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WETLANDS SYMPOSIUM
THE SEVENTY-FIFTH
ANNUAL SESSION

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INTRODUCTION

Ronald H. Fortney and Steven L. Stephenson
Wetlands Symposium Co-Chairs

With the passage of the Federal Clean Water Act of 1972 and the implementation of the Section 404 regulatory program provided under the Act, the impetus for the development of a new field-based discipline, *wetland science*, was set. Many federal, state, and private programs centered on wetland protection, enforcement, preservation, restoration, study, and education following the 1972 congressional mandate, as amended later. This new science had as its roots, the ecological movement of the 1960s, and was initially regarded as just a subfield of ecology. However, by the end of the 1980's, promoted by federal court rulings and continued scientific advancements, wetland science had emerged as a distinct discipline, one for which separate textbooks were written, courses were taught, professional associations were formed, and institutes were created to foster its development.

Until recently, wetland science was regarded chiefly as a North American discipline. Europe has not as yet embraced it as a separate field of study. During the 2000 Annual meeting of the Society of Wetland Scientist, one of us (Fortney) heard the director of the German Max Plank Institute of Ecology, Dr. Wolfgang Junk, indicate that in Europe they do not consider the study of wetlands to be a separate discipline.

What distinguishes wetland science is that it is truly interdisciplinary. The effective study of a wetland encompasses several traditional fields of biology and ecology, plus soil science, hydrology, and geology, just to name the most obvious disciplines. Today, if you call yourself a wetland scientist, you must define the area in which you work.

As a young science, wetland science paradigms are generally poorly defined and applied and its pedagogies often vague. It is for this reason that conferences like this one are important. They serve as venues to share information, develop strategies, sort through the basic knowledge needed to refine and develop new pedagogies, and examine new initiatives.

In 1982, the West Virginia Department of Natural Resources, the U.S. Army Corps of Engineers, and West Virginia University jointly sponsored a wetland symposium entitled *Symposium on Wetlands of the Unglaciated Appalachian Region*. The proceedings of the symposium were later published. This symposium capped a three-year wetland research program in West Virginia funded by the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and West Virginia Department of Natural Resources. The goals for this symposium were to report the findings of original recent wetland investigations and advance the development of methodologies for evaluating the functions of wetlands.

Since 1982 wetland research in the mid-Appalachian Mountain region has been limited. In an effort to rekindle interest in wetlands in West Virginia, the West Virginia Academy of Science held a special symposium, *Wetlands of West Virginia*, as part of its 2000 Annual Meeting at Fairmont State College. There were two principal goals for the symposium: First, to report on the state of our information base on wetlands in West Virginia. Second, to determine what areas should be the focus of wetland research over the next 20 years in the state.

Keynoting the symposium was Mr. Ralph Tiner, Regional Wetland Coordinator with the U.S. Fish and Wildlife Service for Region 5, Hadley, Massachusetts. His paper, *Watershed-based Wetland Conservation Tool Kit: A Collection of Tools to Strengthen Wetland Management*, described a state-of-the-art approach used to manage wetland resources.

The other speakers were asked to assess the state of knowledge of wetlands in West Virginia within their respective disciplines and to address the needs for future research. The presenters, all of whom are actively involved in wetland research, together covered most of the major disciplines comprising wetland science—geology, soils, floristics, plant communities, and various groups of animals. Bio-geochemistry and hydrology were two areas not covered in the symposium. There has been limited work in these areas in West Virginia and in adjacent regions of the mid-Appalachians.

Including the paper by Ralph Tiner, the total number of papers presented was nine; the other papers are listed below.

- Edwin D. Michael, Division of Forestry West Virginia University, Morgantown, WV, *Wetland Mammals of the Central Appalachians.*
- John C. Sencindiver, Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV, *Wetland Soils in West Virginia.*
- Thomas K. Pauley, Department of Biological Sciences, Marshall University, Huntington, WV, *Amphibians and Reptiles in Wetland Habitats of West Virginia.*
- Bruce Edinger, Department of Bioscience, Salem International University, Salem, WV, *Wetland Birds of West Virginia.*
- William Grafton, Division of Forestry and Wildlife, West Virginia University, Morgantown, WV, *Floristics of wetlands in West Virginia.*
- Rodney Bartgis, The Nature Conservancy, Elkins, WV, *Floristics of Wetlands in West Virginia, Ridge and Valley Province.*
- Robert E. Behling, Department of Geology and Geography, Morgantown, WV, *Observations on the Birth, Life, and Death of Wetlands in the Unglaciated Appalachian Region.*
- Ronald H. Fortney, Department of Civil and Environmental Engineering, West Virginia University, Morgantown, WV, *Plant Communities of West Virginia Wetlands*

Included in this special issue of the *Proceedings of the West Virginia Academy of Science* are six of the nine papers presented at the symposium. Figure 1 shows the distribution of wetlands in West Virginia. We wish to acknowledge the West Virginia Academy of Science for providing the opportunity and financial support for the symposium, the Fairmont State College Department of Biology for hosting the symposium, and the West Virginia University Department of Civil and Environmental Engineering for its financial support for the symposium.

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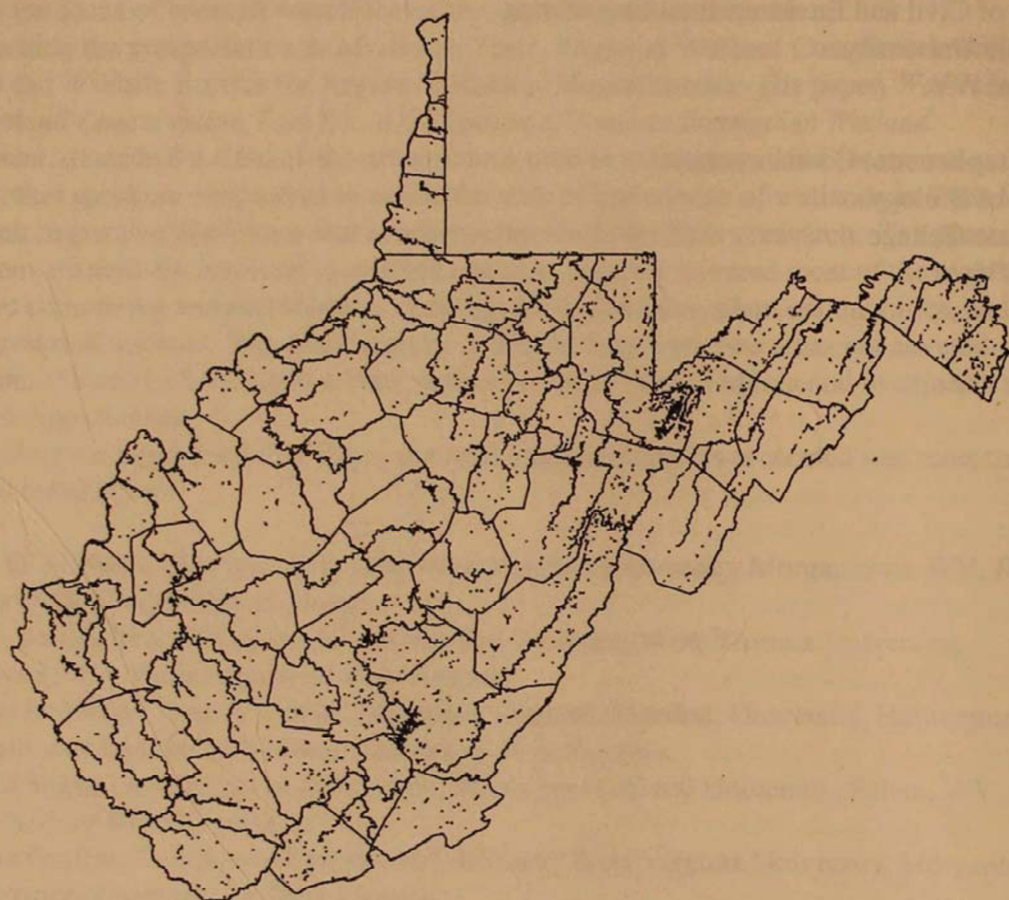

Figure 1. Distribution of wetlands in West Virginia including riverine, palustrine and lacustrine systems. The data set comes from the U.S. Fish and Wildlife Service (1976-1992) and was compiled at the statewide level by the WV Department of Environmental Protection (Source: WV GIS Technical Center, Morgantown, WV).

A Watershed-based Wetland Conservation Tool Kit: A Collection of Tools to Strengthen Wetland Management

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ABSTRACT

Over the last decade, there has been rising interest in managing wetlands and other aquatic resources on a watershed level. Natural resource data have become more available in digital formats suitable for analysis using geographic information system technology. The U.S. Fish and Wildlife Service's National Wetlands Inventory Program has been producing digital wetland data since the early 1980s. These data can now be enhanced and expanded to create tools to aid resource managers interested in watershed management. The tools include reports, maps, and a geographic information system containing information on wetland types (location, extent, and characteristics), potential wetland functions, wetland trends, the condition of wetland and waterbody buffers (e.g., stream corridors), potential wetland restoration sites, and the overall condition and extent of natural habitat in a watershed. These data provide a comprehensive geospatial natural resource database that can be used to aid efforts to conserve, manage, and restore watersheds across the country. The tools of a watershed-based wetland conservation tool kit are described and examples are provided, along with a discussion of the use of these tools for strengthening wetland and watershed management.

INTRODUCTION

Geographic information system (GIS) technology has made it possible to integrate and analyze huge amounts of geospatial information for natural resource management applications. For wetland managers and decisionmakers, geospatial information on wetlands is available for much of the country from the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) Program. Digital data for soils and land use/cover are also becoming more accessible, with the latter data being updated periodically. The existence of digital databases, coupled with the relative ease of data processing and the availability of desktop GIS (e.g., ArcView), has given natural resource planners and managers a powerful tool for making assessments over large geographic areas as well as for site-specific projects.

Citation: Tiner, R.W. 2000. A wetland-based wetland conservation tool kit: a collection of tools to strengthen wetland management. Proc. W. Virginia Acad. Sci. 72(3):5-30.

The purpose of this paper is to address the use of GIS technology for watershed-based wetland planning and evaluation. In particular, the construction of a GIS database and the production of reports and maps -- tools for a wetland conservation tool kit -- to aid in wetland resource planning, evaluation, and conservation will be emphasized.

What is a watershed? In simple terms, a watershed is the area drained by a particular stream or river. It encompasses the land mass and associated waterbodies upstream of the receiving waterbody (e.g., stream, river, lake, reservoir, or coastal embayment). For example, the watershed of a stream is the catchment area (basin) above the stream. It is delineated by lands and surface waters upstream where precipitation falling on the surface and ground water discharging to the surface flow off the land and move downhill (through seepage) or downstream (through channelized flow) into the subject stream.

Watersheds are variable in size, shape, and environmental characteristics. The actual size of a watershed for analysis is defined by the user (e.g., federal, state, or local resource agencies or local land trust and their resource management objectives or interests). The largest watershed in the United States is the Mississippi River watershed containing the drainage areas of the Ohio, Missouri, Arkansas, and Red Rivers and parts of numerous physiographic regions. At the state level, major and minor watersheds can be distinguished from subbasins, the smallest "watershed." The largest watershed in West Virginia is the Ohio River watershed, which contains all watersheds draining into the Ohio River. Other major watersheds in the state would be the individual watersheds emptying into the Ohio and Potomac Rivers. These watersheds are represented by areas containing several eight-digit U.S. Geological Survey hydrologic units (e.g., 05050001-05050009 for the Kanawha watershed). Minor watersheds are represented by a single eight-digit hydrologic unit (e.g., 05050007 for the Elk River), which constitutes a collection of subbasins draining into a common river or stream. A subbasin is, for practical purposes, the smallest watershed for resource management and is typically defined by the drainage area of a small stream like Big Sandy Creek and represented by an eleven-digit hydrologic unit code. Subbasin size may range from roughly 810 hectares (324 acres or 0.47-square mile) or less to 16,200 hectares (6,480 acres or 10-square miles) or more. For site-specific assessments, smaller "watersheds" or drainage areas can be designated.

Components of a Watershed-based Wetland Conservation Tool Kit

Wetland conservation includes protection, management, restoration, and enhancement. A watershed-based wetland conservation tool kit provides a set of tools to aid planners and decisionmakers in their efforts to protect, conserve, and restore wetlands and associated resources. In planning for wetlands, planners would benefit from having the following information: (1) location, extent, and characteristics of existing wetlands, (2) an assessment of wetland functions, (3) historical perspective of wetland trends, (4) condition of wetland buffers, (5) location and characteristics of potential wetland restoration sites, and (6) an overall assessment of natural habitat and land use in the watershed.

Reports, maps, and a GIS database are the tools provided in a wetland conservation tool kit. A single report or series of reports could be produced to present the above information. Maps are integral parts of these reports and are needed for visual representations of study findings. A comprehensive GIS database is the foundation for such work, as it is required to perform the watershed analysis and produce vital statistics and maps. Later, this database could be used to perform other geospatial analyses for a multitude of other projects of interest to planners. While some of the desired information exists in digital form, much of the data will have to be collected, evaluated, and/or converted to digital form for GIS applications.

When assembling or using a watershed-based wetland conservation tool kit, it is vital to realize that the tools have limitations based on the quality of the data collected and the ability of the compiler to improve and refine the datasets comprising the tools. Anyone who has worked on wetland inventories or even wetland delineation should recognize that such efforts are, by necessity, approximations of perceived reality. There are inherent limitations of remote sensing for wetland mapping (see later discussion; Tiner 1990, 1997a) as well as limitations in our ability to accurately identify and delineate drier-end wetlands on the ground (see Tiner 1999). Such handicaps, however, should not deter us from building watershed tool kits as they do provide the holistic (big-picture) view of wetlands for large geographic areas and one that can only be gained through application of remote sensing and GIS technology.

Building a Comprehensive Geospatial Wetland Digital Database

The backbone of the watershed-based wetland conservation tool kit is a comprehensive geospatial digital database that emphasizes wetlands, but also includes data on waterbodies and uplands. Using geospatial digital data such as the NWI data, U.S. Geological Survey (USGS) hydrology data (digital line graphs - DLGs), U.S.D.A. Natural Resources Conservation Service soil survey data, and land use/cover data from various sources, one can build a database for large geographic areas (e.g., major and minor watersheds; counties; states). Once a watershed is defined, several steps must be taken to create a geospatial database for use in developing other tools for a watershed-based wetland conservation tool kit.

The first step is to assemble existing wetland information and, where necessary, convert it to digital form for GIS applications. Sources of geospatial wetland data may include: (1) National Wetlands Inventory (NWI) maps, (2) state wetland maps, (3) county soil survey reports, and (4) local wetland maps. NWI maps are available for about 91% of the conterminous U.S., all of Hawaii, and 35% of Alaska. Maps in digital form are available for 46% of the conterminous U.S. and 18% of Alaska. These maps were derived from photo-interpretation of mid-level to high-altitude aerial photographs with limited field checking. This process, coupled with the nature of wetlands (e.g., drier-end types difficult to distinguish even in the field, especially in low-gradient landscapes), makes for conservative wetland mapping in most areas. Many NWI maps were prepared over 15 years ago, which is before standardized methods for wetland delineation were developed. Table 1 outlines some of the major limitations of NWI maps (see Tiner 1997b for details). NWI data could be merged with other available digital data (e.g., hydric soil map unit data from digital soils layer for counties). The digital soils data are becoming more widely available but tend to be of limited availability in most places. Some states have produced digital data from their own wetland inventories that may be suitable for integration with NWI

Table 1. Examples of major NWI map limitations (from Tiner 1997b).

Factor	Limitation
Target Mapping Unit (tmu)	A tmu is an estimate of the minimum-sized wetland that the NWI is attempting to consistently map; it varies due to several factors, mainly the scale and emulsion of the aerial photography used and specific project objectives. For the Northeast, tmu = 1 acre (1:40K photos), 1-3 acres (1:58K), and 3-5 acres (1:80K). A tmu of 3-5 acres means that most wetlands greater than 5 acres should be mapped.
Spring Photography	Aquatic beds and non-persistent emergent wetlands are under-represented as they are generally classified as they appeared on the photography - as open water.
Leaf-on Photography	When used, severely limits wetland mapping, especially of forested wetlands due to canopy cover.
Forested Wetlands	Certain types are among the most difficult wetlands to photointerpret, especially evergreen, seasonally saturated, and temporarily flooded types. Mapping of forested wetlands is usually conservative.
Intertidal Flats	Boundaries are often approximate, since aerial photography is not low-tide synchronized.
Farmed Wetlands	Usually not mapped, except for cranberry bogs, pothole wetlands, playas, and diked former tidelands (California).
Linear Wetlands	Often not mapped since they are too narrow to show at a map scale of 1:24,000; users should expect them to occur along streams, especially in low-relief landscapes.
Partly Drained Wetlands	Mapped based on photo-signature; many are likely to be missed as only one season of photography is analyzed.
Map Date	Map users should pay careful attention to the date of the aerial photography used to prepare the NWI maps. This is shown on legend. Older maps may be obsolete, except where little change in land use has occurred during the intervening period. Pre-1990s NWI mapping tends to be conservative, since standardized wetland identification and delineation methods were published in 1989 and aerial photography had more limitations than 1990s-1:40K color infrared photography.

digital data or use outright.

The next step would be to update and improve the wetland database. This is a must for many areas, as most NWI maps and accompanying digital data are based on late 1970s and early to mid-1980s aerial photographs. These data are therefore nearly 20 years old and, in many cases, do not reflect current conditions. Improvements in the spatial resolution of wetlands can be accomplished by photo-interpretation of 1:40,000 color infrared photography captured at leaf-off (e.g., in spring for northeastern U.S.) and more intensive field verification. Photo-interpretation should include more thorough consideration of hydric soil map units as possible wetlands. Hydric soil map units can be located on large-scale maps included in county soil survey reports published by the U.S.D.A. Natural Resources Conservation Service. When soils data are available in digital form, hydric soil map units can be plotted on existing NWI maps to show possible wetland omissions. Photo-interpretation should also emphasize delineation of linear wetlands along the margins of streams as well as the narrow streams themselves, since connectivity between wetlands is an important feature for functional analysis. Finally, available state and local wetland maps should also be consulted, whenever possible, to construct a comprehensive wetland database. Field investigations are necessary to verify the results. Such studies should include an examination of landscape positions likely to support wetland formation (e.g., toes of slopes, broad flats, narrow stream valleys, and saddles between hills and mountains). If such features have a high correlation with wetland occurrence and ambiguous photo-signatures (i.e., not distinct enough for wetland detection), one may consider mapping such areas as "areas of high probability of wetland occurrence" as suggested by Tiner (1996). One must realize that the time and effort placed on this phase of the project will strengthen the utility of the wetland conservation tool kit.

Once a more complete wetland inventory and digital database have been built, the next step would be to expand the database by providing more information on characteristics of mapped wetlands. Such data could include: (1) hydrogeomorphic properties of wetlands, (2) the condition of wetland and waterbody buffers, (3) potential wetland restoration sites, and (4) additional information on waterbodies. The U.S. Fish and Wildlife Service has developed a set of descriptors for classifying landscape position, landform, water flow path, and waterbodies (LLWW descriptors, Tiner 1997c, 2000). These descriptors are summarized in Table 2. They are being added to existing NWI digital databases on a project-by-project basis to prepare watershed-based wetland characterizations and preliminary assessments of wetland functions (discussed later in this paper). All future NWI maps and digital data produced in New York will include these classifications per the state's request and financial support. Wetland and waterbody buffer analysis require matching the improved NWI digital data with available digital land use/cover data or creating a special buffer layer through remote sensing (i.e., photo-interpretation or satellite image processing). Potential wetland restoration sites can be determined by first comparing an existing wetland coverage to a hydric soil map unit coverage to identify candidate sites, then examining recent aerial photographs to determine the current land use to decide if restoration may be possible. Field verification should be conducted to check the results. More information on the characteristics of waterbodies, such as lake, pond, river, stream, estuary, and ocean types, water flow paths associated with lakes, tidal ranges and estuarine hydrologic circulation patterns may also be added to the NWI database (Tiner 2000).

Table 2. Definitions of LLWW descriptors for wetlands (from Tiner 2000).

Descriptors	General Definition
Landscape Position	
Marine	Wetlands representing the intertidal zone of ocean shorelines (e.g., beaches and rocky shores)
Estuarine	Wetlands occurring in the intertidal zone associated with estuarine waters (the estuary - where sea water mixes with fresh water; often a semi-closed system with variable salinity due to ocean-derived salts); includes salt and brackish tidal marshes, swamps, and shores, plus freshwater tidal swamps behind slightly brackish (oligohaline) marshes
Lotic	River and streamside wetlands (e.g, with rivers and streams running through them)
Lentic	Lakeside wetlands (formed in lake basins); may in water year-round, periodically flooded by rising lake levels, or have water tables strongly influenced by lake levels (e.g., behind barrier beaches of Great Lakes)
Terrene	Wetlands not associated with a lake or bisected by a river or stream; usually isolated from surface waters or serving as source of streams (headwater; stream coming from it but not running through it)
Landform	
Slope	Wetlands formed on noticeable slopes, generally 3% or greater
Basin	Wetlands developed in depressional features
Floodplain	Wetlands established on alluvial soils
Interfluve	Wetlands formed in interstream divides (interfluves) on the coastal plains, glaciolacustrine plains, and similar flat landscapes
Flat	Wetlands established on nearly level landforms
Island	Wetlands surrounded by water
Water Flow Path	
Inflow	Surface water flows into a wetland lacking an outlet
Outflow	Surface water flows out of a wetland with no significant surface inflow

Table 2. Continued.

Descriptors	General Definition
Throughflow	Surface water moves in, through, and out of a wetland
Bidirectional Flow	Surface water moves in and out of a wetland due to tides, lake seiches, or seasonal fluctuations in lake levels
Isolated	Water enters through surface water runoff and/or ground water discharge, and surface water inflow (inlet) or outflow (outlet) is not apparent or known to occur; wetland is not visibly or known to be hydrologically connected to other wetlands and waters

Assessing the Overall Ecological Condition of the Watershed

Besides building a geospatial wetland-waterbody digital database, it is important to evaluate the ecological condition of uplands in the watershed, since various land uses adversely affect wetlands and other aquatic habitats and their fish and wildlife populations. There are many ways to assess land use/cover changes and habitat disturbances. To accomplish this for a large geographic area, the Northeast Region of the U.S. Fish and Wildlife Service developed a set of remotely-sensed "natural habitat integrity" indices. Data for these indices are derived through air photo-interpretation and/or satellite image processing coupled with knowledge of the historical extent of wetlands and open waterbodies. These indices are proposed as one tool for reporting on the ecological state of the environment. They are coarse-filter variables for assessing the overall condition of watersheds. They are intended to augment, not supplant, other more rigorous, fine-filter approaches for describing the ecological condition of watersheds (e.g., indices of biological integrity) and examining relationships between human impacts and the natural world. The natural habitat integrity indices can be used to develop "habitat condition profiles" for individual watersheds of varying scales (i.e., subbasins to major watersheds). Indices can be used for comparative analysis of subbasins within watersheds and to compare one watershed with another. They may also serve as one set of statistics for reporting on the State-of-the-Environment for government agencies and environmental organizations.

The indices are rapid-assessment types that allow for frequent updating (e.g., every 5- to 10-years). They may be used to assess and monitor the amount of "natural habitat" compared to the amount of disturbed aquatic habitat (e.g., channelized streams, partly drained wetlands, and impounded wetlands) or developed habitat (e.g., cropland, grazed meadows, mined lands, suburban development, and urbanized land). The index variables include several features important to natural resource managers attempting to lessen the impact of human development on the environment. The indices may also be compared with other environmental quality metrics such as indices of biological integrity for fish and/or macroinvertebrates or water quality parameters. If significant correlations can be found, they may aid in projecting a "carrying capacity" or threshold for development in individual subbasins. This would require further classification of the developed land category into agricultural types and urban/suburban types, but such breakdowns are usually available from the original dataset. In a study of Wisconsin watersheds, Wang et al. (1997) found that habitat quality and index of biotic integrity (IBI) scores were positively correlated with the amount of forest and negatively correlated with the amount of agricultural land and urban land in the watershed and in the 100m stream buffer. When watersheds were more than 10-20% urbanized, IBI scores were very low, whereas in rural watersheds, IBI scores dropped significantly when more than 50% of the watershed was in agricultural use. This suggests that these percentages may be threshold levels for these types of land uses in Wisconsin watersheds.

To date, a total of nine indices have been developed (see Table 3 for brief definitions) to represent habitat condition in a watershed.

Table 3. Summary of "remotely-sensed natural habitat integrity indices."

Index	Brief Description
Natural Area	Measure of the amount of "natural area" (e.g., old fields, shrub thickets, forests, and vegetated wetlands) remaining
Stream Corridor Integrity	Measure of the extent of stream corridor that remains in natural vegetation
Wetland/Other Waterbody Buffer Integrity*	Measure of the extent of wetland and other waterbody buffer that remains in natural vegetation
Wetland Extent	Estimate of the extent of original wetlands remaining
Standing Waterbody Extent	Estimate of the extent of standing waterbody extent versus original extent
Dammed Stream	Measure of the extent of impounded streams in a watershed
Channelized Stream	Measure of the extent of channelized streams in a watershed
Wetland Disturbance	Measure of the extent to which remaining wetlands have been ditched, excavated, and/or impounded
Remotely-sensed Natural Habitat Integrity Index	Measure of the overall ecological condition of a watershed as expressed by the weighted averages of the above 8 indices

*Note: This index can be further divided into three separate indices for buffers around: (1) wetlands, (2) lakes, and (3) ponds.

Five indices address habitat extent -- the amount of natural habitat occurring in the watershed and along wetlands and waterbodies: natural cover, stream corridor integrity, wetland and waterbody buffer integrity, wetland extent, and standing waterbody extent. "Natural" habitat is defined as a plant community that has become established naturally or has been planted for long-term growth (e.g., commercial forests). It includes vegetated wetlands, upland forests, shrub thickets, prairies, savannas, tundra meadows, vegetated sand dunes, abandoned fields ("old fields"), and other areas that are not developed (e.g., impervious surfaces, lawns, and turf), cropped, pastured, mowed, or mined. Natural habitat is not annually harvested (including agricultural fields in fallow rotation), mowed, or grazed. Three indices emphasize human-induced alterations to streams and wetlands -- dammed stream flowage, channelized stream flowage, and wetland disturbance. All indices have a maximum value of 1.0 and a minimum value of zero. For the habitat extent indices, the higher the value, the more natural habitat available. For the disturbance indices, the higher the value, the more disturbance. The eight specific indices are combined into a single, composite index presently called "remotely-sensed natural habitat integrity index" for the watershed. For the remotely-sensed natural habitat integrity index, all indices are weighted, with the disturbance indices subtracted from the habitat extent indices to yield an overall "natural habitat integrity" score for the watershed.

Presently, the indices do not include much qualitative information on the condition of the existing habitats (habitat quality) as reflected by the presence, absence, or abundance of invasive species or by fragmentation of forests, for example. It may be possible to add such data in the future, but our intent is to provide a simple set of meaningful indices for a baseline analysis and frequent updating. Another consideration would be establishment of minimum size thresholds to determine what constitutes a viable "natural habitat" for analysis (e.g., 0.04 hectare/0.1 acre patch of forest or 0.4 hectare/1 acre minimum?). Other indices may also need to be developed to aid in water quality assessments (e.g., index of ditching extent for agricultural and silvicultural lands).

Habitat Extent Indices

Habitat extent indices are intended to convey the extent of "natural" habitat in various locations in the watershed and the extent of inland standing open water. The natural cover index addresses the entire watershed, while other indices emphasize certain ecosystems or zones (e.g., wetlands, standing waterbodies, stream corridors, and wetland buffers).

The Natural Cover Index (I_{NC}) is derived from a simple percentage of the subbasin that is wooded (forested or shrub land, including vegetated wetlands) and "natural" open land (e.g., emergent wetland or open, "old" fields, not cropland, hayfield, lawn/turf, or pasture) -- land supporting "natural vegetation," excluding open water (ponds, rivers, lakes, streams, and coastal bays):

$$I_{NC} = A_{NV}/A_W$$

where A_{NV} (area in natural vegetation) equals the area of the watershed's land surface in "natural" vegetation (e.g., woodland, open land [wildlife habitat, not farms, golf courses, ballparks, or playgrounds], and vegetated wetland). This index addresses only the land portion of the watershed (excludes open water from the calculations), so the area of "watershed" (A_W) for this index will exclude bodies of open water.

The Stream Corridor Integrity Index (I_{SCI}) addresses the condition of the stream corridors.

$$I_{SCI} = A_{VC}/A_{TC}$$

where A_{VC} (vegetated stream corridor area) is the area of the stream corridor that is colonized by "natural vegetation" and A_{TC} (total stream corridor area) is the total area of the stream corridor. The width of the stream corridor may be varied to suit project goals, but for this index, a 100-meter corridor (50m on each side of the stream) will be evaluated at a minimum, due to its well-recognized role in water quality maintenance and contributions to aquatic habitat quality. For most projects to date, a 200-meter corridor has been evaluated. If wildlife travel corridors are a primary concern, a larger corridor (e.g., 400m) may be examined.

The Wetland and Other Waterbody Buffer Index (I_{WWB}) represents the condition of a buffer zone of a specified width (e.g., 100m) around mapped wetlands and waterbodies (mainly lakes and estuaries, excluding river/stream corridors).

$$I_{WWB} = A_{VB}/A_{TB}$$

where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone. Note that this index can be separated into other indices to evaluate the buffer around individual habitat types (e.g., wetland buffer index, lake buffer index, and pond buffer index).

The Wetland Extent Index (I_{WE}) relates to the current extent of vegetated wetlands (excluding open-water wetlands - ponds, mudflats, and unconsolidated shores, for example) compared with the estimated historic extent - the approximate percent remaining. The I_{WE} is an approximation of the extent of the original wetland acreage remaining in the watershed. If data on historical wetland area are not available, this index can be calculated by either evaluating one or more relatively undisturbed subbasins in the watershed (i.e., one with similar properties of landscape, soils, and surficial geology) or by using the area of hydric soils as the historic extent of vegetated wetlands. While this index is based on limited data, it is useful for providing a historical perspective on today's wetlands.

$$I_{WE} = A_{CW}/A_{HW}$$

where A_{CW} is the current wetland area in the watershed and A_{HW} is the historic wetland area in the watershed (estimated).

One should recognize that areal extent of historic hydric soils could be less than the current extent due to level of mapping detail (e.g., scalar issues) or to wetland-creation activities, especially due to beaver influence and shallow pond construction. Such situations would require some additional verification to insure that this is not simply a scalar issue. When the current extent of wetlands (e.g., percent of watershed) is determined to be greater than the historic estimate, for purposes of this landscape-level assessment, it is assumed that wetland loss is not significant and the I_{WE} is recorded as 1.0.

The Standing Waterbody Extent Index (I_{SWE}) addresses the current extent of standing fresh waterbodies (e.g., lakes, reservoirs, and open-water wetlands - ponds) in a watershed relative to the historic area of such features. The historic number is created by either consulting older

USGS topographic maps or simply by subtracting the area of new large fresh waterbodies (e.g., reservoirs and large impoundments) from the current area.

$$I_{SWE} = A_{CSW}/A_{HSW}$$

where A_{CSW} is the current standing waterbody area and A_{HSW} is the historic standing waterbody area in the watershed.

When numerous large open waterbodies have been created (i.e., reservoirs, impoundments, and excavations), we assume that such action has clearly increased the total area of open water, so it is not necessary to calculate this index. Simply, use a I_{SWE} value of 1.0 when applying this index to determine the remotely-sensed natural habitat integrity index. Although this is the typical case for many, if not most, watersheds in urban and agricultural areas and the index's likelihood of changing in the future may be low, it is still useful to inform the public that such waterbodies are not decreasing in extent.

The focus to date has been on inland waterbodies, but a similar index could be employed for the extent of coastal waters. Such index might be valuable for keeping track of changes in estuarine waters due to sea level rise and to human alteration (e.g., dredging and filling) where such activities are not regulated (e.g., in many countries).

Stream and Wetland Disturbance Indices

Three disturbance indices are presented to profile major alterations to rivers, streams, and wetlands. Two of the indices address flowing waterbodies (i.e., dammed stream flowage index and channelized stream length index). The other index emphasizes alterations of existing wetlands (i.e., wetland disturbance index). In watersheds where alteration of natural lakes is a problem, then one may want to create a disturbance index for these habitats.

The Dammed Stream Flowage Index (I_{DSF}) highlights the direct impact of damming on rivers and streams in a watershed.

$$I_{DSF} = L_{DS}/L_{TS}$$

where L_{DS} is the length of perennial rivers and streams impounded by dams (combined pool length) and L_{TS} is the total length of perennial rivers and streams in the watershed. It does not attempt to predict the magnitude of downstream effects from such dams.

The Channelized Stream Length Index (I_{CSL}) documents the extent of channelization of streams within a watershed.

$$I_{CSL} = L_{CS}/L_{TS}$$

where L_{CS} is the channelized stream length and L_{TS} is the total stream length for the watershed. This index only addresses stream channelization; it does not include the length of artificial ditches excavated in farmfields and forests.

The Wetland Disturbance Index (I_{WD}) describes the proportion of existing wetlands that are diked/impounded, ditched, or excavated. Wetlands are represented by vegetated and nonvegetated (e.g., shallow ponds) types and include natural and created wetlands.

$$I_{WD} = A_{DW}/A_{TW}$$

where A_{DW} is the area of disturbed or altered wetlands and A_{TW} is the total wetland area in the watershed or study region.

Composite Habitat Index for the Watershed

The Index of Remotely-sensed Natural Habitat Integrity (I_{RNHI}) is a combination of the preceding indices. It seeks to express the overall condition of a watershed in terms of its potential ecological integrity or the relative intactness of natural plant communities and waterbodies. Variations of I_{RNHI} may be derived by considering buffer zones of different widths around wetlands and streams (e.g., $I_{RNHI\,100}$ or $I_{RNHI\,200}$) and by applying different weights to individual indices. The following equation is an example of one that emphasizes a 200-meter buffer and a 400-meter stream corridor.

$I_{RNHI\,200} = (0.6 \times I_{NC}) + (0.1 \times I_{SCI400}) + (0.1 \times I_{WWB200}) + (0.1 \times I_{WE}), + (0.1 \times I_{SWE}) - (0.1 \times I_{DSF}) - (0.1 \times I_{CSL}) - (0.1 \times I_{WD})$, where the condition of the 200-meter buffer is used throughout.

Examples of Components of a Watershed-based Wetland Conservation Tool Kit

At the time of the West Virginia Wetlands Symposium, my colleagues and I had not completed all elements of a wetland conservation tool kit for a single watershed. Since then, colleagues and I have prepared this information for two watersheds in Maryland (i.e., the Nanticoke River and the Coastal Bays watersheds) for the Maryland Department of Natural Resources. The results of this study are posted on the NWI website: wetlands.fws.gov (first click on "publications" and then scroll down until you find the report "Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds: A Preliminary Assessment Report"). Rather than repeat this information in this paper, I present some examples from other areas where similar work has been done. Also, a wetland characterization report for the Delaware portion of the Nanticoke River watershed for the Delaware Department of Natural Resources and Environment Control has been completed and posted on the NWI website.

Wetland Characterization

A wetland characterization is a report describing the results of a wetland inventory contained within an expanded wetland database. Acreage data on wetlands are summarized for the inventoried types (i.e., by NWI type and by LLWW type). A brief description of representative wetland plant communities may also be included in the report based on field observations and a literature review.

A wetland characterization report has been published for the Casco Bay watershed (Tiner et al. 1999). The report was prepared for the Maine State Planning Office to aid in watershed planning for wetland conservation. The Casco Bay watershed encompasses a 1,216-square mile area in southern Maine that empties into Casco Bay east of Portland. About eight percent of the land mass is covered by wetlands. Examples of summary data on wetland types are shown in Tables 4 and 5, while Figure 1 shows an example of a GIS-generated color map displaying the distribution of wetlands by landform type. The combination of NWI type and LLWW type information forms the baseline data for conducting a preliminary assessment of wetland functions for the watershed.

Table 4. Example of wetland summary statistics for the Casco Bay watershed, southern Maine (from Tiner et al. 1999), with wetlands classified by NWI wetland type to the class level (Cowardin et al. 1979). (Note: Other modifiers, such as beaver, diked/impounded, and partly drained, have been deleted from NWI types for this compilation.)

NWI Wetland Type	Acreage (hectares)	NWI Wetland Type	Acreage (hectares)
Marine Wetlands		*Palustrine Wetlands*	
Aquatic Bed	1550.4 (627.7)	Aquatic Bed	8.3 (3.4)
Reef	9.4 (3.8)	Emergent (Nontidal)	3260.7 (1320.1)
Rocky Shore	417.1 (168.9)	Emergent (Tidal)	64.6 (26.2)
Unconsolidated Shore	2625.7 (1063.0)	Emergent/Scrub-Shrub (Nontidal)	1101.5 (445.8)
Subtotal	4602.6 (1863.4)	Emergent/Scrub-Shrub (Tidal)	49.7 (20.1)
Estuarine Wetlands		Broad-leaved Deciduous Forested (Nontidal)	6944.1 (2811.4)
Aquatic Bed	215.7 (87.3)	Broad-leaved Deciduous Forested (Tidal)	17.6 (7.1)
Emergent	1491.7 (603.9)	Needle-leaved Deciduous Forested	3.4 (1.4)
Rocky Shore	18.7 (7.6)	Needle-leaved Evergreen Forested (Nontidal)	6632.4 (2685.2)
Unconsolidated Shore	4799.2 (1943.0)	Needle-leaved Evergreen Forested (Tidal)	75.3 (30.5)
Subtotal	6525.3 (2641.8)	Mixed Forested (Nontidal)	5494.6 (2224.5)
Lacustrine Wetlands		Mixed Forested (Tidal)	2.4 (1.0)
Unconsolidated Shore	13.5 (5.5)	Forested/Emergent	120.4 (48.7)
Subtotal	13.5 (5.5)	Evergreen Forested/Scrub-Shrub	432.7 (175.2)

Table 4. Continued.

NWI Wetland Type	Acreage (hectares)
Palustrine Wetlands	
Deciduous Forested/Scrub-Shrub	107.6 (48.6)
Dead Forested	154.7 (62.6)
Deciduous Scrub-Shrub (Nontidal)	6736.8 (2727.4)
Deciduous Scrub-Shrub (Tidal)	79.2 (32.1)
Broad-leaved Evergreen Scrub-Shrub	370.3 (149.9)
Needle-leaved Evergreen Scrub-Shrub (Nontidal)	419.2 (169.7)
Needle-leaved Evergreen Scrub-Shrub (Tidal)	5.6 (2.3)
Evergreen Scrub-Shrub (unspecified/Nontidal)	155.9 (63.1)
Mixed Scrub-Shrub (Nontidal)	1292.3 (523.2)
Mixed Scrub-Shrub (Tidal)	8.7 (3.5)
Unconsolidated Bottom (Nontidal)	1986.5 (804.3)
Unconsolidated Bottom (Tidal)	14.8 (6.0)
Subtotal	35539.3 (14388.4)
GRAND TOTAL (All Wetlands)	46680.7 (18899.1)

Preliminary Assessment of Wetland Functions

With a wide range of characteristics attributed to individual wetlands and knowledge of correlations between these features and wetland functions, one can develop preliminary assessments of wetlands for watersheds or other geographic areas. For the Casco Bay watershed, the Maine Wetlands Steering Committee and local experts helped the U.S. Fish and Wildlife Service develop these relationships for a number of wetland functions. Ten functions were evaluated for the watershed: (1) surface water detention, (2) streamflow maintenance, (3) nutrient cycling, (4) sediment and particulate retention, (5) coastal storm surge detention and shoreline stabilization, (6) inland shoreline stabilization, (7) fish habitat, (8) waterfowl and waterbird habitat, (9) other wildlife habitat, and (10) biodiversity. Protocols developed for each of these functions were used to designate wetlands of potential significance for these functions. The

Table 5. Example of wetland summary statistics for the Casco Bay watershed in southern Maine (Tiner et al. 1999), with wetlands classified by landscape position, landform, and water flow path (Tiner 1997c). (Note: Marine fringe and island wetlands were not included in these statistics.)

Landscape	Landform	Water Flow	# of Wetlands	Acreage (hectares)
Position				
Terrene (TE)			5336	14281.4 (5781.9)
	Slope (SL)		224	1602.1 (648.6)
		Inflow (IN)	10	52.6 (21.3)
		Isolated (IS)	84	391.2 (158.4)
		Outflow (OU)	114	1055.7 (427.4)
		Throughflow (TH)	16	102.6 (41.5)
	Basin (BA)		5104	12473.6 (5050.0)
		Inflow (IN)	57	136.5 (55.3)
		Isolated (IS)	4171	5779.6 (2339.9)
		Outflow (OU)	856	6358.2 (2574.2)
		Throughflow (TH)	20	199.3 (80.7)
	Flat (FL)	Outflow (OU)	8	205.7 (83.3)
Lentic (LE)			312	1688.3 (683.5)
	Basin (BA)		199	1285.9 (520.6)
	Fringe (FR)		99	390.8 (158.2)
	Island (IS)		14	11.6 (4.7)
Lotic River (LR)			324	3582.8 (1450.5)
	Basin (BA)		91	1817.4 (735.8)

Table 5. Continued.

Landscape	Landform	Water Flow	# of Wetlands	Acreage (hectares)
	Flat (FL)		11	169.4 (68.6)
	Floodplain (FP)		217	1589.8 (643.6)
	Fringe (FR)		2	1.0 (0.4)
	Island (IS)		3	5.2 (2.1)
Lotic Stream (LS)			1781	15831.1 (6409.4)
	Basin (BA)		1408	11639.1 (4712.2)
	Flat (FL)		89	1697.1 (687.1)
	Floodplain (FP)		27	1224.3 (495.7)
	Fringe (FR)		43	171.1 (69.3)
	Slope (SL)		214	1099.5 (445.1)
Estuarine (ES)			373	1805.9 (731.1)
	Basin (BA)		24	137.6 (55.7)
	Fringe (FR)		340	1664.3 (673.8)
	Island (IS)		9	4.0 (1.6)

assessment represented a first-cut at considering the ability of individual wetlands to perform each of the listed functions. Wetlands highlighted in the acreage tabulations and thematic maps were predicted to have a significant potential for performing the given function. The general findings for the Casco Bay watershed are summarized in Table 6. A sample map showing the distribution of wetlands of potential significance for providing waterfowl and waterbird habitat is presented in Figure 2.

Wetland Restoration Site Database

Given the intrinsic values of wetlands to society, government agencies and others have initiated projects to restore lost or damaged wetlands. Much of the restoration work to date has been done without a broad-scale view of restoration opportunities in a watershed. Knowing the location and characteristics of potential sites could significantly improve wetland restoration

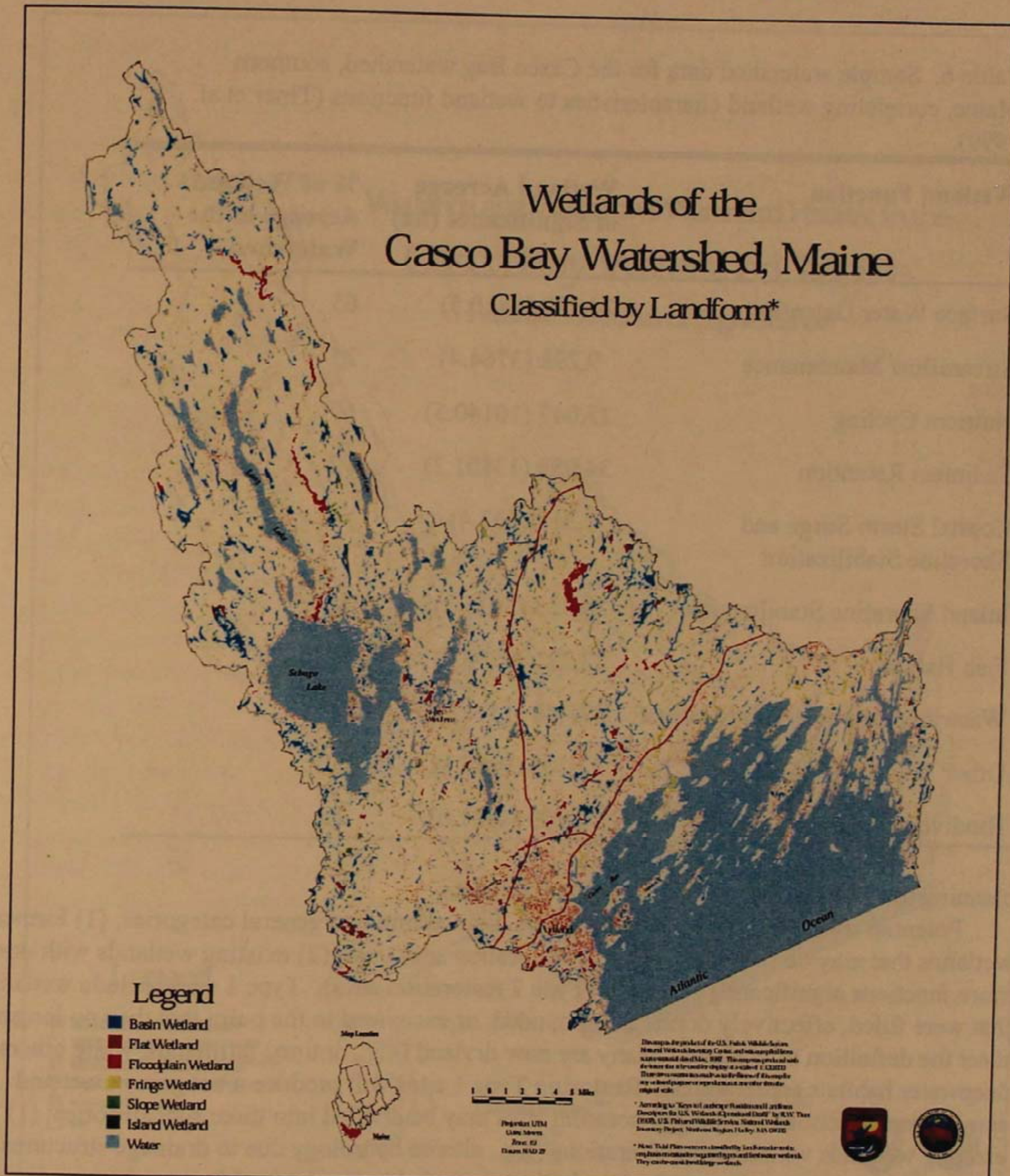

Figure 1. Wetlands classified by landform. (Note: White areas along Casco Bay's shoreline are intertidal flats that were not originally classified by landform. They can be considered fringe wetlands.)

Table 6. Sample watershed data for the Casco Bay watershed, southern Maine, correlating wetland characteristics to wetland functions (Tiner et al. 1999).

Wetland Function	**Wetland Acreage of Significance (ha)**	**% of Wetland Acreage in the Watershed**
Surface Water Detention	24,232 (9810.5)	65
Streamflow Maintenance	9,298 (3764.4)	25
Nutrient Cycling	25,047 (10140.5)	67
Sediment Retention	34,089 (13801.2)	92
Coastal Storm Surge and Shoreline Stabilization	1,315 (532.4)	4
Inland Shoreline Stabilization	20,835 (8435.2)	56
Fish Habitat	22,225 (8998.0)	60
Waterfowl and Waterbird Habitat	27,448 (11112.6)	74
Other Wildlife Habitat	23,709 (9598.8)	51
Biodiversity Conservation	10,500 (4251.0)	22

planning to maximize benefits of individual projects.

Potential wetland restoration sites can be divided into two general categories: (1) former wetlands that may be restorable (Type 1 restoration sites), and (2) existing wetlands with one or more functions significantly impaired (Type 2 restoration sites). Type 1 sites include wetlands that were filled, effectively drained, impounded, or excavated to the point that they no longer meet the definition of wetland. Many are now dryland (e.g., drained farmland), while others are deepwater habitats (open water). Restoring Type 1 sites will produce a net gain in wetland acreage and functions. Type 2 restoration sites may be divided into three subcategories: (1) existing wetlands with internal alterations (e.g., altered hydrology due to drainage structures or impoundment; excavations producing shallow water habitat; colonized by invasive species such as common reed *Phragmites australis* or purple loosestrife *Lythrum salicaria*), (2) wetlands impaired due to external factors (e.g., chemical contamination from surrounding land such as cropland, livestock yards, lawns, industrial plants, and landfills; sedimentation from adjacent uplands), and (3) combinations of #1 and #2. Restoration of Type 2 sites will typically yield a net gain in wetland function, but no significant increase in wetland acreage since they are already

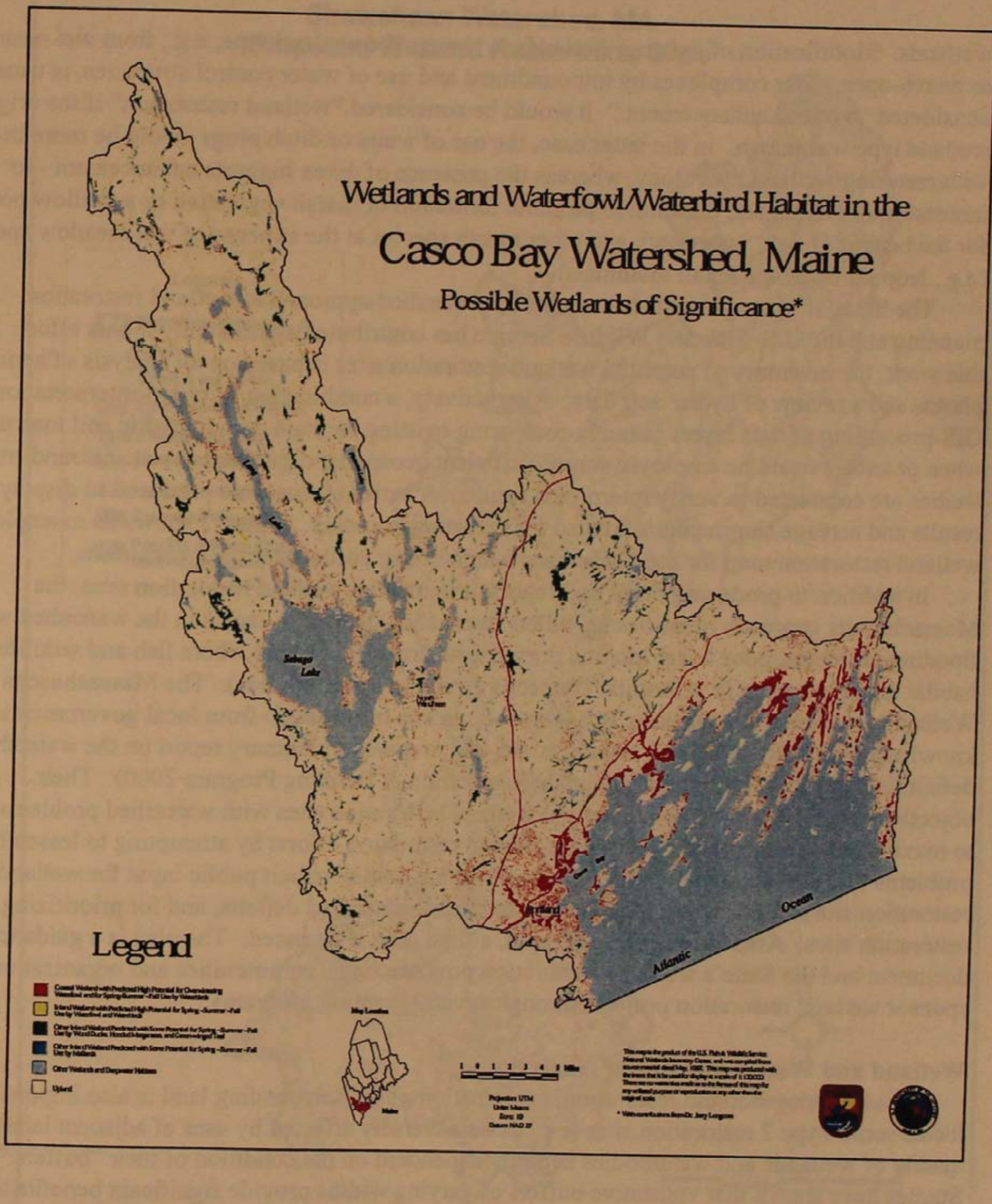

Figure 2. Wetlands of potential significance for providing waterfowl and waterbird habitat.

wetlands. Modification of existing wetlands to change the wetland type, e.g., from wet meadow to marsh-open water complexes by impoundment and use of water control structures, is usually considered "wetland enhancement." It would be considered "wetland restoration" if the original wetland type was marsh. In the latter case, the use of weirs or ditch plugs would be more in-tune with restoring wetland hydrology, whereas the presence of dikes suggests enhancement - to increase water depth and duration to promote formation of marsh vegetation or a shallow pond for the benefit of fish, waterfowl, and other marsh species at the expense of wet meadow species (e.g., leopard frogs and small mammals).

The State of Massachusetts has adopted a watershed-approach to wetland restoration planning and the U.S. Fish and Wildlife Service has contributed significantly to this effort. For this work, the inventory of potential wetland restoration sites is based on an analysis of aerial photos and a review of hydric soil data. Alternatively, a combination of photo-interpretation and GIS-processing of data layers (namely comparing existing wetland data to hydric soil map units when possible) could be employed where sufficient geospatial digital data exist. Ground-truthing studies are conducted to verify interpreted results. A series of maps are produced to display the results and acreage summaries tabulated for reporting purposes. Figure 3 shows an example of a wetland restoration map for the Shawsheen watershed in northeastern Massachusetts.

In addition to producing maps and reports on potential wetland restoration sites, the Massachusetts approach identifies so-called "watershed deficits" -- areas in the watershed with flooding problems, poor water quality, diminished streamflows, and where fish and wildlife habitat needs attention (e.g., habitat connectivity and invasive species). The Massachusetts Wetlands Restoration & Banking Program solicits this information from local governments and knowledgeable individuals and organizations and prepares a summary report on the watershed deficit findings (Massachusetts Wetlands Restoration & Banking Program 2000). Their objectives are to be able to link potential wetland restoration sites with watershed problems and to maximize the benefits of government-funded restoration efforts by attempting to lessen these problems through wetland restoration. Meetings are held to solicit public input for wetland restoration site identification, location and nature of watershed deficits, and for prioritizing restoration sites. After receiving such input, a final plan is prepared. The plan is a guidance document and the State's wetlands restoration program helps communities and organizations sponsor wetland restoration projects through several granting programs.

Wetland and Waterbody Buffer Analysis

In addressing wetland restoration, examination of the surrounding land is also important to locate some Type 2 restoration sites (i.e., those adversely affected by uses of adjacent land). The quality of wetlands and waterbodies is partly dependent on the condition of their "buffers." Studies have shown that vegetative buffers of varying widths provide significant benefits to wetlands and streams for improving water quality, fish habitat, and other wildlife habitat (e.g., Castelle et al. 1994; Croonquist and Brooks 1993; Burke and Gibbons 1995; Desbonnet et al. 1994; Keller et al. 1993; Kilgo et al. 1998). An evaluation of the condition of wetland and

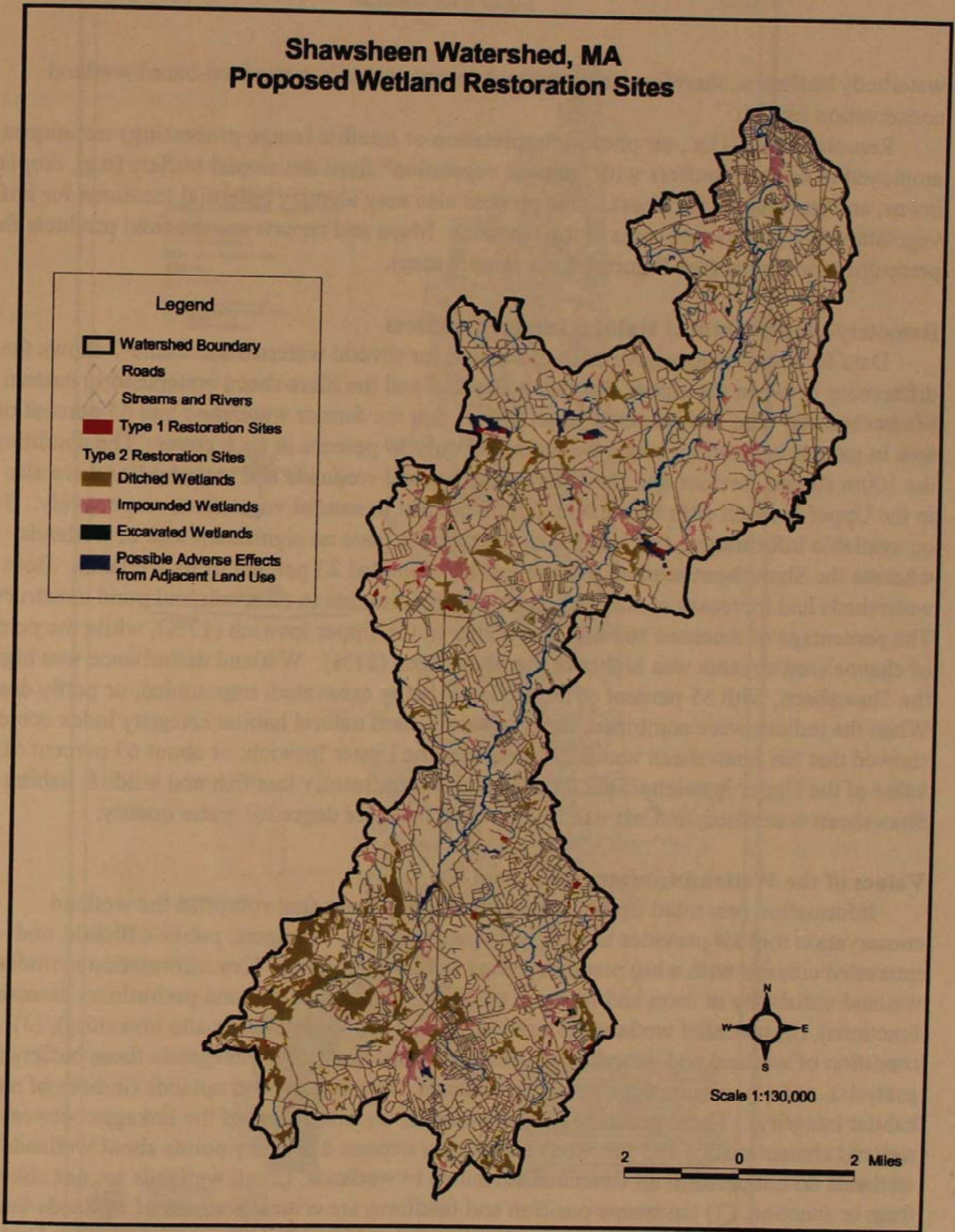

Figure 3. Potential wetland restoration sites for the Shawsheen watershed.

waterbody buffers is, therefore, an important component of a watershed-based wetland conservation tool kit.

Remote sensing (i.e., air photo-interpretation or satellite image processing) techniques are employed to separate buffers with "natural vegetation" from developed buffers (e.g., cropland, lawns, and impervious surfaces). This process also may identify potential locations for buffer re-vegetation (e.g., cultivated areas along streams). Maps and reports are the final products for presenting the results (see Figure 4 for a sample map).

Remotely-sensed Natural Habitat Integrity Indices

Data for these indices have been calculated for several watersheds. Table 7 shows the differences between the Upper Ipswich watershed and the Shawsheen watershed in eastern Massachusetts. The natural cover index shows that the former watershed had 65 percent of its area in natural vegetation, while the latter had only 39 percent in such cover. The conditions of the 100m stream corridor and the 100m buffer around wetlands and waterbodies were also better in the Upper Ipswich with 86 percent and 67 percent in natural vegetation, respectively. Based on available information, this watershed appeared to have no significant loss of wetlands, whereas the Shawsheen seemed to have lost an estimated 23 percent of its wetlands. Both watersheds had increases in standing fresh waterbodies due to reservoir and pond construction. The percentage of dammed streams was higher in the Upper Ipswich (17%), while the percentage of channelized streams was higher in the Shawsheen (21%). Wetland disturbance was higher in the Shawsheen, with 55 percent of the wetlands being excavated, impounded, or partly drained. When the indices were combined, the remotely-sensed natural habitat integrity index score showed that the Shawsheen was 0.228 less than the Upper Ipswich, or about 67 percent of the value of the Upper Ipswich. This translates into significantly less fish and wildlife habitat for the Shawsheen watershed, and increased likelihood for more degraded water quality.

Values of the Wetland Conservation Tool Kit

Information presented in the various reports and maps that comprise the wetland conservation tool kit provides natural resources planners, managers, public officials, and interested citizens with a big picture view of wetland resources. Key information includes: (1) wetland variability in form and function (wetland characterization and preliminary assessment of functions), (2) potential wetland restoration sites (wetland restoration site inventory), (3) condition of wetland and waterbody buffers and opportunities to revegetate these buffers (buffer analysis), and (4) relationships between wetlands, waterbodies, and uplands (indices of natural habitat integrity). These products promote a better understanding of the linkages between wetland characteristics and functions and clearly express a few key points about wetlands: (1) all wetlands do not perform all functions attributed to wetlands, (2) all wetlands are not alike in form or function, (3) landscape position and landform are critical features of wetlands that greatly affect their ability to perform many functions, (4) while individual wetlands clearly perform many functions, it is the collection of wetlands in a watershed that defines the watershed's ability to store flood waters, recycle nutrients, provide habitat for a diverse

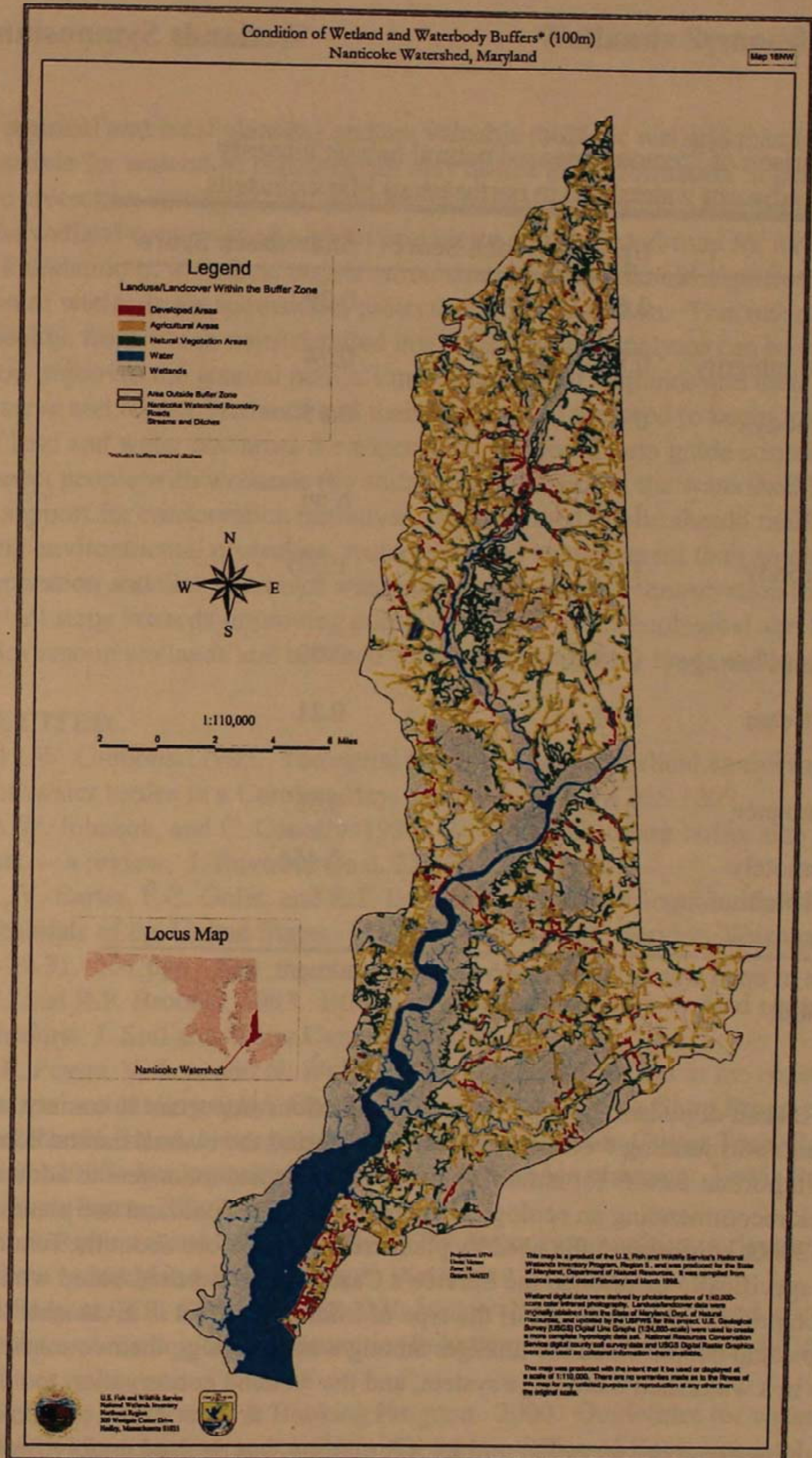

Figure 4. Condition of wetland and waterbody buffer zones for the Nanticoke watershed.

Table 7. Comparison of "remotely-sensed natural habitat integrity indices" for two adjacent watersheds in northeastern Massachusetts.

Index	Upper Ipswich Score	Shawsheen Score
Natural Cover	0.65	0.39
Stream Corridor Integrity	0.86	0.74
Wetland/Waterbody Buffer	0.67	0.55
Wetland Extent	1.00	0.77
Standing Waterbody Extent*	1.00+	1.00+
Dammed Stream Flowage	0.17	0.08
Channelized Stream Length	0.08	0.21
Wetland Disturbance	0.34	0.55
Composite Remotely-sensed Natural Habitat Integrity Index	0.684	0.456

*Note: Increase in open water due to reservoir, impoundment, and pond construction.

assemblage of certain organisms, and perform other functions important to society, and (5) the condition of lands surrounding wetlands and waterbodies and the overall habitat condition of the watershed are important factors for natural resource planners and managers to address.

In his book recommending an ecological approach to municipal land use planning, Honachefsky (2000) emphasized the need by planners to know more about the functions of wetlands. He specifically mentioned the Service's Casco Bay watershed-based wetland characterization project as an example of the type of information that is invaluable to municipal planners. Maps help people visualize linkages among wetlands (e.g., their connectivity) and their vital positions in a watershed's drainage system, and the wetland conservation tool kit contains many maps.

Because the wetland conservation tool kit information was derived mainly from remote sensing, it may be readily updated and can serve as a monitoring tool for reporting on the status of wetlands and of the watershed as a whole. The watershed characterization products provide a framework for regional and local planning and are valuable tools for wetland management. Agencies responsible for watershed management may utilize this information to help develop natural resource protection strategies, and possibly wetland conservation plans for individual watersheds. The wetland conservation tool kit provides a guide or road-map for natural resource planners -- the foundation of a wetland conservation strategy -- and should significantly help in the prioritization of wetlands for acquisition, protection, and restoration. This information establishes a baseline from which more detailed investigations and analyses can be carried out. Such information improves the general public's understanding of wetlands and their functions, the need to conserve and restore wetlands and their buffers, and the need to begin to foster better management of land and water resources for watersheds. It should help guide conservation efforts -- to connect people with wetlands (by addressing functions at the watershed level), and to broaden public support for conservation initiatives. An informed public should make better choices regarding environmental protection, restoration, and enhancement than an uneducated public. The preparation and distribution of watershed-based wetland conservation tool kits represent important steps towards improving public awareness of the ecological and functional interdependencies among wetlands and between wetlands and adjacent lands and waters.

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Wetland Soils in West Virginia

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ABSTRACT

Wetland determinations are based upon hydrology, vegetation, and soils. The objective of this paper is to discuss properties of wetland/hydric soils. Wetland soils typically have aquic moisture conditions. Soils with aquic conditions are those that currently undergo continuous or periodic saturation and reduction. Aquic conditions are indicated by the presence of redoximorphic features. These features consist of redox concentrations, redox depletions, and reduced matrix. A hydric soil is formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Fourteen soil series have been identified as hydric soils in West Virginia. These soils are classified into four different orders of Soil Taxonomy: Mollisols (1), Inceptisols (6), Alfisols (3), and Ultisols (4). Caution must be used when comparing the list of hydric soil series to soil survey maps. Many of the soils on the list have ranges of certain properties that allow them to range from hydric to nonhydric depending on the location. Also, mapping units that are delineated on soil maps may have inclusions of soils with properties that differ from the named soil. Therefore, the presence of hydric soils should be determined on site with the use of field indicators.

INTRODUCTION

Section 404 of the Clean Water Act of 1972 (CWA) authorizes the Secretary of the Army, acting through the Corps of Engineers, to issue permits regulating the discharge of dredged or fill material into the waters of the United States, including wetlands (Environmental Laboratory 1987). Implementation of these regulations requires the identification and delineation of jurisdictional wetlands. These wetlands are most commonly delineated with the three parameters outlined in the Corps of Engineers Wetland Delineation Manual (Environmental Laboratory 1987; hereafter referred to as the 1987 Manual). To meet the definition of a wetland according to the 1987 Manual, wetland hydrology, hydrophytic vegetation, and hydric soils must be present. Hydrology is a major driving force in the development of wetlands, but it is not always observable in the field. Ground water levels vary on a daily, seasonal, and annual basis, and cannot always be determined absolutely during on-site visits. Therefore, the identification of hydrophytic vegetation and hydric soils become very important.

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Many soils in West Virginia show evidence that water saturates at least part of the profile at some times of the year, but not all soils showing evidence of wetness are hydric. The purpose of this paper is to discuss the factors affecting hydric soil identification.

AQUIC CONDITIONS

Soils with aquic (Latin, *Aqua,* water) conditions are those that undergo continuous or periodic saturation and reduction (Soil Survey Staff 1999; Vepraskas 1996). The presence of these conditions in mineral soils is indicated by redoximorphic features, formerly called mottles. These features result from alternating periods of reduction and oxidation of iron (Fe) and manganese (Mn) in the soil. Reduction occurs during saturation with water, and oxidation occurs in those parts of the soil that are no longer saturated or have never been saturated with water. Reduced Fe and Mn become mobile and may be transported by water moving through the soil. Characteristic color patterns are developed by these processes. Zones of reduction normally have grayish colors with chromas of ≤ 2 and values of ≥ 4 determined by Munsell Soil Color Charts (Munsell Color 1998). Zones of Fe oxidation usually have reddish colors with chromas >2. Oxidized Mn occurs as dark brown or black coatings on peds (soil structural units) or along pores. These colors commonly have chromas and values of ≤ 3.

A soil is considered saturated when the soil water pressure is zero or positive. Saturation can generally be determined by observing free water in an unlined auger hole, although the use of well-sealed piezometers or tensiometers is recommended. The duration of saturation required for creating aquic conditions varies, depending on the soil environment. Three types of saturation have been defined (Soil Survey Staff 1999). <u>Endosaturation</u> occurs when all layers from the upper boundary of saturation to a depth of 200 cm or more from the mineral soil surface are saturated with water. <u>Episaturation</u> occurs when one or more layers of soil within 200 cm of the mineral soil surface are saturated with water, and one or more layers are unsaturated. Episaturation normally occurs when the zone of saturation is perched above a relatively impermeable layer. <u>Anthric saturation</u> is similar to episaturation but occurs in soils that are cultivated and irrigated (flooded). No soils with anthric saturation have been officially identified in West Virginia. However, small areas of anthric saturation are known to exist in some parts of the state where waste water has been disposed by above-ground irrigation methods over long periods of time.

Obtaining accurate measurements of reduction in soils is difficult. However, it can be determined using platinum microelectrodes to measure oxidation-reduction potentials (redox potentials or Eh values). The critical redox potentials needed for Fe reduction are a function of pH and should be determined from an Eh-pH diagram (Collins and Buol 1970). A simple field test is available to determine if reduced Fe is present in soil solution. A freshly broken surface of field-wet soil sample is treated with alpha, alpha-dipyridyl dye dissolved in neutral 1N ammonium acetate (Childs 1981; Vepraskas 1996). The appearance of a strong red color indicates the presence of reduced Fe.

Zones of oxidation-reduction in soils may be indicated by the presence of redoximorphic features in soil profiles (Soil Survey Staff 1999; Vepraskas 1996). These features include redox concentrations, redox depletions and reduced matrix. They are formed by the reduction, translocation in soil solution, and oxidation of Fe and Mn oxides. Redox concentrations are zones of apparent oxidation and accumulation of Fe-Mn oxides. They include nodules, concretions, masses, and pore linings. Nodules and concretions are cemented bodies that can be removed from the soil intact. Concretions typically have concentric layers that are visible to the naked eye, while nodules have no internal organized structure. Masses are noncemented concentrations of Fe-Mn oxides within the soil matrix. Pore linings are zones of accumulation along pores that may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores. Redox depletions are zones of normally grayish or low chroma (≤ 2) colors where either Fe-Mn oxides alone or both Fe-Mn oxides and clay have been stripped out. A reduced matrix is a soil matrix that has a low chroma (≤ 2) *in situ* but undergoes a change in hue or chroma within 30 minutes after the soil material has been exposed to air.

HYDRIC SOILS

Several terms are commonly used when referring to hydric soils. These terms are: (1) hydric soil definition, (2) hydric soil criteria, (3) hydric soil lists, and (4) hydric soil indicatiors (Hurt and Carlisle 1997; Hurt 2000). Hydric soil is defined as: "A soil formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (Soil Conservation Service 1994). All soils delineated as hydric soils must meet this definition. Soils that are artifically drained or protected (for example, by levees) are hydric soils if the soils in the undisturbed state meet this definition.

The USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, introduced hydric soil criteria (Table 1) (Natural Resources Conservation Service 1995). These criteria are based on selected soil properties and the taxonomic classification as documented in Soil Taxonomy (Soil Survey Staff 1999). The original wording of the criteria has been modified (Soil Survey Division 2000) to incorporate recent changes to Soil Taxonomy, but these changes have not caused any soils to be added or deleted from the list. The criteria were designed primarily to generate a list of hydric soils from the national database of Map Unit Interpretation Records. Use of these criteria in the field to determine the presence of hydric soils is considered impractical and is discouraged (Vapraskas and Sprecher 1997). Criteria 1, 3, and 4 serve both as database criteria and as indicators for identification of hydric soils in the field. Criterion 2 serves only to retrieve soils from the database.

The presence of a soil on the hydric soil list does not mean that the same soil in the field will always be hydric. Some soils that meet the hydric soil criteria are not saturated, flooded, or ponded long enough during the growing season to meet the hydric soil definition. Some of the soils on the list have ranges in depth to water table that may allow the soil to range from hydric to nonhydric depending on the location of the soil on the landscape. Also, taxonomic names or units are pure; however, mapping units of the same name are not pure. Mapping units normally include small areas of soils that have some properties differing from the named soil. Therefore, these mapping units may have a hydric soil name, but may include some areas of soils within the landscape delineation that do not meet the hydric soil definition. Likewise, inclusions of hydric

Table 1. Criteria for Hydric Soils (Natural Resources Conservation Service 1995)

1. All Histels except Folistels and Histosols except Folists, or
2. Soils in Aquic suborders, great groups, or subgroups, Albolls suborder, Pachic subgroups, or Cumulic subgroups that are:
    a. Somewhat poorly drained with a water table equal to 0.0 ft (0 cm) from the surface during the growing season, or
    b. Poorly drained or very poorly drained and have either:
        (1) water table equal to 0.0 ft (0 cm) during the growing season if textures are coarse sand, sand, or fine sand in all layers within 20 in. (50 cm), or for other soils
        (2) water table at less than or equal to 0.5 ft (15 cm) from the surface during the growing season if permeability is equal to or greater than 6.0 in./h (15 cm/hr) in all layers within 20 in. (50 cm), or
        (3) water table at less than or equal to 1.0 ft (30 cm) from the surface during the growing season if permeability is less than 6.0 in./h (15 cm/hr) in any layer within 20 in. (50 cm), or
3. Soils that are frequently ponded for long duration or very long duration during the growing season, or
4. Soils that are frequently flooded for long duration or very long duration during the growing season.

soils may occur in mapping units of nonhydric soils. Therefore, the hydric soil list is only an interpretive rating to determine potential hydric soils, used for general land-use planning or for general wetland inventories such as the National Wetland Inventory (Soil Survey Division 2000; Vapraskas and Sprecher 1997). Hydric soil interpretations for accurate wetland delineations must be confirmed by on-site investigations using hydric soil indicators. Hydric soil indicators are soil morphological properties related to aquic conditions that are used in the field to identify soils which meet the hydric soil definition (USDA-Natural Resources Conservation Service 1998). In the 1987 Manual, Histosols, histic epipedons, sulfidic material (presence of hydrogen sulfide gas or rotton egg odor), gley (gray) colors, and low chroma ($\leq$2) matrix colors with high chroma mottles near the surface are listed as indicators of hydric soils. Presence of one or more of these indicators is evidence that the hydric soil definition has been met, whereas lack of an indicator does not exclude the soil from being classified as hydric. A more detailed list of field indicators was made available with the publication of *Field Indicators of Hydric Soils in the United States* (USDA-NRCS 1998). Indicators in this publication are designed to be regionally specific. West Virginia fits within two Land Resource Regions (LRR). The eastern panhandle lies within LRR S (North Atlantic Slope Diversified Farming), and the remainder of the state lies within LRR N (East and Central Farming and Forage). Relevant indicators for West Virginia soils are presented in Table 2.

Table 2. Field indicators of hydric soils in West Virginia (Land Resource Regions N and S). For descriptions of these indicators see *Field Indicators of Hydric Soils in the United States* (USDA-NRCS 1998).

Indicator Number*	Indicator Name	Land Resource Region
A1	Histosol	N, S
A2	Histic Epipedon	N, S
A3	Black Histic	N, S
A4	Hydrogen Sulfide	N, S
A5	Stratified Layers	N, S
A10	2 cm Muck	N, for testing in S
F1	Loamy Mucky Mineral	N, S
F2	Loamy Gleyed Matrix	N, S
F3	Depleted Matrix	N, S
F4	Depleted Below Dark Surface	N, S
F5	Thick Dark Surface	N, S
F6	Redox Dark Surface	N, S
F7	Depleted Dark Surface	N, S
F8	Redox Depressions	N, S
F12	Iron/Manganese Masses	N
S1	Sandy Mucky Mineral	N, S
S4	Sandy Gleyed Matrix	N, S
S5	Sandy Redox	N, S
S6	Stripped Matrix	N, S
S7	Dark Surface	N, S

Table 2. Continued.

Indicator Number*	Indicator Name	Land Resource Region
S8	Polyvalue Below Surface	S
S9	Thin Dark Surface	S
TF2	Red Parent Material	N, S
TF4	2.5Y/5Y Below Dark Surface	S
TF7	Thick Dark Surface 2/1	N, S
TF10	Alluvial Depleted Matrix	N, S

* Field indicators beginning with letters A, F, and S are currently accepted for use. Indicators beginning with T are those being tested for use in specific LRRs.

The procedure for documenting a hydric soil in the field is explained in *Field Indicators of Hydric Soils in the United States* (USDA-NRCS 1998) and is summarized here. The process consists of first removing all loose leaf matter, needles, bark, and other easily identified plant material to expose the soil surface. Then a hole should be dug to a depth of at least 50 cm and the soil profile should be described. The profile description is used to identify which field indicators have been matched. For some soils, such as Mollisols (thick, dark, high pH surface), an examination of deeper than 50 cm may be required. The upper horizons of these soils often contain no visible redoximorphic features due to the masking effect of organic matter. Therefore, lower horizons should be observed.

Particular attention should be focused on changes in microtopography over short distances. The shape of the landform can greatly affect the movement of water through the landscape. After sufficient exploratory observations have been made to understand the soil-hydrologic relationships, more shallow excavations may be used at subsequent sampling points. When soil properties seem to be inconsistent with the landscape, it may be necessary to obtain the assistance of an experienced soil scientist to determine if the soil is hydric.

HYDRIC SOILS IN WEST VIRGINIA

Fourteen soil series mapped in West Virginia have been identified as hydric soils by the hydric soil criteria (Table 3) (Soil Survey Division 2000). These soils made the list because of hydric soil criterion 2b3, which is, water table at less than or equal to 1.0 ft (30 cm) from the surface during the growing season if permeability is less than 6.0 in./h (15 cm/h) in any layer within 20 in. (50 cm). All of these soils are poorly or very poorly drained. In addition, several of the soils on the list are frequently ponded or frequently flooded for a long or very long duration during the growing season (criteria 3 and 4). Frequently ponded or frequently flooded means the soil will be inundated ≥50 times in 100 years (Soil Survey Division Staff 1993). Long duration means that a single inundation event lasts from 7 days to 1 month. An inundation of very long duration lasts for ≥1 month. All Histosols (a soil order that means organic soil)

Table 3. Hydric Soils List for West Virginia.

Soil Series	Taxonomic Subgroup	Drainage Class[1]	Hydric Criteria Number[2]
Andover	Typic Fragiaquults	P	2b3
Atkins	Fluvaquentic Endoaquepts	P	2b3
Blago	Typic Umbraquults	P, VP	2b3
Brinkerton	Typic Fragiaqualfs	P	2b3
Dunning	Fluvaquentic Endoaquolls	P, VP	2b3
Elkins	Fluvaquentic Endoaquepts	P, VP	2b3, 3, 4
Ginat	Typic Endoaqualfs	P	2b3
Holly	Fluvaquentic Endoaquepts	P, VP	2b3, 4
Lickdale	Humic Endoaquepts	VP	2b3, 3
Melvin	Fluvaquentic Endoaquepts	P	2b3, 4
Nolo	Typic Fragiaquults	P	2b3
Purdy	Typic Endoaquults	P, VP	2b3, 3
Robertsville	Typic Fragiaqualfs	P	2b3
Trussel	Aeric Fragiaquepts	P	2b3

[1] P = poorly drained, VP = very poorly drained.

[2] Numbers indicate the criteria causing the soil to be included in the hydric list.

identified in West Virginia would be considered hydric soils both by the criteria and by field indicators. Although it is known that Histosols occur in some of the major wetlands of the state, the actual area covered by these soils is unknown. Their general extent is so small that series have not been correlated. Therefore, these soils do not appear on the hydric soil list.

The taxonomic name of any soil provides information about the properties of that soil. In Soil Taxomony (Soil Survey Staff 1999), soils are classified into six categories: order, suborder, great group, subgroup, family and series. Table 4 presents examples of the complete classification of two of the hydric soils from Table 3. The important category for identifying hydric soils in West Virginia is the suborder. The suborders of the soils listed in Table 3 are Aqualfs, Aquepts, Aquolls or Aquults (see Table 4 for specific examples). The "aqu" prefix means these soils have aquic conditions at or near the surface, and it is a strong clue to the presence of hydric soil indicators.

Table 4. Examples of the classification of two hydric soils at all categories of Soil Taxonomy.

Categories	Soil 1	Soil 2
Order	Ultisols (ults)	Inceptisols (epts)
Suborder	Aquults	Aquepts
Great Group	Fragiaquults	Endoaquepts
Subgroup	Typic Fragiaquults	Fluvaquentic Endoaquepts
Family	Fine-loamy, mixed, active, mesic Typic Fragiaquults	Fine-loamy, mixed, acid, mesic Fluvaquentic Endoaquepts
Series	Andover	Atkins

Some soils are mapped at a level in Soil Taxonomy higher than series. An example of this type of mapping unit is Fluvaquents, a great group that was mapped in Kanawha County (Van Houten et al. 1981). Series were not identified for this unit because of soil variability. Therefore, this mapping unit will not appear on most hydric soil lists. However, it is normally a hydric soil because it is classified in the aquic suborder of Aquents.

SUMMARY

Wetland soils have evidence of redoximorphic features indicating aquic conditions. These soils may or may not satisfy the definition of hydric soils; however, hydric soils must be present to formally delineate a jurisdictional wetland. Hydric soil criteria are used to develop a hydric soil list in each state. Caution must be used when comparing the list of hydric soil series to soil survey maps. Many of the soils on the list have ranges in water table depths that allow the soil to range from hydric to nonhydric depending on the location. Also, some mapping units of nonhydric soils may have inclusions of hydric soils, or hydric soil mapping units may have inclusions of nonhydric soils. Lists of hydric soils along with soil survey maps are good off-site ancillary tools to assist in wetland determinations, but they are not a substitute for on-site investigations where field indicators are used to identify the presence of hydric soils.

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Plant communities of West Virginia Wetlands

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ABSTRACT

Plant communities in West Virginia wetlands are highly diverse because of variability in topography, substrate characteristics, and water quality. Of equal importance are anthropocentric activities that influence wetlands by creating and maintaining early successional communities. Forested communities are commonly associated with streams and rivers as either bottomland overflow or swamp wetlands. At low elevations, *Acer saccharinum* and *A. negundo* are frequent dominants, with *Picea rubens, Tsuga canadensis* and *Betula allegheniensis* dominants at high elevations. Swamp and overflow forests are best represented along the Kanawha and Meadow Rivers. Frequent dominants in shrub communities are *Alnus rugosa, A. serrulata, Spiraea alba, Hypericum densiflorum, Vaccinium spp.* and *Viburnum spp.*, with *A. rugosa* and *Vaccinium* spp. occurring mostly in wetlands located above 750 meters in elevation. Herbaceous-dominated wetlands are more variable, with species dominants correlated with hydrologic regime and soil characteristics. The most frequently occurring herbaceous species on mineral soils are *Typha latifolia, Juncus effusus, Leersia oryziodes, Phalaris arundinacea* and various species of *Carex* spp. and *Scirpus* spp. On acidic peatlands at high elevations, *Sphagnum* spp. and *Polytrichum* mosses characteristically form a continuous ground cover. Overall, studies of wetland plant communities in West Virginia have been limited. To better understand the functional aspects of wetlands, the species diversity, phytosociology, soils, geology, and biogeochemistry of both small and large wetlands should subjected to additional study. Further, geospatial studies using GIS technology should be a priority for further wetland studies.

INTRODUCTION

West Virginia has a surface area of approximately 6,236,057 ha (24,078 sq. miles). Of this area, approximately 112,539 ha, or 1.8% of the state's landscape, is classified as wetland (Evans et al. 1982). This is one of the lowest amounts of wetlands per unit area of any state. The reason for this relative paucity of wetland habitats is the state's hilly to mountainous terrain.

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West Virginia falls totally within the Appalachian Plateaus Physiographic Province (Fenneman 1938), an area of rugged, highly dissected landscape typified by low to high mountains with moderate to steep slopes and narrow valleys. As a result, terrain suitable for wetland development is limited, generally restricted to valleys and to flat-lying mountain plateaus. In this landscape, wetlands tend to be small and isolated. Relatively few exceed 100 ha, and many are less than 10 ha. The largest single wetland is Canaan Valley, a high elevation wetland complex of approximately 3,400 ha.

Ecological studies of wetland plant communities in West Virginia have been limited. Few wetlands, large or small, have had detailed vegetation studies conducted on their plant communities. Those areas that have been studied are generally ones known to have unusual or rare plant species, such as the marl wetlands of Jefferson County in the Eastern Panhandle and bog habitats of mountainous areas, including Cranberry Glades, Big Run Bog, Canaan Valley, and Cranesville Swamp.

SCOPE AND OBJECTIVES

The primary purpose of this paper is to broadly describe the principal vegetation types of wetlands in West Virginia. Specifying objectives are (1) to describe the content and scope of past vegetation community studies in wetlands, (2) to review and summarize the vegetation units or plant communities described in these studies, and (3) to identify research needed to develop a better understanding of plant community development, species composition, geospatial relationships, structure, and ecosystem functions of wetland vegetation in West Virginia.

METHODS

A review was carried out of all available publications and technical reports in which the plant communities or other levels of species groupings in wetlands were quantitatively described. For a species to be considered herein, the plant community descriptions had to include empirical data that described the physical structure and species dominance based on structural organization. Furthermore, for a study to be considered it must have met one or more of the criteria listed below:

1. Published as a peer-reviewed journal article.
2. Published in a meeting proceedings.
3. Reported as a thesis or dissertation.
4. Submitted as a technical report an agency or organization.

Studies that were strictly floristic descriptions were not included.

As anticipated, each study reviewed was unique in that its methods and standards for naming and organizing vegetation into units were different. Unfortunately, the classification units used varied widely, including plant communities, cover types, and vegetation types. For consistency, *plant community* was chosen as the basic classification unit, assuming that most researchers, in describing and naming plant groups, were attempting to categorize vegetation into natural identifiable assemblages of plant species that could potentially be found elsewhere. There was consistency, however, in the use of plant names (common, genus, or genus and species) to designate communities. In a limited number of instances, classification units were used that seemed to be specific to a specific area and those not widely adaptable to other wetlands. For unique vegetation types, this was regarded as acceptable. These unique names included locally dominant or co-dominant species, such as balsam fir (*Abies balsamea*) and larch (*Larix laricina*). These special communities were included in most cases but in other cases, where local combinations of species representing co-dominants were reported, they were either not recognized as potentially repeatable plant communities or included in categories where most of the taxa used in describing the community dominance were the same. Consistency in the type of habitat described for a community also was a factor.

As a way of characterizing important species at each study site, the species cited as dominant or co-dominant were listed separately. Generally, dominant and co-dominant species refer to the tallest vegetation strata that exert the most influence on the community as a whole. Where bryophytes consistently were reported to form a prominent ground cover layer, a bryophyte ground cover layer was included in addition to the herbaceous and shrub layers. Special note was made where a bryophyte ground cover was described as occasionally occurring with a specific plant community.

A few of the studies reviewed included site-specific empirical data on soils, hydrology, and geology. Although these are important study components, they are not discussed in this paper, other than noting which investigation included them as a study component. For consistency, Strasbaugh and Core (1977) was used as the taxonomic authority.

DESCRIPTION OF VEGETATION STUDIES

A total of 21 journal articles, theses/dissertations, proceedings papers, and technical reports were reviewed, and these described a total of 15 wetlands (Table 1 and Figure 1). Table 1 summarizes these documents, listing the type of document, author, date published, title, county, elevation, and site-specific data. Wetland sites are grouped by ecological region in the state, as modified from Core (1966). Core described three physiographic regions for West Virginia: Western Hills, Mountain and Upland, and Ridge and Valley, each with a corresponding predominant forest type. These physiographic regions are used here in as broad ecological regions, with the Western Hills region subdivided into low- and mid-elevation sections.

DESCRIPTION OF STUDY SITES

Western Hills

The sites included in the low elevation portion of the Western Hills region are Winfield Swamp, Greenbottom Swamp, and Buckley Island (Table 1). Winfield Swamp, which is bisected by State Route 35, is located on the floodplain of the Kanawha River. At the time of

Table 1. Summary of publications and technical reports on the vegetation of wetlands in West Virginia.

Site/Ecological Region	Document Type	Author(s)	Date	Title	Elevation (m)	Data Collected		
						Vegetation Data	Soils	Hydrology or Water Chemistry
Allegheny Mountain and Upland								
Canaan Valley	Dissertation/ Technical Rpt.	Fortney	1975, 1997	The Vegetation of Canaan Valley West Virginia: A Taxonomic and Ecological Study	986	Yes	No	No
Cranberry Glades	Dissertation/Thesis	Edens/Kokesh	1973/1988	The Bog Forest Community at Cranberry Glades, West Virginia	1028	Yes	No	No
Cranesville Swamp	Thesis	Robinette	1964		775	Yes	No	Yes
Big Run Bog	Thesis/Symposium Proceedings/Journal	Weider et al./ Walbridge and Lang	1981/1982	Major Plant Communities and Paters of Community Distribution in Four Wetlands of the Unglaciated Appalachian Region	> 760 m	Yes	No	No
Cupp Run	Thesis/Symposium Proceedings	Walbridge, Lang	1982	Same as Big Run Bog	> 760 m	Yes	No	No
Laurel Run	Thesis/Symposium Proceedings	Walbridge, Lang	1982	Same as Big Run Bog	> 760 m	Yes	No	No
Tub Run	Thesis/Symposium Proceedings	Walbridge, Lang	1982	Same as Big Run Bog	> 760 m	Yes	No	No
Ridge and Valley						Yes	No	No
Altona Marsh	Thesis	Bartgis	1983	Vegetation Ecology of Marl Wetlands in Eastern WV	158	Yes	Yes	Yes
Louise Lake Marsh	Thesis	Bartgis	1983	Same as Altona Marsh	152	Yes	Yes	Yes
Town Marsh	Thesis	Bartgis	1983	Same as Altona Marsh	128	Yes	Yes	Yes
Western Hills								
Buckley Island	Tech. Rept.	Fortney et al.	2000	Evaluation of the Effects of Bridges on Wildlife	< 455 m	Yes	Yes	No
Greenbottom Swamp	Thesis	Stark	1993	Flora and Vegetation of Green Bottom Wildlife Management Area	< 455 m	Yes	No	No
Meadow River Wetland	Tech. Rpt.	Williams			455 to 760 m	Yes	No	Yes
Meadowville Wetland	Tech. Rpt.	Fortney et al.	2000	Evaluation of Three Constructed and Three Mitigation Wetlands constructed by the West Virginia Division of Highways	456 to 760 m	Yes	No	No
Winfield Swamp	Proceedings	Brumfield, Evans	1982	Flora and Vegetation of Three Wetlands in the Lower Kanawha River Floodplain, West Virginia	< 455 m	Yes	No	No

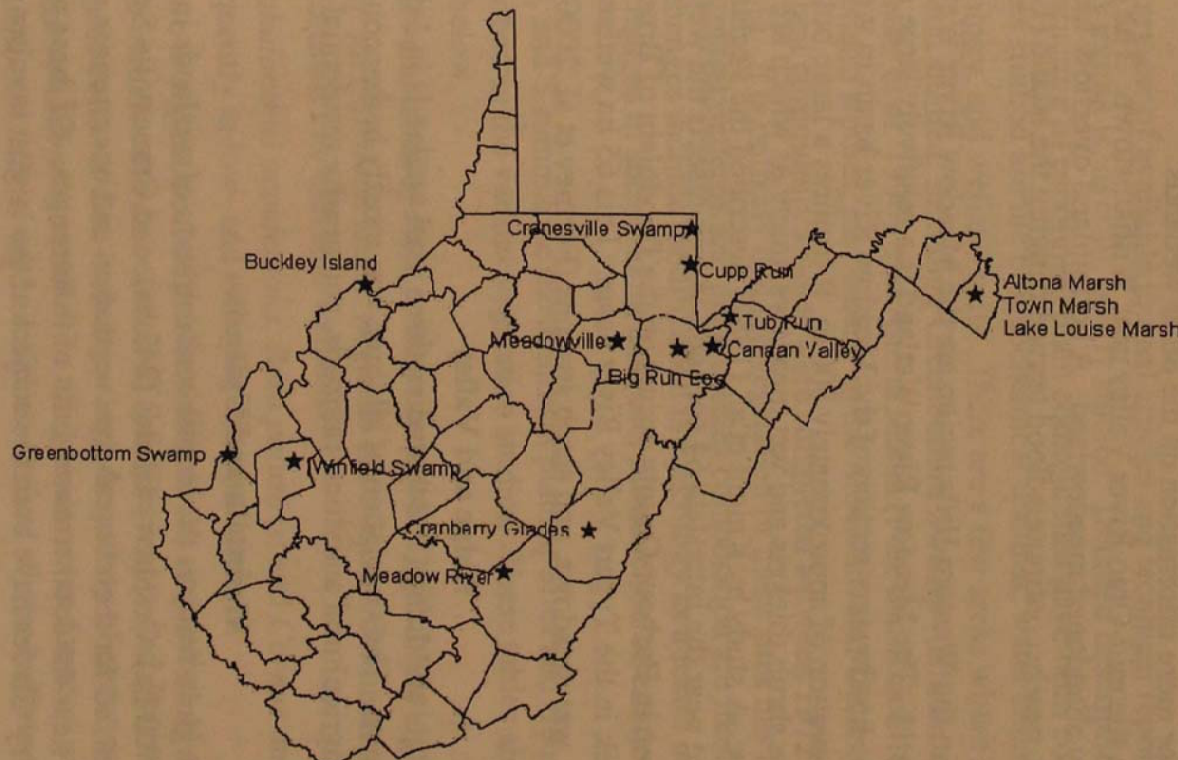

Figure 1. Map showing locations of wetlands in West Virginia for which vegetation studies have been conducted.

the study by Brumfield and Evans (1982), most of the area was a forested swamp, with shrub and herbaceous communities occurring mostly in areas with permanently or semi-permanently flooded hydrological regimes. Today, many of the forest communities have been flooded and replaced by open water and shrub swamps as a result of elevated water tables due to beaver activities.

Greenbottom Swamp occurs on the floodplain of the Ohio River. Like Winfield Swamp, it was once mostly forested, but changes in hydrologic regimes due to highway construction and beaver activities have resulted in the conversion of woody cover to herbaceous dominated plant communities and open water (Stark 1993).

West and Evans (1982) developed plant succession models for three wetlands in the lower Kanawha River region of West Virginia. The Winfield Swamp was also included in this study. See West and Evans (1982) for more information on the other wetlands.

Buckley Island occurs in the mid-Ohio River Valley near Williamstown. The center portion of the Island is predominantly abandoned meadowland. A bottomland overflow hardwood swamp forest occupies a low, nearly continuous flood terrace fringing the island (Edinger et al. 1998).

Two other sites studied in the Western Hills region are the Meadow River Wetland and Meadowville Swamp (Figure 1). The Meadow River Wetland is a relatively large area of approximately 7,750 ha in the headwaters section of the Meadow River basin in western Greenbrier County. At an elevation of approximately 800 m, it features a large bottomland overflow forest and extensive shrub thickets and wet meadows, many of which are maintained through agricultural practices. A study by Knight et al. (1982) described the vegetation of a limited section of the wetland near the Interstate 64 corridor, which bisects the wetland.

The Meadowville Swamp in Barbour County occurs on the floodplain of Brushy Fork, a small tributary of Sugar Creek in the Tygart Valley River basin. This 65 ha wetland features a complex pattern of marshes, wet meadows, and shrub swamps (Fortney et al. 2000).

Ridge and Valley

Bartgis (1983) and Bartgis and Lang (1984) studied three marl wetlands in Jefferson County in the Ridge and Valley section. The vegetation of all three was mostly herbaceous, and they were heavily influenced by agricultural activities, railroads, and nearby residential developments.

Mountain and Uplands

This region of West Virginia features the largest concentration of wetlands in the State. It includes Canaan Valley (3,400 ha), Cranberry Glades (243 ha), and Cranesville Swamp (230 ha), three major wetlands recognized for their boreal-type vegetation and occurrences of many northern plant species at or near the southernmost limit of their ranges. Of these wetlands, Canaan Valley and Cranberry Glades have been the subject of the largest number of vegetation studies. The studies in Canaan include those by Fortney (1975, 1997). The principal studies in Cranberry were those by Darlington (1942), Edens (1973), and Kokesh (1988). Robinette (1964) described the vegetation of Cranesville Swamp. Lang and Topa (1982) described the solution chemistry of streams and surface waters in Cranesville. Walbridge (1982), Walbridge and Lang (1982) and Wieder et al. (1981) studied other wetlands in this section. The wetlands studied were Big Run Bog, Cupp Run, Laurel Run, and Tub Run. In another study, Larabee (1986) described the late-Quaternary vegetation and geomorphic history of Big Run Bog. These wetlands, which range in size from 6-64 ha, are all located in either Preston or Tucker County (Table 1).

RESULTS AND DISCUSSION

Based on the review of available journal articles and technical reports, the vegetation of wetlands in West Virginia is, overall, poorly studied. Detailed descriptions of the species composition and structure of prominent plant communities have been compiled for only 15 wetlands. Even less studied are the biogeochemical features, water chemistry, surface and groundwater hydrology, and wetland soils. There are a few areas where some of these parameters have been studied, including Greenbottom Swamp (Gilliam et al. 1999), Big Run Bog (Wieder 1985, Wieder et al. 1990), and Altona Marsh (Putz and Kelch 1989). There have been several floristic wetland studies, particularly in the Mountain and Upland section.

Most of the plant community studies were completed between 1972 and 1982, making them 20 years or more old. It is unlikely that the vegetation of these sites has remained static. Therefore, the geospatial patterns and plant species composition are likely to have changed. The reasons for these changes include modification in hydrology as a result of beaver activity, natural plant succession, changes in surrounding land use, introduction of exotic species, and changes in water quality.

Tables 2, 3, 4, and 5 summarize the dominant plant species and frequently occurring plant communities described in the various vegetation studies. These tables show several vegetation patterns, as noted below.

1. There are several plant species occurrence patterns within ecological regions.
    a. *Acer saccharinum* and *A. negundo* are frequent dominant or co-dominant species in forested low elevated wetlands.
    b. *Cephalanthus occidentalis*, *Rosa palustris*, and *Cornus amomum* occur most frequently in low- and mid-elevation wetlands.
    c. There is a great deal of predictability in the vegetation of mountainous wetlands. This includes the association of *Sphagnum* spp. and *Polytrichum* spp. mosses with organic soils. It also includes a high frequency of occurrence of *Picea rubens*, *Tusga canadensis*, and *Betula allegheniensis* in forested wetlands; *Hypericum densiflorum*, *Alnus rugosa*, *Ilex verticilata*, *Pyrus melanocarpa*, and *Spiraea alba*

in shrub swamps; and *Carex rostrata, Juncus effusus, Rubus hispidus, Solidago uliginosa*, and *Eriophorum virginicum* in herbaceous dominated wetlands.

d. Canaan Valley is the most diverse wetland for both wetland plant species and plant communities. It is also the largest wetland in the State.

e. *Quercus palustris* and *Q. bicolor* occur only at low and mid elevations.

f. Marl areas of Eastern Panhandle have many species in common but collectively also have a unique set of species.

g. Extensive *Alnus rugosa* thickets occur only in mid- and high-elevation wetlands.

2. *Spiraea alba, Leersia oryzoides*, *Carex lurida,* and *Typha latifolia* are hydrophytic plants often associated with recent disturbance.
3. A few species are common at all elevations. These include *Carex lurida, Leersia oryzoides, Typha latifolia, Chelone glabra, Polygonum sagittatum*, *Hypericum densiflorum,* and *Acer rubrum*.
4. Except for the plant cover in a few wetlands, such as Cranberry Glades and Big Run Bog, the vegetation of most wetlands has been highly altered by past land use practices, including agricultural activities, logging, fire, and manmade ponds and lakes. Beaver activities that include dam building and ponding have also lead to alterations in vegetation cover. As a result, the vegetation in most wetlands is typically dominated by herbaceous and shrub cover of a type associated with early successional stages.

Based on available literature and reports, there are several general patterns in terms of where wetlands have been studied and what parameters have been examined in each instance. These are outlined below.

1. Mid-elevation wetlands and wetlands in the southern and southeastern sections of West Virginia are the least studied.
2. There has been limited investigation of geochemical, biogeochemical, and hydrologic components of wetlands.
3. Only the vegetation in Canaan Valley has been mapped using GIS technology; therefore, advanced studies in geospatial relationships among vegetation types, species occurrences, and physical environmental factors in the State's wetlands have been limited.

CONCLUSIONS

Overall, wetland plant communities in West Virginia are understudied. To better understand the functional aspects of wetlands, the species diversity, phytosociology, soils, geology, and biogeochemical of both small and large wetlands should be studied. Further, geospatial studies using GIS technology should be a priority for further wetland studies.

Table 2. Common dominant species and plant communities cited in wetland vegetation studies for three low elevation wetlands in the Western Hills region of West Virginia. Note: P = present.

Forested Wetland Communities	Study Sites		
	Buckley Island	**Greenbottom Swamp**	**Winfield Swamp**
Dominant Species			
Sweet gum (Liquidambar styraciflua)			P
Silver maple (Acer saccharinum)	P	P	P
Red maple (A. rubrum)		P	P
Box elder (A. negundo)	P	P	P
Pin oak (Quercus palustris)			P
White swamp oak (Q. bicolor)			P
American ash (Fraxinus americana)			
Cottonwood (Populus deltoides)	P		
Hackberry (Celtis Occidentalis)	P		
Common Forest Communities			
Liquidambar-Acer			P
Acer-Quercus			P
Quercus-Liquidambar			P
Acer-Fraxinus			
Acer saccharinum	P	P	
Acer-Populus	P		
Acer		P	
Dominant Shrub Species			
Buttonbush (Cephalanthus occidentalis)		P	P
Swamp rose (Rosa palustris)		P	P
Silky cornel (Cornus amomum)		P	P
St. Johnswort (Hypericum densiflorum			
Poison ivy (Rhus radicans			P
Common Shrub Swamp Communities			
Cephalanthus occidentalis			P
Cephalanthus-Rosa			P
Cornus-Cephalanthus			P
Dominant Herbaceous Species			
Common rush (Juncus effusus)		P	P
Carex scoparia		P	P
C. vulpinoidea		P	P
Reed canary gr. (Phalaris arundinacea)			P
Rice cutgrass (Leersia oryzoides)			P
Cattail (Typha latifolia)			P
Smartweed (Polygonum punctatum)			P
Mild water pepper(P. hydropiperoides)			P
Swamp-loosestrife (Decodon verticilata)			P
Common Herbaceous Communities			
Juncus-Carex Wet Meadow			P
Calamagrostis Wet Meadow			P
Carex-Polygonum Wet Meadow			P
Leersia Wet meadow			P
Typha Marsh			P
Decodon verticillata Wet Meadow			P

Table 3. Common dominant species and plant communities cited in wetland vegetation studies for two mid elevation wetlands in the Western Hills region of West Virginia. Note: P = present.

Forested Wetland Communities	Study Sites	
	Meadow River	Meadowville
Dominant Shrub Species		
Brookside alder (Alnus serrulata)	P	P
Swamp rose (Rosa palustris)	P	P
Silky dogwood (Cornus amomum)	P	P
Winterberry (Ilex verticillata)		P
Spirea (Spiraea alba)	P	P
St. Johnswort (Hypericum densiflorum)	P	P
Dominant Shrub Communities		
Alnus-Ilex Tall Shrub Thicket		P
Rosa-Cornus Tall Shrub Thicket		P
Spiraea Tall Shrub Thicket	P	P
Hypericum Low Shrub Thicket	P	P
Rosa palustris Shrub Thicket	P	
Alnus serrulata Shrub Swamp	P	
Dominant Herbaceous Species		
Cattail (Typha latifolia)	P	P
Sedge (Carex stricta)		P
Sedge (Carex crinita)		P
Leersia oryzoides (Rice cutgrass)	P	P
Impatiens (Impatiens capensis)		P
Bluejoint grass (Calamagrostis canadensis)	P	
Tall goldenrod (Solidago altissima)		P
Common Community		
Typha latifolia Marsh	P	P
Carex stricta Wet Meadow		P
Carex-Leersia Wet Meadow		P
Leersia oryzoides Wet Meadow	P	P
Mixed Forb Wet Meadow		P
Carex-Forb Wet Meadow	P	P

Table 4. Common dominant species and plant communities cited in wetland vegetation studies for three low elevation wetlands in the Ridge and Valley region of West Virginia. Note P = present.

Forested Wetland Communities	Stuty Sites		
	Altona Marsh	Town Marsh	Lake Louise
Dominant Herbaceous Species			
Typha latifolia	P	P	
Phalaris arundinacea	P		
Solidago altissima	P		
Aster puniceus	P		
Carex stricta	P	P	P
Scirpus acutus	P		
Water horsetail (Equisetum fluviatile)	P		
Juncus balticus	P		
Burreed (Sparganium eurycarpum)	P		P
Marsh fern (Thelypteris palustris	P		
Polygonum coccineum		P	
Manna grass (Glyceria canadensis)			P
Marsh mallow (Hybiscus moscheutos)			P
Common Herbaceous Communities			
Carex Wet Meadow	P	P	P
Juncus-Thelypteris Marsh	P		
Phalaris Marsh	P	P	P
Typha Marsh	P	P	P
Typha-Equisetum Marsh	P		
Solidago-Aster Wet Meadow	P		
Hibiscus-Glyceria Wet Marsh			P
Sparganium Marsh			P
Dominant Shrub Species			
Salix discolor (Willow)	P	P	
Cornus amomum (Silky cornel)	P	P	
Common Shrub Communities			
Salix-Cornus Swamp	P	P	
Dominant Tree Species			
Plantanus occidentalis	P		P
Fraxinus pensylvanica	P		P
Common Tree Communities			
Fraxinus-Platanus Swamp	P		P

Table 5. Common dominant species and plant communities cited in wetland vegetation studies for six high elevation wetlands in the Mountain and Upland region of West Virginia (from Fortney in press). Note: P = present.

Forested Wetland Communities	Study Sites					
	Canaan Valley	Cranesville Swamp	Cranberry Glades	Big Run Bog	Cupp Run	Laurel Run
Dominant Tree Species						
Hemlock (Tsuga canadensis)	P	P	P		P	P
Red spruce (Picea rubens)	P	P	P	P		
Yellow birch (Betula alleghaniensis)	P	P	P			
Wild black cherry (Prunus serotina)	P	P	P			
Red maple (Acer rubrum)	P	P				
Balsam fir (Abies balsamea)	P					
Quaking aspen (Populus tremuloides)	P					
Black ash (Fraxinus nigra)	P	P				
Larch (Larix laricina)		P				
Common Forest Communities						
Mixed Conifer-Hardwood*	P	P	P			
Picea rubens*	P	P	P	P		
Abies-Picea-Tsuga*	P					
Larix-Picea-Tsuga		P				
Fraxinus-Betula	P	P				
Tsuga Swamp*	P				P	P
Populus Grove	P					
Dominant Shrub Species						
Speckled alder (Alnus rugosa)	P	P	P		P	
Spirea (Spiraea alba)	P					
St. Johnswort (Hypericum densiflorum)	P	P	P	P	P	P
Winterberry (Ilex verticillata)	P	P				
Viburnum (Viburnum spp.)	P		P			P
Blueberry (Vaccinium spp.)	P	P	P			
Black Chokeberry (Pyrus melanocarpa)	P	P	P			
Willow (Salix spp.)		P			P	P
Common shrub Communities						
Alnus incana*	P	P	P		P	P
Spiraea Thicket	P		P			
Vaccinium-Pyrus*	P	P	P			
Hypericum thicket*	P	P	P			P
Viburnum-Pyrus*			P			
Alnus-Viburnum*	P		P		P	
Salix Shrub	P					P
Dominant Herbaceous Species						
Sedge (Carex rostrata)	P	P	P			
Sedge (Carex scoparia)	P					
Sedge (Carex stricta)	P				P	
Sedge (Carex canescens)	P				P	P
Cottongrass (Eriophorum virginicum)	P			P		P
Beak Rush (Rhynchorspora alba)						
Common rush (Juncus effusus)	P	P	P	P		
Rush (Juncus brevicaudatus)	P	P				
Rush (Juncus subcaudus)					P	P
Mannagrass (Glyceria spp.)	P					P
Dewberry (Rubus hispidus)	P	P	P	P	P	
Bog goldenrod (Solidago uliginosa)	P	P		P		P
Bluejoint grass (Calamagrostis canadensis)	P					
Broad-leaf cattail (Typha latifolia)	P		P		P	P
Rice Cutgrass (Leersia oryzoides)	P				P	
Woolgrass (Scirpus atrocintus)	P					
Cinnamon fern (Osmuda cinnamomea)			P			
Three-way sedge (Dulichium arundinaceum)			P	P		
Common Plant Communitites						
Sphagnum-Carex Bog	P	P	P		P	P
Sphagnum-Glyceria-Carex Bog	P					
Sphagnum-Eriophorum Bog	P	P				
Sphagnum-Rhynchospora Bog		P				
Polytrichum-Solidago-Rubus Bog	P			P		P
Polytrichum-Eriophorum Bog	P	P		P		
Polytrichum-Carex-Juncus Bog	P				P	
Sphagnum-Dulichium Bog			P	P		
Polytricum-Solidago-Eriophorum Bog				P		
Mixed Graminoid Forb Meadow*	P					
Juncus-Carex Meadow*	P					
Leersia oryzoides Meadow		P	P			P
Typha-Osmunda Marsh	P		P	P	P	
Typha latifolia Marsh	P	P				
Calamagrostis Meadow	P					

* May include bryophyte ground cover.

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Floristics of Southern and Western West Virginia Wetlands

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Wetlands of western West Virginia are divided geographically into three groups based on floristics. They are Ohio River Lowlands, Southern Plateau, and High Western Hills. The Ohio River Lowlands include all areas along the full length of the Ohio River in West Virginia, the Kanawha River upstream to Charleston, and other Ohio River tributaries upstream to approximately the 1000-foot elevation contour. These areas occur largely on former ice age lake beds or Permian geologic period deposits and have been highly disturbed by farming, river navigation, and commercial development of towns, cities, roads and railroads. Wetland soils mostly occur on deep alluvial and colluvial deposits where streams have changed channels or where manmade structures impede water flow. Some of the better known wetlands on the Ohio River Lowlands are Green Bottom Wildlife Management Area, Boaz Swamp, Little Wet Meadows, Williamstown Marsh, Blennerhassett Swamp, Tomlinson Run Swamp, McClintic Wildlife Management Area, and numerous embayments at the mouth of larger streams entering the Ohio River.

The Southern Plateau wetlands are mostly swamps and wet meadows occurring in Mercer, Monroe, Raleigh, Summers, Fayette, Nicholas, and Greenbrier Counties. These wetlands are primarily located between 2000 and 3000 feet elevation. They occur where soft shales overlay hard sandstones that resist weathering and act as a dam by slowing water flow from the flatter shale areas. Many of these wet thickets and forests were cleared and drained for farms and meadows. Wetland soils were formed in place from the shales and tend to be heavy textured clays.

The wetlands on the headwaters of Meadow River (Greenbrier and Fayette Counties) are the third largest in West Virginia. Other well known wetlands are as follows:

1. Nicholas County - Big and Little Beaver Creeks, Muddlety, and Deer Creeks
2. Fayette County - Big Glade, Paint, Meadow, and Mann/Glade Creeks
3. Raleigh County - Marsh Fork, Glade, Kates Branch, and Piney Creeks

Citation: Grafton, W.N. 2000. Floristics of southern and western West Virginia wetlands. Proc. W. Virginia Acad. Sci. 72(3):55-77.

4. Mercer County - Brush Creek
5. Monroe County - Devil Creek
6. Summers County - Meadow and Stony

The Crumps Bottom wetland lying along New River/Bluestone Lake is lower in elevation than the other wetlands and more typical of those in the Ohio River Lowlands.

The High Western Hills mostly occur between 1000 and 2500 feet elevation along the headwaters of major Ohio River tributaries flowing westward from the summits of the Allegheny Mountain Range. The area receives higher rainfall than the lowlands because of the orographic effects of moisture moving from west to east up the west slopes of the Alleghenies. Many wetlands of this area are seeps, small swampy thickets, and wet meadows. Most of these wetlands occur as the result of a hard impervious layer of sandstone that erodes much slower than the softer shales lying above it. Some of the more prominent wetlands are as follows:

1. Barbour County – Teter Creek Lake, Pleasant Creek Wildlife Management Area, Big Run near Volga, and Glady Creek near Meadowville
2. Preston County – upper Deckers Creek and Big Sandy Creek
3. Monongalia County - Mountaineer Boy Scout Camp
4. Randolph County – Tygart Valley River near Dailey and Valley Bend
5. Upshur County – Turkey Run, French Creek, and Holly Grove on the Little Kanawha River.

Species Commonality

Many species were found in all three wetland groups. The following plants were dominant in areas ranging from a few square meters to several acres.

Trees

Acer rubrum – Red maple

Fraxinus americana – White ash

F. nigra – Black ash

Platanus occidentalis – Sycamore

Salix nigra – Black willow

Shrubs and vines

Cephalanthus occidentalis – Buttonbush

Cornus amomum – Silky cornel

Ilex verticillata – Winterberry holly

Physocarpus opulifolius – Ninebark

Rosa palustris – Swamp rose

Salix sericea – Silky willow

Smilax glauca – Saw brier

Ferns and fern allies

Onoclea sensibilis – Sensitive fern

Grasses/sedges

Carex atlantica – Sedge

C. crinita – Sedge

C. cristatella – Crested Sedge

C. frankii – Sedge

C. intumescens – Sedge

C. lupulina – Sedge

C. lurida – Sedge

C. scoparia – Sedge

C. squarrosa – Sedge

C. stipata – Sedge

C. torta – Sedge

C. tribuloides – Sedge

C. vulpinoidea – Foxtail sedge

Cinna arundinacea – Wood reedgrass

Cyperus strigosus – Galingale

Dichanthelium clandestinum- Deertongue grass

Dulichium arundinaceum – Three-way sedge

Eleocharis obtusa – Spikerush

Eleocharis tenuis – Kill cow

Glyceria striata – Fowl mannagrass

Holcus lanatus – Velvet grass

Juncus brevicaudatus – Rush

J. effusus – Common rush

Leersia oryzoides – Rice cutgrass

L. virginica – White grass

Panicum rigidulum – Redtop panic grass

P. rigidulum var. *elongatum* – Tall flat panic grass

Phalaris arundinacea – Reed canary grass

Scirpus atrovirens – Black bulrush

S. cyperinus – Woolgrass

S. polyphyllus – Bulrush
S. tabernaemontani – Great bulrush
Other herbs (spring)
Acorus americanus – Sweet flag
Cardamine bulbosa – Bulbous cress
Ranunculus hispidus var. *nitidus* – Hispid buttercup
Senecio aureus – Golden ragwort
Other herbs (summer/autumn)
Alisma subcordatum – Common water plantain
Apios americana – Groundnut
Aster lanceolatus – Panicled aster
A. lateriflorus – Goblet aster
A. puniceus – Purple-stem aster
Bidens. aristosa – Ozark tickseed-sunflower
Boehmeria cylindrica – False nettle
Callitriche terrestris – Austin's water starwort
Chelone glabra – Turtlehead
Cicuta maculata – Water hemlock
Clematis virginiana – Virgin's bower
Epilobium coloratum – Purple-leaved willow-herb
Eupatorium fistulosum – Common Joe-pye weed
E. perfoliatum – Boneset
Euthamia graminifolia – Grass-leaved goldenrod
Galium obtusum – Stiff marsh bedstraw
G. tinctorium – Clayton's bedstraw
Gratiola neglecta – Clammy hedge-hyssop
Helenium autumnale – Yellow sneezeweed
Hypericum mutilum – Small-flowered St. John's-wort
Impatiens capensis – Spotted touch-me-not
Lindernia dubia – False pimpernel
Lobelia cardinalis – Cardinal-flower
L. siphilitica – Great blue lobelia
Ludwigia alternifolia - Seedbox
L. palustris – Marsh purslane

Lycopus americanus – Water horehound
L. uniflorus – Northern bugleweed
L. virginicus – Bugleweed
Lysimachia ciliata – Fringed loosestrife
L. nummularia – Moneywort
Lythrum salicaria – Purple loosestrife
Mentha spicata – Spearmint
M. x *piperita* – Peppermint
Mimulus ringens – Common monkey-flower
Penthorum sedoides – Ditch stonecrop
Polygonum hydropiper – Common smartweed
P. hydropiperoides – Mild water pepper
P. pensylvanicum – Pennsylvania smartweed
P. persicaria – Lady's thumb
P. punctatum – Water smartweed
P. sagittatum – Arrowleaf tearthumb
Rudbeckia laciniata – Tall coneflower
Sagittaria latifolia – Duck potato
Scutellaria lateriflora – Mad-dog skullcap
Solidago rugosa - Wrinkle-leaf goldenrod
Sparganium americanum – American burreed
Thalictrum pubescens – Late meadowrue
Toxicodendron radicans – Poison ivy
Typha latifolia – Broad-leaved cattail
Verbena hastata – Blue vervain
Verbesina alternifolia – Wing-stem
Vernonia gigantea – Tall ironweed
V. noveboracensis – New York ironweed
Viola cucullata – Marsh blue violet
V. striata – Striped violet

Aquatic

Lemna valdiviana – Valdivia's duckweed
Najas gracillima – Slender water-nymph
Nuphar lutea ssp. *advena* – Cowlily

Potamogeton diversifolius – Variable pondweed
Utricularia macrorhiza – Greater bladderwort
Wolffia brasiliense – Dotted watermeal

Rare Plants of Western West Virginia Wetlands

The following rare plants are followed by designations of N-native, A-adventive, I-introduced and E-exotic.

Ohio River Lowlands Rare Plants

Ammania coccinea – Scarlet ammania A
Amorpha fruticosa – False indigo N
Ampelopsis cordata – Raccoon-grape A
Carex grayi – Sedge N
Lemna valdiviana – Valdivia's duckweed N
Ludwigia decurrens – Primrose-willow N
L. leptocarpa – Primrose-willow N
L. peploides – Creeping primrose-willow A
L. uruguayensis – Primrose-willow A
Myosoton aquaticum – Giant chickweed E
Najas gracillima – Slender water-nymph N
Nelumbo lutea – American lotus I
Ranunculus sceleratus – Cursed crowfoot N
Rumex verticillatus – Swamp dock N
Sparganium eurycarpum – Large burreed N
Typha angustifolia – Narrow-leaved cattail N
Utricularia gibba – Humped bladderwort A
U. macrorhiza – Greater bladderwort A
Veronica scutellata – Marsh speedwill N
Wolffia brasilense – Dotted watermeal N

Southern Plateau Rare Plants

Andropogon glomeratus – Broomsedge N
Aster radula – Low rough aster N
Calopogon tuberosus – Grass pink N
Eupatorium pilosum – Vervain thoroughwort N
Fraxinus nigra – Black ash N

Glyceria septentrionalis – Eastern mannagrass N
Lemna valdiviana – Valdivia's duckweed N
Lygodium palmatum - Climbing fern N
Najas gracillima – Slender water-nymph N
Pedicularis lanceolata – Swamp lousewort N
Platanthera flava – Pale green orchid N
P. peramoena – Fringeless purple orchid N
Pogonia ophioglossoides – Rose pogonia N
Polygala cruciata – Cross-leaved milkwort N
Sanguisorba canadensis – Burnet N
Scirpus purshianus – Bulrush N
Sparganium androcladum – Staminate burreed N
Utricularia macrorhiza – Greater bladderwort A
Viburnum lentago – Nannyberry N
Wolffia brasiliense – Dotted watermeal N

High Western Hills Rare Plants

Andropogon glomeratus – Broomsedge N
Aster solidagineus – Narrow-leaved white-top aster N
Carex bromoides – Sedge N
Cleistes bifara – Spreading pogonia N
Eupatorium pilosum – Vervain thoroughwort N
Fraxinus nigra – Black ash N
Lemna valdiviana – Valdivia's duckweed N
Liparis loeselii – Loesel's twayblade N
Najas gracillima – Slender water-nymph N
Platanthera grandiflora – Large purple fringed orchid N
Rhus vernix – Poison Sumac N
Rhyncospora globularis – Beaked rush N
Scirpus purshianus – Bulrush N
Scleria triglomerata – Nutrush N
Utricularia gibba – Humped bladderwort A
U. macrorhiza – Greater bladderwort A
Vitis labrusca – Fox grape N
Wolffia brasiliense – Dotted watermeal N

Xyris torta – Yellow-eyed grass N

Ohio River Lowlands Floristics

The Ohio River Lowland wetlands are subdivided into two groupings. The first are floodplain riparian communities that are open stream/river banks, mudflats, or sand/gravel bars. These "riparian" communities are composed of pioneer species and are very unstable because of frequent changes in water levels, flooding, and wave action from barges. The second group consists of wet meadows and swamps.

Riparian trees

Acer negundo – Boxelder

A. saccharinum – Silver maple

Betula nigra – River birch

Platanus occidentalis – Sycamore

Salix alba – White willow

S. nigra – Black willow

Riparian shrubs

Amorpha fruticosa – False indigo

Cephalanthus occidentalis – Buttonbush

Cornus amomum – Silky cornel

Physocarpus opulifolius – Ninebark

Riparian grasses/sedges

Cyperus erythrorhizos – Sedge

C. esculentus – Edible Nutgrass

C. odoratus – Sedge

C. strigosus – Galingale

Eleocharis obtusa – Spikerush

E. tenuis – Kill cow

Panicum rigidulum – Tall flat panic grass

Phalaris arundinacea – Reed canary grass

Riparian – other herbs (summer/autumn)

Ammania coccinea – Scarlet ammania

Bidens cernua – Bur marigold

Gratiola neglecta – Clammy hedge-hyssop

Helenium autumnale – Yellow sneezeweed

Justicia americana – Water-willow
Lindernia dubia – False pimpernel
Lobelia cardinalis – Cardinal-flower
L. siphilitica – Great blue lobelia
Ludwigia decurrens – Primrose-willow
L. leptocarpa – Primrose-willow
L. palustris – Marsh purslane
L. uruguayensis – Primrose-willow
Lycopus americanus – Water horehound
L. uniflorus – Northern bugleweed
L. virginicus – Bugleweed
Lythrum salicaria – Purple loosestrife
Mentha arvensis – Wild mint
Mimulus alatus – Winged monkey-flower
M. ringens – Common monkey-flower
Myosoton aquaticum – Giant chickweed
Penthorum sedoides – Ditch stonecrop
Polygonum amphibium – Water smartweed
P. cuspidatum – Japanese knotweed
P. lapathifolium – Dock-leaved smartweed
P. pensylvanicum – Pennsylvania smartweed
P. sachalinense – Sachalin
Ranunculus sceleratus – Cursed crowfoot
Rorippa sylvestris – Creeping yellow cress
Rumex altissimus – Tall dock
R. verticillatus – Swamp dock
Saururus cernuus – Lizard's tail
Verbena hastata – Blue vervain

Trees of swamps/thickets

Fraxinus americana – White ash
Liquidambar styraciflua – Sweetgum
Populus deltoides – Cottonwood
Quercus bicolor – Swamp white oak
Ulmus americana – American elm

Shrubs and vines of swamps/thickets
Ampelopsis cordata – Raccoon-grape
Ilex verticillata – Winterberry holly
Physocarpus opulifolius – Ninebark
Rosa palustris – Swamp rose
Salix sericea – Silky willow
Smilax glauca – Saw brier
Vitis riparia – Riverbank grape
Ferns and fern allies of wet meadows, marshes and swamps
Athyrium filix-femina ssp. *angustum* – Northeastern lady fern
Onoclea sensibilis – Sensitive fern
Thelypteris palustris – Marsh fern
Grasses/sedges of wet meadows, marshes, and swamps
Agrostis gigantea – Redtop
Carex atlantica – Sedge
C. crinita – Sedge
C. cristatella – Crested sedge
C. frankii – Sedge
C. grayi – Sedge
C. intumescens – Sedge
C. lupulina – Sedge
C. lurida – Sedge
C. scoparia – Sedge
C. squarrosa – Sedge
C. stipata – Sedge
C. torta – Sedge
C. tribuloides – Sedge
C. vulpinoidea – Sedge
Cinna arundinacea – Wood reedgrass
Dichanthelium clandestinum – Deertongue grass
D. sphaerocaropn – Small-fruited panic grass
Dulichium arundinaceum – Three-way sedge
Echinochloa crus-galli – Barnyard grass
Elymus riparius – Rye

E. virginicus – Virginia wild rye
Glyceria striata – Fowl mannagrass
Holcus lanatus – Velvet grass
Juncus brevicaudatus – Rush
J. effusus – Common rush
Leersia oryzoides – Rice cutgrass
L. virginica – White grass
Panicum dichotomiflorum – Spreading witch grass
P. rigidulum – Redtop panic grass
P. rigidulum var. *elongatum* – Tall flat panic grass
Scirpus atrovirens – Black bulrush
S. cyperinus – Woolgrass
S. polyphyllus – Bulrush
S. tabernaemontani – Great bulrush
Spartina pectinata – Prairie cordgrass

Other herbs of wet meadows, marshes, and swamps

Acorus americanus – Sweet flag
Alisma subcordatum – Common water plantain
Angelica atropurpurea – Purple angelica
Apios americana – Groundnut
Asclepias incarnata – Swamp milkweed
Aster lanceolatus – Panicled aster
A. lateriflorus – Goblet Aster
A. puniceus – Purple-stem aster
Bidens aristosa – Ozark tickseed-sunflower
Boehmeria cylindrica – False nettle
Callitriche terrestris – Austin's water starwort
Chelone glabra – Turtlehead
Cicuta maculata – Water hemlock
Clematis virginiana – Virgin's bower
Conium maculatum – Poison hemlock
Epilobium coloratum – Purple-leaved willow-herb
Eupatorium fistulosum – Common Joe-pye weed
E. perfoliatum – Boneset

Galium obtusum – Stiff marsh bedstraw
G. tinctorium – Clayton's bedstraw
Gratiola neglecta – Clammy hedge-hyssop
Hypericum mutilum – Small-flowered St. John's-wort
Impatiens capensis – Spotted touch-me-not
Ludwigia alternifolia – Seedbox
Lysimachia ciliata – Fringed loosestrife
L. nummularia – Moneywort
L. terrestris – Bulbous loosestrife
Mentha spicata – Spearmint
M. x *piperita* – Peppermint
Nelumbo lutea – American lotus
Pilea pumila – Clearweed
Polygonum hydropiper – Common smartweed
P. hydropiperoides – Mild water pepper
P. persicaria – Lady's thumb
P. sagittatum – Arrowleaf tearthumb
Rudbeckia laciniata – Tall coneflower
Sagittaria latifolia – Duck potato
Scutellaria lateriflora – Mad-dog skullcap
Solidago rugosa – Wrinkle-leaf goldenrod
Sparganium americanum – American burreed
S. eurycarpum – Large burreed
Thalictrum pubescens – Late meadowrue
Toxicodendron radicans – Poison ivy
Typha angustifolia – Narrow-leaved cattail
T. latifolia – Broad-leaved cattail
Verbesina alternifolia – Wing-stem
Vernonia gigantea – Tall ironweed
V. noveboracensis – New York ironweed
Veronica scutellata – Marsh speedwell
Viola cucullata – Marsh blue violet
V. striata – Striped violet

Aquatics

Lemna valdiviana – Valdivia's duckweed
Najas gracillima – Slender water-nymph
Nuphar lutea ssp. *advena* – Cowlily
Potamogeton diversifolius – Variable pondweed
Utricularia gibba – Humped bladderwort
U. macrorhiza – Greater bladderwort
Wolffia brasiliense – Dotted watermeal

Southern Plateau Floristics

Trees

Acer rubrum – Red maple
Betula nigra – River birch
Fraxinus americana – White ash
F. nigra – Black ash
Malus coronaria – Wild crab apple
Nyssa sylvatica – Black gum
Platanus occidentalis - Sycamore
Quercus bicolor – Swamp white oak
Q. palustris – Pin oak
Salix nigra – Black willow

Shrubs and vines

Alnus incana ssp. *rugosa* – Speckled alder
A. serrulata – Brookside alder
Aronia melanocarpa – Black chokeberry
Cephalanthus occidentalis – Buttonbush
Cornus amomum – Silky cornel
Corylus americana – Hazelnut
Crataegus spp. – Hawthorns
Hypericum densiflorum – Glade St. John's-wort
H. prolificum – Shrubby St. John's-wort
Ilex verticillata – Winterberry holly
Lindera benzoin – Spicebush
Lyonia ligustrina – Maleberry

Physocarpus opulifolius - Ninebark
Rhododendron arborescens – Smooth azalea
R. nudiflorum – Pinxter
Rosa palustris – Swamp rose
Salix sericea – Silky willow
Sambucus canadensis – Black elderberry
Smilax glauca – Saw brier
Spiraea alba – Meadowsweet
S. tomentosa – Hardhack
Viburnum dentatum var. *lucidum* – Smooth arrowwood
V. lentago – Nannyberry
V. nudum – Wild raisin

Ferns and fern allies

Lygodium palmatum – Climbing fern
Onoclea sensibilis – Sensitive fern
Osmunda cinnamomea – Cinnamon fern
O. regalis – Royal fern
Thelypteris noveboracensis – New York fern
T. palustris – Marsh fern

Grasses/sedges

Agrostis perennans – Autumn bent grass
Andropogon glomeratus – Broomsedge
Calamagrostis coarctata – Reedgrass
Carex atlantica – Sedge
C. crinita – Sedge
C. cristatella – Crested sedge
C. frankii – Sedge
C. gracillima – Sedge
C. gynandra – Sedge
C. intumescens – Sedge
C. lupulina – Sedge
C. lurida – Sedge
C. scoparia – Sedge
C. squarrosa – Sedge

C. stipata – Sedge
C. stricta – Sedge
C. torta – Sedge
C. tribuloides – Sedge
C. vulpinoidea – Foxtail sedge
Cinna arundinacea – Wood reedgrass
Dicanthelium clandestinum – Deertongue grass
Dulichium arundinaceum – Three-way sedge
Eleocharis obtuse – Spikerush
E. tenuis – Kill cow
Glyceria melicaria – Mannagrass
G. septentrionalis – Eastern mannagrass
G. striata – Fowl mannagrass
Holcus lanatus – Velvet grass
Juncus brevicaudatus – Rush
J. effusus – Common rush
Leersia oryzoides – Rice cutgrass
L. virginica – White grass
Panicum rigidulum – Redtop panic grass
P. rigidulum var. *elongatum* – Tall flat panic grass
Phalaris arundinacea – Reed canary grass
Rhyncospora capitellata – Beaked rush
Scirpus americanus – American bulrush
S. atrovirens – Black bulrush
S. cyperinus – Woolgrass
S. polyphyllus – Bulrush
S. tabernaemontani – Great bulrush

Other herbs (spring)

Acorus americanus – Sweet flag
Cardamine bulbosa – Bulbous cress
Ranunculus hispidus var. *nitidus* – Hispid buttercup
Senecio aureus – Golden ragwort

Other herbs (summer/autumn)

Alisma subcordatum – Common water plantain

Apios americana – Groundnut
Asclepias incarnata – Swamp milkweed
Aster lanceolatus – Panicled aster
A. lateriflorus – Goblet aster
A. puniceus – Purple-stem aster
A. radula – Low rough aster
A. umbellatus – Flat-top white aster
Bidens aristosa – Ozark tickseed-sunflower
Boehmeria cylindrica – False nettle
Callitriche terrestris – Austin's water starwort
Calopogon tuberosus – Grass pink
Chelone glabra – Turtlehead
Cicuta maculata – Water hemlock
Clematis virginiana – Virgin's bower
Epilobium coloratum – Purple-leaved willow-herb
Eupatorium fistulosum – Common Joe-pye weed
E. perfoliatum – Boneset
E. pilosum – Vervain thoroughwort
Euthamia graminifolia – Grass-leaved goldenrod
Galium obtusum – Stiff marsh bedstraw
G. tinctorium – Clayton's bedstraw
Gentiana andrewsii – Bottle gentian
Gratiola neglecta – Clammy hedge-hyssop
Helenium autumnale – Yellow sneezeweed
Helianthus giganteus – Giant sunflower
Hypericum mutilum – Small-flowered St. John's-wort
Impatiens capensis – Spotted touch-me-not
Lilium superbum – Turk's cap lily
Lindernia dubia – False pimpernel
Lobelia cardinalis – Cardinal-flower
L. siphilitica – Great blue lobelia
Ludwigia alternifolia – Seedbox
L. palustris – Marsh purslane
Lycopus americanus – Water horehound

L. uniflorus – Northern bugleweed
L. virginicus – Bugleweed
Lysimachia ciliata – Fringed loosestrife
L. nummularia – Moneywort
L. terrestris – Bulbous loosestrife
Lythrum salicaria – Purple loosestrife
Mentha spicata – Spearmint
M. x *piperita* – Peppermint
Mimulus ringens – Common monkey-flower
Oenothera fruticosa ssp. *glauca* – Common sundrops
O. perennis – Sundrops
Oxypolis rigidior – Cowbane
Pedicularis lanceolata – Swamp lousewort
Penthorum sedoides – Ditch stonecrop
Platanthera clavellata – Small green wood orchid
P. flava – Pale green orchid
P. peramoena – Fringeless purple orchid
Pogonia ophioglossoides - Rose pogonia
Polygala cruciata – Cross-leaved milkwort
Proserpinaca palustris – Mermaid weed
Polygonum hydropiper – Common smartweed
P. hydropiperoides – Mild water pepper
P. pensylvanicum – Pennsylvania smartweed
P. persicaria – Lady's thumb
P. punctatum – Water smartweed
P. sagittatum – Arrowleaf tearthumb
Rubus hispidus – Hispid dewberry
Rudbeckia laciniata – Tall coneflower
Sagittaria latifolia – Duck potato
Sanguisorba canadensis – Burnet
Scutellaria lateriflora – Mad-dog skullcap
Solidago rugosa – Wrinkle-leaf goldenrod
Sparganium americanum – American burreed
S. androcladum – Staminate burreed

Spiranthes cernua – Nodding ladies' tresses
Thalictrum pubescens – Late meadowrue
Toxicodendron radicans – Poison ivy
Typha latifolia – Broad-leaved cattail
Verbena hastata – Blue vervain
Verbesina alternifolia – Wing-stem
Vernonia gigantea – Tall ironweed
V. noveboracensis – New York ironweed
Viola cucullata – Marsh blue violet
V. striata – Striped violet

Aquatics

Lemna valdiviana – Valdivia's duckweed
Najas gracillima – Slender water-nymph
Nuphar lutea ssp. *advena* - Cowlily
Potamogeton amplifolius – Large-leaved pondweed
P. diversifolius – Variable pondweed
Utricularia macrorhiza – Greater bladderwort
Vallisneria americana – Eelgrass
Wolffia brasiliense – Dotted watermeal

High Western Hills Floristics

Trees

Acer rubrum – Red maple
A. saccharinum – Silver maple
Fraxinus americana – White ash
F. nigra – Black ash
Liquidambar styraciflua - Sweetgum
Malus coronaria – Wild crab apple
Nyssa sylvatica – Black gum
Platanus occidentalis – Sycamore
Quercus imbricaria – Shingle oak
Q. palustris – Pin oak
Salix nigra – Black willow

Shrubs and vines
Alnus serrulata – Brookside alder
Aronia arbutifolia – Red chokeberry
A. melanocarpa – Black chokeberry
Cephalanthus occidentalis – Buttonbush
Cornus amomum – Silky cornel
Ilex verticillata – Winterberry holly
Lindera benzoin – Spicebush
Lyonia ligustrina – Maleberry
Physocarpus opulifolius – Ninebark
Rhododendron maximum – Great laurel
Rhus vernix – Poison sumac
Rosa palustris – Swamp rose
Salix sericea – Silky willow
Sambucus canadensis – Black elderberry
Smilax glauca – Saw brier
Spiraea alba – Meadowsweet
Viburnum dentatum var. *lucidum* – Smooth arrowwood
V. nudum – Wild raisin
Vitis labrusca – Fox grape
Ferns and fern allies
Onoclea sensibilis – Sensitive fern
Osmunda cinnamomea – Cinnamon fern
Thelypteris palustris – Marsh fern
Grasses/sedges
Andropogon glomeratus – Broomsedge
Calamagrostis coarctata – Reedgrass
Carex atlantica – Sedge
C. baileyi – Sedge
C. bromoides - Sedge
C. crinita – Sedge
C. cristatella – Crested sedge
C. folliculata – Sedge
C. frankii – Sedge

C. gracillima – Sedge
C. intumescens – Sedge
C. lupulina – Sedge
C. lurida – Sedge
C. scoparia – Sedge
C. squarrosa – Sedge
C. stipata – Sedge
C. stricta – Sedge
C. torta – Sedge
C. tribuloides – Sedge
C. vulpinoidea – Foxtail sedge
Cinna arundinacea – Wood reedgrass
Dichanthelium clandestinum – Deertongue grass
Dulichium arundinaceum – Three-way sedge
Eleocharis obtusa – Spikerush
E. tenuis – Kill cow
Glyceria melicaria – Fowl mannagrass
G. striata – Mannagrass
Holcus lanatus – Velvet grass
Juncus brevicaudatus – Rush
J. effusus – Common rush
Leersia oryzoides – Rice cutgrass
L. virginica – White grass
Panicum clandestinum – Deertongue grass
P. rigidulum – Redtop panic grass
P. rigidulum var. *elongatum* – Tall flat panic grass
Phalaris arundicacea – Reed canary grass
Rhyncospora capitellata – Beaked rush
Scirpus atrovirens – Black bulrush
Scirpus cyperinus – Woolgrass
S. polyphyllus – Bulrush
S. purshianus - Bulrush
S. tabernaemontani – Great bulrush

Other herbs (spring)
Acorus americanus – Sweet flag
Caltha palustris – Marsh marigold
Cardamine bulbosa – Bulbous cress
Chrysoplenium americanum – Golden saxifrage
Iris pseudoacorus – Yellow iris
Ranunculus hispidus var. *nitidus* – Hispid buttercup
R. repens – Creeping buttercup
Senecio aureus – Golden ragwort
Symplocarpus foetidus – Skunk cabbage
Other herbs (summer and autumn)
Alisma subcordatum – Common water plantain
Apios americana – Groundnut
Asclepias incarnata – Swamp milkweed
Aster lanceolatus – Panicled aster
A. lateriflorus – Goblet aster
A. puniceus – Purple-stem aster
A. umbellatus – Flat-top white aster
Bidens aristosa – Ozark tickseed-sunflower
Boehmeria cylindrica – False nettle
Callitriche terrestris – Austin's water starwort
Chelone glabra – Turtlehead
Cicuta maculata – Water hemlock
Clematis virginiana – Virgin's bower
Epilobium coloratum – Purple-leaved willow-herb
E. coloratum ssp. *ciliatum* – Northern willow-herb
E. leptophyllum – Linear-leaved willow-herb
Eupatorium fistulosum – Common Joe-pye weed
E. perfoliatum – Boneset
E. pilosum – Vervain thoroughwort
Euthamia graminifolia – Grass-leaved goldenrod
Galium asprellum – Rough bedstraw
G. obtusum – Stiff marsh bedstraw
G. tinctorium – Clayton's bedstraw

Gentiana andrewsii – Bottle gentian
Gratiola neglecta – Clammy hedge-hyssop
Helenium autumnale – Yellow sneezeweed
Helianthus giganteus – Giant sunflower
Hydrocotyle americana – American water-pennywort
Hypericum canadense – Canadian St. John's-wort
H. ellipticum – Elliptic-leaf St. John's-wort
H. mutilum – Small-flowered St. John's-wort
Impatiens capensis – Spotted touch-me-not
Lilium superbum – Turk's cap lily
Lindernia dubia – False pimpernel
Lobelia cardinalis – Cardinal-flower
L. siphilitica – Great blue lobelia
Ludwigia alternifolia – Seedbox
L. palustris – Marsh purslane
Lycopus americanus – Water horehound
L. uniflorus – Northern bugleweed
L. virginicus – Bugleweed
Lysimachia ciliata – Fringed loosestrife
L. nummularia – Moneywort
Lythrum salicaria – Purple loosestrife
Mentha spicata – Spearmint
M. x *piperita* – Peppermint
Mimulus ringens – Common monkey-flower
Myosotis laxa – Smaller forget-me-not
Nuphar lutea ssp. *advena* – Cowlily
Penthorum sedoides – Ditch stonecrop
Platanthera clavellata – Small green wood orchid
P. grandiflora – Large purple fringed orchid
P. lacera – Ragged fringed orchid
Polygonum hydropiper – Common smartweed
P. hydropiperoides – Mild water pepper
P. pensylvanicum – Pennsylvania smartweed
P. persicaria – Lady's thumb

P. punctatum – Water smartweed
P. sagittatum – Arrowleaf tearthumb
Rubus hispidus – Hispid dewberry
Rudbeckia laciniata – Tall coneflower
Sagittaria latifolia – Duck potato
Sagittaria latifolia var. *pubescens* – Hairy arrowhead
Scutellaria lateriflora – Mad-dog skullcap
Solidago rugosa – Wrinkle-leaf goldenrod
Sparganium americanum – American burreed
Spiranthes cernua – Nodding ladies' tresses
Thalictrum pubescens – Late meadowrue
Toxicodendron radicans – Poison ivy
Triadenum virginicum – Marsh St. John's-wort
Typha latifolia – Broad-leaved cattail
Verbena hastata – Blue vervain
Verbesina alternifolia – Wing-stem
Vernonia gigantea – Tall ironweed
V. noveboracensis – New York ironweed
Veronica anagallis-aquatica – Water speedwell
Viola cucullata – Marsh blue violet
V. striata – Striped violet

Aquatics

Lemna valdiviana – Valdivia's duckweed
Najas gracillima – Slender water-nymph
Nuphar lutea ssp. *advena* – Cowlily
Potamogeton diversifolius – Variable pondweed
Utricularia gibba – Humped bladderwort
U. macrorhiza – Greater bladderwort
Wolffia brasiliense – Dotted watermeal

Amphibians and Reptiles in Wetland Habitats of West Virginia

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ABSTRACT

Wetland habitats are used extensively by several species of amphibians and reptiles for life functions such as shelter, foraging, breeding, egg deposition, and larval development. Wetland habitats used by amphibians and reptiles include riverine floodplains, permanent ponds, beaver ponds, fens, ephemeral pools, roadside ditches, and road rut pools. Amphibians that commonly use these wetlands include ambysomtid salamanders, newts, four-toed salamanders, mud salamanders, red salamanders, two-lined salamanders, spadefoot toads, American and Fowler's toads, cricket frogs, gray treefrogs, chorus frogs, spring peepers, bullfrogs, green frogs, wood frogs, leopard frogs, and pickerel frogs. Reptiles frequently found in wetlands during some time in their life histories include snapping turtles, spotted turtles, wood turtles, painted turtles, stinkpots, water snakes, and ribbon snakes. Protection of wetlands is essential to prevent further declines of this secretive segment of the Mountain State's biodiversity.

INTRODUCTION

Until the last decade, most faunal studies in wetlands in West Virginia dealt with birds and mammals. Recent concerns of the apparent worldwide decline of some amphibian species and populations have ignited an interest in ecological studies of amphibians and reptiles. The understanding by biologists that amphibians and reptiles are important components of the wetland food web and their significant role as bioindicators in wetland habitats has increased scientific interest in these vertebrates (Ohmart and Anderson 1986; Dunson et al. 1992).

Like most of the rest of the eastern United States, studies of amphibians and reptiles in wetlands of West Virginia have lagged behind such studies in the western United States (e.g., Vitt and Ohmart 1978; Bury 1988; Bury and Corn 1988; Jones 1988; Corn and Bury 1989; Gomez and Anthony 1996). Prior to the late 1980's, few studies, other than anecdotal reports, are found in the literature that deals with the ecology of amphibians and reptiles in wetland habitats in West Virginia.

Citation: Pauley, T.K. 2000. Amphibian and reptiles in wetland habitats of West Virginia. Proc. W. Virginia Acad. Sci. 72(3):78-88.

Since 1987, the author and his graduate students have conducted several studies on the ecology and conservation of amphibians and reptiles in wetlands in the state. To date, the results of most of these studies are in the form of government reports and unpublished masters' theses. Some of these studies addressed the natural history of the Pickerel Frog (*Rana palustris*), Leopard Frog (*R. pipiens*), Northern Green Frog (*R. clamitans melanota*), Mountain Chorus Frog (*Pseudacris brachyphona*), Marbled Salamander (*Ambystoma opacum*), Red-spotted Newt (*Notophthalmus v. viridescens*), Black-bellied Salamander (*Desmognathus quadramaculatus*), Seal Salamander (*Desmognathus monticola*), Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*), Four-toed Salamander (*Hemidactylium scutatum*), and Southern two-lined Salamander (*Eurycea cirrigera*). Other studies have included: (1) the effects of acid deposition and ultraviolet radiation on breeding success and egg and larval development of amphibians in high elevation fens; (2) the use of artificial road-rut pools in clearcuts as anuran reproductive sites; (3) amphibian breeding phenology in a riverine floodplain swamp and marsh, wildlife ponds in valley fills, and higher elevations pools; (4) the effects of insecticides on forest salamanders; (5) the effects of an artificially acidified watershed on forest salamanders; (6) effectiveness of various monitoring techniques for amphibians; and (7) inventories for amphibians and reptiles in upland wetlands in the New River Gorge National River and in riparian and upland wetlands in the Bluestone National Scenic River and Meadow River Wildlife Management Areas. Currently, ongoing studies in the state include amphibians and reptiles found in the riparian zone and upland habitats in the Gauley River Recreational River and along the navigable section of the Kanawha River (from the mouth to the upper end of the London Pool). Another study of interest is the establishment of long-term frog and toad survey routes across the state. This study is part of the North American Amphibian Monitoring Program sponsored by United States Geological Survey and the United States Environmental Protection Agency.

Amphibian and Reptile Biodiversity in West Virginia

There are 87 species of amphibians (48 species) and reptiles (39 species) in West Virginia. Of the 48 species of amphibians, 3 are toads, 11 are frogs, and 34 are salamanders. There are 13 species of turtles, 6 species of lizards, and 20 species of snakes.

Amphibian and Reptile Biodiversity in Wetland Habitats

Amphibian and reptile assemblages in wetland habitats are diverse. No group of vertebrates is more dependent on lentic habitats to complete life cycles than amphibians. For many species, eggs are deposited in wetlands and larvae develop there. Amphibians in these lentic habitats have complex life histories, and several stages of some species may occur in the same wetland. Amphibians serve as both prey and predator. They are food items for fish, reptiles, birds, and mammals. Fish prey on amphibian eggs, larvae, and adults. In addition, many species of amphibians do not breed or forage in pools inhabited by fish. Amphibian larvae and adults prey upon a myriad of insects and other invertebrates. Amphibians and reptiles use water as a shelter from unfavorable environmental factors and predators.

The classification of wetland habitats is irresolute (Mitsch and Gosselink 1993). For this paper, I have used those wetland definitions I believe capture most types of lentic habitats used by amphibians and reptiles in West Virginia. Table 1 shows the species that occur in some stage of their life histories in these seven habitat types: riverine floodplains, permanent pools, beaver ponds, fens, ephemeral pools, roadside ditches, and road rut pools. Some species are obligates and thus are dependent on wetlands for breeding and early development. Other species are facultative and will live or reproduce in wetlands but are not limited to them. Eight species of salamanders are obligates (Table 2). Three species of salamanders, 8 species of turtles, and 3 species of snakes are facultative (Table 3). All 14 species of toads and frogs in West Virginia are obligates. The only species of reptile that could be considered obligate is the spotted turtle, but it will also breed in streams.

Table 1. Wetland habitats listed below represent the most common habitat in which each species of amphibian and reptile has been recorded in West Virginia. These habitats are used for reproduction, foraging, or shelter. Habitats = wooded swamps (WS), marshes (M), oxbows (OB), pools of standing water (SW), permanent pools (PP), beaver ponds (BP), fens (F), ephemeral pools (EP), and roadside ditches and road rut pools (RD).

Salamanders	
1. Streamside salamander	EP, RD
2. Small-mouthed salamander	EP, RD
3. Jefferson salamander	PP, BP, F, EP, RD
4. Spotted salamander	PP, BP, F, EP, RD
5. Marbled salamander	PP, BP, EP
6. Red-spotted newt	WS, OB, PP, BP, F, EP, RD
7. Four-toed salamander	F, BP, EP, RD
8. Midland mud salamander	WS, M, BP, F
9. Northern red salamander	PP, F, RD
10. Northern two-lined salamander	PP, BP, F
11. Southern two-lined salamander	PP, BP

Table 1. Continued.

Toads and Frogs	
1. Eastern spadefoot	EP, SW
2. American toad	WS, M, OB, SW, BP, F, EP, RD
3. Fowler's toad	OB, SW, EP, RD
4. Eastern/Blanchard's cricket frogs	WS, M, PP, BP, RD
5. Gray treefrog	WS, M, SW, PP, BP, F, EP, RD
6. Cope's treefrog	WS, M, SW, PP, BP, F, EP, RD
7. Mountain/Upland chorus frogs	EP, RD
8. Northern spring peeper	WS, M, SW, PP, BP, F, EP, RD
9. American bullfrog	WS, M, OB, PP, BP, F
10. Southern green frog	WS, M, OB, PP, BP, F, EP
11. Wood frog	WS, M, PP, BP, F, EP, RD
12. Northern leopard frog	WS, M, PP
13. Pickerel frog	WS, M, PP, BP
Turtles	
1. Eastern snapping turtle	WS, M, OB, PP, BP, F, EP, RD
2. Eastern musk turtle	WS, M, OB, PP, BP
3. Spotted turtle	M, PP, BP, F, EP
4. Wood turtle	WS, M, OB, PP, BP
5. Painted turtles	WS, M, OB, PP, BP, F
6. Red-eared slider	OB, PP, BP
7. River cooter	OB
8. Red-bellied turtle	OB

Table 1. Continued.

Snakes	
1. Northern watersnake	WS, M, OB, PP, BP, F, EP, RD
2. Queen snake	WS, M, OB, PP, BP
3. Eastern ribbonsnake	WS, M, PP, BP

Table 2. Obligate wetland amphibian and reptile species in West Virginia.

AMPHIBIANS

Salamanders

1. Streamside salamander (*Ambystoma barbouri*)
2. Small-mouthed salamander (*Ambystoma texanum*)
3. Jefferson salamander (*Ambystoma jeffersonianum*)
4. Spotted salamander (*Ambystoma maculatum*)
5. Marbled salamander (*Ambystoma opacum*)
6. Red-spotted newt (*Notophthalmus v. viridescens*)
7. Four-toed salamander (*Hemidactylium scutatum*)
8. Mud salamander (*Pseudotriton montanus diasticus*)

Toads and Frogs

1. Eastern spadefoot (*Scaphiopus holbrookii*)
2. American toad (*Bufo americanus*)
3. Fowler's toad (*Bufo fowleri*)
4. Eastern/Blanchard's cricket frogs (*Acris c. crepitans*/*Acris c. blanchardi*)
5. Gray treefrog (*Hyla versicolor*)
6. Cope's gray treefrog (*Hyla chrysoscelis*)

Table 2. Continued.

Toads and Frogs
7. Mountain chorus frog (*Pseudacris brachyphona*)
8. Upland chorus frog (*Pseudacris triserata feriarum*)
9. Northern spring peeper (*Pseudoacris c. crucifer*)
10. American bullfrog (*Rana catesbeiana*)
11. Southern green frog (*Rana clamitans melanota*)
12. Wood frog (*Rana sylvatica*)
13. Northern leopard frog (*Rana pipiens*)
14. Pickerel frog (*Rana palustris*)
REPTILES
Turtles
1. Spotted turtle (*Clemmys guttata*)
Lizards
None
Snakes
None

Riverine Floodplains

Riverine floodplains frequently support wooded swamps, marshes, oxbows, and standing water (Mitsch and Gosselink 1993). Most of these habitats support fish.

Permanent Pools

Permanent pools retain water throughout the year and vary from artificial farm ponds to natural sinkholes. Most permanent pools have fish.

Beaver Ponds

Beaver ponds are impoundments of small streams by beavers. These ponds are found in high and low elevations in the state and are used by numerous species of amphibians. Beaver ponds may support fish.

Table 3. Facultative wetland amphibian and reptiles species in West Virginia

AMPHIBIANS

Salamanders

1. Northern red salamander (*Pseudotriton r. ruber*)
2. Northern two-lined salamander (*Eurycea bislineata*)
3. Southern two-lined salamander (*Eurycea cirrigera*)

Toads and Frogs

None

REPTILES

Turtles

1. Eastern snapping turtle (*Chelydra s. serpentina*)
2. Eastern musk turtle (*Stenotherus odoratus*)
3. Wood turtle (*Clemmys insulpta*)
4. Painted turtles (*Chrysemys picta*)
5. Red-eared turtle (*Trachemys scripta elegans*)
6. River cooter (*Pseudemys concinna*)
7. Northern red-bellied cooter (*Pseudemys rubriventris*)

Lizards

None

Snakes

1. Northern watersnake (*Nerodia sipedon*)
2. Queen snake (*Regina septemvittata*)
3. Eastern ribbonsnake (*Thamnophis s. sauritus*)

Fens

Fens are depressions, found in areas characterized by cool climates and abundant moisture, that retard the rate of decomposition resulting in an accumulation of organic matter (Welsch, et al. 1995). Fens can be distinguished from bogs in that fens receive water from inflowing streams and the major water source of bogs is precipitation (Welsch, et al. 1995). Fens may support fish.

Ephemeral Pools

Temporary pools are usually small, fishless wetlands that typically become dry in late summer and early fall. Most ephemeral pools support many species of amphibians and reptiles (Roble 1989, Mitchell 1997).

Roadside Ditches

Roadside ditches are formed when a road forms a dam for water runoff or from mechanical ditching to prevent water from running over or inundating a road. These wetlands are frequently overlooked and drained during routine road maintenance. Roadside ditches do not support fish.

Road Rut Pools

Road rut pools are depressions in muddy roads as a result of vehicular tires. Like roadside ditches, these wetlands are not always recognized, and filling the ruts with fill materials can destroy a productive amphibian breeding and development habitat. Road rut pools do not support fish.

Riparian Zones

There are many definitions for riparian zones. These zones are the terrestrial connection between wetlands and upland terrestrial habitats. Species of amphibians and reptiles that migrate to and from wetlands and terrestrial habitats must transverse riparian zones. This puts a great deal of importance on riparian zones. They are as important as wetlands for successful reproduction of many species of amphibians and reptiles.

Research priorities

Basic natural history studies of amphibians and reptiles are woefully lacking for many species in the United States. While great strides in distributional and life history studies of amphibians and reptiles have been made in West Virginia during the past decade, such information is still lacking for several species (Table 4).

Protection and management of wetlands

Wetland acreage in West Virginia has decreased from an estimated 134,000 acres in the late 1700's to approximately 102,000 acres in the mid-1980's, a 24% loss (National Wetlands Inventory 1988). Given that many species of amphibians and reptiles use wetlands for reproduction and development, the loss of wetlands could be a factor in the decline of amphibian species. This is particularly true for species of salamanders (e.g., *Ambystoma*), toads (e.g., *Scaphiopus*), and frogs (e.g., ranids) that have specific habitat requirements such as the location of breeding pools adjacent to nonbreeding habitats. Tree frogs (Family Hylidae), true toads (Family Bufonidae), and some true frogs (Family Ranidae) can successfully reproduce in mitigated wetlands. For species with more restrictive requirements, development of wetlands is more complex and less successful. Ambystomatid salamanders spend the non-breeding season in subterranean habitats and migrate to pools during the breeding season. They migrate to their birth pools or pools near their foraging habitats. If breeding pools are destroyed, they cannot move great distance in search of pools. Spadefoots spend a good deal of their life in subterranean burrows. They emerge during hard rains from April to October and breed in pools near their burrows. Larvae of some ranid frogs (e.g., bullfrogs) require one or two seasons to develop. Most species in this family cannot successfully use ephemeral pools and other small wetlands. As such, the loss of large permanent pools will be detrimental to these species.

Table 4. Amphibian and reptile species in West Virginia lacking recent natural history studies.

Salamanders
1. Streamside salamander
2. Small-mouthed salamander
3. Jefferson salamander
4. Spotted salamander
5. Midland mud salamander
6. Northern red salamander
Toads and Frogs
1. Eastern spadefoot
2. American toad
3. Fowler's toad
4. Eastern/Blanchard's cricket frogs
5. Gray treefrog
6. Cope's treefrog
7. Mountain/Upland chorus frogs
8. Northern spring peeper

Table 4. Continued.

Toads and Frogs
9. American bullfrog
10. Wood frog
11. Northern leopard frog
12. Pickerel frog
Turtles
1. Eastern snapping turtle
2. Eastern musk turtle
3. Painted turtles
4. Red-eared turtle
5. River cooter
6. Red-bellied turtle
Lizards
1. Northern fence lizard
2. Eastern six-lined racerunner
3. Little brown skink
4. Broad-headed skink
5. Northern coal skink
Snakes
1. Northern watersnake
2. Queen snake
3. Eastern ribbonsnake

In summary, amphibians and reptiles represent a major component of the hidden biodiversity in wetlands in West Virginia. Protection of wetland habitats will sustain these valuable ecological niches for amphibians and reptiles.

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Wetland Mammals of the Central Appalachians

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ABSTRACT

The primary objective of this paper was to identify those mammals within the Central Appalachians that are wetland dependent. A secondary objective was to describe the population status and research priorities for each wetland mammal. Six mammals are considered wetland dependent. These are the star-nosed mole (*Condylura cristata*), northern water shrew (*Sorex palustris*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), mink (*Mustela vison*), and river otter (*Lutra canadensis*). Mink, river otters, and water shrews are dependent on riverine wetlands; star-nosed moles are dependent on palustrine wetlands; beaver and muskrats are dependent on riparian habitats. The beaver, muskrat, mink, and river otter are classified as obligate wetland species, while the star-nosed mole and water shrew are classified as facultative wetland species. Certain other mammals could possibly be classified as facultative, but specific habitat requirements are unknown; examples include the raccoon (*Procyon lotor*) and certain bat species. Population status ranges from abundant with wide distribution (beaver and muskrat) to rare with limited distribution (water shrew and river otter). The status of the star-nosed mole and the mink is unknown. Research priorities include (1) determining population density and distribution (star-nosed mole, water shrew, mink, and river otter) and (2) developing methods to control damage (beaver and muskrat).

INTRODUCTION

Wetlands are the most intensively studied ecosystems in North America because of their values to humans, their attractiveness to scientists, and their degradation. However, most of these studies have been centered around those geographic areas characterized by relatively flat topography, primarily coastal regions and inland prairies. The wetlands of the Central Appalachians have received relatively little attention due to their scarcity. As a result, these wetlands may be the least understood of all wetlands throughout North America.

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Central Appalachian wetlands are different from those of other regions due to their topography, underlying parent material, climate, and prior lack of glaciation.

Mammals are the least studied of all vertebrates found in wetlands, due to their relative scarcity and the numerous problems involved in conducting surveys. Those few species of mammals that are dependent on wetlands cannot be quantified as easily or as reliably as can other vertebrates. Amphibians can be monitored through their calls and/or eggs, reptiles can be easily trapped, and birds can be monitored through their calls or direct sightings. Wetland mammals are primarily nocturnal, thus direct observation cannot be used to determine population abundance. Live trapping is difficult, if not impossible, for the majority of wetland mammals. None of the wetland mammals can be monitored through their calls because these mammals rarely exhibit vocalizations that can be detected by humans. Although animal signs (tracks, scent stations, food caches, and lodges) provide data on relative abundance, these data can be obtained for only three of the wetland mammal species (beaver, muskrat, and river otter) and only within a small portion of their ranges throughout the Central Appalachians.

Although the numbers of mammals present in the wetlands of the Central Appalachians are relatively low, the ecological value of these few species is as important as that of other more numerous vertebrates. Wetland mammals do not migrate; thus, their entire life is typically spent in the same wetland community. Wetland mammals (especially the predators) are excellent indicator species because their survival is dependent upon the quantity and quality of food available within the wetland community.

The primary objective of this paper was to identify those mammal species within the Central Appalachians that are dependent upon wetlands. A secondary objective was to describe the population status and research priorities for each wetland species.

METHODS

The study area considered in this paper was defined as the Central Appalachians, with emphasis on West Virginia. Research involving mammals from western Maryland, western Virginia, northwestern North Carolina, and southwestern Pennsylvania was incorporated into this paper. The sources of information included (1) my personal research in West Virginia during the last 30 years, (2) theses from West Virginia University, (3) annual reports of the WVDNR Wildlife Division, (4) records of the WVDNR Natural Heritage Program, and (5) numerous books and scientific journals.

RESULTS

Six mammal species are considered as dependent on wetlands. These are the star-nosed mole (*Condylura cristata*), northern water shrew (*Sorex palustris*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), mink (*Mustela vison*), and river otter (*Lutra canadensis*). Source of scientific names was Jones et al. (1997). Although individuals of these six species may occasionally wander away from the wetland community that contains their permanent den, such excursions can be best classified as temporary. Muskrat and beaver regularly leave the bodies of water that constitute the center of their home ranges as they venture onto land to obtain essential plants that form their diets. Likewise, mink will venture onto land to obtain the animal prey that form their major diet.

Certain other species of mammals are possibly dependent on wetlands, but their specific habitat requirements are currently unknown. For example, some species of bats (Chiroptera) frequently feed over wetlands, which apparently provide a major portion of their insect diets. During late summer and early fall, large numbers of bats commonly feed over open water (streams, rivers, ponds, and lakes) associated with wetlands. If the protein provided by these wetland insects provides an essential portion of the pre-hibernation diet, then these bat species may indeed be dependent upon wetlands. However, no studies have been conducted to determine the proportion of feeding hours associated with wetlands, nor whether certain bat populations feed above wetlands. Due to the preponderance of upland habitats (compared to wetland habitats) throughout the Central Appalachians, the majority of insects available to bats would seem to be present above non-wetland habitats. This would include fields, meadows, pastures, shrub communities, and even the space immediately above the canopies of the hardwood forests that occupy approximately 75% of West Virginia. Because the majority of insects available to bats are found in upland habitats, it seems unlikely that any species of bats are dependent upon wetlands within the Central Appalachians. However, if there is a bat species within West Virginia that is dependent upon wetlands, it would most likely be the little brown bat (*Myotis lucifigus*).

While many other species of mammals frequently use wetlands, they are not dependent on them and only small portions of their populations throughout the Central Appalachians occur within wetlands. The raccoon (*Procyon lotor*) is one of the best examples of such a species. Throughout other geographic regions, raccoons may reach their greatest densities in marshes (both coastal and inland) and within riverine habitats. Although a few individual raccoons within the Central Appalachians may be dependent upon wetlands, even these individuals probably obtain a major portion of their diet from non-wetland habitats during certain seasons. Few wetlands in the Central Appalachians are productive enough during all seasons to provide the abundance of food required by a population of raccoons. Throughout West Virginia and the Central Appalachians, most raccoons obtain a significant portion of their diet from mast-producing hardwood trees, especially oaks. Most raccoons in West Virginia occupy upland habitats dominated by oaks and spend little, if any, of their lives in wetland habitats. Merritt (1987) reported that during late summer, autumn, and winter, raccoons mainly ate acorns, apples, beechnuts, blackberries, corn, elderberries, pokeberries, wild cherries, and wild grapes.

Mammals present in wetlands can be classified as obligate, facultative wetland, or facultative species. Beaver, muskrat, mink, and river otter are obligate wetland species, with a >99% probability that individuals will occur in a wetland under natural conditions. The star-nosed mole and water shrew are facultative wetland species, with a 67-99% probability that individual moles or water shrews will occur in a wetland.

Certain other mammals are possibly facultative wetland (67-99% probability) or facultative (34-66% probability), but specific habitat requirements are unknown. Examples include certain bat species. It appears unlikely that any of these could be classified as obligate wetland species.

The essential life prerequisite for five of the six species dependent on wetlands is standing water. Only those wetlands associated with standing water are capable of supporting populations of water shrews, beaver, muskrats, mink, or river otters. Star-nosed moles are dependent on palustrine wetlands, water shrews, mink, and river otters are dependent on riverine wetlands; while beaver and muskrats are dependent on riparian habitats.

Beaver and muskrats need open water for travel, protection from predators, and transport of food materials and dam/lodge materials. Plants comprising their diet may grow within the wetland (for both beaver and muskrat) or in the adjacent riparian habitats (especially beaver).

Mink are not directly dependent upon open water as are beaver and muskrat, but they are dependent upon the water to support their prey base. The carnivorous diet of mink includes almost any animal that can be easily captured and killed, including crayfish, fish, frogs, salamanders, snakes, turtles, birds, and mammals. Although mink have been observed traveling through upland habitats, there are no data to support the idea that any individual mink occupy non-wetland habitats. Brooks wrote in 1912, however, that there existed a mountain mink or black mink that was found only in the boreal regions of West Virginia. He wrote that this mink was smaller than the typical brown mink, and its color was a darker shade of brown, in some cases almost black.

Water shrews and river otters are carnivorous and apparently need standing bodies of water to obtain the prey that constitute their diet. River otters are dependent upon fish, but mussels, crayfish, frogs, salamanders, snakes, and turtles are also consumed. The diet of the northern water shrew is poorly understood, but they are thought to consume primarily small fishes and larger invertebrates that inhabit small streams.

Optimum habitat for the northern water shrew appears to be small mountain streams, which often lack a distinct riparian zone. Many of these mountain streams may not possess the characteristics of wetlands due to their steep gradient, lack of hydric soils, and lack of aquatic vegetation. Pagels et al. (1998) conducted extensive trapping in Virginia and characterized sites where this shrew was captured as having (1) high gradient streams (7-14% slope), (2) predominately well-sorted cobble substrate with woody debris, (3) fully-vegetated channel banks with extensive undercut areas and many crevices, (4) riparian canopy trees composed primarily of northern hardwoods, and (5) a macroinvertebrate community dominated by stoneflies (Plecoptera), mayflies (Ephemeroptera), and midges (Diptera).

The star-nosed mole is the only mole that resides in wetlands (Rankin 1997) and is the only semi-aquatic mole, spending time underground and in water. Merritt (1987) reported that they prefer water-saturated soils but also can be found in deep, mucky soils of wet bottomlands as well as on steep slopes and in wet areas on dry ridges. Merritt also indicated that "In southwest Pennsylvania it may be found in wet bottomlands of alder, silky dogwood, and arrowwood with an understory of skunk cabbage, green hellebore, marsh marigold, cattails, and rushes." Hall and Kelson (1959) reported that the star-nosed mole prefers damp or muddy soil and this, rather than the type of plant cover, largely determines the local distribution. According to Hamilton and Whitaker (1979) these moles prefer mucky pastures or slow-flowing streams which have muddy bottoms. The diet of star-nosed moles consists principally of insect larvae (caddisflies, stone flies, and midges), worms, crustaceans, molluscs, and small fish (Merritt 1987).

The population status of the six wetland mammal species within the Central Appalachians ranges from abundant with wide distribution (beaver and muskrat) to rare with limited distribution (water shrew and river otter). The mink, and probably the star-nosed mole, are widely distributed throughout the region, but their population status is unknown.

Beaver, muskrat, mink, and river otter were probably common throughout West Virginia during the 1700's, but trapping during the 1800's and habitat destruction during the 1900's resulted in major declines. Beaver were originally quite numerous in what is now West Virginia, but they were practically, if not totally, exterminated by 1825 (Swank 1948). River otter were probably extirpated from West Virginia and the rest of the Central Appalachians by 1950, but the species had been pushed to near extinction in the region by 1900 (WV Division of Natural Resources 1997).

Populations of wetland fur-bearers rebounded during the mid-1900's as rivers were dammed and many ponds and lakes were constructed. The WV Conservation Commission and the U.S. Forest Service initiated a restocking program in 1930, with beaver procured from Michigan and Wisconsin (Swank 1948). During 1922-1937, 64 beaver were released into Mineral, Nicholas, Pocahontas, Randolph, Summers, Tucker, Wetzel, and Wyoming counties.

River otters are now present throughout the Central Appalachians due to a successful transplant program by each state in the region. West Virginia obtained 245 otters from Louisiana, Maryland, North Carolina, and Virginia during 1984-1997, and released them into 14 major rivers throughout West Virginia. The states of Maryland and Virginia have transplanted river otters from their coastal marshes into the western counties, and Pennsylvania has released river otters throughout many river systems in southern portions of the state. Increased fish populations, resulting from damming rivers and creating ponds and lakes, have provided an excellent prey base for river otters. River otters are thought now to occur in at least 20 counties throughout West Virginia and will most likely become established in every county in West Virginia during the next 25 years.

Beaver, muskrat, and mink probably are present in every county in West Virginia. Both beaver and muskrat are found throughout the Central Appalachians and populations have increased to the point that both species are causing extensive damage. Beaver cut down prized trees in residential areas, parks, and woods, while also killing many trees as a result of damming streams and small rivers. Muskrats cause damage to farm ponds and small lakes by digging burrows through the dams, which results in water levels dropping.

Although a trapping season for both beaver and muskrat occurs throughout every state in the Central Appalachians, the number of animals taken by trappers is not adequate to control populations of these fur-bearers. Trappers harvested an average of 1,000 beaver and 30,000 muskrats per year from 1970 through 1999 (Table 1). However, the annual harvest has fluctuated widely, due primarily to fluctuations in fur prices.

The number of beaver harvested annually has increased from 1990 to 1999, but the number of muskrats harvested has declined steadily from a peak of nearly 100,000 per year in the late 1970's to a low of 2,833 in 1998-1999 (Table 1). Trappers throughout West Virginia harvest several hundred mink each year, indicating a fairly wide-spread population. However, the number of mink pelts sold annually has declined from a high of over 4,000 per year during the late 1970's and early 1980's to a low of 211 in 1998-99 (Table 1).

The annual harvests of mink and muskrats in West Virginia have declined over 95% during the past 20 years, and there is reason to believe that this has occurred throughout the Central Appalachians (Evans, WVDNR, personal communication). Unfortunately, there are no data for West Virginia or any other state in the Central Appalachians to document this population decline. Also, there are no studies to determine the causes of this apparent decline. Muskrats are the major food eaten by mink, thus a decline in muskrat populations would result in a decline in mink populations.

The northern water shrew is the least known of any of the wetland mammals and one of the most difficult to capture. Water shrews spend most of their active hours in the pursuit of prey within the small mountain streams they inhabit. Laerm et al. (1995) reported that the Appalachian water shrew (*Sorex palustris punctulatus*) is the rarest and most localized shrew in the southeastern United States. It has been reported from only 14 counties in 7 states, extending from southwestern Pennsylvania to northern Georgia. The Appalachian water shrew was listed by the state of Virginia as an endangered species in 1990 and a recovery plan was published in 1991. Pagels et al. (1998) reported that in Virginia the Appalachian water shrew had been found in only Bath and Highland counties. All capture sites for this shrew were "...fully-canopied first or second order streams with habitat characteristics and a macroinvertebrate community typical of relatively pristine, high-altitude, headwater streams."

The Appalachian water shrew was discovered in West Virginia at Cheat Bridge and at Cranesville Swamp in 1942. It has been reported from five counties in West Virginia -- Pendleton, Pocahontas, Preston, Randolph, and Tucker (WV Division of Natural Resources 1996).

The star-nosed mole has been recorded from nine counties in West Virginia -- Greenbrier, Jefferson, Monongalia, Pendleton, Pocahontas, Preston, Randolph, Roane, and Tucker (WV Division of Natural Resources 1999). These moles are extremely difficult to trap and no studies have attempted to document the distribution or densities of this species in the Central

Appalachians.

RESEARCH PRIORITIES

The primary research goal should be to determine the population abundance and distribution of all six wetland mammals, with special emphasis on the star-nosed mole, water shrew, mink, and river otter.

Table 1. West Virginia annual fur harvest, based on fur buyers reports (WVDNR 1999).

	Number of Pelts				Number of Pelts		
Season	**Beaver**	**Mink**	**Muskrat**	**Season**	**Beaver**	**Mink**	**Muskrat**
1970-71	526	629	22,857	1986-87	1,748	1,393	34,397
1971-72	865	736	34,259	1987-88	1,905	1,746	34,643
1972-73	1,087	1,413	38,178	1988-89	1,131	547	13,234
1973-74	1,167	1,942	57,706	1989-90	1,170	380	6,669
1974-75	866	2,851	79,900	1990-91	683	268	4,692
1975-76	622	3,299	66,319	1991-92	999	587	11,148
1976-77	588	3,685	71,367	1992-93	759	368	7,074
1977-78	862	3,027	94,602	1993-94	357	260	5,661
1978-79	840	3,452	80,826	1994-95	1,313	322	8,419
1979-80	1,720	4,432	76,167	1995-96	649	237	4,233
1980-81	1,551	4,435	72,415	1996-97	2,126	521	9,440
1981-82	1,060	3,840	45,236	1997-98	2,322	393	7,474
1982-83	721	3,202	38,055	1998-99	1,621	211	2,833
1983-84	573	2,006	28,804	**Mean**	1,087	1,655	34,294
1984-85	921	849	19,795				
1985-86	741	968	18,134				

Specific research objectives would consist of (1) developing guidelines for sampling and monitoring populations, (2) determining geographic distribution, (3) identifying potential habitat and critical habitat, (4) monitoring population densities, and (5) assessing the effects of habitat loss and degradation on populations.

A secondary goal should be to develop methods to control damage caused by beaver and muskrats. Specific research objectives would include (1) assessing the economic losses annually, (2) documenting the types of damage in each county, and (3) developing acceptable damage control methods that can be used efficiently by individual landowners.

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