at the top of the figure, concept based taxonomy is used to track the concepts, names, and assertions for taxa using Operational Taxonomic Unit (OUT) codes (left). Field plot data (center) are collected, plot data are submitted to the national 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, the monograph is published, and the description made available.

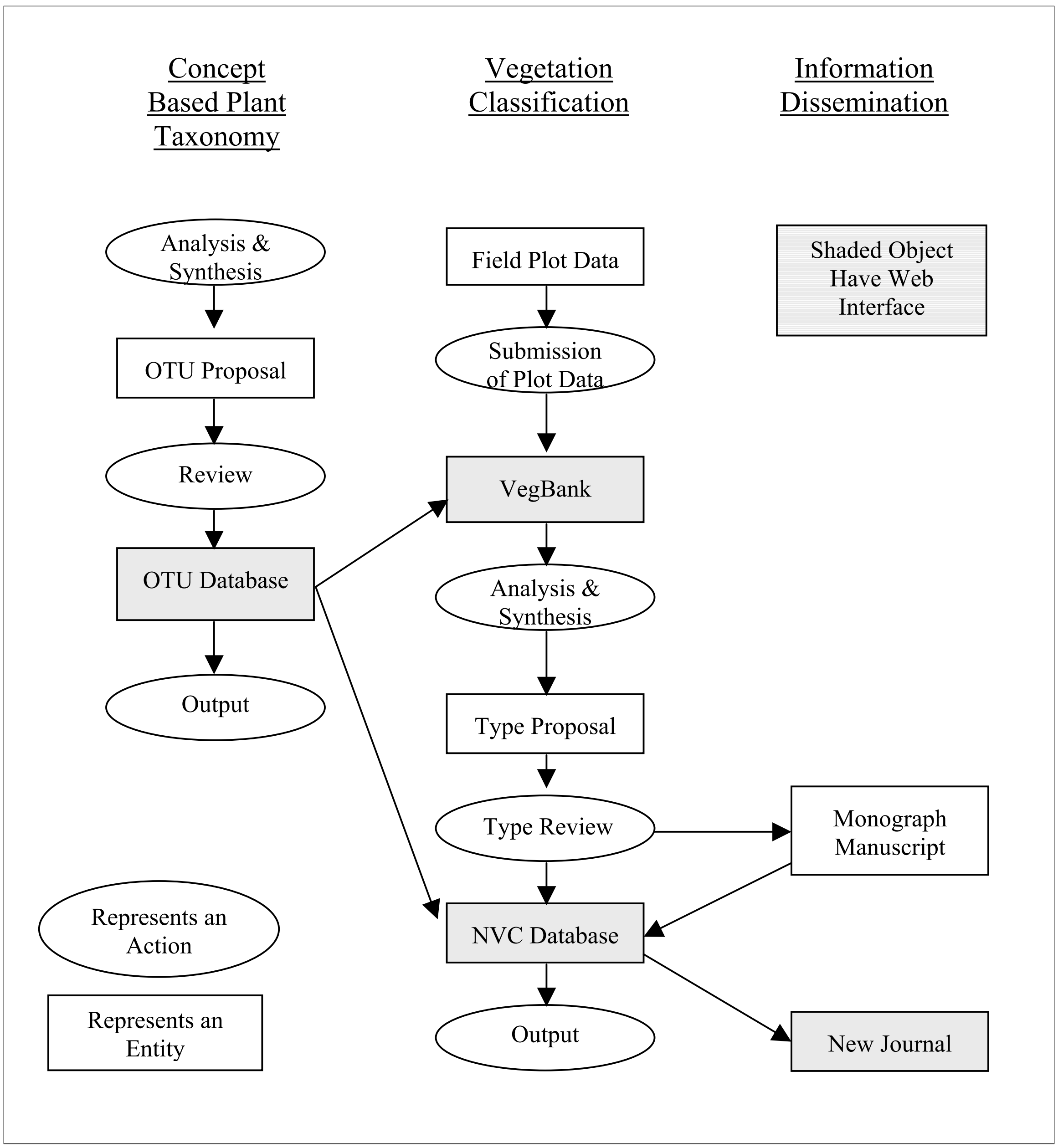
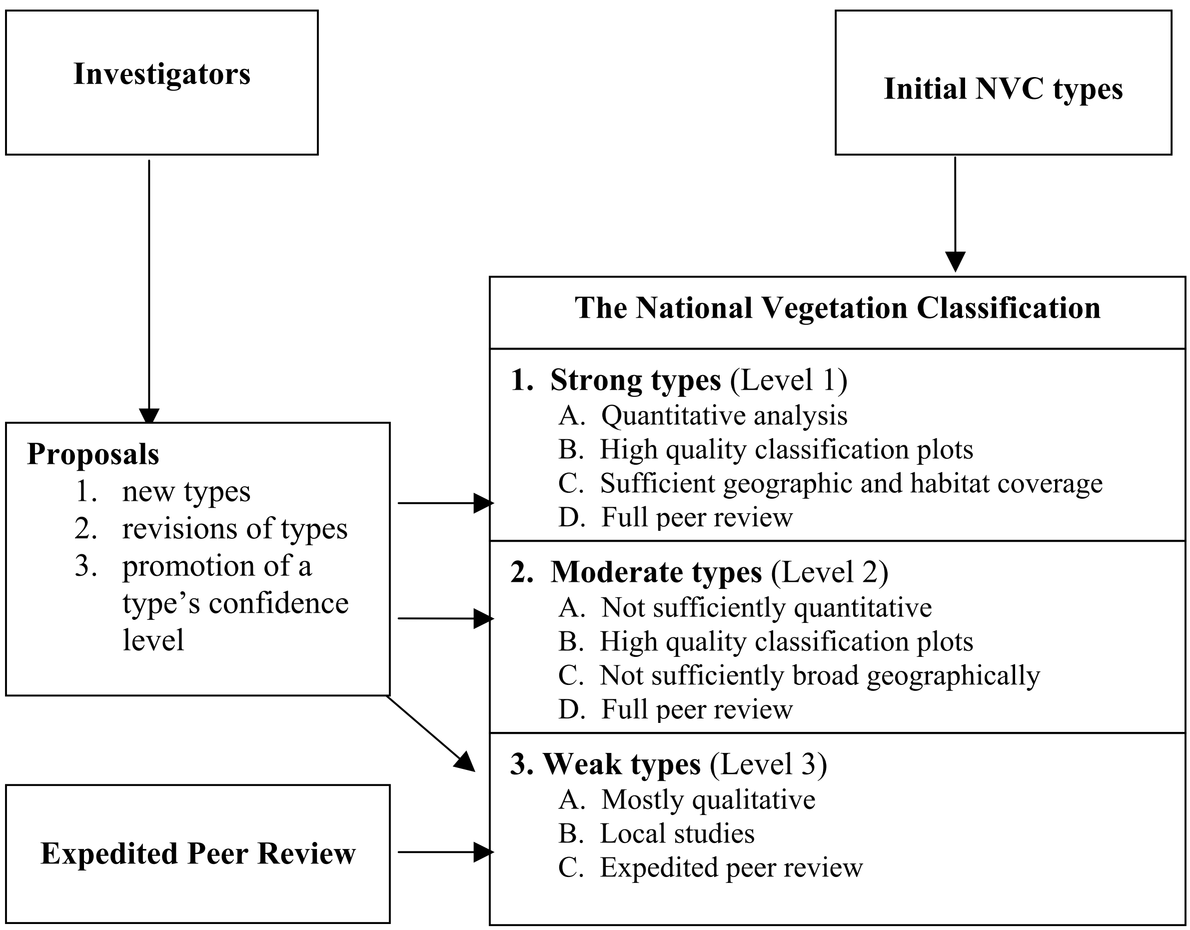


Figure 3. Schematic diagram of the peer-review process.



TEXT BOXES

Box 1. Guiding principles of the FGDC National 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. The 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).
- The upper levels of the NVCS are based primarily on the physiognomy (life form, cover, structure, leaf type) of the vegetation (not individual species). The life forms (e.g., herb, shrub, or tree) in the dominant or uppermost stratum will predominate in the classification of the vegetation type. Climate and other environmental variables are used to help organize the standard, but physiognomy is the driving factor.
- The 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.

Box 2. Definition of alliances and associations (FGDC 1997).

Alliance - A physiognomically uniform group of Associations sharing one or more diagnostic (dominant, differential, indicator, or character) species, which, as a rule, are found in the uppermost stratum of the vegetation.

Association - A physiognomically uniform group of vegetation stands that share one or more diagnostic (dominant, differential, indicator, or character) overstory and understory species. These elements occur as repeatable patterns of assemblages across the landscape and are generally found under similar habitat conditions. (The Association refers to existing vegetation, not a potential vegetation type).

Box 3. Underlying principles for the US-NVC floristic vegetation classification standards.

1. The US-NVC must be based fundamentally on floristic as well as physiognomic units of vegetation that conform to published standards.

2. The US-NVC floristic units must be based on field plot data that meet minimum standards.

3. The US-NVC must be open to change in the sense that any person (independently, or representing some institution) is free to submit proposed additions and changes, and that the rules, standards, and opportunities are the same for all potential contributors regardless of their institutional affiliations.

4. The US-NVC must have a formal impartial, scientifically rigorous peer-review process for floristic units, whereby proposals to recognize new units or change accepted units are evaluated.

5. The US-NVC system should be sufficiently robust, well documented, and in the public domain, so that the loss of any of the supporting organizations from the collaborative effort would not result in failure or collapse of the US-NVC and its information system.

6. The chief aim of the US-NVC is to support a basic understanding of vegetation and to serve as a practical tool for the conservation and management of the nation's vegetation resources.

Box 4. 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.
4. A 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. A description of the range/distribution.
12. A list of U.S. states and Canadian provinces where the type occurs or may occur.
13. A list of any nations outside the U.S. and Canada where the type occurs or may occur.

PLOT SAMPLING AND ANALYSIS

14. 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 Chapter 7).

CITATIONS

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

DISCUSSION

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