INTRODUCTION

This document presents a revised framework for the classification of natural communities in North Carolina. Natural communities are central to the work of the Natural Heritage Program. Tracking occurrences of good examples of them comprises a substantial portion of the program's inventory and database work. Natural communities are also primary drivers of land conservation decisions by the North Carolina Land and Water Fund, by state land conservation agencies, and by some private organizations. Classification of natural communities is also useful for a wide variety of other purposes, including guiding research, organizing ecological information, characterizing sites, and defining habitat for particular species.

Natural communities are important components of biodiversity, with the different kinds representing different combinations of species interactions and of ecosystem processes. They also represent a crucial means of conserving species diversity, as they offer a means of providing representation for many of the poorly-known and untracked species that occur in them. The vast majority of species are not tracked and most in the invertebrate and microbial realms have not even been assessed for their rarity; many are not even known.

Increasingly important as the climate changes, natural communities also represent the variety of physical environments as they affect the biota. Physical site stratifications may be done by slicing important environmental gradients into units in many ways, but the sites representing the diversity of natural communities as they exist today indicate the combinations of factors and their thresholds that are also most likely to drive new communities of the future.

DEFINITION OF NATURAL COMMUNITIES

A natural community is defined as:

> "a distinct and reoccurring assemblage of populations of plants, animals, bacteria, and fungi naturally associated with each other and their physical environment."

This definition remains the same as in previous versions of the North Carolina classification. It implies an attempt to account for a wide variety of ecological components, so that the units will represent differences in local-scale ecosystem function and structure, as well as differences in species composition. It implies that we seek to define units that are the result of the processes of nature, that differ in ways that are enduring and significant rather than transient or minor, and that would be found again in other places with similar environments.

Natural community classification considers a wide range of ecological characteristics, including vegetation composition and physiognomy, assemblages of animals or other organisms, topography, substrate, hydrology, soil characteristics, other enduring site characteristics, and prevailing natural disturbance regimes. It thus differs conceptually from classifications that are based solely on vegetation, such as the National Vegetation Classification. In practice, however, this large number of factors is tightly correlated, and the natural community units usually correspond well to units defined by the vegetation that exists in the most natural, least altered examples that can be found.

NEED FOR A NEW APPROXIMATION

The 3rd Approximation was published in 1990. Much new information, experience, and understanding have accumulated since that time. Indeed, the study of natural communities in North Carolina has expanded as never before. Natural Heritage Program inventories have found hundreds of new, good examples of natural communities. Numerous graduate studies and published scientific papers offer new insights. The Carolina Vegetation Survey has systematically amassed the largest set of vegetation plot data ever collected in the state. The National Vegetation Classification (NVC) has developed, offering different perspectives on the crucial vegetation component of natural communities in North Carolina as well as giving information on communities in other states. We now know of the importance of distinctions that were not recognized in 1990, we know of kinds of communities that we didn't know existed then, and we have a better understanding of the nature of most of our communities.

One particular challenge has been a trend toward increased splitting of community units. The NVC has much more finely divided units than the 3rd Approximation. The demand for these more detailed units, along with a desire to tie the North Carolina classification into the NVC as much as possible, has been a major driver in the way the 4th Approximation has developed.

Much remains to be learned about all of our natural communities and how they are related to each other. This edition of the classification, as previous ones, is called an approximation. This is meant to remind the user that, while it is the best synthesis of knowledge the author can offer at this time, and can be useful, our understanding will continue to evolve.

DEVELOPMENT OF THE 4TH APPROXIMATION

Work on the 4th Approximation began in the late 1990s. Early drafts of the classification were made available for field testing and review. These informed later development and the final form. After the primary classification was worked out, the 4th Approximation Guide was completed in 2012. At that time, the Natural Heritage Program began using the classification as its primary means of naming and tracking examples of natural communities and using them to rate site significance. A commitment was made to provide a more detailed descriptive book for the communities defined. This document is that detailed book.

The use of the classification through the ten years needed to complete this book has provided additional testing and experience with the communities as they are defined. New research, new development of the NVC, and new analysis of CVS data have led to new understandings of the communities. Some new communities have been discovered. The draft descriptions have been provided to botanists and ecologists and been available for feedback. For all these reasons, the classification and the community units described here have evolved since 2012. A few units have been dropped, a few added, the boundaries of a few changed, the relationship to the NVC has been revised for some. Cumulatively, there are enough changes that this document could as readily be called a 5th Approximation. The name of 4th Approximation is retained, as it has been in continuous use as the work has developed. For perspective, this version of the classification is roughly as close to the 2012 version as the 1st Approximation was to the 2nd, but is less changed than the 3rd Approximation was from the 2nd, and much less changed than the earlier 4th Approximation was from the 3rd.

STRUCTURE OF THE 4TH APPROXIMATION CLASSIFICATION

The 4th Approximation is structured largely the same as the previous editions. This includes limited upper-level hierarchy, with the finer units, the primary focus, being called types, subtypes, and variants. Subtypes are the units tracked by the Natural Heritage Program, in the way that varieties and subspecies are tracked as the elements of biodiversity at the "species" level. Subtypes are the scale the Natural Heritage Program considers appropriate to use as separate targets for biodiversity representation. Subtypes are a similar ecological scale to the associations of the NVC, the primary level viewed as biodiversity conservation targets when that classification was developed.

Variants are less formal, finer-scale divisions of subtypes, used to name recognizable differences that are either too poorly known or considered too fine-scale to use as conservation targets. Variants may also be the testing ground for new subtypes. Most of the subtypes newly recognized in the 4th Approximation were treated as variants in the 3rd Approximation. The experience gained from using them contributed to their adoption as subtypes.

Types are useful if a slightly coarser classification is desired, and they provide a way of tying classification back to the 3rd Approximation units. Most type-level units are unchanged between the 3rd and 4th Approximations.

The community types are nested in biological themes. The 32 themes were defined in 1993 to provide a meaningful coarser ecological classification for purposes where that was needed. Since they were published in the 1993 Natural Heritage Program Protection Plan, they have seen widespread use, including in the State Parks System Plans and the Wildlife Action Plan. Small changes have been made in them here to fit the 4th Approximation. The themes are different from the informal ecological groups that were used in earlier approximations and in the earliest drafts of the 4th Approximation. Using the ecological themes should increase the versatility of the 4th Approximation, offering meaningful classification entities at three levels over a great range in breadth. As with the previous grouping, the themes are a grouping rather than a top down hierarchy. Some community types could reasonably be placed in two different themes.

A single additional top level of hierarchy consists of the wetland systems of Terrestrial, Palustrine, and Estuarine. This roughly follows Cowardin et al. (1979). In that document, Riverine and Lacustrine categories were considered deepwater areas only, and vegetated communities associated with rivers and lakes are classified as Palustrine. Some deviation from Cowardin et al. (1979) occurs in the floodplains and wet savannas, where some communities that are not generally treated as jurisdictional wetlands are included as Palustrine because their ecological processes and affinities are nevertheless driven by water and their closest affinities are with communities that are jurisdictional wetlands.

CLASSIFICATION METHODS

Classification approach

The 4th Approximation, as in previous approximations, uses an integrative approach which considers all of the ecological characteristics that are known, and attempts to group them in ways that they are naturally correlated. It attempts to find units that will go beyond simply describing one kind of data and will allow predictions of patterns in ecological process and in unstudied biota such as invertebrates. It is thus not a pure vegetation classification nor a pure ecological land classification; it attempts to capture aspects of both. It classifies the environment, but from the point of view of the biota. It classifies vegetation but based on how it responds to the environment. It does not explicitly classify animal communities but it attempts to describe habitat in ways that would affect assemblages of animals, especially of smaller and less wide-ranging animals.

The greatest emphasis is upon vegetation and upon readily observable aspects of the physical environment such as topography, elevation, and wetness. This is justified because plants are good indicators of the most important environmental influences, and they integrate the effects of those influences over time. It is also necessary, because plants are most easily observable, and we have much more information on them than on any other component. However, vegetation is interpreted in light of what it tells us about the environment and how that may be important for animals and other organisms. Differences in vegetation that indicate short-term fluctuations or human alteration are downplayed; those that indicate prevailing natural disturbance regimes, soil fertility, moisture levels, and other enduring environmental factors are emphasized. Conversely, aspects of the environment that can be seen to affect the flora are emphasized. Aspects of the environment considered likely to affect other biota without affecting vegetation may be used, but only if confidence in their importance is high.

Potential 4th Approximation types and subtypes were evaluated for suitability by a set of criteria:

- The unit represents a difference in enduring natural character and is not just a short-lived part of a natural cycle. Communities that are parts of longer term, naturally shifting mosaics are recognized if they will persist for a number of years or if they will not likely return to the original state, while predictable and short-lived shifts are not recognized as different types. Thus, beaver ponds are recognized in the classification, while the drastic differences in vegetation stature that follow fire in pocosins but which fade in just a few years are considered part of natural temporal variation within the same community.
- The unit's distinctness is a result of natural environment and natural processes and is not an artifact of a different history of human alteration. All existing community occurrences have at least some human alteration, which we seek to understand. However, we use the least altered existing examples, along with our knowledge of how things are altered, to base classification on underlying natural characteristics.
- The differences between the unit and related units matter for biodiversity conservation. They are great enough that we would not consider the units interchangeable for conservation purposes but would seek to protect examples of both. They represent an appropriate balance between broad brush ecosystems and a view of every site as irreconcilably unique.
- The occurrences of the unit are at the appropriate spatial scale to be conservation planning targets – ¼ acre to hundreds or potentially thousands of acres, depending on the physical structure and contrast with adjacent areas. Micro-ecosystems such as the mosses on fallen logs in forests or on individual boulders may have strong contrast but are too small to be practical conservation targets. (Being conservation planning targets does not mean that we seek to conserve them without their landscape context, just that we must think about them specifically to make sure they are conserved.)
- The unit is well enough understood that we would recommend conservation action on it. It is well enough understood that other people can be told how to recognize it and to distinguish it from related units.

Two additional major considerations in developing the 4th Approximation were to minimize disruption to users of the 3rd Approximation, and to provide as much commonality with the National Vegetation Classification (NVC) as possible. Recognizing most of the new units at the subtype level, while keeping most community types unchanged, means that most users familiar with the 3rd Approximation should easily be able to transfer that knowledge. All NVC associations attributed to North Carolina were considered for creation of equivalent 4th Approximation types or subtypes. However, no such units were adopted without meeting the above tests. This led to substantial one-to-one correspondence with the NVC but not complete agreement. Where units were particularly uncertain, comments indicate that they are accepted provisionally. Others with less confidence are treated as variants.

The 3rd Approximation names were changed only where there was a significant change in the concept of the type or where new understandings or past confusion made a compelling case for a different name. Most community type names remain the same, and for many of the changes, the connection to the old name should be apparent. A table of new names for which the 3rd Approximation equivalent name is not obvious is included at the end of this introduction.

Data sources for classification – qualitative and quantitative data

The classification approach used here integrates several sources of quantitative and qualitative information. The 3rd Approximation used what quantitative data and analysis were available, in the form of published literature and what unpublished theses and dissertations were accessed. Most of these were analyses of a range of vegetation in a site or small region. A few were focused on a narrower set of communities across their range or at least across a broader area. Much more quantitative information is now available than was present in 1990. More studies of these two kinds have been conducted. However, the Carolina Vegetation Survey (CVS) represents a major new and distinct source of community data. Through "pulse" events involving hundreds of volunteers over 26 years, and additionally pooling data from many other studies with compatible sampling methodology, CVS has compiled a vast database of plot data from North Carolina and nearby states (Peet et al. 1998; Peet et al. 2012). The CVS data are far from being fully analyzed, but analyses done on target groups of communities, by students and by the CVS principal investigators, have provided tremendous clarification for some communities. Additionally, the CVS database has been used heavily by the author in describing the 4th Approximation vegetation and clarifying differences among them.

Qualitative information used in the 3rd Approximation consisted primarily of unpublished "gray literature" in the Natural Heritage Program files, including many reports by classes taught by Al Radford and reports by Natural Heritage Program staff, along with the author's experience. This source of information also has vastly expanded since 1990. The Natural Heritage Program's county inventory effort and increased pace of protection work has expanded the number of site descriptions by more than an order of magnitude. It also has provided incomparable feedback on the 3rd Approximation and new ideas for improvements to classification. Well-argued proposals by Richard LeBlond, Bruce Sorrie, Harry LeGrand, Ed Schwartzman, and others have become the basis for many new community units in the 4th Approximation. The author's own growing experience with communities and with applying the classification in the field are now a much larger contributor than they were in earlier approximations. Ongoing collaboration with the other members of the CVS has also been a major contributor to new classification ideas.

The NVC stands as one of the largest new sources for the 4th Approximation, albeit of a different kind that spans both qualitative and quantitative input. Projects done by NatureServe on National Park, National Forest, and other sites provide new plot data and analysis that have informed the NVC. Additional input from other states to the NVC provide insights and perspectives for the 4th Approximation. The NVC and the North Carolina classification grew up in conversation with each other, with 3rd Approximation units, including variants, being adopted into the NVC, all North Carolina associations in the NVC being considered for the 4th Approximation, and the NVC being modified in response to input based on field testing of draft 4th Approximation units.

Specific published sources and formal unpublished sources such as theses are specifically cited in the community descriptions. Unpublished site descriptions and reports, individually cited in earlier approximations, have become too numerous to cite individually at this time. Where there once were several, now there are dozens, sometimes more than 100. While the individual contribution of each such source is thus generally diminished, the role of them collectively, and of their contributors in the Natural Heritage Program and in the ecological and botanical community, is gratefully acknowledged.

Qualitative and quantitative data

The continued use of qualitative as well as quantitative data for the 4th Approximation has been done to benefit from the strengths of both and to cover the weaknesses of both. Quantitative data are considered the standard for scientific work. If sufficient appropriate measurements are collected accurately, they provide a level of objectivity, precision, and rigor that cannot be achieved any other way. The weaknesses come partly in the ways that these ideals are not met. Despite the largest plot dataset ever assembled in our region, it is clear that some communities are not sufficiently represented. In Lee et al. (2000), a standard of five plots per association was met for 59% of the associations in the region. Experience of the author and others suggest that even five plots is not sufficient to answer many questions about community differences. The plots that exist have not generally been randomly or objectively located. More directed plot placement has been necessary, as random or systematic location would have resulted in even poorer representation of the rarer communities, but it carries with it a likely share of bias in addition to statistical noise. Plots are additionally limited to lands on which sampling is allowed and which can readily be reached, in some cases a geographically limited, biased, or otherwise inadequate sample. Finally, there is bias inherent in what vegetation has remained relatively unaltered.

Additional limitations come up in analyzing and using the data. Ideal methods for analyzing large sets of plot data are still being worked out. Unsupervised classification of vegetation plots often yields results that reflect geographic variation, degree of alteration, or other factors that are not useful for a classification that is related to the environment or is likely to represent unknown species. Or it may produce clusters that resemble existing classification units but are different in ways that are not necessarily improvements. In addition, at present, though some careful analyses of plot data have yielded useful new classifications, most of the CVS data have not been analyzed. They can be used for quantitative characterization of communities, but this characterization is based on assignment of plots to communities on the basis of decidedly nonquantitative individual judgement.

Qualitative data, in the form of site descriptions and whole-site species lists, are less precise, more variable, and, in the author's experience, can sometimes be hard to replicate. However, they offer several advantages to offset these weaknesses. There are many more sites and much more area represented by them, allowing a broader geographic and ecological scope. They represent the communities for which inadequate, or no, quantitative data are available. They better characterize a whole site or whole stand of a community. They can better represent the rarer or more sparsely distributed species that are often missed in plots. They often have information on characteristics not captured by standard plot data, such as spatial or gradient relationships among communities, additional environmental factors, variation in vegetation, and relationship of vegetation to site history. One form of intermediate data analysis has also been used. Species lists for sites are often divided by communities. This represents a kind of data that can be analyzed in a rough quantitative way, by determining frequency of species among sites. This has been done to inform community descriptions and to investigate distinctions among communities where plot data were not adequate for the purpose.

The 4th Approximation classification therefore represents a synthesis of quantitative and qualitative study. It aims to cover all natural communities that seem sufficiently distinct to recognize, regardless of the state of data. The circumscription of the subtypes is done with the best combination of data available. For some groups, such as longleaf pine communities, Piedmont floodplains, seeps, and high elevation rock outcrops, this is a comprehensive quantitative analysis, interpreted to accept the units that seem to represent natural vegetation variation that is related to enduring or repeating environmental influences. For other groups, such as Coastal Plain floodplains, pocosins, and many oak forests, it is a qualitative combination of several less comprehensive quantitative analyses along with many site descriptions and the author's experience. For others, such as the boulderfield communities, elevation rock outcrops, and glades, it is primarily based on site reports.

Relationship to the National Vegetation Classification

Much effort has been made to have the 4th Approximation and the NVC correspond at the level of the subtype and association respectively. This has been substantially achieved, with a one-to-one correspondence between comparable units in a large majority of cases. Many NVC associations are based on 3rd Approximation or draft 4th Approximation communities and correspond exactly, while other 4th Approximation subtypes were adopted from the NVC. Feedback to the NVC has resulted in some associations being changed to more closely match the 4th Approximation, or to clarify that associations do not occur in North Carolina.

For the minority of subtypes that do not correspond to associations, there are several reasons. Some are differences in breadth of concepts. Many of these cases are noted in the descriptions, but some may not have been recognized. In some cases, the concept of NVC associations is not clear, making it unclear how close the fit to the association is. In some cases, the author did not believe the association met the criteria for ecological distinctness, enduring natural character, and conservation significance list above. In other cases, it was inadequately clear if it met the criteria. The NVC has several conceptual differences from the 4th Approximation. It is conceived as solely a classification of existing vegetation. It includes a goal of including anthropogenic and semi-natural vegetation as well as natural. Given these differences, substantial correspondence is perhaps remarkable. However, the conversation between the two classifications, the involvement of many of the same ecologists, and the interest in natural features and conservation of all has led to convergence.

Community nomenclature

4th Approximation communities are named with the intent of providing convenient, memorable titles by which to refer to them, while minimizing confusion. No single form of names, such as all environmental names or all plant-based names, is used. Instead, the correlated characteristics that are easiest or most concise to name are used. They are named from the viewpoint of North Carolina, though, with the addition of some regional modifiers, they could be used in a broader context.

Some descriptors used in names must be interpreted in light of the common usage and range of variation in factors within North Carolina or within the range of similar community types. Thus, savannas are wet to mesic communities and not dry communities as they are in some other regions. Terms such as "marl" and "bog" are used as they are commonly used among North Carolina ecologists but may not fit the geological or hydrological definitions. Other terms are relative to local conditions. Thus, "xeric" refers to the driest conditions in North Carolina, even though desert regions elsewhere are drier. Similarly, "basic" is used as it is used by most North Carolina ecologists, as a convenient word for an intercorrelated set of characteristics that includes a higher soil pH (but not necessarily truly alkaline), higher content of "base" cations (compared to other upland sites but not to alluvial soils), and presence of a distinctive set of species that tend to occur on such soils and not elsewhere. It should be remembered, however, that names are merely "handles" and are not definitions. Much explanation of community concepts and distinguishing features has been given to allow the user to learn the ideas behind the units, and dichotomous keys are provided to aid in practical identification. The user should not assume that the characteristics in the name are either necessary or sufficient to recognize the type but should realize that the relationship between names and characteristics may vary. Thus, High Elevation Red Oak Forests will not naturally lack red oaks, but Dry Oak-Hickory Forests may occasionally have no hickories and Chestnut Oak Forest may occasionally be dominated by scarlet oak.

BREADTH OF UNITS

From the author's childhood with life divided into plant and animal kingdoms, we now find a range from five to nine kingdoms recognized. From the four classical elements of earth, air, water, and fire, we have gone to 118 elements. "There are two kinds of people in the world…." Nature, and human nature, has a way of turning out to be more complex than we think. "It is by the endless subdivisions based upon the most inconclusive differences, that some departments of natural history become so repellingly intricate" said Herman Melville in *Moby Dick*, in reference to whether there were two kinds of right whales. He said it in a chapter entitled "Cetology", in which he had previously declared that whales are fish, and in which he spent much of the space describing how they differ from other fish. Deciding on an appropriate breadth for the classification units – "lumpiness" or "splittiness," is one of the most difficult aspects of classification of any set of natural features. A position must be taken along the scale from "every place is unique" to "you've seen one, you've seen them all."

In the case of natural communities, as with many things, there is no single objective measure of breadth of a category. One can look at how many examples of each category there are, but there is no expected number and no reason to expect numbers to be equal. We expect there to be common units and rare communities. One can look at the statistical properties of groups of vegetation plots and get hints, but only if you have a lot of plot data, have classified them well, and know them to represent the range of variation within the communities on the ground that they represent. Even in the rare cases where this standard can be met, it is clear that it isn't the full answer. Not all vegetational variation represents enduring natural ecological character. Some is the result of alteration we don't want to enshrine in the classification, some is statistical noise. In practice, appropriate breadth of community units tends to be decided implicitly, by the feedback on individual units, opinions on whether they feel too broad or too narrow, whether they can be distinguished readily enough, and people's intuitive sense of whether the breadth in one part of the classification is comparable to that in another.

While the 4th Approximation keeps most of the basic structure as the 3rd, there is a substantial difference in breadth. The 3rd Approximation had very few community types that were divided into subtypes. In the 4th Approximation, most community types have at least two subtypes, and many have several. Thus, it is much more finely divided. The 4th Approximation contains 343 units at the level of primary focus, where the 3rd Approximation had 112. While some of the new communities, such as several kinds of forested boulderfields, were simply not known to exist in 1990, most of them represent subdivisions of the community types already known. There is no denying that the 4th Approximation is more finely divided, though it should be noted that perhaps half of the new subtypes had been recognized as variants in the 3rd Approximation; that, having stood the test of time, they were given greater recognition.

There are several arguments for this greater division. Most compelling is that it appears to serve biodiversity conservation better. It is much more difficult to conserve things that are not known to be distinct. Some of the diversity that is lumped together may get protected by accident, but in general the rarer parts will be missed. The Natural Heritage Program recognized the weakness of the coarser units for setting conservation goals, rating site significance, and explaining the rationale for protecting particular sites. It had already begun to separately track many of the variants in the 3rd Approximation and use them for these purposes. Demand from other users led in this direction as well. The desirability of matching the NVC as closely as possible was an additional major factor that impelled finer divisions, and the level of the division in the NVC represents in itself a demand for a finer scale.

There is an additional, somewhat paradoxical argument for finer division, which is usability and convenience. Finely divided classifications are more complex and may seem "repellingly intricate," but if the reality behind them is complex, hiding it is not always a benefit. Units which are too heterogenous also come at a price. It is harder to describe them, harder for a user to grasp what they mean, harder to match one's own knowledge with that of others, and harder to determine if a generalization about them applies to a given example. If it takes many pages to explain how whales differ from "other" fish, it might be time to call them something other than fish.

In the end, the benefits and costs of coarseness and fineness must be balanced as seems reasonable. The 4th Approximation attempts to do this, while attempting to fit reasonably well with widespread usage. The author recognizes that in this, more than perhaps in most aspects, some users are disappointed by the lack of recognition for some distinctions they see, while others find some distinctions to be too much effort to make. It is hoped that those who wish for finer division will be able to use the variants, and that they will keep marshalling arguments for the distinctiveness of what they see. It is hoped that those who find the level of detail overwhelming will be able to use the community type level to serve their purposes. In addition, users of the 3rd Approximation should be able to access the 4th relatively easily. Most of the new distinctions recognized in the 4th Approximation are at the subtype level, and most of the community types are unchanged or little changed from the 3rd Approximation.

CONTENT OF DESCRIPTIONS

Species nomenclature

Vascular plant names in this document follow Weakley (2020) to the extent possible. Nonvascular plant, lichen, and animal names, used less frequently in this document, follow the Natural Heritage Program's rare plant and animal lists for rare species and the checklists on the 2020 North Carolina Biodiversity Project web site. Infraspecific taxa are named where there are multiple choices occurring in North Carolina or where it is particularly relevant, but they are sometimes omitted where they provide little additional information to a user familiar with North Carolina's flora.

Much change has occurred in the systematics and nomenclature of both plants and animals in the last several decades, including much since writing of the 4th Approximation began. Changes in nomenclature are challenging when compiling information from older published and unpublished literature, as well as when using plot data collected over a period of years. Particularly challenging are cases where taxa have been split. Such splits have necessarily been handled on an *ad hoc* basis. Where possible, an attempt has been made to choose the finer concept and to use the new name most likely to be present in a given community, or to give both if both are likely. However, when this is not obvious and the new name is ambiguous, the name is used as it was initially applied, or in some cases, both names are listed. Thus, by way of example, mentions of *Pteridium aquilinum* are treated as *Pteridium latiusculum* or *Pteridium pseudocaudatum* according to the regions where each predominates; *Viburnum nudum* is used for what might now be either the newly recognized species *Viburnum nitidum* or the newly narrower concept of *Viburnum nudum*; *Persea palustris* is used for older mentions of *Persea borbonia* for most communities, and both *Persea palustris* and *Persea borbonia* are named in the one community where both occur in North Carolina. Species names used in the NVC names remain as they appear in NVC; many are based on earlier species nomenclature; they may therefore differ from names used elsewhere in the descriptions.

Where well-known plant names have been changed fairly recently, the older names are sometimes given in parentheses. This treatment is not systematic but is given to help the reader where it occurs. There are too many name changes to do this for all, and people vary in which changes they are likely to find confusing.

Subtype and Theme Descriptions

Detailed descriptions are given for each subtype and for each theme. No specific description is given for types, but they are characterized to some degree in both subtype and theme descriptions.

Theme descriptions contain material that is common to all or most of the communities in the theme. This is particularly true for dynamics and for comments on classification history, which often are shared. The relative division of the content is different among different themes. The reader is advised to check both the subtype and theme description to learn all this document contains about a given community.

Descriptions are based primarily on the most intact examples that are known. More altered examples will fit the description to varying degrees and may be recognizable with reasonable interpretation of what has been changed. Pervasive alterations that have been present in all or most examples for a long time are generally incorporated into the descriptions of vegetation and other factors. Thus, mountain forests are described without *Castanea dentata*, but Canada Hemlock Forests continue to note the recent dominance of *Tsuga canadensis*. Vegetation is generally described as it exists after decades of fire suppression for most communities, but for longleaf pine communities, where prescribed burning has occurred in many examples for several decades, examples with regular fire but with past fire suppression are generally what is described.

Keys

Dichotomous keys are given for all community subtypes, organized by themes. The key leads organize and summarize information in the distinguishing features sections of the descriptions but are necessarily sometimes more abbreviated. As in all descriptive material, the keys are based on relatively unaltered occurrences. More heavily altered examples may be identifiable in some cases but not in others.

Specific components of community descriptions

Concept: This is intended to give a brief statement of the idea the community represents. It was included in the 4th Approximation guide but has been substantially revised. In general, the concept is stated hierarchically, describing it first for the type, then for the subtype.

Distinguishing Features: The distinguishing features discussion is focused on the factors that help the user tell the subtype from the most similar communities. Again, generally the type is distinguished first, followed by indications of how to tell the subtype from other subtypes. The reader should pay particular attention to cases where two or more characteristics are needed simultaneously to reach a classification. Care should also be taken with the wording for species in the keys. They may be dominant or abundant, or they may be indicators whose presence as anything more than stray individuals is sufficient. Where suites of species are named, only a few may be present, and any given species may be present only in a minority of examples, but several are generally needed to have confidence in the classification. The vegetation descriptions give more detail about the abundance of species, and name more species. The lists of suites of species are necessarily not exhaustive. Where the suite is characterized (e.g., species indicative of basic conditions), the user may know of other species in the suite that would also work to indicate the community. The length of the distinguishing features section varies widely. The distinction of some communities can be explained in a few words, while others, especially those distinguished by differences in suites of species, may necessarily involve long lists.

Distinguishing features are generally based on communities in relatively natural condition. As communities become more altered, they become harder to tell apart. Ruderal or generalist species tend to become more dominant, and distinguishing species, which often are conservative, become scarer. The ability to identify heavily altered communities improves with experience, but at some level of alteration it becomes impossible.

Synonyms: Closest equivalent crosswalks are given systematically for NVC associations and for NatureServe ecological systems, and intermittently for other classifications. Ecological systems are broader than single subtypes, generally somewhere between types and themes in breadth. Most associations are very similar in breadth, but some may be broader, a few narrower, and a few related in more complex ways. It often is impossible to tell how NVC concepts are applied by other users, so exactness of correspondence is approximate. Occasionally, two associations may be listed as synonyms, indicating that both concepts are subsumed in the subtype but that the first is considered the standard crosswalk. A couple of these have been changed since the publication of the 4th Approximation Guide, some because of changes in the NVC, some because of changed interpretation of the NVC concept. Additional relationships to NVC associations, generally less equal in fit, are noted in the comments section. In a few cases where there is a comprehensive document on classification of a set of communities and it uses a different classification system or nomenclature, it too is synonymized, but no effort has been made to note all the different names a community has been called in local studies or descriptions.

Sites: The site section notes important aspects of the physical environment such as landform, slope position, aspect, geologic substrate, and elevation. Factors are named where they are particularly relevant but are not systematically named where a given character is the default or most common one. For example, occurrence on mafic rocks is often noted but occurrences on felsic rocks, the large majority of the landscape, is not. Similarly, elevations are noted for higher mountain communities but not for communities in the Piedmont or Coastal Plain.

Soils: Soils are characterized to the extent information is available, either by general characteristics or by soil taxa and series that are mapped. The CVS database includes many plots with soil chemistry and texture data, but these have not been compiled or analyzed well at present.

Hydrology: Water conditions, including degree of wetness, kind of wetness, and sometimes sources of water or chemistry of water, are noted.

Vegetation: Vegetation is described in terms of structure and composition of vascular plants. Only occasionally are nonvascular plants noted, where easily distinguished taxa are particularly informative or important. Vegetation descriptions have been almost completely rewritten since the 3rd Approximation. They may be derived in any of several ways, with wording generally indicating which was used. Where comprehensive studies have been done, these are cited and the vegetation description is based largely or completely on them. Some incomplete analyses of CVS data are also indicated. If there is no comprehensive analysis but CVS plots for the community are numerous enough and appear accurately attributed to the community, summary statistics are used to describe the vegetation in detail. Such summaries are usually based on North Carolina plots only but may have included plots of nearby states where the author believed them to be comparable and likely to give a better description. Some vegetation descriptions also combine such statistics from plot data with more crude statistics of species frequency in site descriptions. Site descriptions require their own form of judgment for inclusion, since some species lists are clearly limited in completeness and therefore may contribute to a false impression of species frequency.

Where data are sufficient, species are characterized by both dominance and frequency/constancy. The term "highly constant" generally denotes occurrence in 75% or more of plots or site species lists. "Frequent" or "fairly frequent" indicates species that occur in 25-75% of plots or site species lists. These categories must be regarded as approximate, since inclusion or exclusion of a few plots or sites can move some values across these arbitrary thresholds. Frequency in whole-site species lists means something different than it does in plots, since the area represented is very different. While highly constant and frequent species may be listed in various orders, such as grouping by genus or grouping by sources if there is more than one, they are often listed in order of frequency in the most important source used. Sparsely distributed or patchily distributed species may be frequent in sites but infrequent in plots. Other species may be infrequent even at the site level, perhaps due to dispersal limitations or to small population sizes that can be randomly lost from individual sites.

Species are characterized as dominant if they produce the majority of vegetation cover or (for trees) basal area in the stratum, individually or collectively, and as codominant if they are abundant but roughly equally abundant with other species. It is difficult to characterize the interaction of frequency/constancy and dominance. A species may be usually present but less often dominant, or it may occasionally dominate even though it is present in only a minority of plots or sites. Species may dominate patches, or plots, but not dominate a large portion of the whole stand. Plot data summaries generally give average cover in plots where a species is present, but it can be difficult to tell if that cover is uniform or highly variable among plots. The author's experience or more detailed qualitative descriptions often provide better ideas of the relationship between frequency and dominance than do summarized plot data. Additional species that are neither dominant nor moderately frequent may be named where they are deemed notable. Species described as "characteristic" are those that are believed to have been more abundant or frequent in more natural conditions or those that are believed to indicate the distinctive environment of the community when they occur, even though they appear infrequently. Most communities have a large number of species that are low in cover and frequency. Some of these are accidental in occurrence or are present only in transitions to other communities, while others reflect the site conditions in the same way the frequent species do. Much additional work could be done to describe these aspects of communities in more detail.

Range and Abundance: Because the 4th Approximation is focused on North Carolina, the global rank given is that that has been assigned by NatureServe for the synonymized NVC association. Many of these were assigned some years ago and were done "by inspection" rather than based on the more detailed analysis that is the present standard for element ranks. This analysis of all North Carolina's ranks awaits future work. Where the author believes the current rank to be in error, this is sometimes noted, but the Grank is still given. Abundance and geographic region of occurrence in North Carolina are noted. Ranges in other states are generally based on NatureServe information for the synonymized NVC associations, except where the author has personal knowledge of the range in other states.

Associations and Patterns: Most communities are characterized as small patch, large patch, or matrix communities, after the typology developed by NatureServe. The generalized concepts have been modified to fit the ecological patterns of North Carolina. Matrix communities do not generally single handedly form the landscape matrix, as occurs in some other regions. Instead, matrix communities are regularly repeating parts of a typical landscape mosaic. They could be expected in almost any large piece of that kind of landscape, generally aggregating to substantial acreage even if individual patches are not that large. Large patch communities are those that are not predictable parts of a typical landscape but that occur in large patches and occupy large acreage where they occur. They may be similar to the matrix communities around them or may contrast strongly. Because patches are large, they can have substantial interior area and support large populations of their component species. Small patch communities are unpredictable on the landscape, generally associated with distinctive environments that contrast strongly with the surrounding landscape. They occupy small patches and, though multiple patches may be present, generally they add up to only a few acres. They act as islands of habitat for species that generally have small populations and may either exhibit strong metapopulation dynamics or may support relict populations with little genetic exchange. Despite such isolation and despite small population sizes, or because of them, small patch communities imply long term stability and persistence, since species lost in disturbances or habitat changes would be very slow to recolonize. Small patch communities are inherently subject to strong edge effects even in natural landscapes, from the contrasting adjacent natural communities.

Variation: If variants have been recognized, they are names and briefly described in this section. Most variants recognized in the 3rd Approximation have become new subtypes, so variants are much fewer. Where no named variants are recognized, variation among examples is characterized in more general ways. Some communities are recognized to be highly variable, and it is likely that variants or even subtypes would be recognized with further study. Others are fairly uniform. Some are newly enough recognized or are rare and poorly studied, so that their variation is not well known.

Dynamics: The recognition of the importance of dynamics in natural communities has grown dramatically since the time the 3rd Approximation was published. Though belief in a truly static, unchanging climax state is probably a "straw man" that was never widespread, the role of natural and altered disturbance regimes, the idea of an interplay between static site characteristics and disturbance, the concept of dynamic equilibrium of patches, and other dynamic aspects of communities has certainly grown since that time. Research has been decidedly unequal, with some themes and specific communities being the focus of widespread study while others appear largely ignored. An attempt has been made to characterize what is known about dynamic aspects such as natural disturbance regimes and their importance, patterns of plant reproduction, stability and conservativeness of vegetation, and how particular environmental factors may be responsible for differentiating communities. Because some of these factors are more general than others, some of this discussion is at the theme level, some at the subtype level.

Comments: Comments are made on various aspects of the community that do not fit into other fields. Many of the comments in the 4th Approximation Guide are now placed in one of the other sections, but many communities still have material worthy of comment.

Rare species: In the present draft state, rare species listed are primarily based on those recorded in the Natural Heritage Program database with occurrences of the community. There are plans for a more comprehensive and inclusive listing of rare species that might be sought in a given community. This listing is limited to taxa currently tracked by the Natural Heritage Program. Watch list species are not included.

References: References are those cited in the community description. Additional references relevant to a given subtype may be cited instead in the theme description. General references that are used for many descriptions are not specifically cited. These include reports produced by the Natural Heritage Program, contributed unpublished reports in its files, the CVS database, and the NVC descriptions of associations. Also implicitly used throughout are Weakley (2020), the USDA soil taxonomy, SSURGO soil mapping, and the content of Soil Web.

FUTURE OF NORTH CAROLINA NATURAL COMMUNITY CLASSIFICATION

The 4th Approximation represents more than 30 years of work since the publication of the 3rd Approximation, but the continued use of the term "approximation" in the title indicates the recognition that this book will not be the last word in community classification. Much new understanding may yet gained by ongoing work on the CVS data. Further experience gained by using this classification by the Natural Heritage Program and others will yield new insight. It is hoped that new investigation will be focused on the areas of the classification where uncertainty most clearly remains.

Several areas in the 4th Approximation are already recognized as inadequate and in need of substantial revision. They are mentioned in the various descriptions. Of particular note are the most heterogenous subtypes. Low Elevation Basic Glade (Montane Subtype), Piedmont Alluvial Forest, Coastal Plain Small Stream Swamp, Sandhill Seep, and Maritime Wet Grassland are examples of communities where further work is likely to lead to recognition of new subtypes. The several communities that are accepted as provisional may end up being better described or may end up getting dropped in the future. Increasing prescribed burning, especially in the mountains, may lead to better characterization of communities such as those in the Mountain Dry Coniferous Woodlands and the Piedmont and Mountain Glades and Barrens themes. Better understanding of the ecological behavior of species such as *Pinus strobus* may lead to different interpretation of communities where they are important to classification.

As throughout the development of the 4th Approximation, feedback on the communities and evidence of unrecognized communities, as well as information on unknown good examples, is requested, solicited, and encouraged.

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CHANGES IN 4TH APPROXIMATION AFTER ADOPTION

In the years between the publication of the 4th Approximation guide in 2012 and the current document, several changes have been made to the classification, based on new understandings and new discoveries. These are listed in the order they appear or appeared in the outline and standard ordering.

Added communities

Pine–Oak/Heath (Linville Gorge Subtype)
High Elevation Red Oak Forest (Boulderfield Subtype)
Chestnut Oak Forest (Boulderfield Subtype)
Montane Oak–Hickory Forest (Low Dry Basic Subtype)
Montane Oak–Hickory Forest (Boulderfield Subtype)
Sandhill Seep (Savanna Subtype)

Dropped communities

Community	Now Included In
Montane Grape Opening	Various Mountain Oak Forests, Rich Cove Forests
Montane Cliff (Acidic Lichen Subtype)	Montane Cliff, High Elevation Rocky Summit
Montane Cliff (Carolina Rocktripe Subtype)	Montane Cliff, High Elevation Rocky Summit
Maritime Dry Grassland (Northern Subtype)	Maritime Dry Grassland
Sandhill Seep (Very Wet Subtype)	Sandhill Seep
Vernal Pool (Sphagnum Subtype)	Doesn’t occur in North Carolina
Tidal Freshwater Marsh (Southern Wild Rich Subtype)	Doesn’t occur in North Carolina

4th Approximation names not matching 3rd Approximation names

Most changes in the 4th Approximation are simple divisions into subtypes, without any change in concept at the type level. There are some minor changes in names that should be readily recognizable. This table lists 3rd Approximation names where these are not apparent. In many cases, these are newly recognized communities that were not explicitly covered in the 3rd Approximation, and the equivalent is a poorly fitting concept. A few newly discovered communities are distinctive enough that no 3rd Approximation type is reasonably equivalent.

4th Approximation Name	3rd Approximation Equivalent
High Elevation Birch Boulderfield	Boulderfield Forest
Cape Fear Valley Mixed Bluff Forest	no equivalent – newly discovered
Low Mountain Pine Forest (Shortleaf Pine Subtype)	Pine–Oak/Heath
Low Mountain Pine Forest (Montane Pine Subtype)	Pine–Oak/Heath
Southern Mountain Pine–Oak Forest	Montane Oak–Hickory Forest
Southern Mountain Pine–Oak Woodland	Pine–Oak/Heath
Calcareous Oak–Walnut Forest	Mesic Mixed Hardwood Forest (Montane Calcareous Subtype)
Mixed Moisture Hardpan Forest	Dry Oak–Hickory Forest, Dry-Mesic Oak–Hickory Forest
Swamp Island Evergreen Forest	Coastal Fringe Evergreen Forest
Montane Cliff (Acidic Subtype)	Montane Acidic Cliff
Montane Cliff (Mafic Subtype)	Montane Mafic Cliff
Montane Cliff (Calcareous Subtype)	Montane Calcareous Cliff
Talus Vineland	High Elevation Rocky Summit, Montane Acidic Cliff
Piedmont Cliff (Acidic Subtype)	Piedmont/Coastal Plain Acidic Cliff
Piedmont Cliff (Basic Subtype)	Piedmont Mafic Cliff, Piedmont Calcareous Cliff
Coastal Plain Cliff	Piedmont/Coastal Plain Acidic Cliff
Granitic Flatrock Border Woodland	Granitic Flatrock
Low Elevation Acidic Glade	Low Elevation Rocky Summit, Low Elevation Granitic Dome
Low Elevation Basic Glade	Low Elevation Rocky Summit, Low Elevation Granitic Dome
Montane Red Cedar–Hardwood Woodland	no equivalent – but adopted before 4th Approximation
Granitic Dome Basic Woodland	Montane Oak–Hickory Forest, Basic Oak–Hickory Forest
Acidic Shale Slope Woodland	no equivalent – but adopted as “Dry Rocky Slope” before 4th Approximation

4th Approximation Name	3rd Approximation Equivalent
Calcareous Shale Slope Woodland	no equivalent – but adopted as "Dry Rocky Slope" before 4th Approximation
Piedmont Acidic Glade	Low Elevation Rocky Summit
Piedmont Basic Glade	Low Elevation Rocky Summit
Xeric Piedmont Slope Woodland	Dry Oak–Hickory Forest
Live Dune Barren	Dune Grass
Stable Dune Barren	Maritime Dry Grassland
Maritime Vine Tangle	Maritime Dry Grassland
Calcareous Coastal Fringe Forest	no equivalent – but adopted before 4th Approximation
Marsh Hammock	Maritime Evergreen Forest
Coastal Fringe Shell Woodland	no equivalent – but adopted as Calcareous Coastal Fringe Forest before 4th Approximation
Dry Piedmont Longleaf Pine Forest	Piedmont Longleaf Pine Forest
Sand Barren	Xeric Sandhill Scrub
Mesic Pine Savanna	Mesic Pine Flatwoods
Brownwater Levee Forest	Coastal Plain Levee Forest (Brownwater Subtype)
Blackwater Levee/Bar Forest	Coastal Plain Levee Forest (Blackwater Subtype)
Brownwater Bottomland Hardwoods	Coastal Plain Bottomland Hardwoods (Brownwater Subtype)
Blackwater Bottomland Hardwoods	Coastal Plain Bottomland Hardwoods (Blackwater Subtype)
Cypress–Gum Swamp (Intermediate Subtype)	Cypress–Gum Swamp (Blackwater Subtype)
Sandhill Streamhead Swamp	Coastal Plain Small Stream Swamp (Blackwater Subtype)
Riverine Floating Mat	no equivalent
Montane Floodplain Slough Forest	Montane Alluvial Forest
Piedmont Alluvial Forest	Piedmont/Low Mountain Alluvial Forest
Piedmont/Mountain Levee Forest	Piedmont Levee Forest
Piedmont/Mountain Swamp Forest	Piedmont Swamp Forest
Piedmont/Mountain Bottomland Forest	Piedmont Bottomland Forest
French Broad Valley Bog	Southern Appalachian Bog (Southern Subtype)
Low Mountain Seepage Bog	Southern Appalachian Bog (Southern Subtype)
High Elevation Boggy Seep	High Elevation Seep

4th Approximation Name	3rd Approximation Equivalent
Rich Montane Seep	High Elevation Seep, Low Elevation Seep
Piedmont Boggy Streamhead	no equivalent – but adopted before 4th Approximation
Coastal Plain Seepage Bank	no equivalent
Pocosin Opening	Low Pocosin
Peatland Canebrake	Pond Pine Woodland
Streamhead Canebrake	Streamhead Pocosin
Wet Piedmont Longleaf Pine Forest	Piedmont Longleaf Pine Forest
Wet Sandy Pine Savanna	Pine Savanna
Wet Loamy Pine Savanna	Pine Savanna
Very Wet Loamy Pine Savanna	Pine Savanna
Northern Wet Pine Savanna	Pine Savanna
Small Depression Shrub Border	Small Depression Pond, Cypress Savanna
Coastal Plain Depression Swamp	Nonriverine Swamp Forest
Small Depression Drawdown Meadow	Small Depression Pond
Floating Bog	no equivalent
Interdune Marsh	Interdune Pond
Estuarine Fringe Pine Forest (Loblolly Pine Subtype)	Estuarine Fringe Loblolly Pine Forest
Estuarine Fringe Pine Forest (Pond Pine Subtype)	Pond Pine Woodland
Estuarine Beach Forest	no equivalent
Freshwater Marsh Pool	Tidal Freshwater Marsh
Tidal Red Cedar Forest	no equivalent – but added before 4th Approximation
Tidal Mud Flat	no equivalent
Sand Flat	Upper Beach