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ARTICLE

Proposed Hydrogeomorphic Classification for Wetlands of the Mid-Atlantic Region, USA

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Abstract We propose a regional classification for wetlands of the Mid-Atlantic region, USA. It combines functional characteristics recognized by the hydrogeomorphic (HGM) approach with the established classification of the National Wetland Inventory (NWI). The HGM approach supplements the NWI classification by recognizing the importance of geomorphic setting, water sources, and flow dynamics that are key to functioning wetlands. Both NWI and HGM share at their highest levels the Marine, Estuarine, and Lacustrine classes. This classification departs from the NWI system by subdividing the Palustrine system into HGM classes of Slope, Depression, and Flat. Further, the Riverine class expands to include associated Palustrine wetlands, thus recognizing the interdependency between channel and floodplain. Deepwater habitats of NWI are not included because they differ functionally. Mid-Atlantic regional subclasses recognize two subclasses each for Flat, Slope, and Marine Tidal Fringe; three subclasses for Depression; four subclasses for Lacustrine Fringe and Estuarine Tidal Fringe, and five subclasses for Riverine. Taking a similar approach in other geographic regions will better characterize wetlands for assessment and restoration. This approach was applied successfully during a regional wetlands condition assessment. We encourage additional testing by others to confirm its utility in the region.

Keywords Estuarine wetlands · National Wetlands Inventory

Introduction

The inherent variability in natural characteristics defines wetlands, leads to their diverse ecological functions, and instills societal values that have challenged those seeking to classify them. The classification developed by Cowardin et al. (1979) was designed as the basis for nation-wide mapping and inventory in the USA, where it is the prevalent method used for the National Wetlands Inventory (NWI). It has been applied successfully in other geographic regions of the world (Vives 1996; Finlayson et al. 2002). As such, it has been used to "…furnish units for mapping, and provide uniformity of concepts and terms." (Cowardin et al. 1979). Five systems and related subsystems form the basis of the hierarchical classification. The NWI arrangement, however, does not highlight differences in morphometry, landscape position, or dominant water source, factors that also contribute to characterizations of wetland functions. Given the expansion

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of knowledge about wetlands over the nearly 40 years following the Clean Water Act (NRC 1995), and additional needs to assess their condition and restore them (NRC 2001), functional classification of wetlands also can play a prominent role (Brinson 1993a).

There have been a few previous efforts using functional properties to develop wetland classification systems; a functional classification for coastal ecological systems (Odum et al. 1974), a classification of mangrove ecosystems (Lugo and Snedaker 1974), and links between wetland classification and hydrogeomorphic functions in the northeastern USA (Tiner 2000, 2003). Empirical evidence suggests that there is utility in classifying all wetland types based on their hydrogeomorphic (HGM) characteristics, specifically the source of water, flow dynamics, and geomorphic setting (Brinson 1993a; Brooks 2004a, Cole et al. 2006). The overall HGM system, modified from Brinson (1993b), recognizes seven major classes: Mineral Soil Flat, Organic Soil Flat, Slope, Depression, Lacustrine Fringe, Riverine, and Tidal Fringe (Marine and Estuarine) (Smith et al. 1995). These can be further divided into regional and local subclasses.

We developed regional subclasses for the Mid-Atlantic while participating in the Atlantic Slope Consortium, a regional research project that was part of a national effort to develop ecological and socio-economic indicators for aquatic ecosystems (e.g., Niemi et al. 2004; Brooks et al. 2007). During that project, we sought ways to blend similar research approaches being conducted between estuarine segments of coastal systems and the freshwater wetlands of small watersheds (Brooks et al. 2006). In addition, during development of a Stream-Wetland-Riparian Rapid Assessment Index (Brooks et al. 2009), we needed a way to consistently describe components of aquatic ecosystems among ecoregions. Based on these experiences, we developed this regional classification system for the following reasons:

1. We recognized the need for a standardized classification system for estuarine and freshwater wetlands in the region that linked inventory and mapping activities with ground-based monitoring and assessment efforts.
2. We wanted a system that emphasized fundamental hydrogeomorphic characteristics rather than dominant vegetation classes (Bedford 1996; Winter 1992).
3. We wanted to design a system that built on the existing NWI terminology, but that was not constrained by it (e.g., expansion of subclasses currently lumped under Palustrine system).
4. We wanted a system that would provide consistency in nomenclature, use, and communication across a large geographical region.

Study Area

In spite of the broad range of physiography in the region, the Mid-Atlantic has physiographic patterns that warrant the development of relevant regional subclasses specific to the area (Fig. 1). The climate is moist temperate, natural vegetation is mostly forest, the coastline of mostly unconsolidated substrate is exposed to severe storms, and the area drains both toward the Atlantic coast and into the Ohio River Basin from the Appalachian Mountains. To the east, these drainages connect marine and estuarine ecosystems with freshwater wetlands as far away as the Allegheny Plateau physiographic province in the continental interior. Biotic connections include anadromous fish species between the ocean and coastal plain streams and north-south migration of avifauna along the Atlantic Flyway.

Many of the Mid-Atlantic watersheds cut across several of eight geopolitical boundaries (Pennsylvania, New York, New Jersey, Delaware, Maryland, West Virginia, Virginia, North Carolina), giving further justification for working from a regional classification based on functional types. Toward the west, several major rivers collect water from tributaries from the Appalachians, and link waters to the Mississippi River Basin through the Ohio River. A small portion of the Mid-Atlantic watersheds flow north into various segments of the St. Lawrence and Great Lakes basins. Despite these diverse drainage patterns and having both glaciated and unglaciated landscapes, the wetlands within the region display many similarities, which led to our decision to formulate the proposed classification system.

Combining NWI and HGM Classes for Regional Classification

We propose a classification system for coastal and inland wetlands of the Mid-Atlantic region that begins with the system level defined by NWI and incorporates additional classes recognized by HGM. We further propose regional subclasses based on HGM characteristics, NWI vegetation types, and other modifiers. The lesser reliance on vegetation cover is recognition that similar species composition can be found in very different geomorphic settings and flow dynamics (Fig. 2). For example, red maple (*Acer rubrum*), a facultative wetland species, is so ubiquitous as to defy its usefulness in distinguishing wetland types.

The collective experience of the authors of this paper in wetland classification and assessment covers eight states of an expanded Mid-Atlantic Region (Fig. 1). Here, we describe how the two systems were blended and revised, at the highest, hierarchical level; we have adopted the HGM term class, rather than the NWI term system, for this

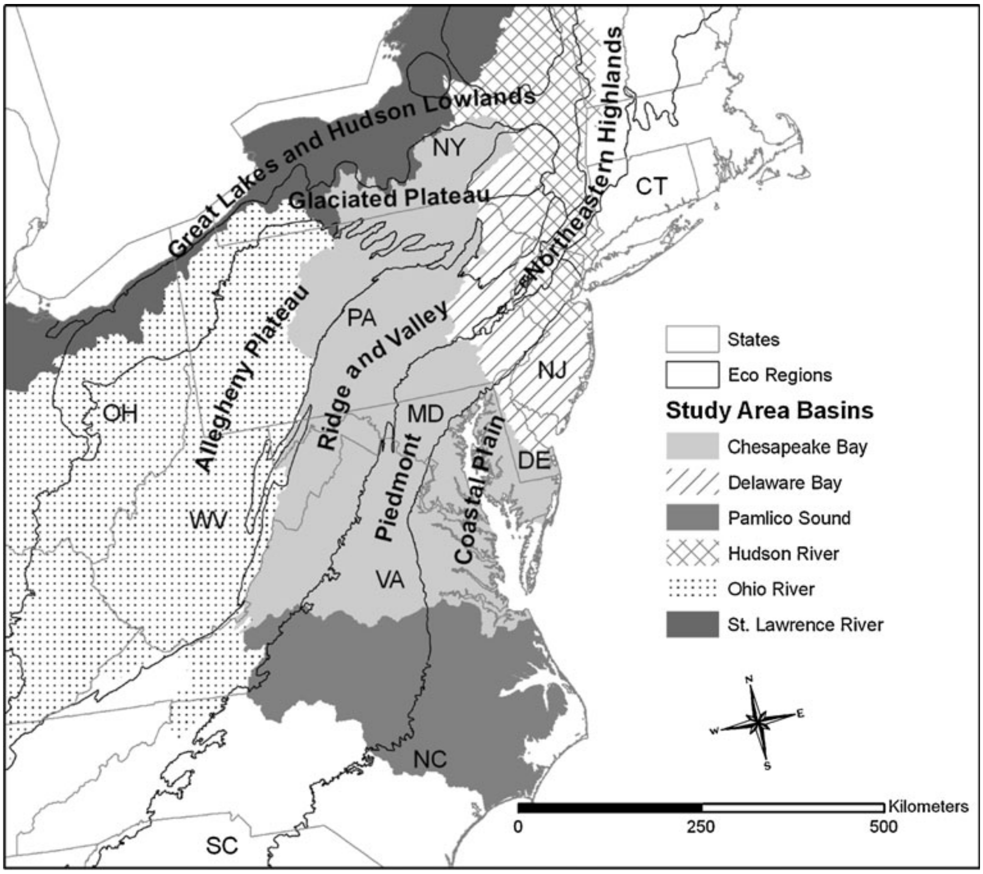

Fig. 1 The extended Mid-Atlantic region for which regional subclasses of wetlands were developed

highest level. This is followed with descriptions of specific regional subclasses. We used a combination of NWI and HGM classes as a starting point, evolved a series of regional subclasses through discussions, and selectively added the NWI vegetation types and specific examples to complete the hierarchical system. In a HGM approach to classification, regional subclasses are locally recognized types, often with names that can be readily associated with HGM terminology (Brinson 1993a). For example, Delmarva bays are depression wetlands and pocosin peatlands are organic soil flats. We believe that this approach to classification has region-wide and national applicability for assessing wetland functions and for developing ecological indicators of wetland condition. Terminology draws from Cowardin et al. (1979) and Smith et al. (1995), as well as terms developed to address features specific to wetlands of the Mid-Atlantic.

For consistency with the NWI, the upper levels of our regional HGM classification system for Mid-Atlantic wetlands begin with four of the five designated systems

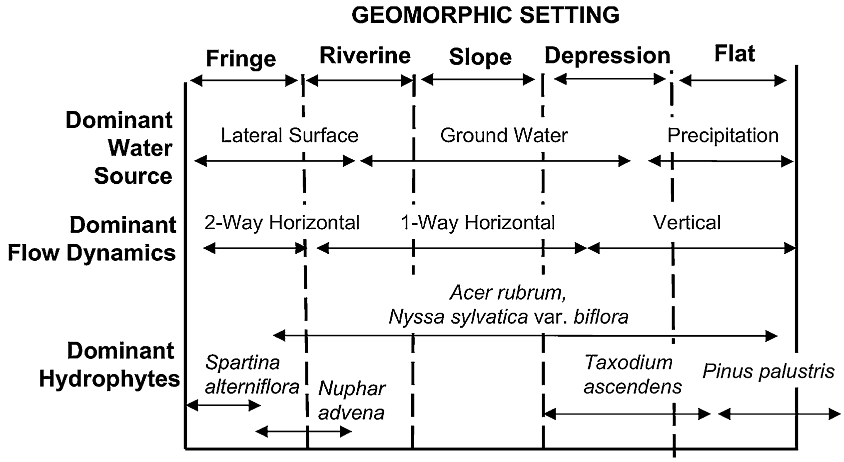

Fig. 2 The relationship of geomorphic settings and dominant waters source and flow dynamics. Some dominant hydrophytes span several geomorphic settings

(i.e., Marine, Estuarine, Riverine, and Lacustrine). The exception is the Palustrine system (Cowardin et al. 1979) that we considered too broad for characterizing the diversity of freshwater, vegetated wetlands. In its place, we substituted the HGM classes of Flat, Slope, and Depression (Table 1). The Riverine HGM class is expanded to encompass the adjacent Palustrine types of NWI that occur in the floodplain, which heretofore, were delineated as distinct Palustrine polygons on maps, separate from other riverine wetlands. This decision is based on the irrefutable functional interdependency between channel and floodplain for hydrology (Junk et al. 1989; Friedman and Auble 2000), biogeochemistry (Brinson 1990), and habitat (Welcomme 1979). The best way to distinguish vegetated wetlands associated with the Riverine class from others is to note the location of the outer boundary of the floodplain. Those vegetated wetlands occurring between that edge and the river itself should be classified using subclasses of the Riverine class, rather than in Flat, Slope or Depression classes. These latter classes pertain to wetlands that are primarily not under the hydrologic influence of a river during flood stages.

For mapping purposes, we recommend linking these HGM-based classes to the Palustrine (P) mapping conventions of the NWI (W. Wilen, personal communication, 1995; Tiner 2000). Through interactions with colleagues, we were aware of concurrent work to blend NWI and HGM systems for the state of Ohio (e.g., Mack et al. 2000, Mack

Table 1 Comparison of the proposed HGM subclasses for Mid-Atlantic region wetlands with National Wetland Inventory categories of Cowardin et al. (1979)

Hydrogeomorphic Classes	Subclasses for the Mid-Atlantic region	NWI Systems: Subsystems	Common NWI classes in Mid-Atlantic
FLAT	Mineral soil	Palustrine	Forested (FO), Scrub-Shrub (SS), Emergent (EM)
	Organic soil	Palustrine	FO, SS, EM
SLOPE	Topographic	Palustrine	FO, SS, EM
	Stratigraphic	Palustrine	FO, SS, EM
DEPRESSION	Temporary	Palustrine	FO, SS, EM, Aquatic Bed (AB)
	Seasonal	Palustrine	FO, SS, EM, AB
	Perennial	Palustrine	FO, SS, EM, AB
	Human impounded, excavated or beaver impounded	Palustrine	SS, EM, AB
LACUSTRINE FRINGE	Permanently flooded	Lacustrine: Limnetic or Littoral Palustrine	SS, EM, AB
	Semi-permanently flooded	Lacustrine: Littoral Palustrine	FO, SS, EM, AB
	Intermittently flooded	Lacustrine: Littoral Palustrine	FO, SS, EM, AB
	Artificially flooded	Lacustrine: Littoral Palustrine	FO, SS, EM, AB[a] possible but generally suppressed
RIVERINE	Intermittent	Palustrine	FO, SS, EM
	Headwater complex	Palustrine[b]	FO, SS, EM
	Upper perennial	Palustrine and Riverine	FO, SS, EM, AB
	Lower perennial	Palustrine and Riverine	FO, SS, EM, AB
	Floodplain complex	Palustrine and Riverine	FO, SS, EM, AB
	Beaver-impounded	Palustrine, Lacustrine Littoral, and Riverine	FO, SS, EM, AB
	Human-impounded	Lacustrine	FO, SS, EM, AB
ESTUARINE TIDAL FRINGE	Estuarine lunar intertidal	Estuarine: Intertidal	EM, AB
	Estuarine wind intertidal	Estuarine: Intertidal	FO, EM, AB
	Estuarine subtidal	Estuarine: Subtidal	AB
	Estuarine impounded	Estuarine: Subtidal	EM, AB
MARINE TIDAL FRINGE	Marine intertidal	Marine	Unconsolidated Shore (US)
	Marine subtidal	Marine	Unconsolidated Bottom (UB)

[a] Aquatic bed is suppressed where steep banks typical of reservoirs limit habitat

[b] Riverine in NWI is restricted to the channel with the following exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens and (2) habitats with water containing ocean-derived salts in excess of 0.5 ppt

2004) and several other northeastern states (e.g., Tiner 2003, 2004). The Ohio classification system also uses HGM classes at the higher levels of organization, followed by modifiers and then, NWI vegetation classes (Mack 2004). That system addresses the freshwater coastal wetlands of the Great Lakes, at least for those along the Ohio border. We have included both freshwater and saline wetland types in the proposed system, and have attempted to incorporate the range of types found in a large geographic region that encompasses several ecoregions or physiographic provinces.

We made several other changes that diverge from standard nomenclature of the NWI. We elected to place tidal freshwater wetlands in Estuarine Fringe rather than Riverine. Freshwater tidal wetlands have frequent, often twice-daily flooding that is more characteristic of estuarine wetlands than the normally seasonal overbank flooding that defines floodplain wetlands (Odum et al. 1984). Given that hydrology is the most important component of wetland functioning, we choose to maintain tidal effects on water flow, rather than salinity, as the primary control. For habitat functions where structural vegetation differences (i.e., marsh versus forest) disproportionately influence utilization by fauna, the use of vegetation modifiers, including those used in NWI, can be used in the lower levels of the classification hierarchy. This preserves the HGM emphasis of our classification. Similarly, we diverged somewhat from the nomenclature of an earlier HGM classification by Cole et al. (2006) for the Appalachian Mountain portion of region. Our classification provides strong linkages to the existing NWI approach, with the intent of encouraging use of our system not only for functional and condition assessments, but also for mapping and inventory purposes. As is true for most hierarchical classification systems, upper levels preserve consistency across broadly recognized classes, whereas lower levels can be modified to meet the specific needs of the user.

Deepwater habitats of NWI (>2 m depth) are not included in this treatment because of the large functional differences between the primarily planktonic and pelagic life forms found in deep waters and the predominance of rooted plant forms in wetlands and shallow water. To our knowledge, deepwater habitats can potentially be associated with, and segregated from, all classes except for Flat, Slope, and Depression. A major difference occurring among physiographic provinces in the Mid-Atlantic is the restriction of Estuarine Tidal Fringe and Marine Tidal Fringe classes to the Coastal Plain; all other classes occur throughout all physiographic provinces in the region.

Regional Subclasses

Each class of geomorphic setting contains subclasses based on further distinctions in geomorphic setting, water sources, and hydrodynamics (Table 1). These are called regional subclasses because they coincide with wetland types recognized by practicing scientists and naturalists.

- Marine Tidal Fringe is separated based on hydroperiod alone.
- Estuarine Tidal Fringe is first separated by hydroperiod and secondarily by salinity.
- Flats are separated into regional subclasses with mineral soils and those with organic-rich soils. The former would be equivalent to wet pine savannas (Walker and Peet 1983) and the latter to pocosin peatlands (Richardson 1981). These were originally separate classes in Smith et al. (1995).
- Slope wetlands are separated into topographic and stratigraphic subclasses, following Cole et al. (2006). They can be separated further based on soil organic or mineral content, with spring seep and forested fen being examples.
- Depressions are subclassified in much the same way that prairie potholes are divided, with water persistence as the major variable (Stewart and Kantrud 1971). This is tentative because few studies have been conducted to quantify hydroperiods across the range of depression types. Isolated and surface-connected depressions are another way to differentiate types since they may have very different trophic structures (Sharitz and Gibbons 1982; Leibowitz and Nadeau 2003; Brooks 2004c) that may not be apparent from hydroperiod alone. Julian (2009), working along the upper Delaware River on amphibians using breeding ponds, distinguished wetlands by size, water permanence, and degree of isolation from other surface waters. He used the terms strictly isolated, seasonal, and permanent. We adopted similar terms, but apply them to water permanence: temporary, seasonal, and permanent.
- Lacustrine Fringe subclasses are separated by hydroperiod. In the Great Lakes region of the USA, by contrast, distinctions are based largely on degree of protection from waves and geomorphic setting (Keough et al. 1999; Mack 2004).
- Riverine wetlands are separated by watershed drainage area and associated stream order because of the profound effects on the sources of water and the capacity to process nutrient inputs (Brinson 1993b). The decision to encompass floodplain wetlands in the Riverine class has resulted in further modifications to prior systems. We kept intermittent streams separate from upper perennial streams because the two vary in their annual hydrologic cycles and mapping scales. Further, with emphasis on the floodplain portion of the Riverine class, forest species composition in the coastal plain separates more by stream order than it does by

flow persistence (Rheinhardt et al. 1998). We have described two new subclasses, headwater and floodplain complexes. The first represents the mosaic of microhabitats that occur together in the upper reaches of many Mid-Atlantic watersheds. In these areas, groundwater is prevalent, emanates from wetlands at the toe of topographic slopes, providing water to low gradient meandering stream channels, and fills depressions in the riparian zone (formerly called riparian depressions by Cole et al. 1997, 2008). In some cases, the entire valley bottom is saturated (Brooks and Wardrop unpublished data). The proximity and interconnectivity of these microhabitats are critical for amphibian communities (Farr 2003) and other wetland-dependent taxa. Marking relevant boundaries among these microhabitats in the field is difficult, and only becomes more problematic when mapping polygons at landscape scales. Thus, the inclusion of a headwater complex subclass seeks to recognize their hydrologic interdependence and provide a practical solution for mapping small areas of interspersed wetlands. The second, floodplain complexes, serves a similar function for lower perennial streams and rivers, where a mix of microhabitats, often formed during large flooding events, occur in proximity.

We recommend that wetlands classified using this system follow a hierarchical list of labels. We propose a set of standard abbreviations to facilitate consistent labeling and for cross-listing with existing NWI mapping conventions (Table 2, Appendix). NWI vegetation types are included as modifiers to regional subclasses once hydrologic and geomorphic setting have been assigned. For example, an isolated, temporary vernal pool supplied by precipitation in a forested setting, would be labeled as: depression, temporary, forested, or abbreviated as DPAFO. The equivalent NWI abbreviation would be a more generic PFO that is applied to other types as well. Similarly, we have provided additional detail for estuarine wetlands such that an emergent *Spartina* salt marsh would be labeled as: estuarine tidal fringe, lunar intertidal, and abbreviated as EF2lEM, distinguishing it from estuarine wind intertidal, subtidal, and impounded. The equivalent NWI abbreviation would be E2EM. Again, by placing the vegetation component toward the end of the type label, the HGM aspects of the classification are emphasized. The classification remains open ended to allow the addition of other modifiers as needed.

With regard to geographic extent, we recommend use of this regional classification system throughout the states of an expanded Mid-Atlantic Region (Fig. 1). Although our original focus was on the Atlantic Slope, our collective experience with wetlands on the western slope of the Eastern Continental Divide along the Appalachian Mountains, including our field trials held in 2008 and 2009, indicates that these wetlands will be properly classified. Some caution should be exercised when extending this system northward as far as the Adirondacks of northern New York, as Cole et al. (2008) found the wetlands of this portion of the region to be wetter than those in comparable subclasses further south. Despite these differences in the degree of wetness, they were usually assigned to the appropriate HGM class (Cole et al. 2008).

Verification

In 2008 and 2009, we used the proposed system during regional field studies. Two field teams conducting rapid condition assessments visited about 400 wetlands throughout the Mid-Atlantic Region, and applied this classification system. The wetlands assessed were randomly selected using a Generalized Random Tessellation Stratified (GRTS) design, a spatially restricted sampling method (e.g., Stevens and Olsen 2004) from a sampling frame based on digitized NWI polygons. Rapid assessments of wetland condition are considered to be intermediate in the effort required and data collected (Level 2) compared to remote-sensing based landscape assessments (Level 1) and intensive, field-assessments (Level 3)(Brooks et al. 2004; Brooks et al. 2006).

Rapid assessments typically are designed to do two primary tasks, confirm classification during ground reconnaissance, and to observe stressors in and around the targeted wetland (Fennessy et al. 2007). During quality assurance training sessions for the Mid-Atlantic regional wetlands assessment, two field teams consistently classified dozens of wetlands in the field in the same way (Coastal Plain and Piedmont of Virginia in 2008; Piedmont, and Ridge and Valley of Maryland, Virginia and West Virginia in 2009)(Fig. 1). A few minor variations in identifying subclasses were adjusted during on-site discussions (e.g., choosing upper versus lower perennial subclasses for transitions between second and third order streams; separating or combining (as complexes) microhabitats in the assessment area when slopes and depressions are in proximity to upper and lower perennial streams). These discussions evolved around the scale of field sampling, not the correct identification of subclasses.

A second test of this classification system to verify its efficacy and repeatability was conducted in 2010 by two principal investigators of the project (Brooks and Havens, both authors of this paper), after the fieldwork was completed. Twenty sites (5% of the total sample of 400 wetlands) were visited during a Quality Assurance audit for the project. Although all aspects of the rapid assessment

Table 2 Proposed terminology for classifying Mid-Atlantic region wetlands using hydrogeomorphic attributes and descriptive examples

HYDROGEOMORPHIC CLASS[a,b]Regional Subclasses	Dominant water sources of class and flow dynamics	Major source of variation within subclass	NWI vegetation classes[c]	Regional example	Citation
FLAT (FL)	Precipitation; Vertical fluctuation				
Mineral soil (n)		Hydroperiod and fire frequency	FO, SS, EM	Wet pine flats/ wet pine savannas, wet hardwood flats: Broad areas with poor drainage on mineral soils	Walker and Peet (1983); Tiner (1985); Tiner and Burke (1995); Rheinhardt and Rheinhardt (2000), Havens et al. (2001), Rheinhardt et al. (2002)
Organic soil (g)		Peat depths (from histic epipedons to histosols)	FO, SS, EM	Southern peat bogs such as pocosins: Broad areas with poor drainage that accrete organic matter	Richardson (1981)
SLOPE (SL)	Groundwater discharge and interflow; Unidirectional & horizontal				
Stratigraphic (s)	Derived from structural geologic discontinuities, discharging from distinct point(s)	Mineral(n) or organic(g)	FO, SS, EM	Spring seep	Cole et al. (1997); Wardrop et al. (2007)
Topographic (g)	Accumulates at toe-of-slope before discharging	Mineral(n) or organic(g)	FO, SS, EM	Forested fen	WPC (1998)
DEPRESSION (DP)	Precipitation or groundwater; vertical fluctuation				Tiner (1985); Tiner and Burke (1995)
Temporary (A)		No surface outlet; often has a perched water table	FO, SS, EM, AB	Vernal pools that dry during the growing season and often lack fish; Coastal Plain Seasonal Pond Complex (underlying calcium-rich shell marl)	Rawinski (1997); Havens et al. (2003a, b); Brooks (2004b, c)
Seasonal (C)		Infrequent surface connections to other waterbodies; normally in contact with groundwater	FO, SS, EM, AB	Delmarva bays; Interdunal swales	Phillips and Shedlock (1993); Rheinhardt and Faser (2001); Tiner (2003)
Perennial (H)		Frequent surface connections to other waterbodies with inlets and outlets conveying channel flow	FO, SS, EM, AB	Floodplain depressions isolated from overbank flow, vegetated marsh; riparian depressions with steady groundwater flow	Tiner (1985); Hull and Whigham (1987); Tiner and Burke (1995); Cole et al. 1997; Brooks and Hayashi (2002)
Human impounded (i) or excavated (x)		Size of catchment	SS, EM, AB	Borrow pits; some farm ponds; some created wetlands	Jordan et al. (1999); Whigham et al. (2002); Jordan et al. (2003)
LACUSTRINE FRINGE (LF)	Inundation from lake; Bi-directional and horizontal				
Permanently flooded (H)		Hydroperiod; minor fluctuations during year	FO, SS, EM, AB	Natural lake shore	Shafale and Weakley (1990))
Semipermanently flooded (F)		Hydroperiod; varies during growing season	FO, SS, EM, AB	Natural lake shore	Shafale and Weakley (1990)
Intermittently flooded[d] (J)		Hydroperiod: substrate exposed often	FO, SS, EM, AB	Natural lake shore	Shafale and Weakley (1990)
Artificially flooded[e] (K)		Reservoir dam release schedule creates fluctuations resulting in a strong vertical component depending on slope	FO, SS, EM, AB	Piedmont reservoirs	Mack (2004), Havens et al. (2003a, b)
RIVERINE (RV)	Overbank flow from channel and groundwater discharge; Unidirectional				
Headwater complex (3c)		Mosaic of low gradient small streams, depressions in the riparian zone, and toe of slope wetlands generally supported by groundwater; (usually < third order)	FO, SS, EM, AB	Forested	Farr 2003 Brooks and Wardrop unpublished data

Table 2 (continued)

HYDROGEOMORPHIC CLASS[a,b]Regional Subclasses	Dominant water sources of class and flow dynamics	Major source of variation within subclass	NWI vegetation classes[c]	Regional example	Citation
Intermittent (4)		Range of hydroperiods within riparian zone (usually < third order), gradient high, water velocities fast.	FO, SS, EM, AB	Riparian forest, although not usually in the stream channel	Rheinhardt et al. (1998); Rheinhardt et al. (2000); Peterjohn and Correll (1984)
Lower perennial (2)		Range of hydroperiods within 100-y floodplain, including in-stream terraces and bars (usually>third order) Gradient is typically low; water velocities slow.	FO, SS, EM, AB	Bottomland or floodplain forest	NRC (2002)
Floodplain complex (2c)		Range of hydroperiods within 100-yr floodplain, including mosaic of depressions, remnant channels, and groundwater discharges; Gradient is typically low; water velocities slow.	FO, SS, EM, AB	Bottomland or floodplain forest with oxbow lakes, backwaters, toe-of-slope seeps	Brooks, Wardrop and Yetter, unpublished data
Beaver-impounded (b)		Dam more temporary than human-impounded; usually < third order	FO, SS, EM, AB	Beaver pond	Klotz (1998); Correll et al. 2000 Bason and Brinson (in preparation)
Human- impounded[d] (h)		Range of water residence times based on impoundment volume and discharge	FO, SS, EM, AB	Mill ponds; large farm ponds not deemed to be Depressions	
ESTUARINE TIDAL FRINGE (EF)	Mixture of sea and fresh water; bi-directional and horizontal				
Estuarine lunar Intertidal (2 l)		Regularly flooded zone: Flooding by semidiurnal tides Irregularly flooded zone: Flooding by spring and storm tides and precipitation (Salinity ranges—0 to >30 ppt)	EM, AB	*Spartina alterniflora*-dominated zone *Juncus roemerianus* and *S. patens* dominated zone Freshwater tidal swamps	Stevenson et al. (1977); McCormick and Somes (1982);Simpson et al. (1983); Rheinhardt (1992); Havens et al. (2002); Paul (2001)
Estuarine wind Intertidal[f] (2w)		Tide induced by wind seiche (Salinity ranges - 0 to >30 ppt)	FO, EM, AB	Black needle-rush marshes	Brinson (1991)
Estuarine subtidal (1)		Low energy regime allows SAV establishment (Salinity ranges—0 to >30 ppt)	AB	Mud and sand flats; SAV beds; Oyster reefs	Rybicki et al. (2001) Southworth and Mann (2004)
Estuarine Impounded (h)		Flow is blocked by dike, gate, or dam; water source precipitation except for controlled delivery of estuarine water of varying salinity	EM, AB	Waterfowl impoundments	
MARINE TIDAL FRINGE (MF)	Marine source; Bi-directional and horizontal				
Marine intertidal (2)		N/A	US	High energy beach	
Marine subtidal (1)		N/A	UB	Shallow littoral	

[a] Hydrogeomorphic (HGM) classes follow Brinson (1993a) and further refinements from other literature and field experiences of the authors

[b] Upper case in bold are HGM *classes*; lower case in bold are *regional subclasses*, except for deepwater environments. Letters in parentheses are suggested mapping abbreviations, consistent with NWI wherever possible

[c] NWI vegetation classes: forested (FO), scrub-shrub (SS), emergent (EM), aquatic bed (AB), unconsolidated shore (US), unconsolidated bottom (UB), riverine (R), Lacustrine (L), estuarine (E), marine (M)

[d] The landward zones of Lacustrine Fringe may receive groundwater discharge and justify a Slope designation. Regardless, the hydraulic gradient is likely controlled by lake level. Does not include depths >2 m. which is Deepwater Habitat

[e] Technically, reservoirs are an alteration of the Riverine class. However, large reservoirs are generally an irreversible social commitment not amenable to restoration. As a practical matter, their shorelines have strong Lacustrine Fringe characteristics, which justifies placing them in the Fringe category

[f] Pamlico Sound, NC and tributary estuaries are little affected by astronomic tides because of their large volume and relatively small exchanges seawater during a tidal cycle

protocol were examined (i.e., HGM classification, vegetation community, invasive species, stressors), only the results of the wetland classification are reported here. The audit covered a cross section of sites from three of five ecoregions (Piedmont, Ridge and Valley, Allegheny Plateau, four of five states covered by the project (Maryland, Pennsylvania, Virginia, West Virginia)(Fig. 1), and a variety of wetland types. For 19 of 20 sites (95%; for one site, the original field team did not designate the presence of a wetland), the subclass classification described by the original field team agreed with the one chosen by the independent audit team. Three minor discrepancies were related to which microhabitat was chosen as the dominant type for a site when multiple types were present, as in riverine headwater complexes. Thus, based on both the authors' collective experience in wetland identification across the region and two independent assessments of classification accuracy, we believe that the proposed system can be used by multiple observers with a high level of confidence.

Discussion

The classification proposed here has greater region-wide applicability for use in assessing wetland functions and for developing ecological indicators of wetland condition than either of the original approaches by themselves. As such, the framework is presented as an example of what could be applied in many other regional settings. Subclasses elsewhere in the USA have been identified for Riverine in western Kentucky (Ainslie et al. 1999), northern Rocky Mountains (Hauer et al. 2002), western Tennessee (Wilder and Roberts (2002), the Yazoo Basin (Smith and Klimas 2002), and peninsular Florida (Uranowski et al. 2003). Subclasses of Flat have been described for the wet savannas of the Gulf and Atlantic coastal plains (Rheinhardt et al. 2002) and the Everglades (Noble et al. 2002). Subclasses of Depression include intermontane prairie potholes in the northern Rocky Mountains, USA (Hauer et al. 2002), and the Rainwater Basin of Nebraska (Stutheit et al. 2004). Estuarine tidal fringe subclasses have been described for the northwestern Gulf of Mexico, USA (Shafer et al. 2002). Mack et al. (2000) and Mack (2004) proposed HGM classes for both inland and freshwater coastal types. Although the Great Lakes proper are deep environments, their nearshore wetlands would fall into the Lacustrine class of a HGM-based system or the Lacustrine system of Cowardin et al. (1979). The Mid-Atlantic region does not contain comparable habitats to these immense lakes, which produce powerful wave energies and display significant depth variations over time. Thus, appropriate subclasses and modifiers should be developed to better characterize the range of wetland types found there (e.g., Keough et al. 1999). Similarly, regional subclasses can be developed elsewhere as needs are identified.

State and local governments in the USA increasingly have taken on the responsibility for wetland regulation and management, especially in the areas of restoration and implementation of best management practices. As a natural consequence of this regionalization, coupled with increasing awareness by resource managers of variation across wetland types, a natural outcome is to develop classifications that meet local and regional needs. Rather than forcing a top-down approach at the national level, the recognition of regional subclasses identified here can be further subdivided and adapted for inventory, mapping, and selection of reference sites for restoration. Regional subclasses for Slope would differ for mountainous western USA where the distinction is between wetlands in alluvial/colluvial deposits with large groundwater sources and drier sites associated with bedrock landslides with small groundwater sources (Stein et al. 2004). Marine Tidal Fringe in New England and the Maritime Provinces would include rocky shorelines, not found in the Mid-Atlantic region. The introduction of wetland shape, vegetation mosaics, and other patterns (Seminuik 1987; Semeniuk and Semeniuk 1997) could be introduced, if deemed useful. Such flexibility allows a particular classification to be modified or adapted so that it best meets the needs of specific program objectives it serves.

As stated by Cowardin et al. (1979) for the original NWI classification, "Below the level of class, the system [NWI] is open-ended and incomplete." The proposed system presented here is also open-ended and incomplete. We verified the accuracy of using this system during regional field studies and found it to be repeatable by multiple observers. It has not been tested for mapping large geographic regions. We find it useful as a tool, however, for partitioning natural variation among wetland types, communicating distinctions among wetland types, and developing indicators of ecosystem condition across a large geographic region. Further refinement is needed in developing the subclass descriptors or modifiers and providing regional examples.

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Appendix

Key for selecting among tidal and nontidal hydrogeomorphic wetland types in the Mid-Atlantic Region of the U.S. Descriptions and definitions are based on Cowardin et al. (1979), Brinson (1993a, b), Cole et al. (1997, 2006). Classes and subclasses are in **bold**. Please read footnote before using this wetland classification system.[a]

1. Wetland found along tidal fringe of a marine ecosystem (ocean, beach, rocky shore)	2
1. Wetland not associated with marine ecosystem	3
2. Continuously submerged littoral zone	**Marine subtidal** (MF1)
2. Alternately flooded and exposed to air	**Marine intertidal**(MF2)
3. Wetland associated with shallow estuarine ecosystem (mixture of saline and freshwater)	4
3. Wetland not associated with shallow estuarine ecosystem	7
4. Wetland not impounded	5
4. Wetland impounded	**Estuarine impounded** (EFh)
5. Wetland continuously submerged	**Estuarine subtidal** (EF1)
5. Wetland alternately flooded and exposed to air	6
6. Wetland regularly or irregularly flooded by semidiurnal, storm, or spring tides	**Estuarine lunar intertidal** (EF2l)
6. Wetland flooding induced by wind	**Estuarine wind intertidal** (EF2w)
7. Wetland associated with freshwater stream or river	8
7. Wetland not associated with freshwater stream or river	11
8. Wetland associated with permanent flowing water from surface sources	9
8. Wetland dominated by ground water or intermittent flows	10
9. Wetland associated with low gradient tidal creek (see Estuarine types 3)	
9. Wetland associated with low gradient and low velocities, within a well-developed floodplain (typically >3rd order)	**Riverine lower perennial** (R2)
9. Wetland part of a mosaic dominated by floodplain features (former channels, depressions) that may include slope wetlands supported by ground water (see Slope 17)	**Riverine floodplain complex** (R2c)
9. Wetland associated with high gradient and high velocities with relatively straight channel, with or without a floodplain (typically 1st - 3rd order)	**Riverine upper perennial** (R3)
10. Wetland part of a mosaic of small streams, depressions, and slope wetlands generally supported by ground water	**Riverine headwater complex** (R3c)
10. Wetland associated with intermittent hydroperiod	**Riverine intermittent** (R4)
Note: For any riverine type that is impounded, distinguish between:	
Wetland impounded by beaver activity	**Riverine...beaver impounded** (R...b)
Wetland impounded by human activity	**Riverine...human impounded** (R...h)
11. Wetland fringing on a lake or reservoir	12
11. Wetland not fringing on lake or reservoir	14
12. Wetland inundation controlled by relatively natural hydroperiod	13
13. Wetland inundation is permanent with minor fluctuations (year round)	**Lacustrine permanently flooded** (LFH)
13. Wetland inundation is semipermanent (growing season)	**Lacustrine semipermanently flooded** (LFF)

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13. Wetland inundation is intermittent (substrate exposed often)	**Lacustrine intermittently flooded** (LFJ)
12. Wetland inundation controlled by dam releases	**Lacustrine artificially flooded** (LFK)
14. Wetland water source dominated by precipitation and vertical fluctuations of the water table due to low topographic relief	15
14. Wetland differs from above	16
15. Wetland substrate is primarily of mineral origin	**Flat mineral soil** (FLn)
15. Wetland substrate is primarily of organic origin	**Flat organic soil** (FLg)
16. Wetland water source is primarily ground water and has unidirectional and horizontal flows	17
16. Wetland forms a depression	18
17. Water source for wetland derived from structural geologic discontinuities resulting in discharge of groundwater from distinct point(s) on slope	**Stratigraphic slope**(SLs)
17. Water source for wetland accumulates at toe-of-slope before discharging	**Topographic slope** (SLt)
Note: For any slope type, distinguish between:	
Wetland substrate is primarily of mineral origin	**...slope mineral soil** (SL...n)
Wetland substrate is primarily of organic origin	...**slope organic soil** (SL...g)
18. Wetland with frequent surface connections conveying channelized flow	**Depression perennial** (DFH)
18. Wetland with infrequent surface water connections conveying channelized flow	**Depression seasonal** (DFC)
18. Wetland with no surface outlet, often perched above water table	**Depression temporary** (DFA)
Note: For any depression type that is impounded or excavated distinguish between:	
Wetland is impounded by human activities	**Depression...human impounded**(DPh)
Wetland is excavated by human activities	**Depression...human excavated** (DPx)
Wetland is impounded by beaver activities	**Depression…beaver impounded**(DPb)

[a] Before using this wetland classification system:

No classification system can capture effectively all of the inherent variability in natural systems, nor can it provide a foolproof determination given the different experiences of users. This wetland classification system for the Mid-Atlantic region is designed to distinguish among major wetland types with recognizable differences. It also purports to serve both the needs of the regulatory community where certainty is preferred, and the science community that grapples with variability in ecological systems. Given that dual function, it is critical that users consider the landscape and hydrologic contexts of each wetland. How large an area is being classified? A river channel and the associated floodplain on both sides of the channel, or just the wetland associated with a property on the upland edge of a floodplain. Context really matters, and should be carefully and succinctly documented.

When seeking to classify a particular wetland, the most fundamental question the user must ask is, 'How was the wetland formed?", which can be stated as, "What is the origin of the wetland?". If this question is thoughtfully answered and described in a brief narrative, then the actual label assigned to the wetland matters less, because the user will have considered where and how the wetland fits in a given landscape and hydrologic setting. Obviously, this is more relevant for regions where wetlands do not form the dominant matrix of a landscape (e.g., coastal salt marshes, bottomland hardwood forests).

For example, is it a depression that is isolated during drier times of the year, but located in a floodplain setting? Or is it isolated from all riverine influences, and receiving a combination of groundwater and precipitation? Clearly, these wetlands are distinctively different in many of their attributes and functions, but they could have the same morphometric dimensions. Either wetland also could have some characteristics of yet another type, warranting a dual label (e.g., depression/slope) just as NWI mapping recognizes mixed vegetation classes (e.g., forested/scrub-shrub, FO/SS). Thus, it is important to recognize these distinctive elements and document the reasons for labeling the wetland as a specific type. This is especially important when addressing wetlands that occur along a broad hydrologic gradient and when a group of microhabitats occur in a cluster. Thoughtful selection of classes supported by careful documentation will make any classification system more consistent among users.

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