Wetlands Sampling Protocol in support of Hydrogeomorphic (HGM) Functional Assessment

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1.0 INTRODUCTION

This rapid assessment sampling protocol (RAP) was developed by the Penn State Cooperative Wetlands Center (CWC) during the development of Hydrogeomorphic (HGM) Functional Assessment Models. You are welcome to revise the protocol for use in other geographical regions, but please cite the original according to the above title. Contact the CWC for additional information at the address listed above.

This protocol is intended for characterization of wetlands or portions of larger wetlands approximately 0.4 ha (1 acre) in size. The protocol may be altered to accommodate wetlands larger or smaller in size. All information is gathered along a series of transects on which grid points are evenly spaced at 20 m (65.6 ft) intervals. A minimum total transect length of 100 m (328 ft) is suggested. To adequately characterize a wetland of this size, 8 to 12 plots (grid points) should be established. An absolute minimum of six plots should be characterized. If the wetland is smaller than 0.4 ha (1 acre), grid points can be spaced at 10 m (32.8 ft) intervals to achieve the minimum of six grid points. Note that if a grid is spaced at 10 m intervals, characterization of the tree community will have to occur at every other grid point to avoid overlapping of plots (see vegetation sampling portion of the protocol for more information). If the wetland is significantly larger, grid points can be spaced at 30 m (98.4 ft) or 40 m (131.2 ft) intervals. The orientation of the transects is discussed in more detail in a subsequent section. If the wetland is located adjacent to a stream, at least one transect should cross the stream itself in order that stream topography can be characterized.

Variables derived from the data collected for use in HGM models are indicated in each section. Definitions for those variables are listed near the end of this protocol. The Habitat Suitability Index (HSI) Models used for Function 11 are presented separately at the end of this module (Brooks and Prosser 1995).

2.0 FIELD SAMPLING (all measurements to be in metric units, English units are provided for comparison only)

Field sampling methods are presented in detail in the following sections, and are organized by activity type (i.e., mapping, plant sampling, soils, etc.). The field sampling protocol is designed to provide all the necessary information for either rapid reference site characterization or Hydrogeomorphic (HGM) functional assessment. The appropriate variables needed when using the protocol for HGM functional assessment are presented with the relevant portion of the field sampling protocol. For example, the statement, "measure and record the height and radius for all shrubs", indicates the part of the process by which the variables $V_{BIOMASS}$, V_{REGEN}, and V_{ROUGH} are developed. Therefore, $V_{BIOMASS}$, V_{REGEN}, and V_{ROUGH} are indicated in parentheses after the portion of the protocol that describes sampling of the shrub community. Expanded descriptions of each variable included in the HGM functional assessment process are appended to this RAP. The methodology assumes that general site reconnaissance has been completed prior to the initiation of field sampling efforts.

2.1 Baseline and Base Map

- Establish a baseline in an obvious and convenient location parallel to the long axis of the wetland, allowing some upland area between baseline and expected wetland area. Under certain conditions, it may be necessary to establish a baseline in the interior of the wetland (e.g., for reasons of visibility, etc.)
- Starting and ending points should be marked with a reinforcing rod (rebar) or other obvious permanent marker.
- The sketch or base map should include the following features (other important site features should be recorded as necessary):
    - North arrow
    - Position and endpoints of baseline
    - Length (to nearest m or ft) and azimuth of the baseline
    - Approximate location and length of transects, and distance between transects
    - Location and direction corresponding to site photographs
    - Approximate wetland boundary (does not require jurisdictional determination)
    - Wetland vegetative communities that can be differentiated (to 0.04 ha [0.1 ac])
    - Adjacent roads, trails, utility lines, large depressions, debris piles, etc.
    - Features of hydrologic interest such as inlets/outlets, streams, culverts, etc.

- A simple sketch map of the site, with the major features labeled, will be adequate for most applications. However, if an accurate base map is desired and is not already available, one may be created using basic surveying methods (transit, plane table, stadia rod recommended). These procedures are not described in this protocol, but are available from a number of resources.

2.2 Transects

- Using random number generator/table, select the end point of the first transect (to nearest 0.1 m or ft) on baseline. Transects traverse the entire expected wetland area into upland on far side, or to edge of study area. If the wetland is adjacent to a stream, at least one transect should traverse the stream if possible. Transects are generally perpendicular to baseline.
- The remaining transects are established at uniform intervals along the baseline (typically 20 m [65.6 ft], but 5 m [16.4 ft] or 10 m [32.8 ft] can be used on small sites or 40 m [131.2 ft] on large sites). Number of transects depends on area of wetland. For each transect, record starting point on baseline.
- Choose a transect that traverses a representative portion of the wetland as a center transect. There is no minimum length for the center transect, but it should traverse the study area up to a maximum length of 100 m (328 ft).

2.3 Plots

- Using the same intervals as the intervals between each transect, mark grid points (plot centers) along each transect with flags or stakes, keeping to one side (typically the right side) of the transect to avoid trampling vegetation sampling plots. Sampling plots are located at grid points along each transect. Label as T1-1 (Transect 1 - Plot 1), T1-2, T1-3, ..., T2-1 (Transect 2 - Plot 1), etc.

NOTE: In most cases, grid points along each transect should be positioned at the same intervals. However if in setting up the sampling grid, a community type is not represented, plots may be established at shorter or longer intervals to characterize the omitted community.

2.4 Plant Sampling ($V_{BIOMASS}$, V_{EXOTIC}, V_{REGEN}, V_{ROUGH}, V_{SNAGS}, $V_{SPPCOMP}$)

Plots are typically located on the left side of the transect to avoid trampling during characterization activities and grid layout. If the left side of the transect is trampled or lies outside the wetland, affected plot(s) should be placed on the right side of the transect. Three sizes of plots are used to record various measures of the plant community: a 1 m^2 plot, a circular plot with a radius of 3 m (10 ft), and a circular plot with a radius of 11.3 m (38 ft). The plots are "nested", meaning that the 1 m^2 plot is inside the circular plot with a radius of 3 m (10 ft), and this plot is inside the circular plot with a radius of 11.3 m (38 ft). Plants should preferably be identified to species. A representative sample of any plants that cannot be identified in the field should be labeled, pressed and brought back to the lab to be keyed out. The activities in each plot are described separately as follows. We recommend that a random selection of 10% of identified/collected species be kept as voucher specimens to confirm identifications independently.

Trees are defined as any single-stemmed woody species that are greater then 2 cm diameter at breast height (dbh). Shrubs are defined as all multi-stemmed woody species, as well as single stemmed woody species that are less then 2 cm dbh. Any woody species that are less then 0.3 m should be counted in the herb layer.

1 m^2 plot

- Within each plot (2 m x 0.5 m; 6.5 x 1.5 ft), visually estimate the percent cover to the nearest 5% for dominant plant species. Dominant species are defined as those plant species with percent cover estimates exceeding 5% in the 1 m^2 plot. Plant species that are present in the 1 m^2 plot but have less then 5% cover should be included in the 3 m radius plot or can be listed as "trace" in the 1m^2 plot. Record % cover and species name on data sheet (V_{REGEN}, $V_{SPPCOMP}$, V_{EXOTIC}).

3 m radius plot

- To gather data about additional species for species richness, note any other vascular plants observed within a 3 m (10 ft) radius plot centered on the plot point. Also record species in the 1m^2 plot with less then 5% cover for later tally of total number of species and species list (V_{REGEN}, $V_{SPPCOMP}$, V_{EXOTIC}).
- Measure and record the height and radius for all shrubs (or clusters of shrubs) and saplings in a 3 m (10 ft) radius plot centered on the plot point ($V_{BIOMASS}$, V_{REGEN}, V_{ROUGH}). A shrub is defined as any single stemmed woody plant less than 3 cm dbh, or a multi-stemmed woody plant regardless of height (e.g., rhododendron).

11.3 m radius plot

- In wetlands where mature trees are present (natural, planted, volunteer), use a Biltmore stick (or similar tool) to measure and record the dbh to the nearest 1 cm minimum for each individual within a 11.3 m (38 ft) radius circle centered on plot (note: dbh is defined as the stem diameter 1.3 m [4.24 ft] above the ground surface). Standing dead trees should be recorded as "snag" and the dbh measured. ($V_{BIOMASS}$, V_{EXOTIC}, V_{REGEN}, V_{REGEN}, $V_{SPPCOMP}$, V_{SNAGS}).

- Visually estimate and record both the percent herbaceous cover and crown closure within the 11.3 m (38 ft) radius circle plot ($V_{BIOMASS}$, V_{ROUGH})
- In wetlands where transects are 10m apart or where the information being collected is redundant with another plot due to overlap the tree data and visual estimates should be skipped for that transect.

2.5 Soil Sampling (V_{ORGMA}, V_{REDOX}, V_{TEX})

- After transects and plots are mapped, select every other plot for locating soil pits. Soil pits should be characterized after vegetation sampling is completed at a particular plot to minimize trampling of the vegetation. A minimum of 3 soil pits in the wetland should be characterized for a wetland 0.4 ha (1 acre) in size. .
- Dig the soil pit to at least 0.5 m (18 in) within 2 m (6 ft) of the 1 m^2 vegetation plot. At 5 cm (2 in) and 20 cm (8 in) below the O horizon record the following on the data sheets:
  - The dominant matrix and mottle colors and percent mottling (V_{REDOX}).
  - Direct observation of oxidized root channels.
  - An observation of the soil texture (sand; loamy sand; sandy loam & loam; silt loam & finer) using standard field method (see appended sheet) (V_{TEX}).
  - Determine and record the relative wetness of soil.
  - Describe any other hydrologic or hydric soil characteristics observed that would indicate anaerobic activity such as gaseous emissions, strong gleying, or presence of histosols (refer to technical criteria in delineation manuals or other current sources).
  - Describe the soil profile in the pit (make sketch on data sheet of characteristics associated with the varying depths to nearest 1 cm or 1 in).

- Collect soil samples for texture analysis and organic content (V_{ORGMA}) from the sides of the pit at 5 cm (2 in) or less and 20 cm (8 in) depths below the O horizon. Fill at least half of a one quart Ziploc bag (250 ml [8 oz.] minimum) and label with date, site, plot, and depth information.

2.6 Wetland Morphometry (V_{CWD-BA}, V_{CWD-SZ}, V_{MACRO}, V_{ROUGH})

- Estimate the expected wetland area (nearest 0.1 ha or ac). If the wetland is greater then 1.0 ha, estimate the area from aerial photographs.
- Create a detailed microtopographic profile of the wetland by recording relative elevations (nearest cm) taken every meter on the center transect with a 100 m (300 ft) tape and

transit and stadia rod (or comparable method). The location of the transect profile should be recorded on the map (V_{MACRO}, V_{ROUGH}).

- Walk the center transect and count and record the occurrence of downed woody material that crosses the transect (V_{CWD-BA}, V_{CWD-SZ}). If center transect is less then 50 m then multiple transects may be walked and results tallied separately for each transect. Record the length of each transect in meters and indicate the transect number. Remember to keep to one side (typically the right side) of the transect to avoid trampling vegetation sampling plots. Downed material should be tallied by the following size classes:

  Branches and Fallen Saplings (1-12 cm; 0.4-4.7 in. diameter)
  Trees (>12-40 cm; 4.7-15.6 in. diameter)
  Large Trees (>40 cm; 15.6 in. diameter)

<u>2.7 Stream Map</u> (when applicable)

- For floodplain sites, walk a 100 m stream section noting all inlets and outlets. Include a rough sketch of the stream–wetland complex.

<u>2.8 Photographs</u>

- Establish at least three, numbered, permanent photo stations per wetland. One should be a general overview of the site from an accessible vantage point. Another must be a view of typical vegetation in the study area. The third photograph should be taken of the central transect from the instrument. Additional photographs of: typical plots, examples of hydrologic indicators, unusual and problem areas, aerial photographs, etc. are recommended. Mark photo stations on the map, including a directional arrow.

<u>2.9 Faunal Sampling</u> (V_{FWD}, Function 11)

- Record direct and indirect observations of wildlife, fish, and macroinvertebrates during the course of site visits (e.g., animals, tracks, scat).
- Using a suite of 10 modified habitat models, which together form a Wildlife Community Habitat Profile (Brooks and Prosser 1995). Assess the suitability of the habitat for vertebrate species in late summer or by the end of the growing season. Model species include the bullfrog, muskrat, meadow vole, red-winged blackbird, common yellowthroat, American woodcock, green-backed heron, wood duck, wood frog (V_{FWD}), and southern red-backed vole. Assess all species for each site, even if a species is not likely to be found at that particular wetland. For the muskrat, select between marsh or stream models based on conditions at the immediate sample site.

- Two individuals must evaluate the habitat independently. If their values are greater than 0.3 units apart, they must negotiate the difference. The average of their values will be recorded. Values are standardized on a 0.0 - 1.0 scale. See Brooks and Prosser (1995) for models and sampling details.

2.10 Stressor Checklist ($V_{HYDROSTRESS}$, $V_{UNOBSTRUC}$)

For each site a stressor checklist must be filled out. Check indicators that are present at the site for each stressor category. A stressor score is calculated by totaling the number of stressor categories checked. The average buffer width around the site and a characterization of buffer type is also recorded to determine a buffer score.

2.11 Landscape Interpretation (V_{AQCON}, V_{GRAD}, V_{MPS}, V_{SDI}, $V_{UNDEVEL}$, $V_{UNOBSTRUC}$)

For this information, previous work at the CWC (Brooks et al 2004) has utilized a 1-km radius circle around each site to provide the necessary landscape information. This size area was selected because it readily encompassed contributing watershed area for most wetlands, data were relatively easy to obtain, and a 1-km circle matches many biological sampling regimes. The landscape within a 1-km radius circle of each wetland is characterized based on interpretation of 1:40,000, color infrared, aerial photographs. Areas are mapped using seven cover type categories: developed, agricultural, barren, shrub, forest, wetland, and open water. Once data are digitized, a modified version of the SPAN (Spatial Analysis) computer program can be used to process and quantify a number of landscape characteristics: diversity, dominance, contagion, length of forest/nonforest edge, and percent cover, average patch size, and number of patches for each cover type category.

Variables Utilized in the Hydrogeomorphic Functional Assessment

V_{AQCON}

Definition: The degree of aquatic connectivity (streams, wetlands, water bodies) in a 1-km radius circle.

Protocol: Composed of the following three sub-variables:

100FLOOD – presence of wetland in 100 year floodplain (score 0 or 2)

STR INDEX – presence of streams in 1km radius circle (score 1-4)

NEAR DIST – distance to nearest NWI wetland (score 1-4)

These are totaled to get a score between 0 and 10, which is converted into the variable subindex.

$V_{BIOMASS}$ – made up of three sub-variables

Definition: A combination of percent cover of trees, shrubs, and herbs is used to indicate vegetative biomass at the site as well as an indicator of vegetative cover in the roughness variable. A complete explanation of each of these subvariables follows the general protocol for calculating $V_{BIOMASS}$.

Protocol:

% tree – Use the dbh of all trees and saplings in a 11.3 m radius plot centered on plot point to calculate basal area. Average basal area per plot is divided by the total plot area to get a % basal area per plot. This percentage is standardized to make it comparable to shrubs and herbs.

% shrub - Record the height and a circular projection of cover (crown) for all shrubs and saplings in a 3 m radius plot centered on the plot point. % Cover is calculated by using the radius to calculate area and finding an average shrub area per plot. This is divided by the total plot area to get % shrub area per plot.

% herb – Estimates of the percent herbaceous cover within a 11.3-m radius circle centered on sampling plots are made visually and recorded.

% tree - using in combination with shrubs and herbs

Definition: The percent basal area of vegetation in the tree stratum. Trees are defined as single stemmed woody plants with a dbh greater than 2 cm dbh.

Protocol: Percent tree requires recording the dbh of the trees present in 11.3-m radius plot

% shrub - using in combination with trees and herbs

Definition: The percent cover of vegetation (including tree reproduction) in the shrub stratum. A shrub is defined as any single stemmed woody plant less than 2 cm dbh, or any multi-stemmed woody plant regardless of height (e.g., rhododendron).

Protocol: Measure the height and a circular projection of cover (crown) for all shrubs in a 3-m radius plot centered on the plot point.

% herb–using in combination with shrubs and trees

Definition: Percent cover of persistent herbaceous vegetation (including tree reproduction) in the herbaceous stratum.

Protocol: Estimates of percent herbaceous cover within an 11.3-m radius circle centered on plot are made visually and recorded.

V_{CWD} – split into two variables, estimate of basal area ($V_{CWD\text{-}BA}$) and abundance ($V_{CWD\text{-}SIZE}$)

$V_{CWD\text{-}SIZE}$ – presence of CWD in each of the size classes.

Protocol: Count the occurrence of downed woody material that crosses the central transect in the following size classes:

Branches and Fallen Saplings (1-12 cm; 0.4-4.7 in. diameter)

Trees (>12-40 cm; 4.7-15.6 in. diameter)

Large Trees (>40 cm; 15.6 in. diameter)

This number is divided by the length of the transect to calculate a number per unit area.

$V_{CWD\text{-}BA}$ – An estimate of area covered by CWD.

Protocol: An estimate of average basal area is calculated for each size class above using the midpoint of the two smaller size classes, 6.5 cm (2.5 in.) and 26 cm (10.5 in.), respectively. The basal area estimate for the largest size class is determined by averaging the dbh of live trees >40 cm (16 in.) in diameter at the site.

V_{EXOTIC}

Definition: Ratio of native vascular plant species to exotic and invasive vascular plant species present at the site.

Protocol: A plant list is generated for each site using data recorded in 1 m^2, 3-m radius, and 11.3-m radius plots. The ratio of native vascular plant species to exotic and invasive vascular plant species is calculated to determine % of species present that are invasive.

V_{FLOODP}

Definition: Opportunity for flooding and actual evidence of flooding at a site.

Protocol: Possible indicators would include such things as, visual assessment of whether or not the site is experiencing flooding, measurements of bankfull width and floodprone area.

V_{FWD}

Definition: A visual estimate of depth of litter layer from HSI models.

Protocol: Use score from variable three in the woodfrog habitat model (see Brooks and Prosser 1995).

V_{GRAD}

Definition: An indicator of the elevational gradient of the topography up and down stream from a floodplain site.

Protocol: A count of the number of contour lines that are crossed by a stream 1 km upstream and 1km downstream from the site using topographic maps.

$V_{HYDROCHAR}$

Definition: Characteristics at a site that would indicate hydrology is typical of reference standard conditions

Protocol: Indicators such as monitoring well data, or visual assessments of hydrologic conditions that are typical of a non-riverine system could be used here.

$V_{HYDROSTRESS}$

Definition: Modifications and stressors that may affect the hydrology of a site.

Protocol: Count of the number of hydrologic modification indicators from the stressor checklist.

V_{MACRO}

Definition: Macrotopographic relief is used to indicate potential extent and depth of water that can be stored by inundation in pits and/or other depressions.

Protocol: Identify and count the number of macrotopographic depressions encountered along the microtopography transect. Macrotopographic depressions are defined as depressions that are at least 15 cm deep for 1 m in length along transect. Divide the total length of all macrodepressions by the total length of the transect to get a percentage.

V_{MFPS}

Definition: Mean forested patch size in a 1-km radius circle around the site

Protocol: Subindex scores are calculated by dividing the patch size of forested area by the total possible patch size (i.e. if the site was 100% forested).

V_{ORGMA}

Definition: The amount of organic matter in a sample taken from the top 5 cm of the soil pit (below the organic layer).

Protocol: Organic content of the top 5 cm of soil sample for soil pit as determined by ashing.

V_{REDOX}

Definition: The presence of redoxymorphic features in upper portion of the soil profile.

Protocol: Determine from the direct observation of soil characteristics at soil pits. The chroma of the mottles and the matrix are used as indicators of soil moisture conditions.

V_{REGEN}

Definition: The evidence of regeneration of dominant canopy species in each stratum.

Protocol: Examine shrub and herbaceous layers for evidence of regenerating tree species. Trees less than 10 cm dbh are considered in the shrub/sapling layer. Sites are scored based on the presence of trees in the herb, shrub and tree layer.

$V_{ROUGHNESS}$

Definition: This is based on Manning's roughness coefficient (Arcement 1989) and uses a composite weighting score based on source of flow resistance at the site (CWD, microtopography, and vegetation)

Protocol: This variable is a combination of the variables V_{CWD}, V_{MICRO}, and $V_{BIOMASS.}$ However, scoring of each variable is scaled slightly differently than when it is considered as an independent variable.

V_{MICRO}

Definition: Microtopographic complexity is expressed as areas in the wetland that will retain water in a network of pits and/or other topographic low spots. This variable is used only as a subvariable in $V_{ROUGHNESS}$.

Protocol: Identification of elevation changes encountered along the central transect measured at 1 m intervals to nearest 0.00 m using Abney level (or builder's level, or transit), stadia rod, and 100 m tape. Performed on a representative transect, with a maximum transect length of 100 m.

V_{SDI}

Definition: An index of land use types in 1 km radius circle using the natural log of Shannon's Diversity Index.

Protocol: The natural log of Shannon's Diversity Index of land use types is standardized to give a score between 0-1.

V_{SNAGS}

Definition: The presence of dead standing trees in each diameter size class. Size classes are: 0-12 cm, 12-28 cm, 28-40 cm, >40 cm.

Protocol: Record the number and dbh of erect dead woody material in the 11.3-m radius plot .

$V_{SPPCOMP}$

Definition: Use the % of the maximum possible Floristic Quality Assessment Index (Andreas 1995) (hereafter, adjusted FQAI) at each site.

Protocol: Create a species list for each site and calculate the adjusted FQAI score (heareafter, adjusted FQAI) using the following equation:

$$\text{Adj FQAI} = \frac{(R/\sqrt{N})}{(10 * T/\sqrt{T})}$$

where:

Adj FQAI = % of the maximum possible FQAI

R=sum of the COC scores for natives

N=number of different native species recorded

T=total number of different species at the site (natives + exotics)

V_{TEX}

Definition: Soil texture, determined by feel (using standard field methods).

Protocol: This is based on direct observation of soil characteristics in the soil sample pit.

$V_{UNDEVEL}$

Definition: An index of the amount of area not developed in a 1-km radius circle surrounding the site.

Protocol: Made up of % urban area and road density in 1-km circle around the site. Each of these is scored separately then averaged together to come up with $V_{UNDEVEL.}$

$V_{UNOBSTRUC}$

Definition: An index of the amount of area in the landscape around the site and actually at the site that does not have modifications that would affect the natural hydrology.

Protocol: Average scores determined from road density, % urban area in 1-km circle, along with score from $V_{HYDROSTRESS}$.

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Habitat Suitability Index (HSI) Models

INTRODUCTION

Purpose

We compiled a set of habitat models for 10 wetland-dependent wildlife species to be used for making consistent comparisons among wetlands (Brooks and Prosser 1995). By scoring all species on all sites, a standard method of assessing habitats quantitatively and visually can be applied.

Background on Habitat Suitability Index Models

Habitat Suitability Index (HSI) models are written tools used to determine the potential suitability of a habitat for a given species (Anderson and Gutzwiller 1994, Morrison et al. 1992, USFWS 1980, Schamberger and Farmer 1978). They are also used to predict impacts upon a species as a result of changes in environmental conditions (i.e., effects of forest cutting on interior songbirds). HSI models are not designed to predict abundance. They are capable only of determining the potential of a habitat to provide life requisite conditions.

HSI models are designed to evaluate habitats quickly and efficiently. Managers often do not have the time, nor funds to measure specific habitat characteristics, such as prey base, for each species of interest. HSI models, instead, measure habitat on a broader level (food availability, cover, breeding substrate, and water availability). Physical and biological characteristics of a habitat are assigned values ranging from 0.0 to 1.0 (unsuitable to optimal, respectively)(Schamberger and Farmer 1978). A final equation determines the overall habitat suitability of a site by incorporating all of the variables reflected in each of the habitat requisites.

Pennsylvania Modified Habitat Evaluation Procedure (PAMHEP)

Most of the HSI models have been developed for use in specific regions within the United States, thereby making their application to all regions questionable. To overcome this problem, Pennsylvania, working with federal natural resource, agencies modified many of the HSI models for use in Pennsylvania and much of the northeastern U.S. (Palmer et al. 1993).

The Pennsylvania Modified Habitat Evaluation Procedures (PAMHEP) are designed as a streamlined evaluation method that would permit accurate predictions of wildlife and fisheries functions and the impacts to them during normal planning and review activities (PA Game Commission 1982). Since 1982, PAMHEP has been the most widely used environmental impact assessment method for wildlife and fisheries in Pennsylvania (Palmer et al. 1993).

Model Calibration and Validation

Despite widespread use, HSI models are seldom evaluated for internal consistency (calibration and verification) or field-tested (validation). 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. 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. We are in the process of validating the models based primarily on presence/absence data from field studies (versus population estimates of abundance). At this time, we believe the models presented here adequately represent conditions across the range of wetland-riparian habitats in the mid-Atlantic and northeastern states.

Wildlife Community Habitat Profiles

When assessing a habitat for its wetland-dependent wildlife function, we used a standard set of 10 wildlife species. The 10 species were chosen to represent a wide range of taxa, trophic levels, and habitat uses that span the vegetative and disturbance conditions found in wetlands of the northeastern United States. Selected species include: 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 have been arranged in order according to preferred vegetative cover type (Table 1).

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 1), and 4) the vegetative diversity inherent in most wetlands is accounted for by using this diverse set of models.

Figure 1. Example for a Wildlife Community Habitat Profile for a reference emergent wetland.

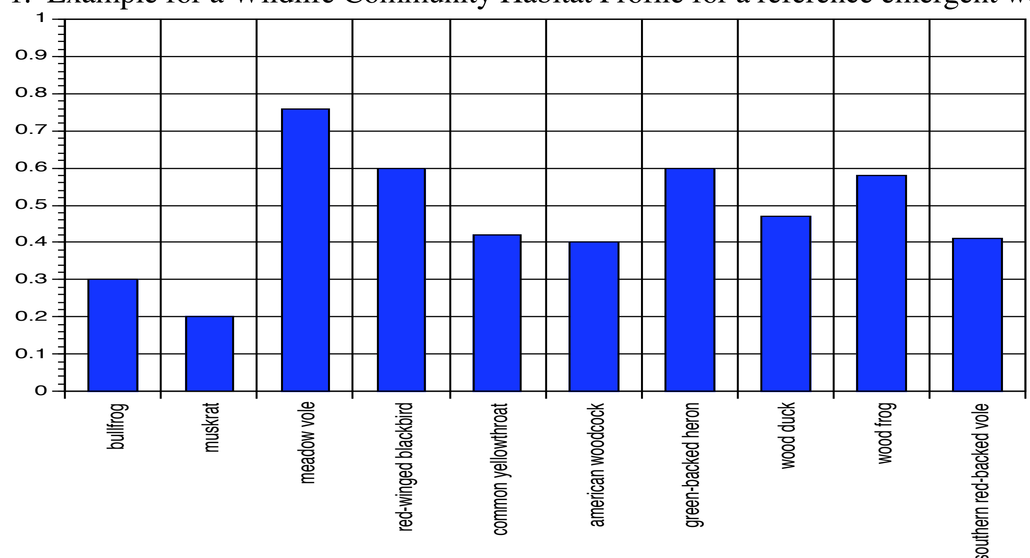

Table 1. Ten wildlife species used as models to evaluate wetland habitats.

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

PROCEDURES

To reduce the probability of an individual's bias, at least two observers should independently rank each variable. The score for each variable will be calculated as an average of the independent scores of each observer. If the score difference is greater than 0.3 units, observers must discuss that variable and reduce the difference to a value that is equal to or less than 0.3 before averaging their scores. Observers may choose intermediate scores other than those listed for each variable, if necessary, to describe specific habitat conditions. Each model contains an equation to calculate the overall HSI value.

A site may be ranked from multiple perspectives, depending on the species model being used. Consider, for example, an open water site with grass-like herbaceous vegetation along the shore. When ranking the meadow vole model, focus mainly on evaluating the grassy shore rather than the open water (because the meadow vole will not be found in the open water). The wood duck, on the other hand, will use both the open water and vegetated shore, therefore focus equally on all portions of the site.

It is critically important to score all species for all sites. Only then can legitimate comparisons be made on the relative habitat condition across a group of sites. After scores are computed for each species, a graph is produced to display the relative rankings. We recommend that the order of species on the x-axis of the graph be held constant to facilitate visual comparisons. We expect this approach to be most useful for detecting shifts in suitable habitat due to anticipated impacts or shifts in habitat type driving mitigation activities.

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PAM HEP HSI MODEL

Species: Bullfrog (Rana catesbeiana)

Cover Types: Palustrine Emergent, Scrub/Shrub, and Forested Wetlands

Revised models 1994

Life History:

Eggs are deposited as a thin film on the water surface usually around plant material. Tadpoles require shallow water with protective cover along the water's edge for larval transformation. Permanent water must be available for one year to complete the larval life stage.

Bullfrogs eat a wide variety of vertebrate and invertebrate foods although insects, crayfish and amphibians form the bulk of their diet. They are opportunistic feeders, feeding on whatever is most available.

Tadpoles feed mainly on diatoms and other algae with small amounts of animal food. Juvenile frogs are largely insectivorous.

Permanent water with both shallow and deep water and submergent vegetation provide optimal bullfrog habitat. Bullfrogs are generally found along the water's edge where there are overhanging tree branches, tall grasses or debris, snags, etc., on the ground. Although frequently associated with dense emergent plant growth such as pickerel weed, lilypads, cattails, and sedges, bullfrog populations also occasionally occur along open shallow edges of reservoirs, cattle ponds, wells and intermittent streams.

Juvenile bullfrogs in Illinois selected very shallow water with abundant short emergent growth vegetation and debris for cover. Density of mature frogs was dependent on the amount of dense cover. Because of their territorial behavior, adult frogs were spaced out further in more open areas. Bullfrogs use deeper water as escape cover. Survival of larval and adult frogs was reduced in mud bottom ponds lacking debris or vegetation.

Bullfrogs prefer larger bodies of water than most frogs. They will use both standing water habitat and slow moving portions of streams. Small streams are used when more optimal habitat is not available. Bullfrogs require permanent water.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. Water: (limiting factor)	
	No surface water	0.0
	Seasonal water > 18 inches	0.0
	Seasonal water < 18 inches	0.0
	Permanent water > 18 inches	0.8
	Permanent water < 18 inches	1.0
	2. Water Current:	
	Fast flowing water (>40"/sec)	0.0
	Moderately fast (24-40"/sec)	0.3
	Moderately slow (6-23"/sec)	0.7
	Still water or slow (<6"/sec)	1.0
Cover	3. Percent herbaceous canopy cover, debris, snags, overhanging brush, etc., along shore and in the littoral zone	
	0%	0.0
	25%	0.3
	50-75%	0.7
	>75%	1.0
	4. Wetland cover type	
	Open water	1.0
	Emergent	1.0
	Field	0.7
	Shrub/scrub	0.5
	Forested	0.0

HSI Determination: [(V1+V2+V3)/3]V4
Limiting Factor: V1 (if V1 is 0, then HSI is 0)

References: WELUT Draft Model, Bullfrog, April 1980

Developed by: Richard W. McCoy, March 15, 1985, USFWS, State College, PA
Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania StateUniversity, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Muskrat (Ondatra zibethicus)

Cover types: Emergent wetlands
Riparian wetlands
Lacustrine wetlands

Revised model, 1994

Life History:

Good muskrat habitat is characterized by permanent, slow-moving water, emergent vegetation, and suitable bank den sites. Home range size averages approximately 200' in diameter in marshes and to 1000' of shoreline in stream environments.

Although young muskrats may be found in either lodges or burrows, studies in Massachusetts, New York, and Pennsylvania indicate muskrat productivity is directly related to the availability of suitable bank burrows.

The primary foods of muskrats are stems, leaves, and rootstocks of emergent vegetation. When present, cattail is usually the dominant food species. In marshes, emergent vegetation should constitute a minimum of 5% of the area, with the optimum amount being 67% or more. In streams, herbaceous bank vegetation and riparian shrub thickets are utilized as important food sources.

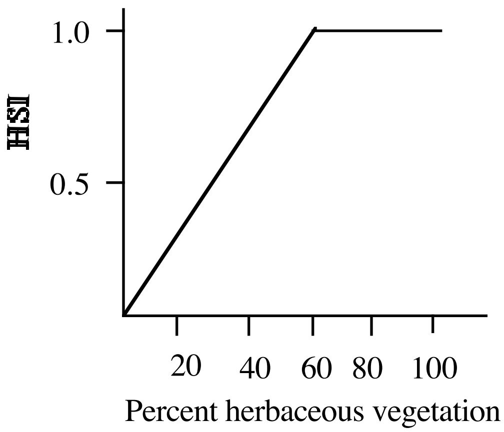
In marshes, cover is provided by dense stands of emergent vegetation supplemented by logs, trees, and shrubs. In stream environments, cover is provided by the same areas that provide food.

Optimum water values are provided by permanent water flowing very slowly. Semi-permanent water and/or water flowing at a faster rate will be utilized by muskrats, but there will be a decreased degree of suitability.

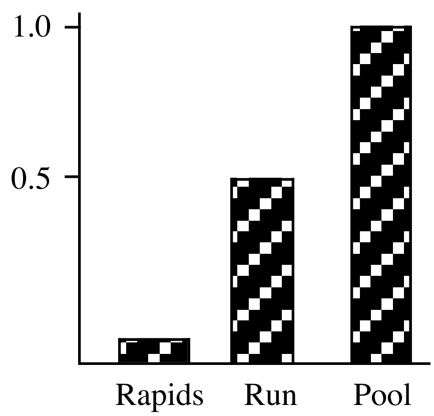
Life Requisite Factors:

STREAM CONDITIONS:

Factor	Conditions	Value
Water Permanence	1. No permanent water	0.0
	Permanent water ≤ 6" (15cm)	0.2
	Permanent water > 24" (61cm)	0.7
	Permanent water 6-24" (15-61cm)	1.0
Riparian bank	2. Percent herbaceous vegetation within 10m of stream	
	0%	0.0
	30%	0.5
	≥60%	1.0
	(see graph)	



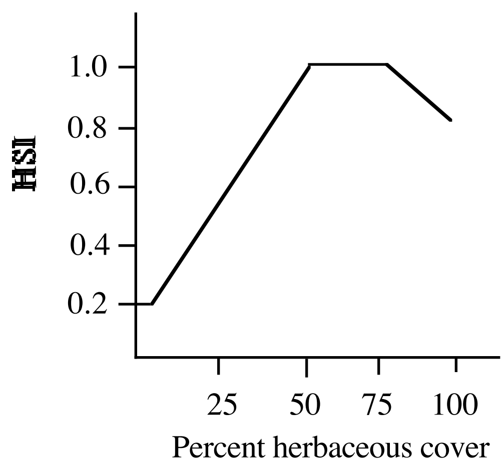
Stream class	3. Rapid / riffles dominate	0.1
	Run	0.5
	Pool / backwater	1.0



Bank Characteristics	4. (average of both sides)	
	≤ 20cm (8") ht., ≤10% slope <u>or</u> badly eroded	0.0
	20-50cm (8-20") ht., 10-20% slope with moderate erosion	0.3
	20-50cm (8-20") ht., 10-20% slope with stable banks	0.5
	> 50 cm ht., > 20% slope and moderate erosion	0.7
	> 50 cm ht., > 20% slope and stable banks	1.0
	5. Distance to emergent vegetation	
	Emergent veg. negligible or > 300m (985') of site	0.2
	Emergent veg. moderately abundant and within 200m (655') of site	0.5
	Emergent veg. abundant and within 100m (330') of site	1.0

MARSH CONDITIONS (NO STREAM):

Factor	Conditions	Value
	1. Percent herbaceous vegetation cover (vs. OW or woody cover)	
	≤5%	0.2
	25%	0.5
	>75%	0.8
	50-75%	1.0



	2. Interspersion	
	Open water with negligible herbaceous veg or herbaceous veg with negligible open water or both are negligible	0.2
	Herbaceous veg is 5 - 50% and open water is 25% of total area	0.5
	Herbaceous veg in a few large patches is 50-100% of area	0.8
	Herbaceous veg in numerous scattered patches is 50-75% of total area	1.0
	3. Water permanence (limiting factor)	
	No permanent water	0.0
	Permanent water ≤ 15cm (6")	0.2
	Permanent water > 61cm (24")	0.7
	Permanent water 15-61cm (6-24")	1.0

HSI Determination"

STREAM CONDITIONS: [(V2 + V3 + V4 + V5) / 4] x V1
MARSH CONDITIONS: [(V1 + V2) / 2] x V3

Revised by Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

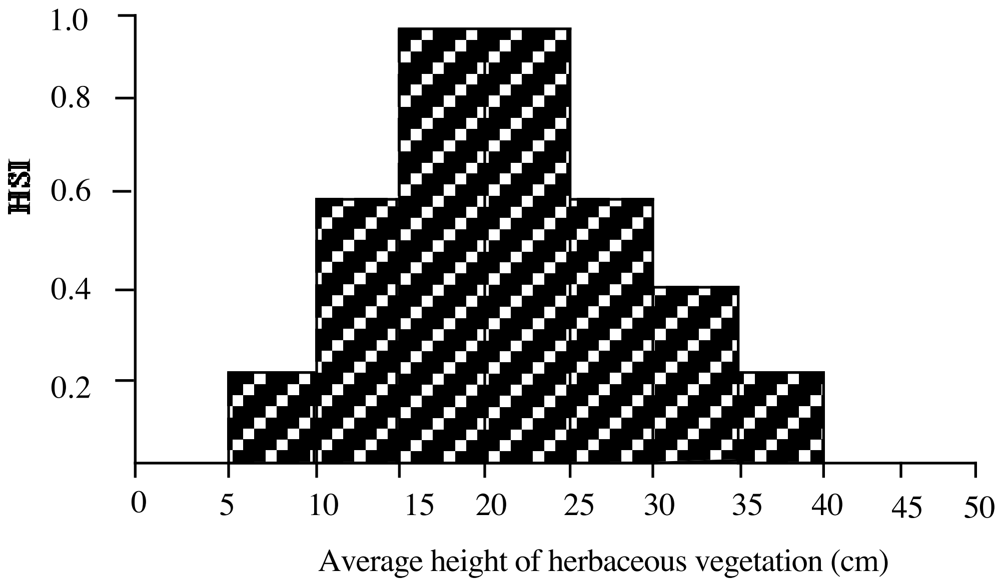
Species: Meadow Vole (Microtus pennsylvanicus)
Cover types: Emergent wetland
Revised model, 1994

Life History:

Meadow voles inhabit grassy areas, preferably moist, and all life requisites can be provided by a single cover type. Home range size varies widely and may be density dependent.
Breeding - The young are born above ground in grassy nests or in pockets connected with underground burrows.
Food - Grass species are the major food eaten by meadow voles. A small amount of insects are also consumed. Food preference is generally determined by plant species availability. During the winter, meadow voles still eat bark from trees and shrubs.
Cover - Meadow voles inhabit moist grassy areas along streams, lakes, and swamps. They will also live in grassy old fields, orchards, fence rows, right-of-ways, pasture, and haylands. The primary cover requirement is the availability of dense grassy vegetation. Voles have been found, in various studies, to be most abundant when herbaceous cover in 80% or greater, grasses or grass-like species comprise 50% or more of the herbaceous cover, and the vegetation height is between 4" and 9". Wooded areas are avoided. Runways are constructed from herbaceous vegetation to enhance cover for travel. Voles may also use underground burrows.
Water - Voles prefer moist areas but have no specific water requirements.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	Not a limiting factor. Needs met by food/cover requirements	
Food/Cover	1. Percent herbaceous crown cover (do not include moss)	
	0%	0.0
	40%	0.5
	≥ 80%	1.0
	2. Average height of herbaceous vegetation (avg. annual conditions)	

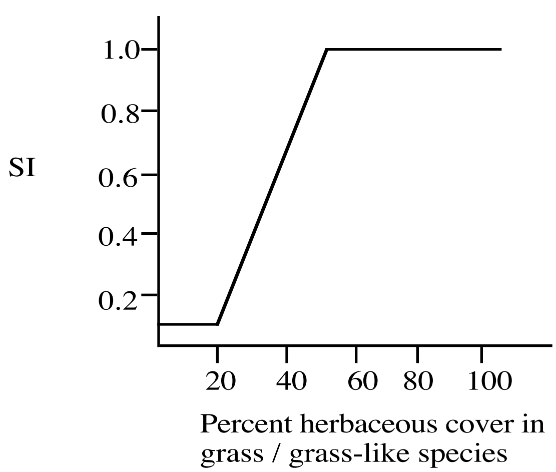


3. Density of herbaceous vegetation

sparse	0.0
moderate	0.7
dense	1.0

4. Percent herbaceous crown cover in grass or grasslike species

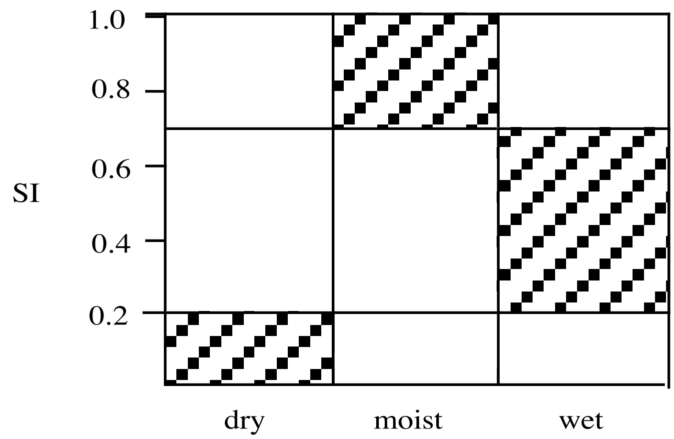
20%	0.1
35%	0.5
50% or more	1.0



5. Soil moisture (average conditions)

Hard or powdery dry soils	0.1
Wet soils with presence of standing water	0.5
Moist soils with no standing water	1.0

(see graph)



HSI Determination:

Food / Cover SI = [V1 + (V2 x V3 x V4)$^{1/3}$ + V5] / 3
Note: 0.0 SI values for V1 and V2 are limiting and the resulting Food/Cover SI will be 0.0.
Water is not a limiting factor. Needs met by food/cover requirements
Reference: WELUT Draft Model, Meadow Vole, June 1979.
Revised: February 1985, Richard W. McCoy, Fish and Wildlife Biologist, USFWS.
October 30, 1987, J. Hugh Palmer, Game Biologist, PAGC.
August 1994, Robert P. Brooks, Diann J. Prosser, Penn State Coop. Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Red-winged Blackbird (Agelaius phoeniceus)

Cover types: Emergent wetland
Shrub-Scrub wetland*
Forested wetland*
* These wetland types are evaluated only if they contain a significant emergent component .

Revised model, 1994

Life History:

The red-winged blackbird is both a summer and winter resident in Pennsylvania. They occur in a diversity of habitat types including shrub and herbaceous wetlands, old fields, grain and hay fields, and pasture.

Red-winged blackbirds prefer wetland habitat for nesting, but can also successfully nest in upland habitats. Optimal wetland nesting is in broad-leafed monocotyledons (primarily Typha spp. and Carex spp.), 1 - 2 feet tall located over water that is deeper than 10 inches.

An additional requirement for nesting habitat is the presence of elevated song perches needed in territory selection and establishment. Territory size ranges from 0.37 to 0.52 acres in wetlands.

Food is generally not a limiting factor if breeding/nesting and cover requirements are met. Red-winged blackbirds are opportunistic feeders and consume vegetative matter (herbaceous fruits including grain, softwood and hardwood fruits), animal matter (insects, arthropods, worms, snails, crustaceans, and other invertebrates), and grit.

If breeding/nesting requirements are met, then cover will not be a limiting factor.

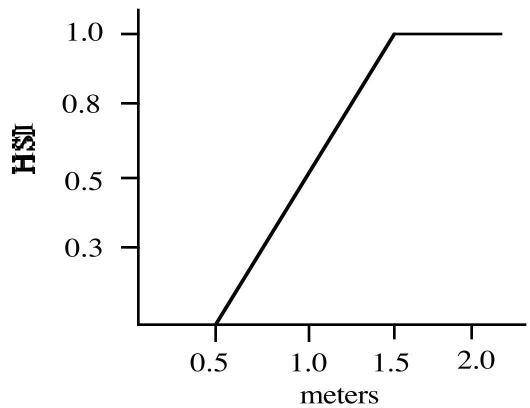
Water is a factor which enhances breeding potential and decreases the degree of predation, and is considered as a function of the breeding/nesting requirements. Drinking water is not a limiting factor.

Life Requisite Factors:

Factor	Conditions	Value
Breeding/ Nesting	1. Area in herbaceous canopy cover	
	0% of area in herbaceous canopy cover	0.0
	15% of area in herbaceous canopy cover	0.5
	30% -50% of area in herbaceous canopy cover, especially dense stands that would readily support nests	0.7
	50% or more " "	1.0

2. No surface water present during breeding season 0.1
   Standing surface water present during **early** breeding season 0.5
   Standing surface water present during **entire** breeding season, or adjacent perennial stream present **< 6"** in depth 0.8
   Standing surface water present during **entire** breeding season, or adjacent perennial stream present **>= 6"** in depth 1.0

3. Average height of herbaceous canopy cover during breeding season



Breeding/nesting SI = (V1+ V2+V3) / 3

Note: 0.0 value for V1 is limiting and resulting Breeding/Nesting SI will be 0.0

Food is not a limiting factor
Cover is integrated with Breeding/Nesting requirements
Water is integrated with Breeding/Nesting requirements

<u>HSI Determination</u>: HSI is equal to Breeding/Nesting SI

<u>References</u>: WELUT HSI model, Red-winged Blackbird, April 1980.
PA Fish and Wildlife Database.

Developed: April 12, 1983, by Calvin DuBrock, Data Base Manager, PAGC.
Revised December 10, 1987, by J. Hugh Palmer, Game Biologist, PAGC.
Revised April 1991, by Robert P. Brooks, Associate Professor of Wildlife Science, and Mary Jo Croonquist, Research Technologist, School of Forest Resources, Pennsylvania State University.
Revised August 1994, by Robert P. Brooks, Diann J. Prosser, Aug. 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Common Yellowthroat (Geothlypis trichas)

Cover types: Emergent (persistent) wetland, Shrub/Scrub wetland

Revised model, 1994

Life History:

The common yellowthroat inhabits grass - shrub communities of old fields and forest edges near water, marshes, or swamps.

The yellowthroat feeds by gleaning among leaves (Willson, 1974). The bird's diet includes beetles, grubs, larvae, butterflies, moths, flies, ants, spiders, plant lice, leafhoppers, leaf rollers, and cankerworms (Bent, 1953).

No drinking water requirements were found in the literature. Yellowthroats prefer areas bordering marshes, swamps, springs, and small brooks (Bent, 1953). This may be related to a preference of the vegetation present in these areas rather than a water requirement (Kendeigh, 1945).

Dense low vegetation is used for cover (Bent, 1953). The most suitable habitat for the yellowthroat has moist to wet soil with trees and thickets 3 to 15 feet (.91 to 4.2m) tall and dense tangled vegetation less than 3 feet (.91m) high.

Nest are built up to 3 feet (.91m) from the ground (Preston and Norris, 1947) in tangled vegetation along brooks, margins of swamps, woodlands, or in grasses and sedges near marshes (Bent, 1953).

No special habitat requirements were found in the literature.

The territory size of the yellowthroat is 0.8 to 1.8 acres (0.32 to 0.73 ha) with an average size of 1.26 acre (0.5 ha) (Stewart, 1953). Suitable habitat for yellowthroats includes brush, old fields, and early successional stages near permanent water or marshes.

Brown-headed cowbirds are sometimes nest parasites on this species (Stewart, 1953).

Life Requisite Factors:

Factor	Conditions	Value
Food	1. Percent of shrub crown cover	
	0 - 25%	0.1
	26 - 50%	0.5
	51 - 75%	1.0
	76 - 100%	0.7
	2. Average height of shrubs	
	1 - 2 m (3-7')	1.0
	2 - 4 m (7-14')	0.5
	> 4 m (14')	0.2
	no shrubs, or < 1m	0.0

Breeding/Nesting

3. Same as V1

4. Same as V2

5. Percent herbaceous cover (relative to other veg cover; ie. not including herbaceous cover under shrubs).

< 25%	0.7
25 - 50%	1.0
51 - 75%	0.5
>75%	0.1

6. Percent of grass or grass-like plants of the herbaceous cover

20%	0.2
50%	0.5
100%	1.0

Special value

7. Soil moisture

dry soil; no permanent water	0.0
dry soil; permanent water	0.5
moist	1.0
wet	1.0
open water	1.0

HSI Determination

Food value: $(V1 \times V2)^{1/2}$

Breeding/Nesting: $[(V3 \times V4)^{1/2} + (V5 \times V6)^{1/2}] / 2$

Special value: V7

The HSI score is the lowest of the 3 above values.

References:

Bent, A.C. 1953. Life Histories of North American Wood Warblers. Bull. 203. U.S. Gov't. Printing Office, Washington, D.C. 734 pp.

Kendeigh, S.C. 1945. Community selection by birds on the Helderberg Plateau of New York. Auk 62: 408 - 436.

Preston, F.W., and R.T. Norris. 1947. Nesting heights of breeding birds. Ecology 28: 241 - 273.

Stewart, R.E. 1953. A life study of the yellowthroat. Willson Bull. 65 (2): 99-115.

Willson, J.F. 1974. Avian community organization and habitat structure. Ecology 55: 1017-1029.

Additional References:

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Audyk, W. D., and K. E. Evans. 1975. In: Symposium on management of forest and range habitats for nongame birds. USDA-Forest Service. Gen. Tech. Rep. WO-1, 343 pp.

Developed: June 1978 by WELUT HSI Model

Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: American woodcock (Philohela minor)
Cover types: Young deciduous forests, Shrub/Scrub wetlands, Forested wetlands, Lowland hardwood, Old fields

Revised model, 1994

Life History:

The woodcock is dependent on moist soils for feeding. About 30-95% of their diet consists of earthworms. They also eat insects, and occasionally seeds. Earthworms are consumed in scrub land thickets. Soil texture is important; sandy-loam or loamy soils preferred.

Woodcocks use wooded areas for diurnal coverts and open fields for night time roosting. The best stands were less than 25 years old and deciduous. They seem to avoid conifers. Lowland areas dominated by alders are preferred in summer - fall.

Woodcocks use open areas of herbaceous vegetation for singing grounds. Nests are on the ground in woody or brushy areas usually within 50 yards of the singing grounds.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. Herbaceous canopy cover > 80%	0.2
	Herbaceous canopy cover 60-80% or < 15%	0.5
	Herbaceous canopy cover 15 - 60%	1.0
	2. Average height of herbaceous canopy > 18" (45cm)	0.0
	Average height of herbaceous canopy 12-18" (30-45cm)	0.5
	Average height of herbaceous canopy < 12" (30cm)	1.0
	3. Canopy coverage of trees or shrubs >60%	0.0
	Canopy coverage of trees or shrubs 0-15 or 40-60%	0.5
	Canopy coverage of trees or shrubs 15-40%	1.0
Food	4. % ground covered by litter 0-10%	0.0
	% ground covered by litter 10-20%	0.5
	% ground covered by litter 20-100%	1.0
	5. Soil coarse to moderately coarse, sandy; fine grained	0.2
	Soil fine textured, clay, loam-clay; soft and sticky	0.5
	Soil medium textured, loams, silt-loams and silt	1.0
	6. Soils dry - crumbles when compressed	0.2
	Soil damp - forms a cast when compressed	0.7
	Soil wet - drips when compressed	1.0
	7. Soil not possible to penetrate	0.0
	Soil difficult to penetrate	0.4
	Soil easily penetrated	1.0

Cover	8. If tree cover is < 15%, then V8 is ignored; use V9 only.	
	Overstory forest age class >10" (25cm)	0.0
	Overstory forest age class 6-10" (15-25cm)	0.5
	Overstory forest age class <6" (15cm)	1.0
	9. Shrub crown cover	
	Dominated by evergreen shrubs **or** deciduous shrub cover 0 - 15%	0.2
	Deciduous shrub cover 15-40%	0.5
	Deciduous shrub cover >40%	1.0

Water - not limiting except in droughts

HSI determination: 1) average each factor separately (breeding, food, cover)
2) take the lowest average of breeding, food, or cover

For small sites (< 1 ha) the HSI score may be lower because surrounding conditions are not taken into consideration. The breeding factor can be examined separately if necessary.

Reference: WELUT HSI Model, April 1980.

Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Green-backed heron (Butorides virescens)

Cover types: Emergent wetland, Shrub/Scrub wetland, Forested wetland

Revised model, 1994

Life History:

Green-backed herons are wading birds that inhabit a wide range of aquatic environments. They are somewhat adaptable and general in their habitat preferences.

Breeding cover is provided by woody material capable of supporting a nest in proximity of suitable feeding areas. Optimum breeding habitat is provided with suitable clumps of deciduous shrubs/trees within 0.25 miles. There must be some breeding cover within 1.0 miles.

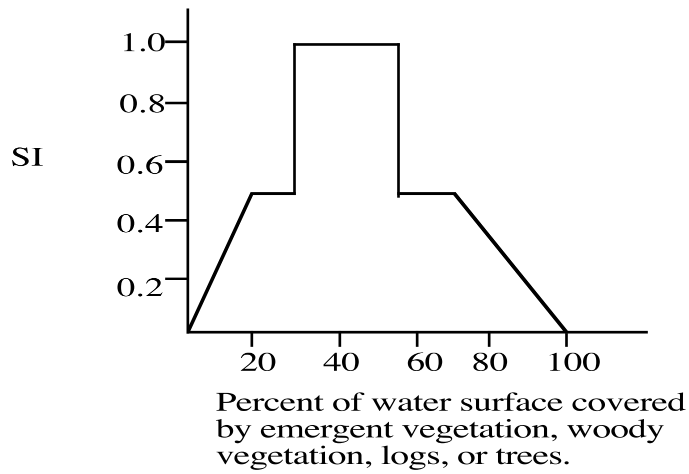
Herons forage in openings, among emergent vegetation, and along soft, muddy borders of shallow water. Good feeding cover requires a muddy or sandy bottom, water less than 10" deep, and a moderate amount of vegetative cover.

Cover is not generally limiting and is provided by the breeding and food requirements.

Green-backed herons require water. Permanent water provides the optimum value while semi-permanent will receive some utilization.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. No shrubs	0.0
	Shrubs on - site or immediate adjacent but majority not overhanging water	0.5
	Shrubs on - site or immediate adjacent with majority overhanging water	1.0
	2. Percent of water surface covered by emergent vegetation, woody vegetation, logs, or trees:	
	35 - 60%	1.0
	20 - 35 or 60 - 75%	0.5
	0 or 100	0.0
	(see graph)	



Water limiting factor	3. No surface water	0.0
	Seasonal water >10" (majority)	0.3
	Seasonal water < 10"	0.5
	Permanent water > 10"	0.8
	Permanent water < 10"	1.0

("Seasonal" water is considered to be surface water present for only part of the year, and "permanent" water is considered to be surface water present year - round).
limiting factor

HSI Determination: (V1+V2+V3) / 3 (if V3=0, then HSI=0)

Limiting Factor: V3

References: WELUT HSI Model, April 1980
PAMHEP HSI Model, Exton Bypass, October 1982

Developed by: J.H. Palmer, PAGC, April 13, 1982

Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Wood duck (Aix sponsa)
Cover types: Emergent (persistent) wetland, Scrub/Shrub wetland, Forested Wetland (deciduous or mixed)

Revised model, 1994

Life History:

Wood ducks are primarily herbivores and forage on the ground or in shallow water. Daily foraging radius for flighted birds may be s much as 25 miles.

Breeding habitat is provided by suitable nest cavity sites within 0.5 mile of suitable brood cover. A suitable nest cavity site is a tree cavity with an opening 3" or more in diameter, 6 or more feet above ground level, and with a dbh of 16" or more. Optimum nest cavity density is 5 or more cavities per acre of brood habitat. The cavity requirement may be met substituting maintained, predator-proof nest boxes for natural cavities at a ratio of 2:5.

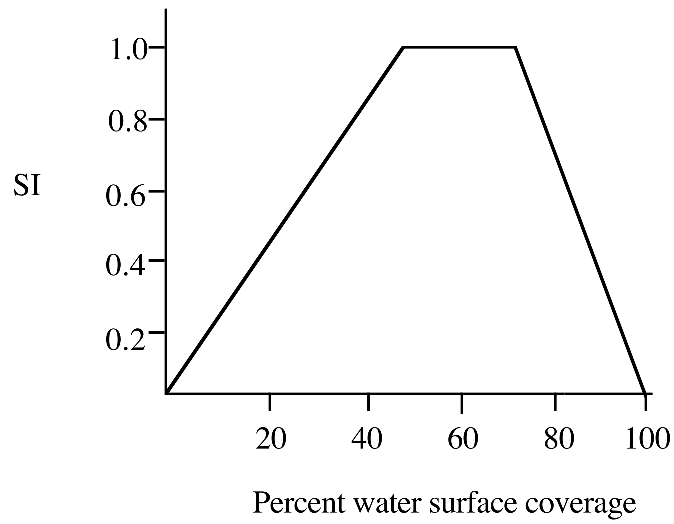
Brood cover is provided by water areas with a combination of living and dead emergent vegetative surface cover. Optimum value is reached when from 50 to 75% of the water surface has such cover. A mixture of shrub and herbaceous cover is preferred to either type individually. Optimum cover includes buttonbush (Cephalanthus occidentalis). Minimum measured brood home range is 2 acres. Brood areas smaller than 2 acres will be utilized if separated from other such areas by 150 feet or less of terrestrial habitat, or connected by 0.25 miles or less of riverine or lacustrine habitat.

Food and cover are not limiting factors. These requirements are provided by the breeding and water requirements.

Wood ducks require water during the breeding season with the optimum value being provided by permanent water.

Life Requisite Factors:

Variable	Conditions	Value
V1	Nest cavities	
	No nest cavities with 0.5 mile of brood habitat	0.0
	2.5 natural nest cavities (1 nest box) per acre of brood habitat within 0.5 mile of such habitat	0.5
	5.0 natural nest cavities (2 nest boxes) per acre of brood habitat within 0.5 miles of such habitat	1.0
V2	Water surface coverage	
	0% or 100% of water surface covered by emergent vegetation, woody vegetation, logs and trees.	0.0
	25% or 87% of water surface covered by emergent vegetation, woody vegetation, logs and trees.	0.5
	50% to 75% of water surface covered by emergent vegetation, woody vegetation, logs and trees. (see graph)	1.0



V3	Vegetative cover	
	Vegetative cover primarily forested	0.2
	Vegetative cover provided primarily by either herbaceous or shrub species	0.4
	Vegetative cover provided by a mixture of herbaceous and shrub species	0.7
	Vegetative cover provided by a mixture of herbaceous and shrub species including buttonbush	1.0
V4 limiting factor	Water (If no permanent water, HSI is 0)	
	Permanent 1st or 2nd order stream	0.0
	Permanent 3rd order stream or river	0.7
	Permanent lake or marsh	1.0
V5	Landscape	
	Wet, forested / shrub	1.0
	Wet, emergent, open water	1.0
	Upland, forest / shrub	1.0
	Upland field / urban / agriculture	0.5

HSI Determination: [(V2 + V3 + V4) / 3] x V5
Breeding V1 - consider separately as a limiting factor (ie. do not consider with overall HSI score)

References:
WELUT Draft Model, Wood Duck, March 1980.
PAM HEP HSI Model, Wood Duck, Loyalhanna Lake, Sept. 1982.
PAM HEP HSI Model, Wood Duck, Jacobs Creek, April 1983.
WELUT HSI Models, Wood Duck, July 1983
Developed: February 1, 1985, by Hugh Palmer, Game Biologist, PA Game Commission.
Revised by:Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

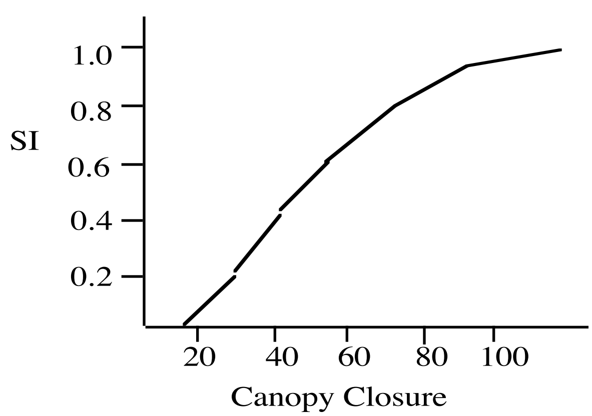
PAM HEP HSI MODEL

Species: Wood frog (Rana sylvatica)
Cover types: Deciduous Forest, Forested Wetland, Shrub/Scrub wetland
Revised model, 1994

Life History:
•The wood frog occurs in cool moist upland and lowland hardwood forests. Forest margins of bogs are prime habitat.
•Ants are the most important food item. Other food includes beetles, spiders, and flies.
•Wood frogs tend to stay along the edge of permanent water. As pools dry up, they will bury in leaf litter for cover. In moist forested areas they are restricted to shaded areas or along stream borders.
•They require permanent or semi-permanent water during early spring (snow melt - June).

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. Water: (limiting factor)	
	Rapid/Riffles dominate	0.0
	Run dominates	0.3
	Pool / Backwater (≥25% of water), or temporary pond	1.0
	Large open water dominates	0.5
	No water	0.0
	Note: if no water even during breeding season, then entire HSI is 0.0.	
Cover	2. Soil moisture	
	Dry soil: crumbles when compressed; no cast	0.0
	Wet soil: drips water when compressed	0.5
	Moist soil: forms cast when compressed; molable	1.0
	3. Leaf litter	
	No leaf litter - bare ground	0.0
	Sparse leaf litter: 1" (2.5cm) deep	0.5
	Abundant leaf litter: >1" (2.5cm) deep	1.0
	4. Tree canopy closure	



HSI Determination: (V1 + V2 + V3 + V4) /4

References:
WELUT Model, June 1978
Developed by: Richard W. McCoy, U.S. Fish and Wildlife Service, State College, PA.
Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Southern Red-backed vole (Cleithrionomys gapperi gapperi)

Cover types: Evergreen, deciduous, and mixed forests; clearcuts within either forest type.

Geographic area: Pennsylvania and the Northeastern U.S.

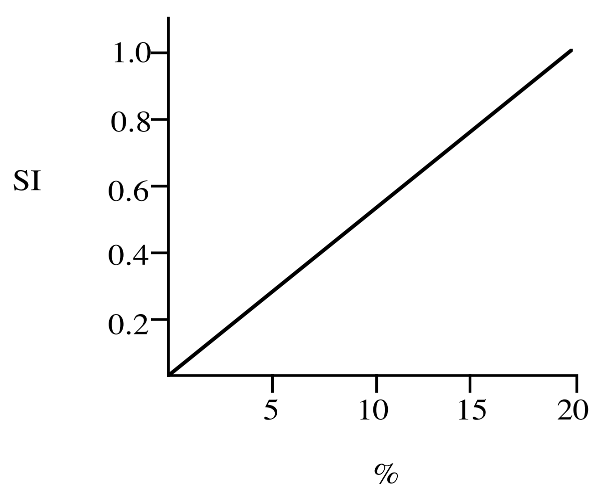
Season: Year-round habitat

Modification of the U.S. Fish and Wildlife Service HSI model for the Southern Red-backed Vole in the western U.S. (Cleithrionomys gapperi), created by Arthur W. Allen.

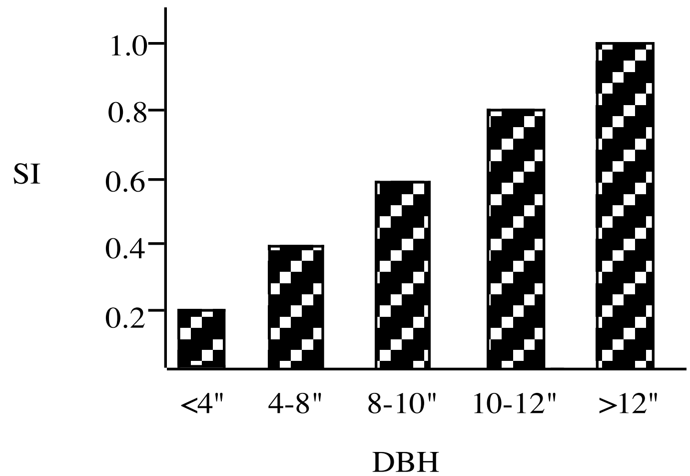
Revised model, 1994

Life Requisite Factors:

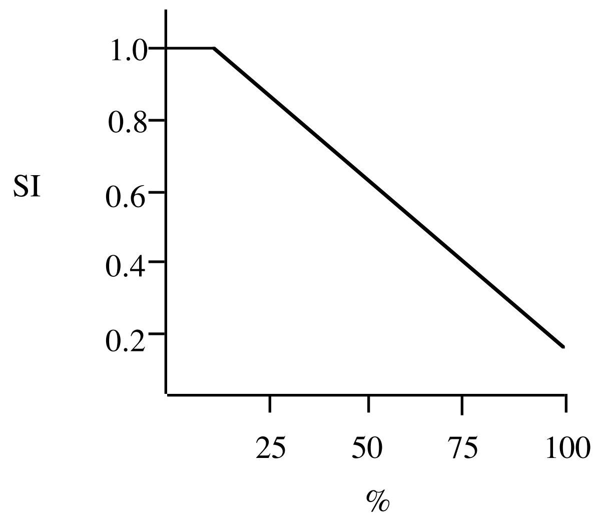
Variable	Conditions	Value
V1	1. Forest type. Forested area must be ≥5 ac. (includes surroundings).	
	no forest	0.0
	dry, deciduous forest	0.1
	wet, deciduous forest	0.6
	mesic, evergreen forest	0.8
	wet, evergreen forest	1.0
V2	2. Percent of ground surface covered by downfall ≥ 7.6 cm (3") in diameter (same as SI for western U.S.)	



V3 3. Average DBH of overstory



V4 4. Percent Grass Canopy Cover
(Same as SI for western U.S.)



The same life requisites (food and cover) were adopted for both C. gapperi and C. gapperi gapperi. As long as the food and cover requirements are met, breeding requirements are assumed to be met. The above habitat variables relate to the food and cover requirements.

HSI Determination: $[(V2xV4)^{1/2} + V1 + V3] /3$

References:

Getz, L.L. 1967. Influence of water balance and microclimate on the local distribution of the redback vole and white-footed mouse. Ecology 49:276-286.

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Kirkland, G.L. Jr. 1991. Personal communication.

Merrit, J.F. 1981. Cleithrionomys gapperi. Mammalian Species 146: 1-9.

Merritt, J.F. 1987. Guide to mammals of Pennsylvania. University of Pittsburgh Press, Pittsburgh. 408pp.

Revised by:
Mary Jo Croonquist and Robert P. Brooks, 1990,School of Forest Resources, Penn State University, University Park, PA.
Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.