Identifying Reference Conditions for Riparian Areas of Ohio

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Abstract

Using pre-European settlement vegetation surveys and studies of the few remaining old-growth remnant forests, we:

- Determined the utility of using these different sources of information to develop reference conditions for riparian forests of Ohio.
- Identified gaps in our understanding of the ecology of Ohio's riparian forests that need to be addressed to help develop reference conditions for these important landscape components.

Based on an extensive review of the available literature, we surmised that while pre-European settlement maps and surveys provide generalized information on the broad forest types that once occurred across the state, they lack the site-specific information on forest stand structure and vegetation-environment relationships needed to adequately predict reference vegetative states.

The studies of the few remaining old-growth remnants do elucidate many of the finer-scale vegetation-environment relationships, providing considerable data on the overstory composition and, in some cases, ground-flora composition of these reference riparian systems. More information, however, is needed on the structure of these riparian forests in order to develop suites of ecologically based reference conditions for Ohio's riparian forests.

Introduction

For a resource manager interested in restoring plant communities in disturbed ecosystems, the identification of reference vegetation conditions is an important step in the process of forest ecosystem restoration (Aronson *et al.*, 1995; Pickett and Parker, 1994). Identifying reference conditions *(e.g.*, composition, structure, and function of woody and herbaceous species) for a specific ecosystem, however, is often a very contentious issue.

Successional pathways and plant community composition and structure can be highly variable, making it difficult to use historical plant communities as templates for restoration (Wyant *et al.*, 1995). This is particularly true for riparian areas, where variation in physiography, disturbance regimes, and soil characteristics can result in a diverse array of plant communities at a variety of spatial scales *(e.g.*, Gregory *et al.*, 1991; Bendix and Hupp, 2000).

A common source of information on historical plant communities that has often been used to identify reference conditions for forest ecosystem restoration is the original surveyor notes of witness trees, such as those developed by the General Land Office (GLO) in the early 1800s. From these surveyors' notes, the pre-European settlement distribu tion of forest ecosystem types has been developed, and relatively detailed information on the historical composition and structure of these forests has been determined.

For example, in Ohio, Gordon (1966) developed a pre-European settlement map of forest types, and many resource managers and conservation organizations use this classification to guide their selection of reference vegetation conditions (Figure 1).

Other less utilized sources of information on reference vegetation conditions for forest ecosystem restoration are the remaining relatively undisturbed old-growth forest ecosystems. Although less than 1% of the pre-European settlement forests remain in Ohio (Davis, 1996), there are examples of minimally disturbed old-growth (> 150 years old) and mature second-growth (120 to 150 years old) forest ecosystems in Ohio, many of which are located on public lands (*e.g.*, Goebel and Hix, 1996).

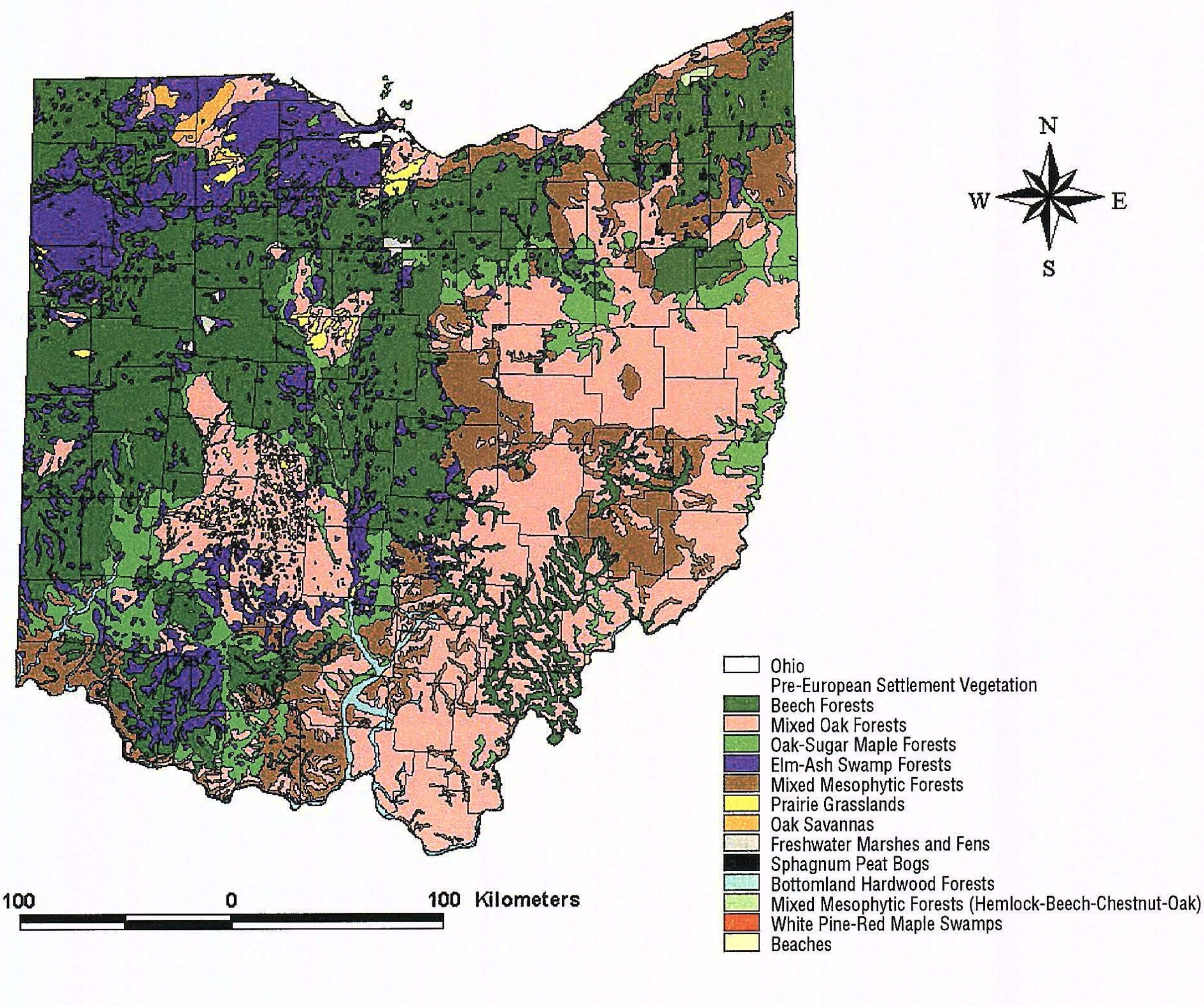

Figure 1. Presettlement forest types of Ohio (based on Gordon, 1966).

Although they often represent a small area, these forests provide an opportunity to study vegetation-environment relationships and develop predictive models of forest ecosystem development that can be used to develop templates for the restoration of forest composition and structure. As many of these old-growth forest ecosystems also have small streams and rivers flowing through them, they may provide useful information to develop reference conditions for riparian forests.

The objective of our report is to review the relevant literature related to the pre-European settlement forest-type surveys and the few remaining old-growth forest ecosystems in each of Ohio's ecoregions (McNab and Avers 1994; Figure 2) to:

- Determine the utility of using each of these sources to develop reference conditions for riparian forests of small and large streams and rivers in each of Ohio's ecoregions.
- Identify gaps in our understanding of the ecology of Ohio's riparian forests that need to be addressed to help develop reference conditions for these important landscape components.

Riparian Areas and Reference Conditions

Riparian areas are functional ecotones or transitional areas located between terrestrial and riverine ecosystems. Despite their limited areal extent, riparian areas promote many ecosystem functions vital to the health and productivity of forested watersheds. Not only do riparian areas regulate the flow of water, sediments, and nutrients across system boundaries, they also contribute organic matter to the aquatic system, increase bank stability, reduce erosion, and provide key wildlife habitat (Gregory *et al.*, 1991; Ilhardt *et al.*, 2000).

Additionally, because of their functional importance, riparian areas serve important roles in mitigating many of the negative impacts of land use on aquatic systems as well as protecting species diversity, providing potential dispersal corridors for wildlife, and mitigating flood waters (Ilhardt *et al.*, 2000; O'Laughlin and Belt, 1995). Unfortunately, we have a poor understanding of the patterns of variation in riparian areas within and among watersheds, or the specific landscape features that control riparian vegetation development.

Increasingly, riparian areas across Ohio are experiencing pressure from a variety of sources, including developers, farmers, and recreationists. Detailed assessments of relatively undisturbed riparian areas are critical elements needed for a variety of ecological purposes, especially for providing a benchmark of reference ecological conditions necessary for evaluating forest ecosystem restoration programs.

Voluntary best management practices (BMPs) promoted by various state agencies (*e.g.*, the Ohio Department of Natu

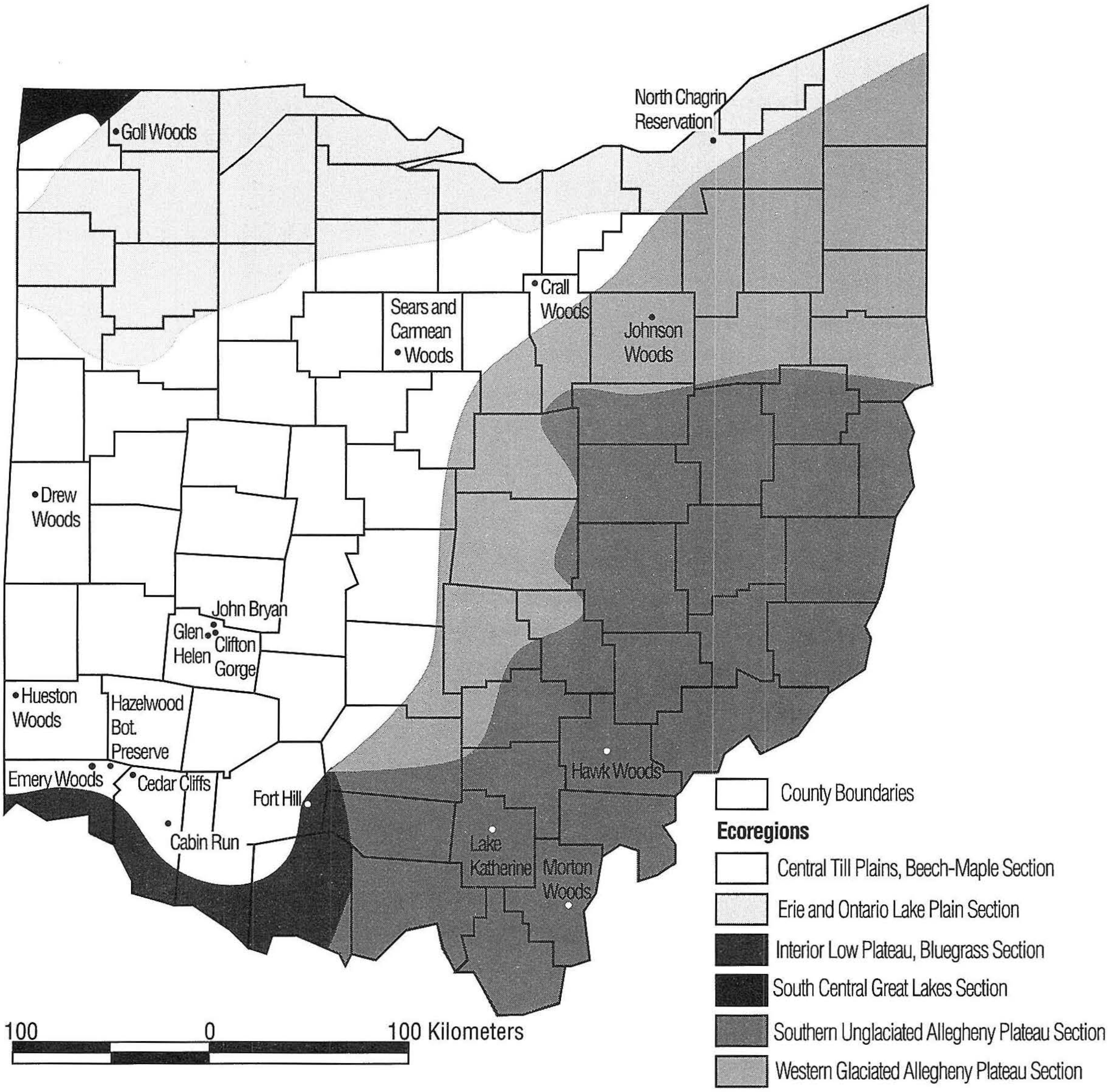

Figure 2. Ecoregions of Ohio (McNab and Avers, 1994) and location of remaining old-growth and mature second-growth forests with information on riparian forests published in a refereed journal article.

ral Resources, ODNR) may be available and utilized in riparian areas (Blinn and Kilgore, 2001). However, the effectiveness of these practices to help restore or even maintain critical ecosystem linkages is untested. These practices are certainly not site-specific in their application (*e.g.*, the width of riparian management zones is often fixed arbitrarily rather than being based on a functional delineation of riparian extent; deMaynadier and Hunter, 1995).

One important consequence of a shift toward a functional definition and delineation of riparian areas is the need for an explicit quantification of reference, or benchmark, riparian conditions (Gregory, 1999). Although current management systems incorporate the best available science, our understanding of specific riparian areas and the extent of the functions associated with these land-water interfaces is often incomplete (Blinn and Kilgore, 2001).

Understanding the range of variability in these reference riparian areas is important as they represent the goal of riparian restoration and management efforts (*i.e.*, the undisturbed riparian area with all ecosystem linkages intact) and provide a metric or standard with which to compare current and future riparian restoration and management programs.

While we know very little about the composition and structure of the riparian forests in the state, many of the current restoration and management systems used in riparian areas in Ohio, as well as other areas in North America, are based on extending our understanding of forest stand dynamics from upland forests or other riparian settings in different regions (Blinn and Kilgore, 2001; Gregory, 1999). The simple fact that there is a diverse array of environmental gradients distributed across riparian areas (*e.g.*, microclimate, flooding) not found in upland settings, or other riparian systems, suggests that these comparisons may not be valid (Gregory, 1999).

Methods

We conducted a review of the refereed and non-refereed literature associated with Ohio's forests, searching a variety of sources, including the Internet, on-line databases (e.g., AGRICOLA), and the OhioLINK library catalog using the following keywords: riparian forest, floodplain, bottomland, streams, rivers, streamside forest, streambank, and old-growth forest. We also reviewed more than 20 M.S. theses and Ph.D. dissertations from Ohio colleges and universities, as well as numerous Ohio Biological Survey and Ohio Agricultural Experiment Station (now the Ohio Agricultural Research and Development Center) forest inventory reports dating back as far as the early 1920s that pertain to the pre-European settlement vegetation of many of Ohio's counties.

Pre-European settlement vegetation descriptions at the state- and county-wide level were compiled to examine the usefulness of this information to develop lists of reference plant communities for riparian forests by ecoregion. We also examined more recent descriptive studies of existing old-growth forests and less disturbed areas across the state and summarized the available information on the major species comprising the overstory (stems > 10 cm diameter at breast height [dbh]; 1.4 m), understory (stems < 10 cm dbh but > 2.5 cm dbh), and the ground-flora (< 1 m tall) by ecoregion as defined by McNab and Avers (1994). We also examined these studies for any useful information that could help identify reference conditions for riparian forests.

It is important to note that a variety of terms that may relate to riparian forests were encountered in these different sources, such as floodplain forests, swamp forests, bottomland forests, and river or stream wetland forests. Consequently, for the purposes of our review, we consider riparian forests to include any forest located near any body of water, such as a lake, stream, or river. Where not defined in the paper, thesis, or report, we considered floodplain and bottomland forests to be associated with larger river systems that have extensive floodplains (*e.g.*, Cuyahoga, Scioto, Little Miami Rivers), and river and stream wetland forests to be associated with smaller rivers and streams lacking extensive floodplain development.

Categorizing the swamp forests was more problematic; as a result we examined the local physiographic conditions using a variety of sources (e.g., local soil survey maps, topographic maps) to determine whether these forests were associated with a larger or smaller stream system. Finally, plant nomenclature follows Kartez (1994); see the Appendix for a list of Latin and common species names.

Summary of Different Survey Types

The first descriptions of the major pre-European settlement forest types for Ohio were developed by Sears (1925) and Sampson (1927), who transcribed the species of bearing or witness trees from the original land surveys conducted in the late 1700s and early 1800s. Sears (1925) classified each township in the state as fundamentally "beech," "oak," or "ash" or various combinations of these types and classified treeless areas into "prairie" types (Sears, 1926).

Transeau and Sampson (1938) also used these original land surveys in conjunction with field studies of remaining undisturbed forests in an effort to classify major forest types, including swamp forests, and develop strategies to better utilize Ohio's forests. Sampson (1927) mapped major plant associations and suggested that the riparian forests of the state were dominated by willow, alder, river birch, and maple-cottonwood-sycamore forest associations.

A similar pre-European forest-type classification as Transeau and Sampson (1938) was developed by Chapman (1944). However, Chapman was the first to provide a reconstructed picture of the pre-European settlement riparian forests, as he documented that elm, ash, soft maple (*e.g.*, red maple), sycamore, burr oak, pin oak, and cottonwood dominated the floodplains of larger streams and rivers, while smaller streams flowing through narrow valleys throughout the state were dominated by hemlock, American beech, and maple.

The most detailed description of the pre-European forests of Ohio (Figure 1) was developed by Gordon (1966, 1969), who synthesized the work of Sears (1925), Transeau and Sampson (1938), and Chapman (1944), as well as many county-level forest-type classifications published as M.S. theses, Ohio Biological Survey (OBS) reports, and state forestry reports published by the Works Progress Administration and the Ohio Agricultural Experiment Station (OAES). For example, Gordon (1969) described major plant associations for different floodplains and swamp forests; however, he realized that these forest types associated with streams and rivers were the least understood and most variable in terms of species composition in the state.

Furthermore, in one of the more detailed early botanical studies of Ohio's regional flora, Griggs (1914) stated no problem was so difficult as the reconstruction of the vegetation of the bottomlands along the large streams and in his words "there is not a vestige left to suggest the original condition of the Hocking bottom between

Lancaster and Logan except the swamps and a few large trees standing in the fields into which it has been converted."

The amount and details of specific information on the vegetation-environment relationships of relatively undisturbed vegetation of Ohio's riparian forests are varied and depend largely on the specific ecoregion. Overall, there tends to be specific information on the overstory composition, but very little data on the understory and ground-flora plant communities. For example, many of the county-level M.S. theses and OBS and OAES reports tend to be distributed across each ecoregion of the state and describe the composition of local riparian forests (e.g., Diller, 1932; Jones, 1936; Norris, 1948).

Furthermore, Andreas (1989) suggests that riparian plant communities of the glaciated Allegheny Plateau ecoregion are related to predictable assemblages of plant communities that are organized on the basis of geology, topography, moisture availability, and aspect. For instance, swamp forests dominated by overstories of red maple (*Acer rubrum* L.), silver maple (*A. saccharinum* L.), white ash (*Fraxinus americana* L.), and American elm (*Ulmus americana* L.) and understories of common elderberry (*Sambucus canadensis* (L.) R. Bolli), beggarticks (*Bidens* spp.), sedge (*Carex* spp.), sweet woodreed (*Cinna arundinacea* L.), Canadian woodnettle (*Laportea canadensis* (L.) Weddell), rice cutgrass (*Leersia oryzoides* (L.) Sw.), sensitive fern (*Onoclea sensibilis* L.), and reed canarygrass (*Phalaris arundinacea* L.) occur across the ecoregion on flat, poorly-drained floodplains associated with small streams and rivers.

Conversely, on silt-laden deposits of floodplains along major river systems of the ecoregion (*e.g.*, Cuyahoga and Scioto Rivers and Killbuck Creek), boxelder (*Acer negundo* L.), silver maple (*Acer saccharinum*), Ohio buckeye (*Aesculus glabra* Willd.), green ash (*Fraxinus pennsylvanica* Marsh.), black walnut (*Juglans nigra* L.), American sycamore (*Platanus occidentalis* L.), eastern cottonwood (*Populus deltoides* Bartr. *ex* Marsh.), and American elm (*Ulmus americana*) dominate the overstory.

The understory of these floodplains along larger streams and rivers is similar to the swamp forests described previously, with the addition of several species including silver false spleenwort (*Deparia acrostichoides* (Sw.) M. Kato), eastern bottlebrush grass (*Elymus hystrix* L. var. *hystrix*), whitegrass (*Leersia virginica* Willd.), ostrich fern (*Matteuccia struthiopteris* (L.) Todaro), Virginia creeper (*Parthenocissus quinquefolia* (L.) Planch.), marshpepper knotweed (*Polygonum hydropiper* L.), jumpseed (*P. virginianum* L.), eastern poison ivy (*Toxicodendron radicans* (L.) Kuntze), cutleaf coneflower (*Rudbeckia laciniata* L.), wingstem (*Verbesina alternifolia* (L.) Britt. *ex* Kearney), and striped cream violet (*Viola striata* Ait.)

However, these sources of reference vegetation conditions often provide generalizations of the different overstory and understory species, but not the site-specific information needed to develop detailed restoration templates for riparian areas across each ecoregion of the state.

While many of the refereed journal articles that examine the ecology of individual old-growth forests do provide site-specific information on the vegetation-environment relationships of riparian forests, they often focus only on overstory composition and rarely on the structure of these riparian forests (Table 1). Additionally, the information provided by these surveys and studies is often disparate, resulting in considerable gaps in our understanding of the factors that regulate the composition and structure of riparian forests across the ecoregions of Ohio (Table 1). In the sections that follow, we document the available information of reference riparian conditions for each ecoregion from these studies of specific old-growth and mature forests.

Table 1. Compositional and Structural Information on Overstory and Ground-Flora Strata of Riparian Forests Provided by Published Studies of Old-Growth Forest Ecosystems.

			Composition			Structure		
Area	Citation	Soils	Over-story	Under-story	Ground Flora	Over-story	Under-story	Ground Flora
Western Glaciated Allegheny Plateau								
Johnson Woods	Braun, 1950	-	x	x	-	-	-	-
	Goebel *et al.*, 2003	x	-	-	x	-	-	x
Southern Unglaciated Allegheny Plateau								
Hawk Woods	McCarthy *et al*,. 1987	x	x	x	-	x	x	-
Lake Katherine	Runkle & Whitney, 1987	x	x	x	-	x	x	-
Morton's Woods	Braun, 1950	-	x	x	-	-	-	-
Interior Low Plateau Bluegrass								
Fort Hill State Memorial	Braun, 1969	-	x	x	x	x	-	-
Central Till Plains, Beech-Maple								
Cabin Run	Cobbe, 1943	-	x	-	x	-	-	-
Cedar Cliffs	Irwin, 1929	-	x	x	x	-	-	-
Crall Woods	Aughanbaugh, 1964	-	x	x	x	x	-	-
Drew Woods	Boerner & Kooser, 1991	-	x	x	-	x	x	-
Emery Woods	Swanson & Vankat, 2000	-	x	x	x	x	x	-
Glen Helen	Anliot 1973	x	x	x	x	-	-	-
Clifton Gorge	Anliot 1973	x	x	x	x	-	-	-
John Bryan State Park	Anliot 1973	x	x	x	x	-	-	-
Hazelwood Bot. Preserve	Segelken, 1929	-	x	x	x	-	-	-
Hueston Woods	Braun, 1950	-	x	-	-	-	-	-
	Werth *et al.*, 1984	-	x	x	x	-	-	-
Sears & Carmean Woods	Cho & Boerner, 1991a,b	-	x	x	-	x	x	-
Erie and Ontario Lake Plain								
Goll Woods	Boerner & Cho, 1987	-	x	x	-	x	x	-
North Chagrin Res.	Williams, 1936	-	x	-	x	-	-	-
South Central Great Lakes								
-	-	-	-	-	-	-	-	-

Riparian Reference Conditions by Ecoregion

Western Glaciated Allegheny Plateau

In the Western Glaciated Allegheny Plateau ecoregion located in northeastern and central Ohio (Figure 2), data are available from four different sources, two of which examine the vegetation-environment relationships of riparian forests that were conducted at the same location (Graeber Woods or Johnson Woods, Figure 3). Braun (1950) documented that along an intermittent stream in this gently dissected morainal system classified by Gordon (1969) as an elm-ash swamp forest type, the lower, poorly drained flats were dominated by red maple *(Acer rubrum)*, American elm *(Ulmus americana)*, and swamp white oak (*Quercus bicolor)*, while on the drier swells or morainal ridges, white oak *(Quercus alba)*, American beech *(Fagus grandifolia* Ehrh.), and sugar maple *(Acer saccharum* Marsh.) dominated the overstory.

Figure 3. Intermittent stream flowing through Johnson Woods State Nature Preserve with an understory dominated by jewelweed, Canadian wood nettle, and stinging nettle.

Although Braun (1950) makes no mention of the herbaceous understory, Goebel *et al.* (2003) found that specific groundflora species were associated with the floodplains located along this intermittent channel, and these were related strongly to landform and soil characteristics. For example, jewelweed *(Impatiens capensis* Meerb.), Canadian woodnettle *(Laportea canadensis),* whitegrass *(Leersia virginica),* and stinging nettle *(Urtica dioica* L.) were all associated with floodplain soils that have finer textures, higher organic matter content, and higher concentrations of total N, nitrate-N, phosphorus, potassium, calcium, and magnesium than adjacent upland communities (P. C. Goebel, unpublished data).

Southern Unglaciated Allegheny Plateau

In the Southern Unglaciated Allegheny Plateau ecoregion (Figure 2), five published studies have examined the vegetation-environment relationships of old-growth or relatively undisturbed forest ecosystems. Both McCarthy *et al.* (1987) and Braun (1950) report information on riparian forests of narrow ravines along small intermittent streams flowing through old-growth forest ecosystems.

McCarthy *et al.* (1987) classified the riparian forests of Hawk Woods in Athens County (Figure 2) as a mixed-mesophytic type, characterized by white oak *(Quercus alba),* northern red oak *(Q. rubra* L.), sugar maple *(Acer saccharum),* tuliptree *(Liriodendron tulipifera* L.), American basswood *(Tilia americana* L.), bitternut hickory *(Carya cordiformis* (Wangenh.) K. Koch), and yellow buckeye *(Aesculus flava* Ait.), and published stand structural information including the basal area and density of overstory and understory woody species, as well as woody species richness (Table 1).

Braun (1950) documented similar overstory composition for the former Morton's Woods in Gallia County (Figure 2), with the addition of American beech *(Fagus grandifolia)* which was a canopy dominant. No information on the riparian groundflora composition or structure is available for either of these old-growth forests (Table 1).

In the western portion of this ecoregion, Braun (1928) characterized many early successional riparian forests of eastern Adams County as being dominated by sweetgum *(Liquidambar styraciflua* L.), which is eventually replaced by more shade-tolerant species such as American sycamore *(Platanus occidentalis)* and other mixed mesophytic species.

Similar results were reported by Runkle and Whitney (1987) at the Lake Katherine State Nature Preserve (Figure 2) where floodplains and terraces along smaller creeks are dominated by canopies of tuliptree *(Liriodendron tulipifera),* yellow birch *(Betula alleghaniensis* Britt.), river birch *(B. nigra* L.), and American sycamore *(Platanus occidentalis)* and an understory of American hornbeam *(Carpinus caroliniana* Walt.), northern spicebush *(Lindera benzoin),* umbrella-tree *(Magnolia tripetala* (L.) L.), American hazelnut *(Corylus americana* Walt.), pawpaw *(Asimina triloba* (L.) Dunal), and boxelder *(Acer negundo).*

Interior Low Plateau Bluegrass

Along the Ohio River in southwestern Ohio in the northern extension of the Interior Low Plateau Bluegrass ecoregion (Figure 2), we found only one study that focused on the vegetation-environment relationships of riparian forests. Braun (1969) characterized the mature riparian forests associated with the rolling lowlands of wide open ravines and gentle slopes located at the Fort Hill State Memorial (Figure 2).

Along the banks of small streams, Braun (1969) described a diverse ground-flora (> 40 species), perhaps best characterized by large patches of bristly buttercup *(Ranunculus hispidus* Michx. var. *nitidus* (Chapman) T. Duncan) and a sparse overstory of American sycamore *(Platanus occidentalis),* American elm *(Ulmus americana),* boxelder *(Acer negundo),* and green ash *(Fraxinus pennsylvanica)* grading into a mixed-mesophytic forest.

Although not associated with a specific forest, Braun (1928) documented that riparian forests associated with frequently flooded flats across Highland County are characterized by an overstory of American sycamore *(Platanus occidentalis),* American elm *(Ulmus americana),* and black willow *(Salix nigra* Marsh.) and a diverse ground-flora including cutleaf coneflower *(Rudbeckia laciniata* L.), crookedstem aster *(Symphyotrichum prenanthoides* (Muhl. *ex* Willd.) Nesom), common sneezeweed *(Helenium autumnale* L.), wingstem *(Verbesina alternifolia* (L.) Britt. *ex* Kearney), cup plant *(Silphium perfoliatum* L.), giant goldenrod *(Solidago gigantea* Ait.), fall phlox *(Phlox paniculata* L.), spotted water hemlock *(Cicuta maculata* L.), and field horsetail *(E. arvense* L.)

Finally, although Bryant (1987) describes California Woods Nature Preserve located in the Cincinnati Metropolitan area (Figure 2) as a ravine community dominated by mixed-mesophytic tree species, no specific information on the composition or structure is provided.

Central Till Plains, Beech-Maple

Twelve studies were found that describe the riparian forests of the Central Till Plains, Beech-Maple ecoregion (Figure 2), with 10 detailing riparian vegetation-environment relationships, making it the most intensively studied of any ecoregion in the state (Table 1). These studies included riparian areas associated with intermittent stream channels, riparian areas along small streams and ravines, and riparian areas associated with large rivers, broad flats or floodplains, and bottomland swamps.

Crall Woods in north-central Ohio and Cabin Run Forest in southwestern Ohio are both examples of old-growth forests traversed by intermittent streams (Figure 2). However, Aughanbaugh (1964), in his study of Crall Woods, does not differentiate the undulating terrain into riparian and upland areas. The major tree species encountered were sugar maple *(Acer saccharum),* American basswood *(Tilia americana),* American beech *(Fagus grandifolia),* tuliptree *(Liriodendron tulipifera),* American elm *(Ulmus americana),* northern red oak *(Quercus rubra),* shagbark hickory *(Carya ovata* (P. Mill.) K. Koch), and hophornbeam

(*Ostrya virginiana* (P. Mill.) K. Koch), with more than 90 herbaceous species recorded in the wooded area.

At Cabin Run Forest along intermittent streams that dissect the upland areas dominated by mixed-mesophytic forests, Cobbe (1943) found that sugar maple *(Acer saccharum),* American beech *(Fagus grandifolia),* tuliptree *(Liriodendron tulipifera),* American basswood *(Tilia americana),* black walnut *(Juglans nigra),* and white oak *(Quercus alba)* were nearly always present in the riparian area, with their abundance dependant on local site and microclimatic conditions.

Cobbe (1943) also documents that a small stream bordering the forest at Cabin Run supported a streamside community where American sycamore *(Platanus occidentalis)* was dominant, along with several other species including sugar maple *(Acer saccharum),* black walnut *(Juglans nigra),* tuliptree *(Liriodendron tulipifera),* and pignut hickory *(Carya glabra).*

The herbaceous layer was composed of rattlesnake fern (*Botrychium virginianum* (L.) Sw.), brittle bladderfern *(Cystopteris fragilis* (L.) Bernh.), Canadian wildginger *(Asarum canadense* L.), Virginia springbeauty *(Claytonia virginica* L.), cutleaf toothwort *(Cardamine concatenata* (Michx.) Sw.), white fawnlily *(Erythronium albidum* Nutt.), fragrant bedstraw *(Galium triflorum* Michx.), jewelweed *(Impatiens capensis),* twinleaf (*Jeffersonia diphylla* (L.) Pers.), great blue lobelia (*Lobelia siphilitica* L.), common yellow oxalis (*Oxalis stricta* L.), wild blue phlox (*Phlox divaricata* L.), mayapple (*Podophyllum peltatum* L.), toadshade *(Trillium sessile* L.), downy yellow violet (*Viola pubescens* Ait.), and striped cream violet (*V. striata* Ait).

The old-growth forest of Emery Woods in Hamilton County (Figure 2) includes an area where ravine slopes, associated with small and often times sluggish streams, are prominent. At Emery Woods, Swanson and Vankat (2000) found that the forests of these ravine bottoms tend to support mixed mesophytic species including sugar maple *(Acer saccharum),* hickory *(Carya* spp.), oak *(Quercus* spp.), American beech *(Fagus grandifolia),* and tuliptree *(Liriodendron tulipifera).*

These finding are similar to those reported by Braun (1936) in her descriptive comparison of ravine slope forests and flats within the Illinoian till plains region of southwestern Ohio. Similar relationships were observed along a small stream draining a large ravine and two main branches with swampy, flat-bottomed floors at the Hazelwood Botanical Preserve (HBP), also in Hamilton County (Figure 2).

A variety of habitats from extremely wet swamp communities to mesophytic associations were observed at HBP. Specifically, Segelken (1929) found that herbaceous vegetation far outnumbered the woody plants on the wetter sites. Those species reported to occur in the wetter areas include yellow marsh marigold *(Caltha palustris* L.), rice cutgrass *(Leersia oryzoides),* arrowleaf tearthumb *(Polygonum sagittatum* L.), jewelweed *(Impatiens capensis),* and broadleaf cattail *(Typha latifolia* L.). Prairie ironweed *(Vernonia fasciculata* Michx.) was common along the stream, while sweetscented joepyeweed *(Eupatorium purpureum* L.) and common elderberry *(Sambucus canadensis* L.) were found on the ravine floor in drier places.

Several black willow *(Salix nigra)* communities were found growing on the ravine floor in both wet and drier sites. Along the sloping margins of the stream bank, American elm *(Ulmus americana)* and American sycamore *(Platanus occidentalis)* were found distributed where hydro-mesophytic conditions prevail.

In addition to these species, Segelken (1929) found the following herbaceous plants on the ravine floor: harvestlice *(Agrimonia parviflora* Ait.), American water-plantain *(Alisma plantago-aquatica* L.), Indianhemp *(Apocynum cannabinum* L.), swamp milkweed *(Asclepias incarnata* L.), shallow sedge *(Carex lurida* Wahlenb.), Canadian honewort *(Cryptotaenia canadensis* (L.) DC.), white turtlehead *(Chelone glabra* L.), ovate spikerush *(Eleocharis ovata* (Roth) Roemer & J. A. Schultes), field horsetail *(Equisetum arvense* L.), cream avens *(Geum virginianum* L.), spotted St. Johnswort *(Hypericum punctatum* Lam.), beggarslice *(Hackelia virginiana* (L.) I. M. Johnston), great blue lobelia *(Lobelia siphilitica* L.), sharpwing monkeyflower *(Mimulus alatus* Ait.), ground ivy *(Glechoma hederacea* L.), pellitory *(Parietaria pennsylvanica* Muhl. *ex* Willd.), ditch stonecrop *(Penthorum sedoides* L.), Canadian clearweed *(Pilea pumila* (L.) Gray), halberdleaf tearthumb *(Polygonum arifolium* L.), dotted smartweed *(Polygonum punctatum* Ell.), common selfheal *(Prunella vulgaris* L.), blue skullcap *(Scutellaria lateriflora* L.), roundleaf goldenrod *(Solidago patula* Muhl. *ex* Willd.), white vervain *(Verbena urticifolia* L.), and summer grape *(Vitis aestivalis* Michx.).

At Cedar Cliffs Prairie, located on a bluff of the Little Miami River (Figure 2), a broad floodplain extends unbroken for miles, with prairie openings that occur in exposed locations where evaporation and exposure are great. The bluff is indented by ravines and gullies of various sizes. These isolated and protected parts are very different from the bluffs themselves.

Irwin (1920) reported that the extremely steep bluff was almost bare of vegetation, whereas the ravines supported a mesophytic habitat where northern red oak *(Quercus rubra)* and sugar maple *(Acer saccharum)* were dominant. American elm *(Ulmus americana)*, black walnut *(Juglans nigra)*, blue ash *(Fraxinus quadrangulata* Michx.), eastern redbud *(Cercis canadensis* L.), and yellow chestnut oak *(Quercus muhlenbergii* Engelm.) occurred as saplings.

The most important species of the diverse herbaceous layer consisted of muhly grass *(Muhlenbergia* spp.), hairy sunflower *(Helianthus hirsutus* Raf.), American bittersweet *(Celastrus scandens* L.), upland boneset *(Eupatorium sessilifolium* L.), longsepal beardtongue *(Penstemon calycosus* Small), and tall rattlesnakeroot *(Prenanthes altissima* L.).

Anliot (1973) reported on the vascular flora of Glen Helen, Clifton Gorge, and John Bryan State Park in north central Greene County (Figure 2). The topography of the study area is fairly flat except where dissected by the Little Miami River and its tributaries. Anliot (1973) found there was great variability associated with soil characteristics and drainage among the floodplain communities.

Willow-eastern cottonwood-American sycamore *(Salix* spp.-*Populus deltoides-Platanus occidentalis)* communities were found mainly along the larger waterways. Where better drainage occurred, silver maple *(Acer saccharinum)*, American elm *(Ulmus americana)*, and ash *(Fraxinus* spp.) were dominant, while either bur oak *(Quercus macrocarpa* Michx.), swamp white oak *(Q. bicolor* Willd.), and shellbark hickory

(Carya laciniosa (Michx. f.) G. Don) or northern red oak *(Quercus rubra)* and American basswood *(Tilia americana)* forest communities dominated the best drained sites. In addition, bur oak *(Quercus macrocarpa)*, silver maple *(Acer saccharinum)*, black walnut *(Juglans nigra)*, butternut *(J. cinerea* L.), Ohio buckeye *(Aesculus glabra)*, and black maple *(Acer nigrum* Michx. f.) also occurred frequently on alluvial deposits along streams.

Anliot (1973) also documented successional patterns along the Little Miami River in old fields abandoned less than 10 years. The fields first became reforested primarily with boxelder *(Acer negundo* L.), American sycamore *(Platanus occidentalis)*, and honeylocust *(Gleditsia triacanthos* L.), often in pure stands. Before a canopy developed, Canada goldenrod *(Solidago canadensis* L. and *S. canadensis* var. *scabra* Torr. & Gray), hairy white oldfield aster *(Symphyotrichum pilosum* (Willd.) Nesom.), white panicle aster *(Symphyotrichum lanceolatum* var. *lanceolatum* (Willd.) Nesom.), wingstem *(Verbesina alternifolia* (L.) Britt. *ex* Kearney), giant ironweed *(Vernonia gigantea* (Walt.) Trel.), Jerusalem artichoke *(Helianthus tuberosus* L.), Canada thistle *(Cirsium arvense* (L.) Scop.), hairy pagodaplant *(Blephilia hirsuta* (Pursh) Benth.), creeping jenny *(Lysimachia nummularia* L.), and stinging nettle *(Urtica dioica)* were common.

Hueston Woods (Figure 2), a nearby state park and nature preserve of comparable size containing old-growth forest remnants, lies near the southern boundary of the Beech-Maple forest region (Braun 1950) near the transition to western and mixed mesophytic forests (Vankat *et al.*, 1975). However, unlike the Glen Helen-Clifton Gorge-John Bryan complex, the mildly dissected topography of Hueston Woods lacks the rocky cliffs and hill prairies of the former areas (Werth *et al.*, 1984).

While the work of Vankat *et al.* (1975) focused on the woody vegetation of the upland portion of Hueston Woods, Werth *et al.* (1984) compiled a list of vascular plant flora collected from areas throughout the park and preserve. Included are 40 streamside species, nine species found in wooded ravines, and 46 from wet woods. Additionally, Braun (1950) lists sugar maple *(Acer saccharum)* as the dominant canopy species occurring on alluvial terraces at Hueston Woods with American elm *(Ulmus americana)*, white oak *(Quercus alba)*, and shagbark hickory *(Carya ovata)* present as minor components.

While the preceding examples are from southwestern Ohio, the Sears Woods and Carmean Woods complex in the till plains of north-central Ohio also exhibit good examples of typical riparian forests of the Central Till Plains, Beech-Maple ecoregion (Figure 2). In the two studies by Cho and Boerner (1991a,b), Sears Woods is described as comprising an area of upland moraine dissected by several major stream drainages and a large, flat floodplain terrace along the Sandusky River. Both areas have moderately well to well-drained soils. In contrast, the topography of Carmean Woods is level with very poorly drained soils.

The old-growth bottomland areas of the Sears-Carmean Woods complex are dominated by silver maple *(Acer saccharinum)*, American basswood *(Tilia americana)*, American elm *(Ulmus americana)*, and sugar maple *(Acer saccharum)*, and the total tree species composition corresponds well to the early descriptions of the red oak-basswood phase of the elm-ash swamp forest as described by Sampson (1930).

Figure 4. Maple and elm riparian forest along the Sandusky River flowing through the Sears-Carmean State Nature Preseve.

The upland forest component, in which white oak *(Quercus alba)*, northern red oak *(Q. rubra)*, and white ash *(Fraxinus americana)* were present in the canopy with co-dominants sugar maple *(Acer saccharum)* and American beech *(Fagus grandifolia)*, also corresponds well to Gordon's (1969) description of beech-sugar maple forest.

No ground-flora information was reported in either study of Sears-Carmean Woods by Cho and Boerner (1991a,b).

Examples of old-growth bottomland swamp forest communities in the Central Till Plains, Beech-Maple ecoregion can be found at Drew Woods, an isolated old-growth forest remnant located on the poorly drained till plains of western Ohio (Figure 2). Boerner and Kooser (1991) reported that "early European settlers found this area covered by a complex of swamp forest and bottomland forest broken only by occasional stream corridors."

Species more abundant on lower, wetter sites included sugar maple *(Acer saccharum)*, swamp white oak *(Quercus bicolor)*, northern red oak *(Q. rubra)*, bur oak *(Q. macrocarpa)*, and shellbark hickory *(Carya laciniosa)*. In contrast, sugar maple *(Acer saccharum)*, white oak *(Quercus alba)*, and shagbark hickory *(Carya ovata)* occupied the higher, drier sites. The community structure of the bottomland areas corresponds well to the description of oak-maple swamp given by Anderson (1982).

Erie and Ontario Lake Plain

The Erie and Ontario Lake Plain ecoregion (Figure 2) extends from the shores of Lake Erie in northeastern Ohio where the topography includes level highlands cut by ravines and develops into broader, flatter areas in the western portions, especially along the Maumee Drainage, commonly described as the Black Swamp. Data on riparian conditions for this ecoregion are available from six sources; however, only three provide information on riparian forest vegetation-environment relationships.

Williams (1936) described the North Chagrin Reservation of the Cleveland Metropolitan Park System in northeastern Ohio (Figure 2) as an area of high bluffs along the Chagrin River valley characteristically cut by short gullies and deep ravines. Williams also noted that no perennial streams run through the study area, but an excess of moisture is always present in the deeper ravines. The ravines might be considered the beginning of a transitional phase toward swamp forest or bottomland conditions where trees often represent bottomland species.

Some of the tree species encountered in the ravines included eastern hemlock *(Tsuga canadensis* (L.) Carr.), sugar maple (*Acer saccharum)*, red maple *(A. rubrum)*, white ash *(Fraxinus americana)*, American elm *(Ulmus americana)*, tuliptree *(Liriodendron tulipifera)*, American basswood *(Tilia americana)*, slippery elm *(U. rubra* Muhl.), northern red oak *(Quercus rubra)*, flowering dogwood *(Cornus florida* L.), black cherry *(Prunus serotina* Ehrh.), black walnut *(Juglans nigra)*, bitternut hickory *(Carya cordiformis)*, and butternut *(J. cinerea)*. Although Williams (1936) lists all herbaceous plants found in the study area, he did not categorize them by habitat type.

Schlesinger (1971) also found similar upland swamp forest communities along the sides and bottom of the large ravine cutting through his study area in eastern Cuyahoga County, but specific information on the vegetation from this area was not sampled or reported.

Vegetation-environment relationships of Goll Woods, the last known uncut old-growth forest remnant of the Black Swamp forest of northwestern Ohio, were studied by Boerner and Cho (1987). They found that the distribution of tree species was regulated by different drainage conditions. Species occupying the poorly drained flats were silver maple *(Acer saccharinum)*, American elm *(Ulmus americana)*, bur oak *(Quercus macrocarpa)*, and ash *(Fraxinus* spp.). As drainage improves, these species were replaced by American basswood *(Tilia americana)*, American hornbeam *(Carpinus caroliniana)*, northern red oak *(Quercus rubra)*, and red maple *(Acer rubrum)* on transitional sites adjacent to the drier beach ridges.

Sampson (1930), Braun (1950), and Gordon (1969) discerned the major influences of elevation, soil drainage, and aeration on forest composition when they delineated the Black Swamp lake plain into several similar regions. Kaatz (1955), in his historical description of the Black Swamp,

Figure 5. Beech-maple-hemlock forests typical of riparian forests of the eastern Erie and Ontario Lake Plain.

described an area surrounding the settlers' route that crossed the swamp from southeast to northwest as low and wet, and being traversed by many streams. Here, the most frequently mentioned trees were ash (*Fraxinus*), elm (*Ulmus*), oak (*Quercus*), maple (*Acer*), basswood (*Tilia*), hickory (*Carya*), and cottonwood (*Populus*) species. Kaatz (1955) also noted that swamp forest species were highly sensitive to small variations in surface drainage which resulted in a great variety of species occupying the wetter sites, in contrast to the beech-maple or oak-hickory forest associations on better drained sites.

South Central Great Lakes

We found no source depicting the South Central Great Lakes ecoregion in Ohio (Figure 2). One study from southeastern Michigan (Hammitt and Barnes 1989), within this ecoregion, examined the vegetation of a 150-year-old upland oak-hickory forest; however, the study does not include any riparian forest ecosystems.

Conclusions

Our review of the potential sources of information available to resource managers on the composition and structure of undisturbed riparian forests of Ohio suggests that these characteristics can be quite variable, depending largely on the influence of surficial geology, stream valley geomorphology, soils, and predominate disturbance patterns. Such relationships are similar to those documented by many others, including Goebel *et al.* (1996), Hupp and Osterkamp (1996), Pabst and Spies (1998), and Bendix and Hupp (2000).

The result is that riparian vegetation is often arrayed in predictable patterns across stream valleys and, with an understanding of the factors that regulate their development, reference vegetative states can be determined.

By and large, while statewide pre-European settlement maps and regional county-wide surveys provide generalized information on the broad forest types that once occurred across the state, they lack the specific information on forest stand structure and vegetation-environment relationships needed to adequately predict reference vegetative states. As such, these sources of information are too coarse for developing restoration templates for on-the-ground riparian forest restoration.

However, the studies of the few remaining old-growth forests in the state elucidate many of the finer-scale vegetation-environment relationships, providing considerable data on the overstory composition of these reference riparian systems. Less information is available on the composition of the herbaceous ground-flora, or the structure of either the overstory or ground-flora vegetation.

Consequently, the available information on reference conditions for riparian forests in the state is limited, making it difficult to identify specific reference vegetation states for riparian areas. Additionally, without some idea of the reference conditions, it is nearly impossible to measure the success of riparian forest restoration efforts.

It should be noted, however, that various small old-growth remnants exist across the state with small streams or rivers (Figure 2). In many of these remnants, some information is available on the riparian vegetation-environment relationships. For example, there are several remnant forests distributed across the state, and information on these forests has been published (*e.g.*, McCarthy *et al.*, 2001); however, no published information was found detailing the composition or structure of the riparian forests, including those at Dysart Woods, Fowler Woods, Davey Woods, and Lawrence Woods (Figure 2). Additionally, there are likely other areas in the state that can be used to help develop riparian reference conditions, including forests owned by The Nature Conservancy and other private organizations.

Based on our review, it is clear that a framework is needed to help identify reference conditions for riparian forests across the state. Hierarchy theory (O'Neill *et al.*, 1986) provides the conceptual basis for an approach we suggest to understanding interrelationships among riparian forests and multi-scale environmental factors that can be used to develop reference or benchmark conditions for riparian areas across Ohio.

When applied to riparian landscapes, hierarchy theory predicts that the upper levels of the hierarchy (e.g., ecoregions, physiographic systems) constrain a complex array of hydrogeomorphic processes that in turn mediate the dynamics of lower hierarchical levels, including stream valley shape, fluvial landforms, and plant communities (Allen and Starr, 1982; Baker and Barnes, 1998; Bendix and Hupp, 2000). Thus, we suggest that through detailed characterizations of the remaining old-growth and least-disturbed mature second-growth riparian forests, reference vegetative conditions for these systems can be developed. Specifically, by quantifying the landscape-scale and local-scale geomorphic features that shape the composition and structure of riparian areas, we can better understand the natural variation in riparian forests and develop suites of reference conditions within and among Ohio's different ecoregions.

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Appendix

Latin Name	Common Name
Acer negundo	boxelder
Acer nigrum	black maple
Acer rubrum	red maple
Acer saccharinum	silver maple
Acer saccharum	sugar maple
Aesculus flava	yellow buckeye
Aesculus glabra	Ohio buckeye
Agrimonia parviflora	harvestlice
Alisma plantago-aquatica	American waterplantain
Apocynum cannabinum	Indianhemp
Asarum canadense	Canadian wildginger
Asclepias incarnata	swamp milkweed
Asimina triloba	pawpaw
Betula alleghaniensis	yellow birch
Betula nigra	river birch
Bidens spp	beggarticks
Blephilia hirsuta	hairy pagoda-plant
Botrychium virginianum	rattlesnake fern
Caltha palustris	yellow marsh marigold
Cardamine concatenata	cutleaf toothwort
Carex lurida	shallow sedge
Carex spp	sedge
Carpinus caroliniana	American hornbeam
Carya cordiformis	bitternut hickory
Carya glabra	pignut hickory
Carya laciniosa	shellbark hickory
Carya ovata	shagbark hickory
Carya spp	hickory
Celastrus scandens	American bittersweet
Cercis canadensis	eastern redbud
Chelone glabra	white turtlehead
Cicuta maculate	spotted water hemlock
Cinna arundinacea	sweet woodreed
Cirsium arvense	Canada thistle
Claytonia virginica	Virginia springbeauty
Cornus florida	flowering dogwood
Corylus americana	American hazelnut
Cryptotaenia Canadensis	Canadian honewort
Cystopteris fragilis	brittle bladderfern
Deparia acrostichoides	silver false spleenwort
Eleocharis ovata	ovate spikerush
Elymus hystrix L. var. *hystrix*	eastern bottlebrush grass
Equisetum arvense	field horsetail
Erythronium albidum	white fawnlily
Eupatorium purpureum	sweetscented joepyeweed

Latin Name	Common Name
Eupatorium sessilifolium	upland boneset
Fagus grandifolia	American beech
Fraxinus americana	white ash
Fraxinus pennsylvanica	green ash
Fraxinus quadrangulata	blue ash
Fraxinus spp	ash
Galium triflorum	fragrant bedstraw
Geum virginianum	cream avens
Glechoma hederacea	ground ivy
Gleditsia triacanthos	honeylocust
Hackelia virginiana	beggarslice
Helenium autumnale	common sneezeweed
Helianthus hirsutus	hairy sunflower
Helianthus tuberosus	Jerusalem artichoke
Hypericum punctatum	spotted St. Johnswort
Impatiens capensis	jewelweed
Jeffersonia diphylla	twinleaf
Juglans cinerea	butternut
Juglans nigra	black walnut
Laportea Canadensis	Canadian woodnettle
Leersia oryzoides	rice cutgrass
Leersia virginica	whitegrass
Lindera benzoin	northern spicebush
Liquidambar styraciflua	sweetgum
Liriodendron tulipifera	tuliptree
Lobelia siphilitica	great blue lobelia
Lysimachia nummularia	creeping jenny
Magnolia tripetala	umbrella-tree
Matteuccia struthiopteris	ostrich fern
Mimulus alatus	sharpwing monkeyflower
Muhlenbergia spp	muhly
Onoclea sensibilis	sensitive fern
Ostrya virginiana	hophornbeam
Oxalis stricta	common yellow oxalis
Parietaria pennsylvanica	pellitory
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Penstemon calycosus	longsepal beardtongue
Penthorum sedoides	ditch stonecrop
Phalaris arundinacea	reed canarygrass
Phlox divaricata	wild blue phlox
Phlox paniculata	fall phlox
Pilea pumila	Canadian clearweed
Platanus occidentalis	American sycamore
Podophyllum peltatum	mayapple
Polygonum arifolium	halberdleaf tearthumb
Polygonum hydropiper	marshpepper knotweed
Polygonum punctatum	dotted smartweed
Polygonum sagittatum	arrowleaf tearthumb

Latin Name	Common Name
Polygonum virginianum	jumpseed
Populus deltoides	eastern cottonwood
Prenanthes altissima	tall rattlesnakeroot
Prunella vulgaris	common selfheal
Prunus serotina	black cherry
Quercus alba	white oak
Quercus bicolor	swamp white oak
Quercus macrocarpa	bur oak
Quercus muhlenbergii	yellow chestnut oak
Quercus rubra	northern red oak
Quercus spp	oak
Ranunculus hispidus Michx. var. *nitidus*	bristly buttercup
Rudbeckia laciniata	cutleaf coneflower
Salix nigra	black willow
Salix spp	willow
Sambucus canadensis	common elderberry
Scutellaria lateriflora	blue scullcap
Silphium perfoliatum	cup plant
Solidago canadensis	Canada goldenrod
Solidago canadensis var. *scabra*	Canada goldenrod
Solidago gigantea	giant goldenrod
Solidago patula	roundleaf goldenrod
Symphyotrichum lanceolatum var. *lanceolatum*	white panicle aster
Symphyotrichum pilosum	hairy white oldfield aster
Symphyotrichum prenanthoides	crookedstem aster
Tilia americana	American basswood
Toxicodendron radicans	eastern poison ivy
Trillium sessile	toadshade
Tsuga canadensis	eastern hemlock
Typha latifolia	broadleaf cattail
Ulmus americana	American elm
Ulmus rubra	slippery elm
Urtica dioica	stinging nettle
Verbena urticifolia	white vervain
Verbesina alternifolia	wingstem
Vernonia fasciculata	prairie ironweed
Vernonia gigantea	giant ironweed
Viola pubescens	downy yellow violet
Viola striata	striped cream violet
Vitis aestivalis	summer grape

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