Hydrogeomorphic Model Building Process

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INTRODUCTION

The accompanying modules contain the most recent iterations of functional assessment models, variable, and sampling protocols for selected hydrogeomorphic (HGM) subclasses of wetlands in selected ecoregions of Pennsylvania and adjacent states. Development of these models relied, in part, on a set of reference wetlands (n = 222) located throughout Pennsylvania. These were established by the faculty, staff, and students of the Penn State Cooperative Wetlands Center (CWC).

In the development of these models, we benefited greatly from parallel efforts throughout the U.S. During the early phases of HGM classification and model development, the CWC was assisted by the dedicated work of a regional assessment team (A-Team). The principal members (with original affiliations) were Robert Brooks, Denice Wardrop, Andrew Cole, (CWC); Brian Yanchik, Paul Minkin, Jennifer Moyer (U.S. Army Corps of Engineers, Baltimore District); Charles Rhodes, David Cutter (U.S. Environmental Protection Agency, Region 3); Kenneth Reisinger (Pennsylvania Department of Environmental Protection); and James Kooser (Rettew Associates, Inc.). Other competent individuals joined the A-Team occasionally.

The HGM classification system for Pennsylvania and an earlier set of models and variables were reviewed during a 2-day peer review workshop held during August 1997 in State College, Pennsylvania. The invited participants included local, regional, and national experts, and was funded by USEPA Region 3. The results were summarized in Wardrop et al. (1998).

The CWC applied an alternative approach to the development and calibration of hydrogeomorphic (HGM) modeling. Although we initially drew heavily upon past work reported by the U.S. Army Corps of Engineers and a peer-review workshop held in August 1997, we later focused on using a combination of variables derived from both landscape-level and site-level measurements and observations. Site-level information, in particular, had to be widely obtainable during rapid site visits to the wetlands being evaluated. Those attempting to develop a regional set of HGM models are encouraged to review the process recommended by the U.S. Army Corps of Engineers (Smith and Wakeley 2001).

Model Building Process

The hydrogeomorphic (HGM) approach to the functional assessment of wetlands is based on the development of a suite of mathematical models developed for a specific wetland subclass. These models are simplified representations of ecosystem functions that the wetland may perform and provide a means of comparison to other wetlands in the same regional subclass (Smith and Wakeley 2001). Each mathematical model is made up of variables that represent characteristics that effect how the wetland performs a specific function. Each variable is represented by a variable subindex score ranging from 0 to 1. Model variables are created from indicators that are either qualitatively or quantitatively measured at the site using a standardized rapid assessment protocol (Smith and Wakeley 2001). Thus, HGM functional assessment models are developed at three basic levels, the overall assessment model, the individual variable and the development of a field measurement or indicator that characterizes that variable.

Variable Calibration

An essential component of the development of HGM functional assessment models is the calibration of data collected at reference sites into a model variable subindex. In all cases, the subindex range is from a low score of zero to a high score of one (Smith et al. 1995). However, in theory, these scores can represent two different assumptions. The first assumption is that sites are scored relative to conditions at the sites that have the least amount of human alteration (i.e., reference standard sites). The second assumption is that sites are scored based on what theoretically will cause the site to perform the function at optimum levels. In our models, the calibration of variables, and the use of either assumption is based on the indicator's response to our disturbance score.

If an indicator shows a relationship with the disturbance score, then the variable subindex is developed with a score of 1.0 representing conditions at reference standard sites and a score of zero representing a site that is not performing the function at all. Scores between zero and 1.0 represent deviations from the reference standard conditions. This assumption can be supported by a strong correlation between human disturbance and the indicator. This relationship is often illustrated using an ecological dose response curve, with the "response" of the data plotted against the "dose" of human disturbance (Figure 1.) (Karr and Chu 1999). When the relationship between our human disturbance score and the indicator were strong, we scored the data using a continuous scoring method (Rheinhardt et al. 1997), where the score for all sites is standardized based on the average of the reference standard sites. This assumes a linear relationship between disturbance and the indicator. Whenever possible, we set reference standard sites equal to 1.0, but in some cases we let the data array display the appropriate score for reference standard sites. This approach assumes that there may be other sites, not studied, that would have higher and, most likely, lower levels of function than sites contained in the reference set of wetlands.

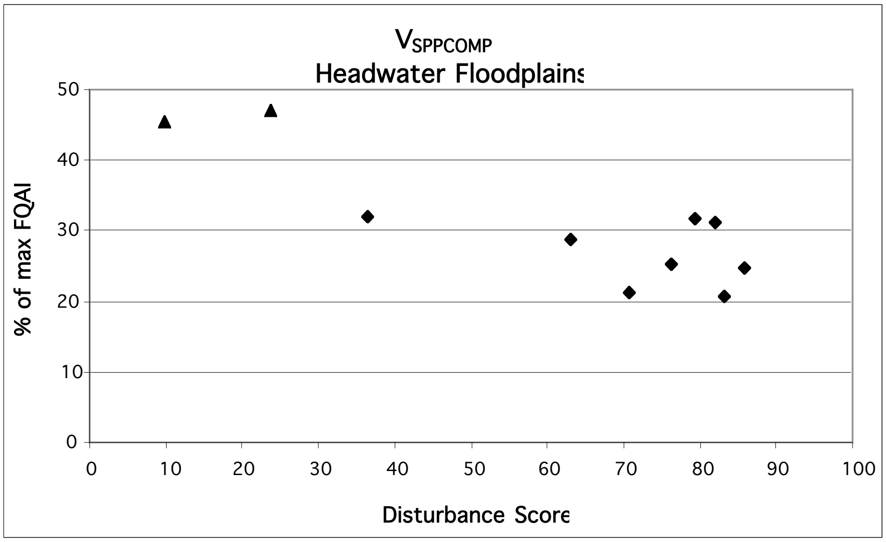
An obvious relationship with disturbance is not always apparent due to variability at the reference standard sites, and the fact that disturbance may not have an affect on some indicators. For example, the variable V_{MACRO} is represented by an estimate of the amount of macrotopographic depressions (macro-depressions) present at a site. Our data show that there is no relationship between the percent of macro-depressions and our disturbance score (Figure 2). When this lack of correlation was encountered, we used the second assumption. This assumption is based on what is known about conditions that would allow a site to theoretically function at the highest level. When conditions represent these high levels of functioning, the variable receives a score of 1.0 and conditions that represent lower levels of function will receive a score closer to zero. Using the example from above, even though there is no relationship to disturbance we assumed that the more macro-depressions present at a site the better a site stores surface water for long periods of time (Function 2). Therefore, a site with a relatively high percent of macro-depressions receives a score close to 1.0, based on the fact that it is functioning at a higher level than a site with few macro-depressions. Due to the lack of a relationship between disturbance and the indicator, the data are scored categorically based on the level of functioning rather then continuously based on reference standard conditions. It should be noted that use of this alternative assumption may change the interpretation of the results of the model. It becomes possible for wetlands with low disturbance to perform a function at the same level as wetlands with high disturbance. Therefore, instead of possibly predicting a change in the function as disturbance changes, the function simply characterizes the level the wetland is performing the function relative to other wetlands in the same regional subclass.

When appropriate, data were calibrated assuming a linear relationship with disturbance on a continuous scale. As a result, 12 out of 22 variables were scored continuously (Table 1). It is important to remember the even though a method based on highest functioning conditions may not be ideal, chances are that any one categorically scored variable will be combined with a continuously scored variable in the final function equation.

In some cases, recognized functions proved difficult to characterize with data collected rapidly in the field. Regarding hydrologic functions, we illustrate typical hydrologic regimes for each HGM subclass where data are available. We present typical hydrographs from reference standard sites. Generally, quantitative data on the hydrology of most wetlands will not be available, so hydrologic functions must be derived from field observations.

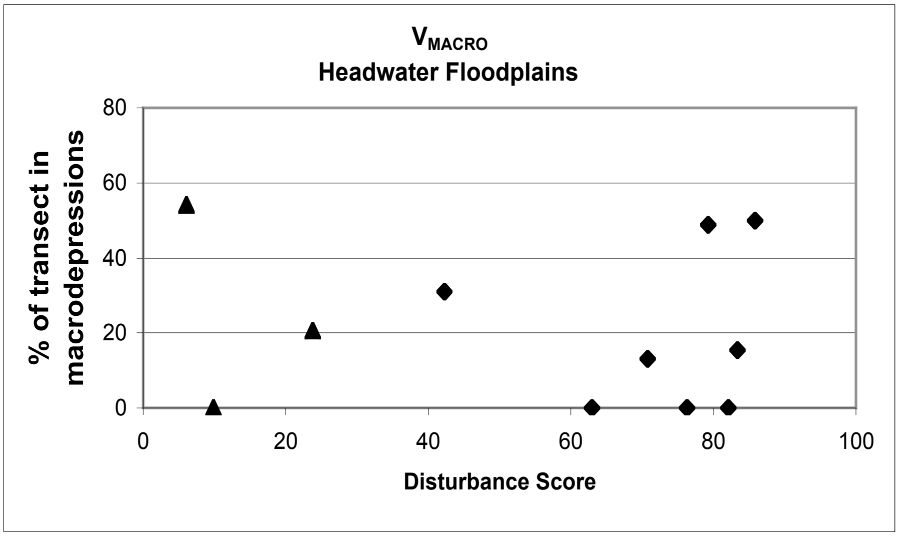
The provision of wildlife habitat is an oft cited function of wetlands. Yet, we seldom have resources to census a diverse wildlife community. A commonly used alternative is to assess potential wildlife use with Habitat Suitability Index (HSI) models (USFWS 1980, Morrison et al. 1992, Anderson and Gutzwiller 1994). The use of HSI models and the associated Habitat Evaluation Procedures (HEP) to assess habitat quality for a single species of wildlife, is widespread. Biologists engaged in environmental impact assessment and regulatory permit reviews make daily decisions about managing wildlife and their habitats, but seldom have the time, nor funds to measure specific habitat characteristics for each species of interest (Schamberger and Farmer 1978). For the function representing wildlife use of wetlands (Function 11), we adopted the parallel approach of Habitat Suitability Index (HSI) models. Variables and calibration procedures for this function were conducted independently from the process used for the other functions. The process used is described below in a separate section. The actual models used, originally produced by Brooks and Prosser (1995), are presented as part of the section on sampling protocols (II.B.3.a.).

Figure 1. An example of a dose-response curve for data with a relationship to disturbance. The model variable subindex was developed using a continuous scoring system based a linear relationship between disturbance and the variable.



_ = Reference Standard Sites

Figure 2. Data with no response to disturbance and high variability among reference standard sites. The model variable subindex was developed using a categorical scoring system based on high levels of functioning.



_ = Reference Standard Sites

Table 1. Model variables and their method of scoring.

Variable	**Method**	**By Subclass**
V_{AQCON}	Categorical	Yes
$V_{BIOMASS}$	Continuous	Yes
$V_{CWD\text{-}BA}$	Continuous	Yes
$V_{CWD\text{-}SZ}$	Categorical	No
V_{EXOTIC}	Continuous	No
V_{FLOODP}	N/A	N/A
V_{FWD}	Categorical	No
V_{GRAD}	Categorical	No
$V_{HYDROCHAR}$	N/A	N/A
$V_{HYDROSTRESS}$	Categorical	No
V_{MACRO}	Categorical	No
V_{MFPS}	Continuous	No
V_{ORGMA}	Categorical/Continuous	Yes
V_{RDDEN}	Continuous	No
V_{REDOX}	Categorical	No
V_{REGEN}	Continuous	Yes
V_{ROUGH}	Continuous	Yes
V_{SDI}	Continuous	No
V_{SNAG}	Categorical	No
$V_{SPPCOMP}$	Continuous	Yes
V_{TEX}	Categorical	No
$V_{UNDEVELOP}$	Continuous	No
$V_{UNOBSTRUC}$	Continuous	No
V_{URB}	Categorical	No

HABITAT SUITABILITY INDEX (HSI) MODELS

For HGM Function 11 – Maintenance of Vertebrate Communities, we adopted HSI for a standard set of 10 wetland-dependent species (Brooks and Prosser 1995) as a means to estimate the level of wetland functioning as wildlife habitat.

HSI models are designed to evaluate habitats quickly and efficiently. Each HSI model is composed of a set of variables related to known habitat requirements, such as food, cover, and breeding substrate. Individual habitat variables are scored on a standard scale from 0 to 1. A composite HSI score is computed, also in a range of 0 to 1, to determine the overall habitat suitability of a site for a given species. If HEP are used, the HSI scores are multiplied by the area of habitat under consideration to generate habitat units (HU) for a single species. Often, these are summed across species to generate HUs for an entire project assessment or management activity. The sum of all HUs represents the amount of habitat lost, impacted, or created depending on the project.

For most assessments, models for several target species are selected and evaluated separately for each type of habitat, such as emergent marsh or forested wetland. Our goal was to assess the function of maintaining characteristic vertebrate communities of natural reference wetlands across vegetative types and disturbance levels for use in a variety of applications such as assessing the level of wetland function using the HGM approach and for evaluating performance of restoration, creation, and mitigation projects. We were not interested in simply replacing equivalent numbers of HUs, but rather, we wanted to determine if certain components of the available habitat might be missing, resulting in a change in suitability for a portion of the wetland wildlife community. Also, we wanted to rapidly assess the potential habitat for the wildlife community without using extensive inventory techniques.

During this project, we discovered a need to have a standard set of species by which all wetlands could be compared, regardless of type or condition. Thus, we developed a Wildlife Community Habitat Profile (WCHP) composed of 10 species chosen to represent a wide range of taxa, trophic levels, and habitats that span the vegetative and disturbance conditions found in freshwater, inland wetlands of the northeastern U.S. (Table 2). We applied the WCHP to all wetland types and sites, thereby providing a means for consistent comparisons among sites. By scoring all species on all sites, a standard quantitative and visual method of assessing habitats can be applied. Results can also be used to suggest improvements in the designs for created wetlands.

Model Selection

From the available pool of "blue book" models developed by the U.S. Fish and Wildlife Service (1980) and similar regional adaptations, such as the Pennsylvania Modified Habitat Procedures (Pennsylvania Game Commission 1982), we selected models for common species whose habitat preferences span both the vegetative and hydrologic gradients found in inland, freshwater wetlands typical of the northeastern U.S. We used a standard set of 10 wildlife species for the WCHP, that included bullfrog *(Rana catesbeiana)*, muskrat *(Ondatra zibethicus)*, meadow vole *(Microtus pennsylvanicus)*, red-winged blackbird *(Agelaius phoeniceus)*, American woodcock *(Philohela minor)*, common yellowthroat *(Geothlypis thrichas)*, green-backed heron *(Butorides striatus)*, wood duck *(Aix sponsa)*, wood frog *(Rana sylvatica)*, and red-backed vole *(Clethriononmys gapperi)*. The species were arranged graphically according to preferred vegetative cover type (Table 2).

The advantages of using the wildlife community habitat profile method include: 1) selection of species models no longer has to be tailored to each site; 2) comparisons among sites are consistent across the same set of species; 3) visual representation of the wildlife community is produced for each site (Figure 3), and 4) the vegetative diversity inherent in most wetlands is accounted for by using this diverse set of models.

Figure 3. Example for a Wildlife Community Habitat Profile for a reference emergent wetland.

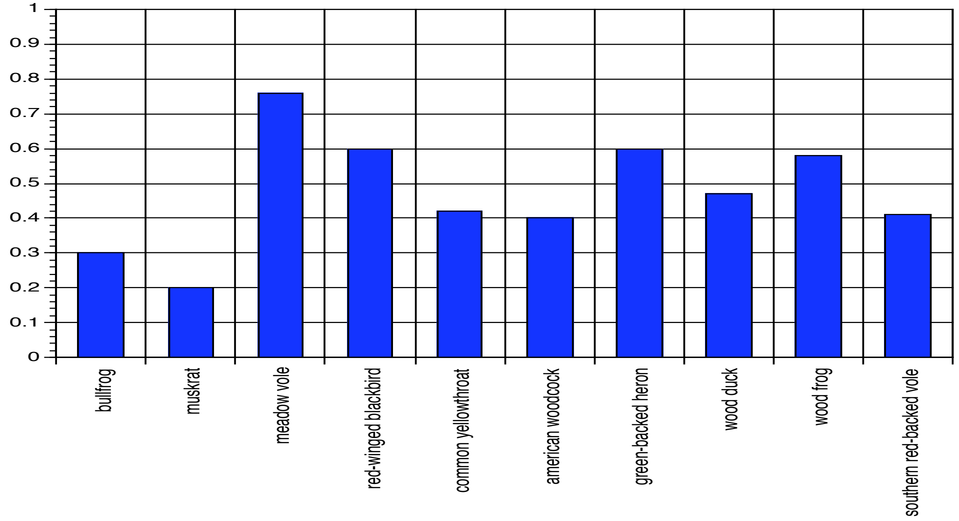


Table 2. Ten wildlife species used as models to evaluate wetland habitats.

COMMON NAME	SCIENTIFIC NAME	TAXONOMIC GROUP	TROPHIC LEVEL
OPEN WATER (WITH SOME EMERGENT ALLOWED)			
bullfrog	*Rana catesbeiana*	amphibian	carnivore
muskrat	*Ondatra zibethicus*	mammal	herbivore
EMERGENT (WITH SOME OPEN WATER OR SHRUBS ALLOWED)			
meadow vole	*Microtus pennsylvanicus*	mammal	herbivore
red-winged blackbird	*Agelaius phoeniceus*	bird	granivore
SCRUB-SHRUB (WITH SOME EMERGENTS OR FORESTED WETLAND ALLOWED)			
American woodcock	*Philohela minor*	bird	invertivore
common yellowthroat	*Geothlypis thrichas*	bird	insectivore
green-backed heron	*Butorides striatus*	bird	carnivore
FORESTED WETLAND (WITH SOME SHRUBS OR EMERGENTS ALLOWED)			
wood duck	*Aix sponsa*	bird	herbivore
wood frog	*Rana sylvatica*	amphibian	carnivore
red-backed vole	*Clethriononmys gapperi*	mammal	herbivore

Model Calibration and Validation

Despite widespread use, HSI models are seldom evaluated for internal consistency (calibration and verification) or field-tested (validation)(Brooks 1997). We identified problems with some models in that their scores did not reflect the full range of habitat conditions on which they were ranked. Thus, we used a calibration procedure to improve model performance and sensitivity. For our 10 models, we evaluated each model's responsiveness to variability in vegetation and disturbance level based on actual sites. If model scores did not accurately reflect the range of conditions observed, variable scoring or model equations were modified. The HSI score for each model was determined for several sites (usually 6 sites) ranging from pristine to severely disturbed. If the scores did not vary across the full range of nearly 0 to 1, we modified the equations (but not the variables) to produce a responsive model. In a few cases, when new information warranted, we modified variables to improve a model. We believe this form of calibration improves the utility of the models for assessing a wide range of habitat quality without altering the essential requisites of each species. Further suggestions on model verification and validation are discussed in Brooks (1997). At this time, we believe the models presented here (II.B.3.a.) adequately represent conditions across the range of wetland-riparian habitats in the mid-Atlantic and northeastern states.

TRANSFERABILITY TO ECOREGIONS

The HGM methods presented here were first developed in the Ridge and Valley ecoregion of Pennsylvania. These methods were then applied to the remaining ecoregions of Pennsylvania. We believe that the ability to transfer the HGM methods to different ecoregions across the state is dependent on the ability to answer three basic questions:

1) Are the functional assessment models transferable across ecoregions?
2) Are the model variables transferable across ecoregions?
3) Are the indicators transferable across ecoregions?

Development of models and variables was accomplished by the culmination of best professional judgment of experts in the field of wetland ecology and a review of the literature on individual functions and the ecosystem properties that affect them. Since development of both of these is primarily theoretical, we believe that functional models and the variables that they are composed of can transfer readily to all ecoregions in Pennsylvania. Table 3 gives a summary of the functions used and their applicability to each HGM subclass. This applicability remains the same regardless of ecoregion. We believe that the most variability across ecoregions lies in the indicators that are used to characterize each variable. Table 4 addresses this question of indicator transferability for each ecoregion and subclass. This table specifies which variables have indicators that can be directly transferred to other ecoregions, which variables have indicators that can be transferred, but with minor adjustments to the scoring method, and which variables could possibly use further investigation to develop a more appropriate, region specific indicator.

Table 3. Summary of functions and their applicability to HGM subclass for all ecoregions

	HGM Subclass					
Functions	**Headwater Floodplain**	**Mainstem Floodplain**	**Slope**	**Riparian Depression**	**Isolated Depressions**	**Fringing**
Hydrologic Functions						
F1 - Energy Dissipation/ Short-tern Surface Water Detention	X	X	X			
F2 - Long-term Surface Water Detention	X	X				
F3 - Maintanence of Characteristic Hydrology			X	X	X	X
F4 - Reserved for alternative hydrology function						
Biogeochemical Functions						
F5 - Removal of Imported Inorganic Nitrogen	X	X	X	X	X	X
F6 - Solute Adsorption Capacity	X	X	X	X	X	X
F7 - Retention of Inorganic Particulates	X	X	X			X
F8 - Export of Organic Carbon (dissolved and particulate)	X	X	X	X		X
Biodiversity Functions						
F9 - Maintanence of Characteristic Plant Community Composition	X	X	X	X	X	X
F10 - Maintanence of Characteristic Detrital Biomass	X	X	X	X	X	X
F11 - Vertebrate Community Structure and Composition	X	X	X	X	X	X
F12 - Maintanence of Landscape Scale Biodiversity	X	X	X	X	X	X

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