PROPOSED HYDROGEOMORPHIC CLASSIFICATION FOR WETLANDS OF THE MID-ATLANTIC REGION, USA

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Abstract: We propose a regional classification for wetlands that is applicable to the Mid-Atlantic region of the USA. It combines functional characteristics recognized by the hydrogeomorphic (HGM) approach with the long-established classification used by National Wetland Inventory (NWI) in the USA and elsewhere. The HGM approach supplements the NWI classification by recognizing the importance of geomorphic setting, water sources, and flow dynamics that are key to the functioning and condition of wetlands. Both NWI and HGM share at their highest levels Marine, Estuarine, and Lacustrine classes. The proposed classification includes departures from the NWI system that subdivides the Palustrine system into HGM classes of Slope, Depression, and Flat. Further, the Riverine class, which includes the stream channel only in NWI, is expanded to include associated Palustrine wetlands, thus recognizing the interdependency between channel and floodplain. Finally, deepwater habitats of NWI are not included because they differ functionally by being dominated by planktonic and pelagic communities coupled with a strongly heterotrophic benthos. Regional subclasses recognized in the Mid-Atlantic are two subclasses each for Flat, Slope, and Marine Tidal Fringe; three subclasses for Lacustrine Fringe, and four subclasses each for Depression, Riverine, and Estuarine Tidal Fringe. Similar approaches can be taken in other geographic regions to better characterize wetlands for condition assessment and restoration. The approach has not been applied to inventory and mapping.

Key words: wetlands classification, hydrogeomorphic, Mid-Atlantic, estuarine wetlands, National Wetlands Inventory

INTRODUCTION

The inherent variability in ecological characteristics that defines wetland functions and instills societal values for wetlands has hindered their classification. The classification system of Cowardin et al. (1979) is the prevalent method in use for the USA by the National Wetlands Inventory (NWI) and has been applied to other parts of the world (Vives 1996, Finlayson et al. 2002). It has been used primarily for mapping and inventory of wetlands from interpretation of aerial photographs to distinguish among wetland types. 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. Previous efforts at taking some of these properties into consideration include a functional classification for coastal ecological systems (Odum et al. 1974) and a classification of mangrove ecosystems (Lugo and Snedaker 1974). Recent 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). The system 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). They can be further divided into regional and local subclasses.

The authors of this paper developed regional subclass for the Mid-Atlantic while participating in the Atlantic Slope Consortium, a regional research project that is part of a national effort to develop ecological and socio-economic indicators for aquatic ecosystems (Niemi et al. 2004). For consistency in use and communication across such a large geographical region (Figure 1), we recognized a need to standardize the classification nomenclature used for characterizing its estuarine and freshwater wetlands. In spite of the broad range of climate and physiography in the region, the Mid-Atlantic has regional patterns that warrant the development of relevant regional subclasses specific to the area. 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 toward the Atlantic coast. 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.

COMBINING NWI AND HGM CLASSES

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 both HGM characteristics and 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 (Figure 2). For example, red maple (*Acer rubrum*) is so ubiquitous as to defy its usefulness in distinguishing wetland type.

Regional subclasses are locally recognized types, often with names that can be readily associated with HGM terminology. 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.

The collective experience of the authors of this paper in wetland classification and assessment spans the eight states of the Mid-Atlantic region (Figure 1). 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. We have begun to use this system during regional field studies and find it to be a useful starting point in evaluating the condition of wetlands across physiographic regions. The condition assessments use a reference approach that determines the degree of departure from relatively unaltered sites (Brinson and Rheinhardt 1996). To separate natural variation from human induced alteration, classification of the kind described here facilitates the process of distinguishing between the two. 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 region.

For consistency with the NWI, the upper levels of the regional HGM classification system for Mid-Atlantic wetlands begins with four of the five designated systems (i.e., Marine, Estuarine, Riverine, and Lacustrine). The exception is the Palustrine system (Cowardin et al. 1979) that we consider 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 floodplain of NWI.

This 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 et al. 1979).

If necessary for mapping purposes, it is possible to link these HGM-based classes to the Palustrine (P) mapping conventions of the NWI (William Wilen, personal communication, 1995; Tiner 2000). Other procedures to link NWI categories and wetland functions have been developed (Tiner 2003). 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. 2001, Mack 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 regions, the Mid-Atlantic, that encompasses several ecoregions.

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 premier control. This may not satisfy some of the habitat functions where structural vegetation differences (i.e., marsh versus forest) disproportionately influence utilization by fauna. In such cases where habitat assessments are a principal component of assessment, NWI categories should be invoked.

The decision to encompass floodplain wetlands in the Riverine class has resulted in further modifications. One is to combine intermittent streams and upper perennial streams. Distinctions between the two vary with annual hydrologic cycles and mapping scales, so they have been combined in the intermittent-upper perennial subclass. 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 a new subclass, Headwater complex, to represent 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. 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.

Deepwater habitats of NWI (>2m depth) are not included in this treatment because of the great functional differences between the largely planktonic and pelagic life forms 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 all classes except in the Flat, Slope, and Depression classes. A major difference among physiographic provinces is the restriction of Estuarine Tidal Fringe and Marine Tidal Fringe classes to the Coastal Plain; all other classes occur throughout the Mid-Atlantic 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.

- 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 similarly based on soil organic 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 (1971). This is tentative as no known studies have been conducted to quantify hydroperiods. 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 2004b) that may not be apparent from hydroperiod alone.
- 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 separate by watershed drainage area and associated stream order because of profound effects on the sources of water and the capacity to process nutrient

inputs (Brinson 1993b). This distinction influences canopy species composition in the region (Rheinhardt et al. 1998).

- Estuarine Tidal Fringe is first separated by hydroperiod and secondarily by salinity.
- Marine Tidal Fringe is separated by hydroperiod alone.

We recommend that wetlands classified using this system follow a hierarchical listing of labeling, beginning with the appropriate NWI system and subsystem designations (Cowardin et al. 1979) or HGM classes followed by subclasses and modifiers. NWI vegetation types are included as modifiers to regional subclasses once hydrologic and geomorphic setting have been assigned. We propose a set of standard abbreviations to facilitate consistent labeling and for cross-listing with existing NWI mapping conventions (Table 2). 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 PFO. 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. 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.

DISCUSSION

The classification developed by Cowardin et al. (1979) was to be used as the basis for nation-wide (USA) mapping and inventory. It has also been used successfully in other geographic regions (Vives 1996, Findlayson et al. 2002). As such, it has been successfully used to "…furnish units for mapping, and provide uniformity of concepts and terms." (Cowardin et al. 1979). However, given the expansion of knowledge about wetlands over the 25 years following the Clean Water Act (NRC 1995), and additional needs to effectively assess their condition and restore them (NRC 2001), functional classification can play a useful role.

Both the NWI and the proposed regional subclasses emphasize individual wetlands or homogeneous types within a larger complex of wetlands. There are noteworthy perspectives at both larger and smaller scales. An extension of classification is to recognize aggregations of wetlands at an even higher level than class. These combinations or complexes have been dubbed "macrosystems" by Neiff (2001) and are consistent with Ramsar wetlands of international importance (http://www.ramsar.org/key_guide_inventory_e.htm), many of which are complexes of several wetland classes. This scale is similar to that identified by Winter (1992) and Bedford (1996) as the hydrogeologic setting that controls water flows and chemistry of surface and ground water sources to wetlands. Recognizing and identifying a macrosystem scale has two principal advantages: 1) complexes at this level have unique combinations of wetland types or have regional importance (i.e., Estuarine Tidal Fringe wetlands adjacent to freshwater seepage slopes , Flats of mixtures of pocosin peatlands and pine savannas on interstream divides draining to headwaters streams, and many others), and 2) the interconnectedness and interdependency among component parts are based not only on spatial configuration, but also on biological linkages maintained by migratory waterfowl and fish. Macrosystems provide a framework for recognizing cumulative effects and a reference point for restoration at scales larger than a single wetland site or type (Bedford 1999). At smaller scales, recognition of subsets within subclasses would be useful especially when distinctions in species composition need to be recognized across the large biogeographic region of the Mid-Atlantic.

Originally the HGM approach was intended not so much as a classification system, but as way of placing emphasis on the role of hydrologic and geomorphic controls on wetland functioning. It has been used in this way to analyze the effectiveness of in-kind replacement in wetland restoration in western Oregon (Gwin et al. 1999), and in separating the role of groundwater in wetlands in Pennsylvania (Cole et al. 1997). In each of those studies, wetlands would all have fallen into the Palustrine system of NWI, with the main distinctions being vegetation type and flooding regime. Within the past few years, NWI has been enhanced to contribute to regional landscape-level assessments (Tiner 2003). As is true for Ohio (Mack 2004), we suggest that regional subclasses of HGM can be brought together with components of the NWI classification to more effectively recognize and characterize wetland diversity and complexity in the Mid-Atlantic and other regions, with modifications. The classification proposed here has greater region-wide applicability for 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 that 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. 2002a), 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. 2002b), and the Rainwater Basin of Nebraska

(Stuheit 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. Similar regional subclasses can be developed elsewhere as needs are identified.

State and local governments in the USA increasingly have taken on the responsibility of 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 shoreline, not found in the Mid-Atlantic region. The introduction of wetland shape, vegetation mosaics, and other patterns (Semeniuk 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 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 have begun to use this system during regional field studies and find it to be defensible, although it has not been tested in mapping. We find it useful as a tool for communicating, partitioning natural variation 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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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	Mineral soil	Palustrine	FO, SS, EM
	Organic soil	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 or excavated	Palustrine	SS, EM, AB
LACUSTRINE FRINGE	Semipermanently 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[1] possible but generally suppressed
RIVERINE	Headwater complex	Palustrine[2]	FO, SS, EM
	Intermittent upper-perennial	Palustrine and Riverine	FO, SS, EM, AB
	Lower perennial	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)

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

[2] 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.

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

HYDROGEOMORPHIC CLASS[1] [2] Regional Subclasses	**Dominant water sources of class and flow dynamics**	**Major source of variation within subclass**	**NWI vegetation classes[3]**	**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); Rheinhardt et al. (2002), Rheinhardt and Rheinhardt (2000), Havens et al. (2001), Tiner (1985), Tiner and Burke (1995)
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				
Mineral soil (n)		None available	FO, SS, EM	Spring seep	Cole et al. (1997)
Organic soil (g)		None available	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)	Brooks (2004b), Rawinski (1997), Havens et al. (2003)
Seasonal (C)		Infrequent surface connections to other waterbodies; normally in contact with groundwater	FO, SS, EM, AB	Delmarva bays; Interdunal swales	Tiner (2003); Rheinhardt and Faser (2001); Phillips and Shedlock (1993)

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[1]

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

[3] 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).

HYDROGEOMORPHIC CLASS[1] [2] Regional Subclasses	**Dominant water sources of class and flow dynamics**	**Major source of variation within subclass**	**NWI vegetation classes[3]**	**Regional example**	**Citation**
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	Brooks and Hayashi (2002), Tiner (1985); Tiner and Burke (1995); Hull and Whigham (1987); Cole et al. 1997
Human impounded (i) or excavated (x)		Size of catchment	SS, EM, AB	Borrow pits; some farm ponds; some created wetlands	Jordan et al. (1999, 2003); Whigham et al. (2002)
LACUSTRINE FRINGE (LF)	Inundation from lake; Bi-directional and horizontal				
Semipermanently flooded (F)		Hydroperiod	FO, SS, EM, AB	Natural lake shore	Shafale and Weakly (1990)
Intermittently flooded (G)[4]		Hydroperiod	FO, SS, EM, AB	Natural lake shore	Shafale and Weakly (1990)
Artificially flooded (K)[5]		Reservoir dam release schedule creates fluctuations resulting in a strong vertical component depending on slope	FO, SS, EM, AB	Piedmont reservoirs	Mack (2001), Havens et al. (2003

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[4] 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 >2m. which is Deepwater Habitat.

[5] 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.

RIVERINE (RV)	Overbank flow from channel and groundwater discharge; Unidirectional				
Headwater complex (0)		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
Intermittent (4) **Upper-perennial (3)**		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)
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[4] (i)		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 (2l)		**Regularly flooded zone:** Flooding by semidiurnal tides **Irregularly flooded zone:** Flooding by spring and storm tides and precipitation (Salinity ranges - 0 to >30ppt)	EM, AB	*Spartina alterniflora*-dominated zone *Juncus roemerianus* and *S. patens* dominated zone Freshwater tidal swamps	Stevenson et al. (1977); McCormick and Somes (1983);Simpson et al. (1983); Havens et al. (2002); Rheihnhardt (1992)
Estuarine wind intertidal[6] (2w)		Tide induced by wind seiche (Salinity ranges - 0 to >30ppt)	FO, EM, AB	Black needle-rush marshes	Brinson (1991)
Estuarine subtidal (1)		Low energy regime allows SAV establishment (Salinity ranges - 0 to >30ppt)	AB	Mud and sand flats; SAV beds; Oyster reefs	Rybicki et al. (2001) Southrworth and Mann (2004)
Estuarine Impounded (i)		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	

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[6] 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.

List of Figures

Figure 1.

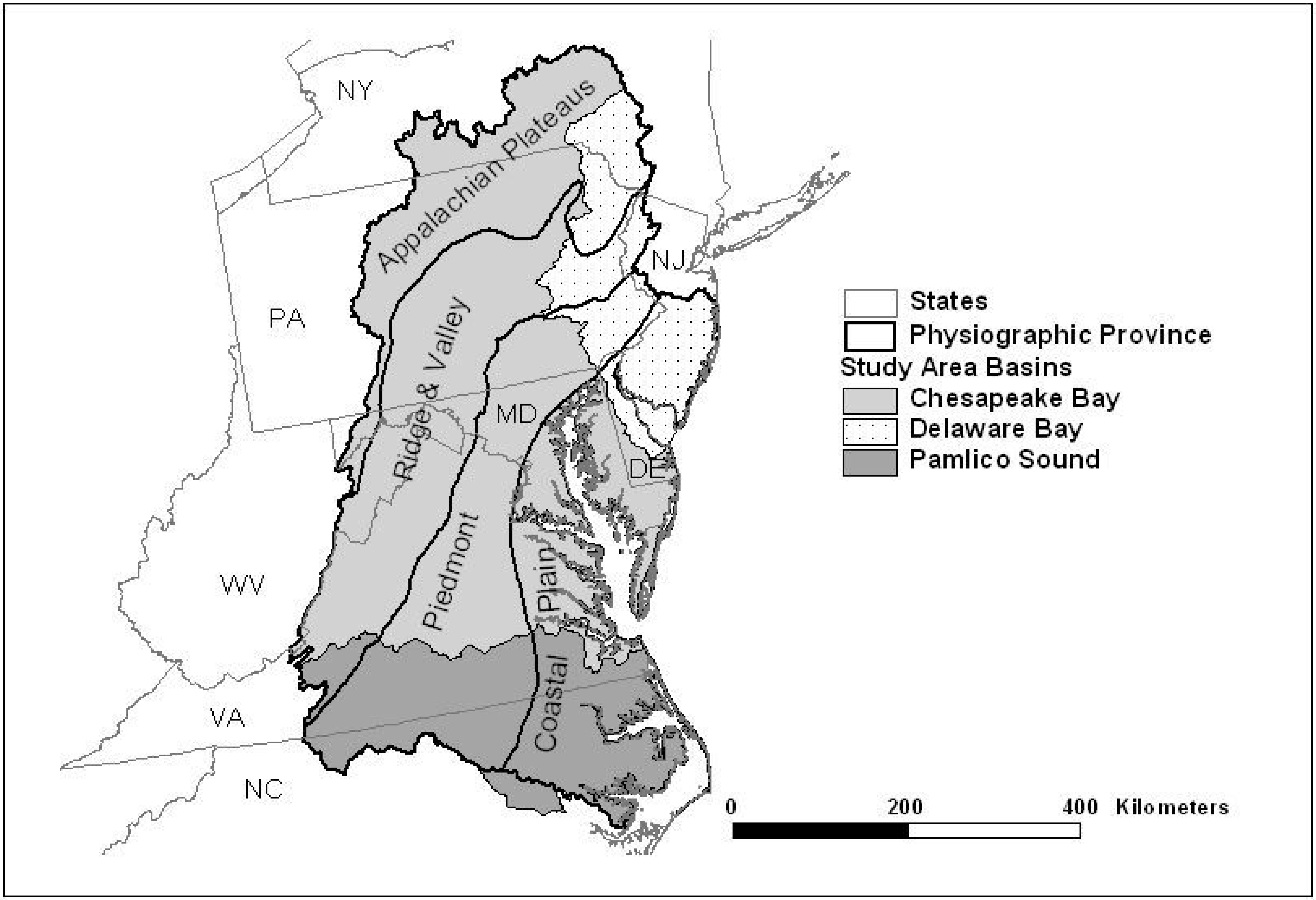
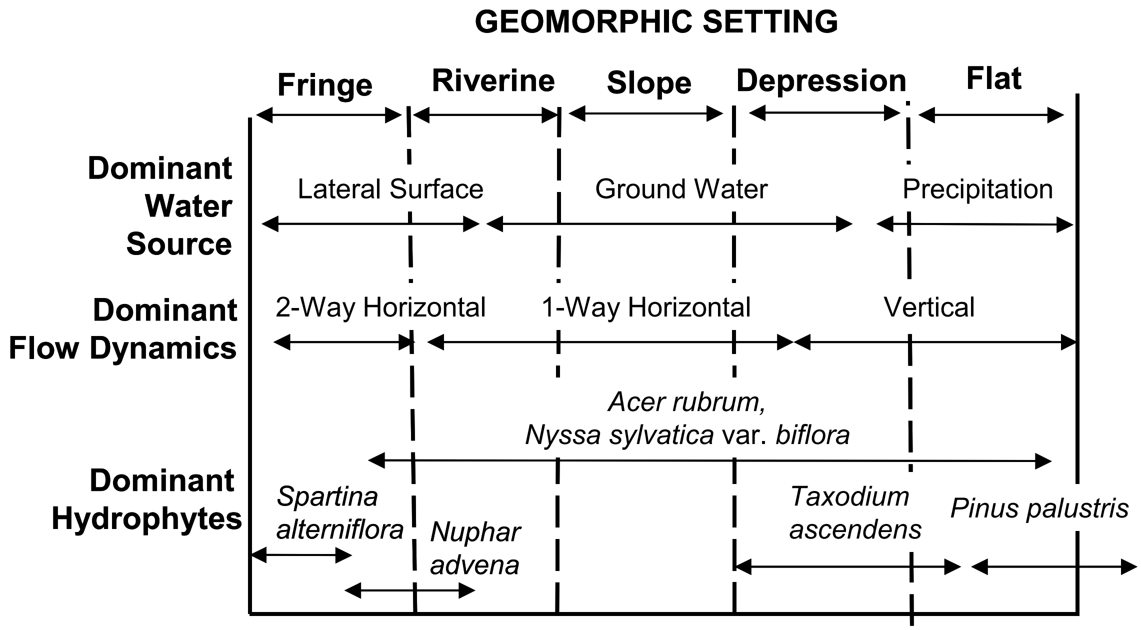

NY
PA
NJ
MD
DE
WV
VA
NC
Appalachian Plateaus
Ridge & Valley
Piedmont
Coastal Plain
States
Physiographic Province
Study Area Basins
Chesapeake Bay
Delaware Bay
Pamlico Sound
0
200
400 Kilometers

Figure 2.


GEOMORPHIC SETTING
Fringe
Riverine
Slope
Depression
Flat
Dominant Water Source
Lateral Surface
Ground Water
Precipitation
Dominant Flow Dynamics
2-Way Horizontal
1-Way Horizontal
Vertical
Acer rubrum, Nyssa sylvatica var. biflora
Dominant Hydrophytes
Spartina alterniflora
Nuphar advena
Taxodium ascendens
Pinus palustris