Draft Woody Depression Wetland HGM Model for the Coastal Plain of Virginia

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Introduction

The Hydrogeomorphic (HGM) method for modeling and assessing wetlands is an emerging standard for many federal and state agencies. Implementation of this approach in Virginia is currently hampered by a lack of appropriate models. This project developed a draft Woody Depressional Wetland HGM model for the coastal plain of the Commonwealth of Virginia.

Forested depressional wetlands in the coastal plain of Virginia generally consist of topographic depressions in the landscape with soil horizon confining layers. The hydrologic cycle is predominately precipitation driven. These systems generally are considered to have no discernible surface water (channel) connections to a hydrologic source.

Many coastal plain sinkhole pond complexes harbor a number of rare plants and animals and are declining throughout the region. One area of particular interest, the Grafton Ponds Complex, located in the City of Newport News and York County, Virginia, consists of approximately 2,640 acres of ponds that range in size from about 12 to 30 meters in diameter.

Tiner et al. (2002) reviewed selected USGS quadrangles throughout the United States and, using a GIS methodology, found 14-16.5% of the wetlands in the one selected area in Virginia to be considered isolated. A GIS analysis of all the NWI mapped wetlands in Virginia found approximately 8% (≈ 95,000 acres) could be considered isolated wetlands (Virginia Institute of Marine Science, 2003).

Development in southeastern Virginia continues to impact these systems (Rawinski 1997). Other impacts to these systems include removal of surrounding forest cover through timbering, utility easement maintenance, hydrologic modification and alteration through ditching or groundwater withdrawal from the unconfined aquifer, and redirection of stormwater input and runoff from agricultural fields and residential areas. Recent court cases have also cast doubt on the long-term federal regulation of these wetlands systems (see http://www.supremecourtus.gov/opinions/00pdf/99-1178.pdf.).

Woody depressional wetlands provide a variety of beneficial functions to ecosystems and society as a whole. Due to their location in landscapes, depressional wetlands tend to store precipitation that, in turn, mitigates flooding effects. Water retained in depressions provides for groundwater recharge and headwater streamflow through contributions to the unconfined groundwater aquifer.

The mosaic of depressions within the landscape, with their varying depths and water storage capacities, provides a variety of hydrologic environments from ephemeral to seasonally ponded. Fluctuating water levels in the landscape provide niches for many species of plants and animals adding to the biodiversity of the region.

In fact, fluctuating water levels are essential habitat for many amphibians. Periodic water level drawdown within depressions eliminates fish that would severely impact the reproductive success of amphibians that rely on these systems for breeding. Many amphibian species spend their adult life in the surrounding forested landscape making depressional wetlands and their forested buffers vital for the conservation of biodiversity. These systems are also utilized by migrating birds and are sometimes the only water source for animals during drought conditions.

Existing research involving the development of assessment models for depressional wetlands was reviewed and evaluated including the Natural Resource Conservation Service (NRCS) 'interim model' for Alabama, Georgia, Florida, and South Carolina. In addition, collaboration with researchers in Maryland and Delaware was conducted to initiate the identification and definition of regional wetland subclass Woody Depressional Wetlands (WDW) for Virginia. This included discussions on defining the WDW reference domain, developing the WDW functional profile, and identifying model variables and the direct and indirect measures of those variables at four workshops (May 02, April 03, May 04, Oct 04).

This report encompasses the draft WDW model including variables, sampling protocol, and functions

Site Location and Selection

Twenty-seven sites were selected in Virginia's coastal plain for data collection and variable development (Figure 1). Seven sites were selected on the Virginia Peninsula for initial model development. These sites were selected because of existing research data and the combination of relatively pristine and disturbed sites (Havens et al. 2003). One site was selected on Virginia's eastern shore. Twenty additional sites were added for continued model development and all sites were assessed for level of disturbance using a stressor checklist (Appendix IV). Sites ranged in size from 0.1 hectares to 8 hectares. Depressional wetland sites are shown with National Wetlands Inventory coverage on Digital Ortho Quarter Quad (DOQQ) aerials in Appendix V.

Sampling Protocol

A review of other protocols, existing literature, and insight gained from the development of a Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils in the Coastal Plain of Virginia (EPA CD#993723-01-0) and Initiating Development of a Forested Depressional Wetland HGM Model for Wetland Management in Virginia (EPA CD#983598-01) led to the development of a modified sampling protocol to develop equations for the following functions: Hydrology, Plant Community Integrity, Wetland Habitat Integrity, and Buffer Integrity. Both the wetland and the adjacent buffer areas were sampled within a 1/10 acre plot (11.35m radius).

After preliminary data collection and workshop discussions with other researchers involved in depression wetland model development, a consensus was reached to sample a basic suite of variables across the various regions (Delaware, Maryland, and Virginia). Periodic workshops were held to compare sampling protocols, variables and functions. The sampling protocol is depicted in Appendix I. Included in the protocol is a stressor checklist (Appendix IV).

Calibration and validation was conducted on the seven sites comparing the data obtained from the sampling protocol with data obtained from an earlier, independent, more intensive research effort at these sites. In addition, an amphibian and habitat/landscape variables study was conducted at the seven sites to determine variable compatibility and to identify the need for protocol adjustments.

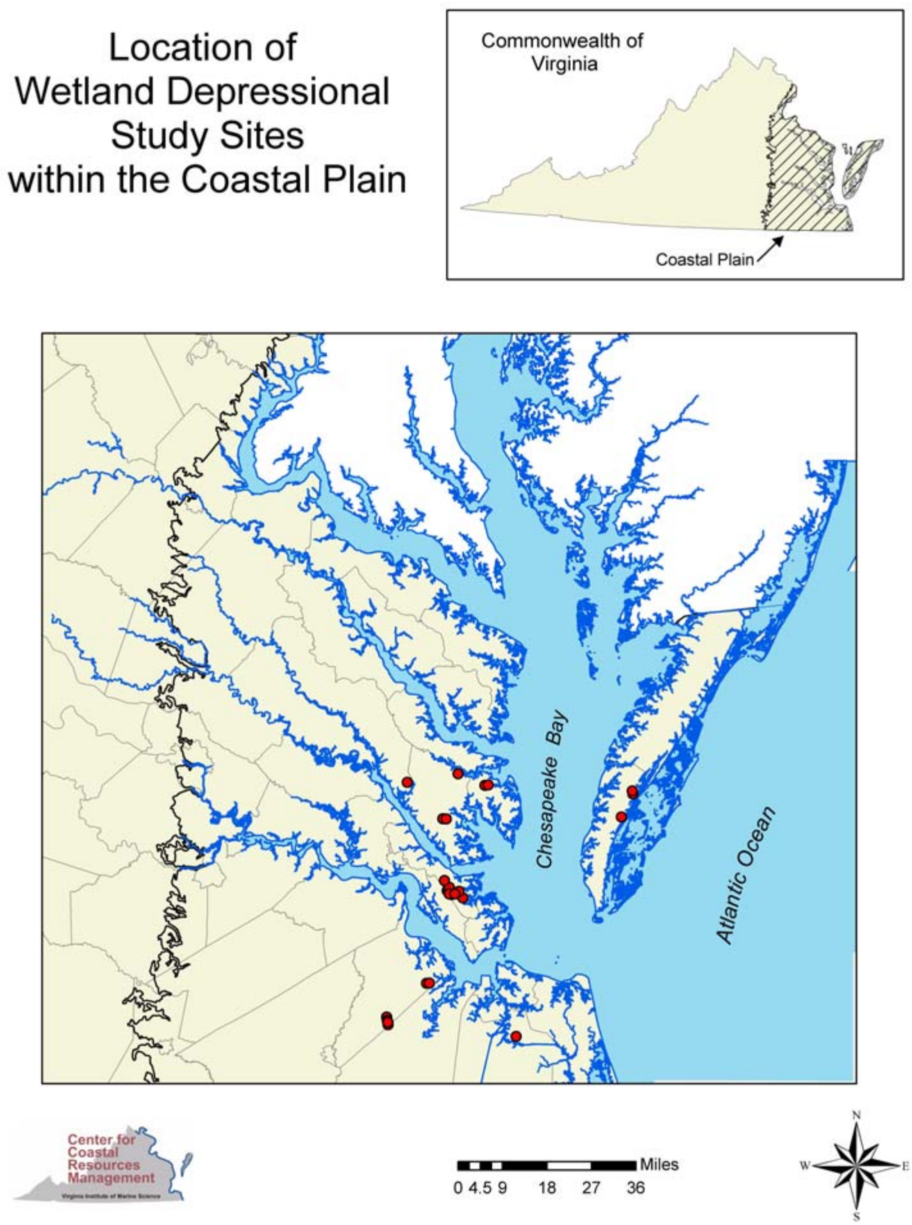

Figure 1. Location of woody depression wetland reference sites with the coastal plain of Virginia.

Variables

Variable: $V_{saplingdensity}$

Variable Name: Sapling density in forested zone

Description: Density of saplings in the forested zone of the depression reflects disturbance to the site. Sapling is defined as >1 m high with a DBH of 1cm to 7.5 cm. Reference standard sites had densities ranging from 148- 716 saplings/ ha. Densities either below or above this range indicate a past disturbance, typically clearing the site. The scaling of this variable is based on densities in reference sites. Sites with densities outside the reference standard range are scored lower. It is assumed that the response of the density of saplings to disturbance is linear.

Importance to function: Indicative of regeneration and biomass production for nutrient recycling and wildlife habitat (DeMaynadier and Hunter 1999, Keddy and Drummond 1996, Morse and Robinson 1998).

Confidence: Confidence in the variable is medium to high due to the high density of saplings or lack of saplings in heavily disturbed sites; however there is large variation in density among reference sites.

Protocol for scaling variable:

1. Sum the number of saplings in each vegetation plot that is located in the forested zone
2. Convert this sum to stems/ ha
3. Average the sums for all plots in the forested zone
4. Use the below table to assign score

Variable scaling:

1.0	Mean density of saplings/ha is $\geq$ 148 and $\leq$ 716
>0.1 and < 1.0	Variable scores between 1.0 and 0.1 are calculated as a continuous variable When sapling density is below 148 – divide the density by 148 When sapling density is above 716 – divide 716 by the density
0.1	Mean density of saplings is $\leq$ 15 saplings/ha
0	There is no forested zone present

Variable: $V_{treedensity}$

Variable Name: Canopy tree density (≥ 15cm DBH) in forested zone.

Description: Density of canopy trees is an indicator of the maturity of the forested zone. Lower densities indicate a disturbance that resulted in reduced density of mature trees. Reference standard sites had densities ranging from 272 - 346 trees/ ha. Densities below this range indicate a past disturbance typically of clearing or selective timbering of the site. The scaling of this variable is based on densities in reference sites. Sites with densities less than the minimum reference standard density are scored lower. Sites that had densities greater than reference standard sites were not scored lower because it is assumed that higher density of mature trees is not an indicator of disturbance.

Importance to functions: Habitat for wildlife by providing for nesting or refuge cavities for birds and mammals, downed woody debris for amphibian habitat, coarse woody debris (CWD) for cycling of nutrients and shade for microenvironment and thermal regulation (DeMaynadier and Hunter 1995, DeMaynadier and Hunter 1999, Morse and Robinson 1998, Braccia and Batzer, 2001).

Confidence: Confidence in this variable is medium because there are not a lot of reference sites that would score below a 1.0. This is probably indicative of the types of disturbances that affect depressions. If a site is disturbed it usually has either been entirely cleared or the surrounding area has been impacted but the trees have not been cleared on the site.

Protocol for scaling variable:

1. Sum the number of overstory trees (≥15cm DBH) in each vegetation plot that is located in the forested zone
2. Convert this sum to stems/ ha
3. Average the sums for all plots in the forested zone
4. Use the below table to assign score

Variable scaling:

1.0	Mean density of canopy trees (≥15cm DBH) > 272 stems/ ha
>0.1 and < 1.0	Variable score between 1.0 and 0.1 is calculated as a continuous variable when tree density is < 272 stems/ha. Variable score is calculated by dividing the density of overstory trees by 272.
0.1	Mean density of canopy trees is ≤ 18.0 stems /ha
0	There is no forested zone present

Variable: V_{treeba}

Variable Name: Canopy tree basal area (≥ 15cm DBH).

Description: Basal area is a measure of the dominance of overstory trees ≥15cm DBH. This variable is an indicator of the maturity of the forest. Disturbance to the site would decrease the basal area of overstory trees by removal of larger trees and/or the regeneration of a younger forest with smaller trees. Reference standard sites had basal areas ranging from 18.5-29.2 m^2/ha. Basal areas below the lowest reference standard variable are scored lower. This variable is based on reference standard data and is a continuous variable.

Importance to functions: Habitat for wildlife by providing for nesting or refuge cavities for birds and mammals, downed woody debris for amphibian habitat, coarse woody debris (CWD) for cycling of nutrients and shade for microenvironment and thermal regulation (Keddy and Drummond 1996, Braccia and Batzer 2001).

Confidence: Confidence in this variable is medium because there are not a lot of reference sites that would score below a 1.0. This is probably indicative of the types of disturbances that affect depressions. If a site is disturbed it usually has either been entirely cleared or the area surrounding the site has been impacted but the trees within the depression have not been cleared.

Protocol for scaling:

1. Calculate the basal area of each tree ≥15cm DBH by
    a. Dividing the DBH by 100 to convert to meters
    b. Dividing the DBH by 2 to get the radius
    c. Squaring this number (radius)
    d. Multiplying the above number by pi (3.1415)
    e. This will give you basal area in m^2
2. Sum the basal area (m^2) for each plot in the forested zone
3. Convert this average to m^2/ ha
4. Average the sums of all plots in the forested zone
5. Use the below table to determine the score

Variable scaling:

1.0	Mean basal area of trees (≥15cm DBH) ≥ 18.5 m^2/ha
>0.1 and < 1.0	If mean basal area is less than 18.5 and greater than 1.9 m^2/ha the variable score between 0.1 and 1.0 is calculated as a continuous variable. Divide the mean basal area by 18.5
0.1	Mean basal area of canopy trees is ≤ 1.9 m^2/ha
0	There is no forested vegetation zone present

Variable: $V_{shrubsp}$

Variable Name: Shrub species richness and composition in wetland, can be in any vegetative zone. Shrubs are defined as a single-stemmed woody plant between 1 m and 3m high or a multi-stemmed woody plant greater than 1m high.

Description: Composition of shrub species can indicate disturbance to a site. This variable is sampled in the field as part of the vegetation plots. Reference standard sites had a minimum of 1 species of shrub and all reference standard sites had *Vaccinium spp.* If no species of shrubs are found or *Vaccinium spp* is not present a lower score is assigned. Disturbance to a site would be expected to change the composition of species present.

Importance to function: Shrub species add to system structure and species representative of reference standard sites provides habitat and food for wildlife species (MacArthur and MacArthur 1961, Kar and Roth 1971, Mills et al. 1991, Keddy and Drummond 1996, Kilgo et al. 1997, DeMaynadier and Hunter 1999, Havens et al. 2002).

Confidence: Confidence in this variable is medium because all reference standard sites had *Vaccinium* species present, however the variable has limited ability to discriminate among moderately disturbed sites.

Protocol for scaling:

1. Examine the shrub datasheet for shrub species present in each of the vegetation plots.
2. Count the total number of species present in all vegetative zones using all vegetation plots that were sampled in this zone
3. Refer to scaling table below to assign a variable score

Variable Scaling:

1.0	One or more species of shrubs present ***Including*** *Vaccinium spp*.
0.50	One or more species of shrubs present ***Not Including*** *Vaccinium spp*.
0	No shrubs present

Variable: $V_{\%nativeveg}$

Variable Name: Percent of plant species that are native in the entire site

Description: Non-native species are indicative of disturbance to a site. A greater number of non-native species may indicate greater disturbance to the site or surrounding the sites that is allowing the transmittal and establishment of these species. Percent is the percent of the total number of species that are native. Reference standard sites did not have any non-native species present, however, sites ranged from 100 to 83% native species found in all vegetation zones. Categories of the % of native species were used to scale the variable since the data did not exhibit a linear relationship from 0 to 100% and the presence of any non-native species is believed to degrade a site.

Importance to function: Native plant species composition can be indicative of a healthy community with minimal disturbance and indicative of ecosystem resistance to environmental perturbations (Va. Dept. of Conservation and Recreation 1999, Sakai et al. 2001, Havens et al. 2003).

Confidence: Confidence in this variable is medium to high because no reference standard site had non-native species present; however there were few sites with non-native species.

Protocol for scaling:

1. Examine the understory species datasheet that lists the understory species (<1m) present in each of the vegetation plots
2. Count the total number of species present in the site including species from all vegetation plots, if a species is found in 2 different vegetation zones only count it once. Make a list of the total number of species found at the site.
3. Determine which species are not native using the Invasive Alien Plant Species List from the VA Dept of Conservation, Division of Natural Heritage list of Invasive Alien Plant Species of Virginia (Appendix III or http://www.dcr.state.va.us/dnh/index.html).
4. Divide the number of native species by the total number of species to determine the percent of native species
5. Refer to table below to assign a variable score

Variable Scaling:

1.0	100% native species present
0.75	∃95% of the species are native
0.50	∃90% #95% of the species are native
0.25	∃80% #90% of the species are native
0.1	<80 % of the species are native

Variable: $V_{hydroalt}$

Variable Name: Hydrologic alteration

Description: Presence of alterations to the hydrology within 30m of the site including ditching (either diverting water out of site or into the site), excavation, filling, and farming activities. This variable is based on best professional judgment on the effect of ditches and other activities on the hydrology of the site. Ditches that do not enter the site are not included in this variable. In addition to hydrologic alteration, presence of these conditions at a site usually indicates that the buffer was penetrated which can also lead to sedimentation and the conveyance of non-native and invasive species into the site. Reference standard sites did not have any of the conditions listed present.

Importance to function: Disruption of wetland hydroperiod can affect nutrient cycling and habitat value (Pechmann et al 1989, Forman and Alexander 1998, Jones et al. 2000, Trombulak and Frissel 2000, Yahner et al. 2001).

Confidence: Confidence in this variable is medium to high because while we do not have direct data showing the effect of ditches and other disturbances on the hydrology of the site; however the literature suggests a strong negative correlation.

Protocol for scaling:
Review the site stressor datasheet and determine the presence of ditching, filling, excavating or farming activities. Do not count historic ditches that are not affecting the hydrology of the site.

Variable scaling:

1.0	No stressors identified within 30m of assessment area
0.80	One stressor excluding ditch or drain stressors identified within 30m of the site
0.65	No ditch/drain stressors but 2 to3 stressors identified on site
0.50	Less than 3 stressors with a ditch/drain stressor identified within 30m of site **OR** 3 to 7 stressors identified on site
0.25	3 to 5 stressors with a ditch/drain stressor identified within 30m of site
0.1	More than 5 stressors with ditch/drain stressors identified on site **OR** more than 7 stressors identified on site.

Variable: $V_{stdeadbuff}$

Variable Name: Standing dead (∃15 cm DBH and > 2m high) measured using a modified point quarter method.

Description: This variable measures the density of standing dead trees over 15cm DBH and over 2m high in the buffer. Standing dead trees are an indicator of a healthy forest system that is cycling carbon through living and dead plant material and contributing to organic matter on the forest floor and in the soil. Standing dead trees provide important habitat for fauna. The range of standing dead tree density in reference standard sites was from 9.6 – 45.7/ha. Sites were scored lower if they were outside of this range. Either very low or very high amounts of standing dead trees could indicate disturbance at a site.

Importance to function: Standing dead wood provides habitat for birds, amphibians and macroinvertebrates, stores carbon, functions in nutrient cycling, and provides microhabitats for succession/species germination (Keddy and Drummond 1996, McGee et al. 1999, Braccia and Batzer 2001).

Confidence: Confidence in this variable is medium to high because there was good discrimination between disturbed and non-disturbed sites. This is probably indicative of the types of disturbances that affect depressions, where the buffer is usually impacted but the depression site is relatively undisturbed.

Protocol for scaling variable:

1. Divide plot into four quarters.
2. From the center of the plot measure the distance in meters (up to 50m) to the nearest standing dead tree greater or equal to 15cm DBH and greater than 2m high.
3. Repeat for each quarter.
4. Calculate density with the following formula:

$$\text{Density} = 10{,}000/(\text{average distance})^2$$

5. If no standing dead trees are identified within 50m from any quarter then assign a value of 4/ha for the site.

Variable Scaling

1.0	If density of Standing Dead trees (≥15cm DBH and 1m high) ≥ 9.6/ha and # 45.7/ha	
#1.0 ∃0.1	If standing dead density is less than 45/ha and greater than 4/ha the variable score between 0.1 and 1.0 is calculated as a continuous variable. When standing dead is less than 45/ha divide density by 45 When standing dead is greater than 50/ha divide 50 by density	
0.1	Density of standing dead trees is 4/ha	
0.0	No forested buffer	

Variable: $V_{\%landcovernatveg}$

Variable Name: Percent Landscape in natural landcover.

Description: This variable measures the percent of the surrounding landscape within 200m of the center of the Assessment area that is in natural landcover (forested, open water, or wetland). As the percent of the surrounding land in un-natural cover such as agriculture or suburban development increases, the site would become more vulnerable to outside disturbances including invasion of non-native species and hydrologic modifications. The percent of natural landcover surrounding reference standard sites ranged from 99-100. Sites with lower percentages of natural landcover would score lower indicating higher potential for disturbance to the site.

Importance to function: Natural land cover provides habitat for species that have large home ranges or species that require a diversity of habitats to complete their life cycle, corridors for species to move among wetlands, and protection of hydrology in surrounding area that may influence the hydrology of the wetland (Vaughan 1978, Douglas and Monroe 1981, Dickman and Doncaster 1989, Harris and O'Meara 1989, Croonquist and Brooks 1991, Mitchell and Beck 1992, Haspel and Calhoon 1993, Mladenoff et al. 1993, Havens et al. 1995, Richter and Azous 1995, Rudis 1995,Vogelmann 1995, Venier and Fahrig 1996, Gibbs 1998, Haig et al. 1998, Keyser et al. 1998, DeMaynadier and Hunter 1999, Skelly et al. 1999, Wickham et al. 1999).

Confidence: Confidence in this variable is high because there is a wide range of condition among the reference set and because of the wealth of information on the importance of the landscape characteristics.

Protocol for scaling variable:

1. Using a GIS platform, delineate all the different cover types within 200m of the center of the Assessment Area. This can be performed by using the buffer function in ArcGIS.
2. Calculate the area of each of the cover types
3. Convert the area to a percent by dividing by the total area
4. Natural landuses are land uses that have not recently been disturbed by human practices, i.e. developed forest >30 years old, wetlands of any cover type, and open water such as a lake or pond.

Variable Scaling

1.0	Percent natural vegetation within 200m is $\geq$ 99%
<0.1 and >1.0	Variable scores between 0.1 and 1.0 are calculated as a continuous variable. Divide the percent natural vegetation by 99
0.1	Percent natural vegetation within 200m is > 1.0 % and $\leq$ 9.9 %
0	Percent natural vegetation is < 1.0 %

Variable: $V_{distancetoroads}$

Variable Name: Distance from wetland to nearest road

Description: This variable measures the distance from the edge of the wetland to the nearest paved road. Roads form barriers for wildlife dispersal to and from other sites, act as corridors for the transmittal of invasive species to an area, can disrupt hydrology, and can contribute chemical and nutrient loads to wetlands. The greater the distance of a site from paved roads, the less the probability of disturbance by these influences. Reference standard sites ranged from 180-900m to the nearest paved road. This variable was scaled as continuous and it was assumed that as the distance to the nearest road decreased the disturbance to the site would increase.

Importance to function: Roads can fragment habitat for species that have large home ranges or species that require a diversity of habitats to complete their life cycle. Mortality along road corridors can inhibit movement of species to or among wetlands. Roads can increase pollutant loads to wetlands (Findlay and Bourdages 2000, Findlay and Houlahan 1997, Forman and Alexander 1998, Jones et al. 2000, Oxley et al. 1974, Trombulak and Frissel 2000).

Confidence: Confidence in this variable is high because most of the disturbed sites had distances less than the reference standard sites.

Protocol for scaling variable:

1. Locate an aerial photo or digital ortho photo of the wetland and surrounding landscape with either a GIS platform or an aerial photograph
2. Measure the distance from the edge of the wetland to the nearest road in meters. Include only paved roads.

Variable Scaling:

1.0	Distance to the nearest road is >180m
<0.1 and >1.0	Variable scores between 0.1 and 1.0 are calculated as a continuous variable. Divide the distance to the nearest road by 180 and round to the nearest tenth.
0.1	Distance to the nearest road is $\leq$ 18m but not within wetland
0	Road intersects wetland

Variable: $V_{bufferba}$

Variable Name: Canopy tree basal area ($\geq$ 15cm DBH) in forested buffer plots

Description: Basal area is a measure of the dominance of overstory trees $\geq$15cm DBH. This variable is an indicator of the maturity of the forest. Disturbance to the buffer would decrease the basal area of overstory trees by removal of larger trees and/or the regeneration of a younger forest with smaller trees. Disturbance to the buffer would thus affect the wetland by reducing the ability of the buffer to intercept stressors in the surrounding area on the wetland. Reference standard sites had buffer basal areas ranging from 20.8-28.2 m^2/ha. Basal areas below the lowest reference standard variable are scored lower. This variable is based on reference standard data and is a continuous variable.

Importance to functions: Habitat for wildlife by providing for nesting or refuge cavities for birds and mammals, downed woody debris for amphibian habitat, coarse woody debris (CWD) for cycling of nutrients and shade for microenvironment and thermal regulation. Large canopy tree basal area indicative of undisturbed buffer. (Temple and Cary 1988, Semlitsch 1998, Morse and Robinson 1998, Kolozvary and Swihart 1999, Lehtinen et al. 1999, Braccia and Batzer 2001, Pechmann et al. 2001).

Confidence: Confidence in this variable is medium because the variable has limited ability to discriminate between moderately disturbed sites.

Protocol for scaling:

1. Calculate the basal area of each tree in the buffer plot $\geq$15cm DBH by
   a. Dividing the DBH by 100 to convert to meters
   b. Dividing the DBH by 2 to get the radius
   c. Squaring this number (radius)
   d. Multiplying the above number by pi (3.1415) for basal area in m^2
2. Sum the basal area (m^2) for each buffer plot
3. Convert this average to m^2/ ha
4. Divide the percent of the landuse (within 200m) of the buffer plot by the total percent forest in the surrounding landscape (i.e. surrounding landscape is 80% forested, buffer plot was in palustrine forested wetland which is 20% of the surrounding landscape so 20/80=0.25).
5. Multiply the basal area/ha by the answer in Step 4 (this is the weighted ba)
6. Sum the weighted ba for all buffer plots
7. Use the table below to determine the score

Variable scaling:

1.0	Weighted buffer basal area of trees ($\geq$15cm dbh) $\geq$ 20.8 m^2/ha
>0.1 and < 1.0	If basal area is less than 20.8 and greater than 2.1 m^2/ha the variable score between 0.1 and 1.0 is calculated as a continuous variable. Divide the mean basal area by 20.8.
0.1	Mean basal area of canopy trees in the forested buffer is $\leq$ 2.1 m^2/ha
0	There is no forested landcover within 200m

Variable: $V_{tree\%oak}$

Variable Name: Percent of overstory trees (∃15cm DBH) that are oak species averaged within forested zone and buffer zone.

Description: Mast producing oak species have high wildlife value and are indicative of less disturbance (i.e. silvaculture practices). This variable is sampled in the field as part of the vegetation plots. Reference standard sites had a minimum of 31.6% oak species. If less than 30% oak species of trees are found a lower score is assigned. Disturbance to a site would be expected to decrease the amount of oak species present.

Importance to function: Presence of oak species is indicative of a least disturbed site and adds wildlife habitat value and biodiversity to the plant community integrity. (Burdick et al. 1989, Forsythe and Roelle 1990).

Confidence: Confidence in this variable is medium to high because there was good discrimination among reference sites and all reference standard sites had a relatively high percentage of oak species.

Protocol for scaling:

1. Examine the tree datasheet for tree species (>15cm DBH) present in each of the vegetation plots.
2. Count the total number of oak species present in all vegetative zones using all vegetation plots that were sampled in both the forested and buffer zones.
3. Calculate an average percent oak species for the site.
4. Refer to scaling table below to assign a variable score

Variable Scaling:

1.0	If percent oak species is $\geq$ 30%
>0.1 and < 1.0	If percent oak species is less than <30% and greater than 3% the variable score between 0.1 and 1.0 is calculated as a continuous variable. Divide the average percent oak species by 30.
0.1	Average percent oak species is between 1 and 3%
0	No oak species recorded in either forested or buffer zones.

Variable: $V_{wildlifefood}$

Variable Name: Wildlife food value associated with vegetation within site and buffer.

Description: This variable represents the importance of food producing plants to the habitat quality of the site. Reference standard sites had a minimum of 14 species with moderate to high wildlife food value and a minimum of 3 species valuable as a winter food source. If less than 14 wildlife food value species and less than 3 winter food source plants are found a lower score is assigned. Disturbance to a site would be expected to decrease the amount of valuable wildlife food species.

Importance to function: Different plant species have various wildlife forage potential depending on the type of fruit and the season in which it is produced (Martin et al. 1961). Both hard seed producing plants (i.e. *Quercus* spp.) and soft fleshy fruit producing plants (i.e. *Asimina triloba*) have value to foraging wildlife.

Confidence: Confidence in this variable is medium because there was limited ability to discriminate among moderately disturbed sites.

Protocol for scaling:

1. Examine the vegetation datasheet for each of the vegetation plots.
2. Count the total number of different types of high value fruit producesrs recorded (See Appendix II list).
3. Refer to scaling table below to assign a variable score
4. Calculate the winter food modifier using the subindex for a final value.

Variable Scaling:

1.0	If the number of moderate to high value fruit producers is $\geq$ 14
>0.1 and < 1.0	If the number of species is less than 14 then the variable score between 0.1 and 1.0 is calculated as a continuous variable. Divide the number of moderate to high wildlife food species by 14.
0.1	If the number of wildlife food species is 1 or 2.
0	If there are no wildlife food species present.

Winter Food Modifier. Winter can be a time of hardship for most wildlife and is a critical period for food supply. The availability of insect and plant food decreases significantly after the first frost. Plants that provide seeds and fruits during this time become highly valued sources of food. If three or more of the families produce fruits or seeds over much of the winter, modify by dividing by 0.8. If the resulting value is greater than 1.0, assign 1.0 to $V_{wildlifefood}$. Winter producing plants are listed below:

Smilax spp
Celtis spp
Ilex spp
Lonicera japonica
Diospyros virginiana
Pinus spp
Toxicodendron radicans
Rhus spp

Functions

Wetland Habitat Integrity =

$$\frac{V_{sapling} + (V_{treedensity} + V_{treeba})/2 + (V_{shrubsp} + V_{wildlifefood})/2 + V_{stdeadbuff}}{4}$$

Buffer Integrity =

$$\frac{\text{Square Root } (V_{\%landcovernatveg} \text{ x } V_{bufferba}) + V_{distancetoroads}}{2}$$

Plant Community Integrity=

$$\frac{(V_{shrubsp} + V_{trees\%oak} + V_{\%nativeveg})}{3}$$

Hydrology=

$$\frac{(V_{hydroalt} + (V_{distancetoroads} + V_{\%landcovernatveg})/2)}{2}$$

Wetland Habitat Integrity

$$\frac{V_{sapling} + (V_{treedensity} + V_{treeba})/2 + (V_{shrubsp} + V_{wildlifefood})/2 + V_{stdeadbuff}}{4}$$

Table 1. Wetland Habitat Integrity

Site	Sapling density (ha)	Tree density (ha)	Tree basal area (m^2/ha)	Shrub species (number)	Wildlife food value (number)	Standing Dead buffer trees density (ha)
FtEustis	148	346	29.2	3 + V	15 + 3	49.4
Arc1	716	272	21	1 + V	14 + 3	45.7
ColoD1	296	173	18.5	1 + V	10 + 2	9.6
NC1D	321	396	25	1 + V	11 + 4	9.2
Catpond3	1037	149	13.4	4 + V	10 + 2	4.7
Boxtree2	346	594	31.9	1	8 + 3	50.8
NC	1828	421	23.7	4 + V	16 + 4	49.4
Glouvet2	716	0	0	1	8 + 3	8.4
Windsor1	99	520	33.7	1	6 + 1	22.3
Windsor4	2470	50	2.1	2 + V	11 + 3	5.6
Glouvet1	74	124	10.1	1	7 + 3	4
Windsor2	247	272	10.3	1 + V	8 + 2	60.6
Catpond2	815	223	18	3 + V	12 + 2	4
168Chesp	173	248	39.8	0	6	73.7
Richneck4	25	347	28.3	2	9 + 3	24.7
Richneck3	1062	99	5.7	3 + V	11 + 1	0
Windsor3	198	124	6.7	1 + V	8 + 3	4
Madison1	1013	124	9.6	0	8 + 2	7.4
Mathews2	1482	322	25.4	1	9 + 3	6.8
Richneck1	642	644	28.5	3 + V	12 + 4	24.7
Mathews1	667	371	15.7	2 + V	9 + 2	8.1
D8	1488	446	27.2	1 + V	8 + 2	7.5
RT17A	5681	0	0	1	3 + 1	0
Denbigh6	593	0	0	2	9 + 3	4
Denbigh7	815	124	2.6	4 + V	9 + 3	4
Plainview1	0	0	0	0	1	0
Richneck2	198	149	12.7	3 + V	14 + 3	24.7

Bolded = Reference standard

Table 2. Wetland Habitat Integrity Index

Site	Vsapling	Vtreedensity	Vtreeba	Vshrubspp	Vwildlifefood	Vstdeadbuff
FtEustis	1.0	1.0	1.0	1.0	1.0	1.0
Arc1	1.0	1.0	1.0	1.0	1.0	1.0
ColoD1	1.0	0.6	1.0	1.0	0.7	0.2
NC1D	1.0	1.0	1.0	1.0	1.0	0.2
Catpond3	0.7	0.5	0.7	1.0	0.7	0.1
Boxtree2	1.0	1.0	1.0	0.5	0.7	1.0
NC	0.4	1.0	1.0	1.0	1.0	1.0
Glouvet2	1.0	0.0	0.0	0.5	0.7	0.2
Windsor1	0.7	1.0	1.0	0.5	0.4	0.5
Windsor4	0.3	0.2	0.1	1.0	1.0	0.1
Glouvet1	0.5	0.5	0.5	0.5	0.6	0.1
Windsor2	1.0	1.0	0.5	0.5	0.6	0.8
Catpond2	0.9	0.8	1.0	0.5	1.0	0.1
168Chesp	1.0	0.9	1.0	0.0	0.4	0.7
Richneck4	0.2	1.0	1.0	0.5	0.8	0.5
Richneck3	0.7	0.4	0.3	1.0	0.8	0.0
Windsor3	1.0	0.5	0.4	1 .0	0.7	0.1
Madison1	0.7	0.5	0.5	0.0	0.6	0.2
Mathews2	0.5	1.0	1.0	0.5	0.8	0.2
Richneck1	1.0	1.0	1.0	1.0	0.8	0.5
Mathews1	1.0	1.0	0.8	1.0	0.6	0.2
D8	0.5	1.0	1.0	1.0	0.6	0.2
RT17A	0.1	0.0	0.0	0.5	0.2	0.0
Denbigh6	1.0	0.0	0.0	0.5	0.8	0.1
Denbigh7	0.9	0.5	0.1	1.0	0.8	0.1
Plainview1	0.0	0.0	0.0	0.0	0.1	0.0
Richneck2	1.0	0.5	0.7	1.0	1.0	0.5

Bolded = Reference standard

Buffer Integrity

$$\frac{\text{Square Root } (V_{\%landcovernatveg} \times V_{bufferba}) + V_{distancetoroads}}{2}$$

Table 3. Buffer Integrity

Site	Percent landcover in natural vegetation (%)	Basal area of buffer canopy trees (m^2/ha)	Distance to nearest paved road (m)
FtEustis	99	20.8	180
Arc1	100	28.2	420
ColoD1	100	24.0	900
NC1D	77	26.4	250
Catpond3	57	12.8	280
Boxtree2	57	30.9	230
NC	92	23.7	400
Glouvet2	69	11.6	5
Windsor1	98	25.4	25
Windsor4	97	22.0	10
Glouvet1	69	11.6	5
Windsor2	93	44.7	210
Catpond2	93	15.3	250
168Chesp	46	33.3	10
Richneck4	98	22.9	220
Richneck3	55	23.0	230
Windsor3	94	0.0*	100
Madison1	43	19.5	5
Mathews2	93	40.3	10
Richneck1	60	16.1	210
Mathews1	93	38.5	10
D8	94	10.4	5
RT17A	32	12.0	10
Denbigh6	84	16.1	15
Denbigh7	69	13.8	8
Plainview1	06	0	0
Richneck2	75	39.0	12

Bolded = Reference standard

* Surrounding forest cleared subsequent to 2002 landcover data.

Table 4. Buffer Integrity Index

Site	$V_{\%landcovernatveg}$	$V_{bufferba}$	$V_{distancetoroads}$
FtEustis	1.0	1.0	1.0
Arc1	1.0	1.0	1.0
ColoD1	1.0	1.0	1.0
NC1D	0.78	1.0	1.0
Catpond3	0.58	0.62	1.0
Boxtree2	0.58	1.0	1.0
NC	0.93	1.0	1.0
Glouvet2	0.70	0.56	0.1
Windsor1	0.99	1.0	0.1
Windsor4	0.98	1.0	0.1
Glouvet1	0.70	0.56	0.1
Windsor2	0.94	1.0	1.0
Catpond2	0.94	0.74	1.0
168Chesp	0.46	1.0	0.1
Richneck4	0.99	1.0	1.0
Richneck3	0.56	1.0	1.0
Windsor3	0.95	0.0	0.6
Madison1	0.43	0.94	0.1
Mathews2	0.94	1.0	0.1
Richneck1	0.61	0.77	1.0
Mathews1	0.94	1.0	0.1
D8	0.95	0.50	0.1
RT17A	0.32	0.58	0.1
Denbigh6	0.85	0.77	0.1
Denbigh7	0.70	0.66	0.1
Plainview1	0.06	0.0	0.0
Richneck2	0.76	1.0	0.1

Bolded = Reference standard

Plant Community Integrity

$$\frac{(V_{shrubsp} + V_{trees\%oak} + V_{\%nativeveg})}{3}$$

Table 5. Plant Community Integrity

Site	Shrub species (number)	Percent oak trees	Percent native vegetation
FtEustis	3 + V	31.6	100
Arc1	1 + V	42.8	100
ColoD1	1 + V	5.9	100
NC1D	1 + V	4.0	93
Catpond3	4 + V	44.7	100
Boxtree2	1	0.0	100
NC	4 + V	7.0	97
Glouvet2	1	4.5	100
Windsor1	1	0.0	100
Windsor4	2 + V	22.5	100
Glouvet1	1	16.5	100
Windsor2	1 + V	3.4	100
Catpond2	3 + V	46.0	100
168Chesp	0	16.0	100
Richneck4	2	4.0	100
Richneck3	3 + V	10.3	100
Windsor3	1 + V	0.0	100
Madison1	0	10.6	100
Mathews2	1	0.0	100
Richneck1	3 + V	2.5	100
Mathews1	2 + V	1.5	100
D8	1 + V	26.2	100
RT17A	1	0.0	100
Denbigh6	2	37.5	83
Denbigh7	4 + V	8.5	86
Plainview1	0	0.0	90
Richneck2	3 + V	15.1	100

Bolded = Reference standard

Table 6. Plant Community Integrity Index

Site	$V_{shrubsp}$	$V_{tree\%oak}$	$V_{\%nativeveg}$
FtEustis	1.0	1.0	1.00
Arc1	1.0	1.0	1.00
ColoD1	1.0	0.20	1.00
NC1D	1.0	0.13	0.50
Catpond3	1.0	1.0	1.00
Boxtree2	0.5	0.0	1.00
NC	1.0	0.23	0.75
Glouvet2	0.5	0.15	1.00
Windsor1	0.5	0.0	1.00
Windsor4	1.0	0.75	1.00
Glouvet1	0.5	0.55	1.00
Windsor2	0.5	0.11	1.00
Catpond2	0.5	1.00	1.00
168Chesp	0.0	0.53	1.00
Richneck4	0.5	0.13	1.00
Richneck3	1.0	0.34	1.00
Windsor3	1 .0	0.00	1.00
Madison1	0.0	0.35	1.00
Mathews2	0.5	0.00	1.00
Richneck1	1.0	0.10	1.00
Mathews1	1.0	0.10	1.00
D8	1.0	0.87	1.00
RT17A	0.5	0.0	1.00
Denbigh6	0.5	1.00	0.25
Denbigh7	1.0	0.28	0.25
Plainview1	0.0	0.00	0.50
Richneck2	1.0	0.50	1.00

Bolded = Reference standard

Hydrology

$$\frac{(V_{hydroalt} + (V_{distancetoroads} + V_{\%landcovernatveg})/2)}{2}$$

Table 7. Hydrology

Site	Stressors with 30m (count) with ditch or drain presence/absence	Distance to the nearest paved road (m)	Percent landcover in natural vegetation (%)
FtEustis	0 + 0	180	99
Arc1	0 + 0	420	100
ColoD1	0 + 0	900	100
NC1D	0 + 0	250	77
Catpond3	1 + 0	280	57
Boxtree2	2 + 0	230	57
NC	0 + 0	400	92
Glouvet2	0 + 0	5	69
Windsor1	0 + 0	25	98
Windsor4	1 + d	10	97
Glouvet1	0 + 0	5	69
Windsor2	0 + 0	210	93
Catpond2	3 + 0	250	93
168Chesp	3 + d	10	46
Richneck4	2 + d	220	98
Richneck3	2 + 0	230	55
Windsor3	5 + d	100	94
Madison1	3 + d	5	43
Mathews2	4 + d	10	93
Richneck1	4 + 0	210	60
Mathews1	3 + d	10	93
D8	5 + d	5	94
RT17A	6 + d	10	32
Denbigh6	8 + 0	15	84
Denbigh7	5 + d	8	69
Plainview1	9 + d	0	06
Richneck2	7 + d	12	75

Bolded = Reference standard

Table 8. Hydrology Index

Site	$V_{hydroalt}$	$V_{distancetoroads}$	$V_{\%landcovernatveg}$
FtEustis	1.0	1.0	1.0
Arc1	1.0	1.0	1.0
ColoD1	1.0	1.0	1.0
NC1D	1.0	1.0	0.78
Catpond3	0.80	1.0	0.58
Boxtree2	0.65	1.0	0.58
NC	1.0	1.0	0.93
Glouvet2	1.0	0.1	0.70
Windsor1	1.0	0.1	0.99
Windsor4	0.5	0.1	0.98
Glouvet1	1.0	0.1	0.70
Windsor2	1.0	1.0	0.94
Catpond2	0.65	1.0	0.94
168Chesp	0.25	0.1	0.46
Richneck4	0.50	1.0	0.99
Richneck3	0.65	1.0	0.56
Windsor3	0.25	0.6	0.95
Madison1	0.25	0.1	0.43
Mathews2	0.25	0.1	0.94
Richneck1	0.50	1.0	0.61
Mathews1	0.25	0.1	0.94
D8	0.25	0.1	0.95
RT17A	0.10	0.1	0.32
Denbigh6	0.10	0.1	0.85
Denbigh7	0.25	0.1	0.70
Plainview1	0.10	0.0	0.06
Richneck2	0.10	0.1	0.76

Bolded = Reference standard

Table 9. Function Scores

Site	Wetland Habitat Integrity	Buffer Integrity	Plant Community Integrity	Hydrology	Total stressors both 0-30m & 30-100m
FtEustis	1.00	1.00	1.00	1.00	0
Arc1	1.00	1.00	1.00	1.00	1
ColoD1	0.71	1.00	0.73	1.00	1
NC	0.85	0.98	0.66	0.98	1
NC1D	0.80	0.94	0.54	0.95	2
Catpond3	0.56	0.80	1.00	0.80	2
Boxtree2	0.90	0.88	0.50	0.72	2
Glouvet2	0.45	0.37	0.55	0.93	3
Windsor1	0.66	0.55	0.50	0.99	3
Windsor4	0.39	0.55	0.92	0.75	3
Glouvet1	0.41	0.37	0.68	0.70	4
Windsor2	0.78	0.98	0.54	0.99	5
Catpond2	0.66	0.92	0.83	0.81	5
168Chesp	0.71	0.39	0.51	0.27	5
Richneck4	0.65	0.99	0.54	0.75	5
Richneck3	0.49	0.87	0.78	0.72	5
Windsor3	0.60	0.30	0.66	0.51	6
Madison1	0.43	0.36	0.45	0.26	7
Mathews2	0.59	0.37	0.50	0.39	8
Richneck1	0.85	0.84	0.70	0.65	8
Mathews1	0.73	0.99	0.70	0.39	9
D8	0.63	0.40	0.96	0.39	10
RT17A	0.11	0.27	0.50	0.16	10
Denbigh7	0.55	0.39	0.51	0.33	12
Richneck2	0.78	0.49	0.83	0.27	16
Denbigh6	0.44	0.46	0.58	0.29	16
Plainview1	0.03	0.00	0.17	0.06	17

Bolded = Reference standard

Validation

Wetlands found in depressional geomorphic settings are widely considered of high value to amphibians which exhibit complex life cycles depending on both aquatic and terrestrial habitats (Semlitsch 1998). To validate selected habitat variables to actual habitat value we surveyed seven of the eight sites for amphibian species. Sites were surveyed on 15 March, 2-3 April, 7-8 May, and 13 June 2002. Most surveys were conducted at night, although some of the reconnaissance in March revealed several species during daytime surveys. Call, netting, and coarse woody debris sampling were conducted. This data was combined with previous survey data (Roble 1998) to obtain a comprehensive listing of species (Table 10) utilizing these sites.

Vegetation within seven of the sites was sampled intensively in 1997 using permanent, circular, contiguous, 100 m^2 plots established along straight transects which crossed the depression from one side to the other (Rawinski 1997). The more rapid assessment used in this field study did not capture the same level of species richness as previous, more intensive sampling, but trends in richness were similar; particularly regarding woody species (Table 10).

Table 10 .Species richness of amphibians in seven depressional wetland sites.

Species	F5[1]	R1*	R2	R3*	R4	D6*	D7*
Rana sphenocephala	X	X	X	X	X	X	
Rana catesbeiana	X		X				
Rana clamitans	X			X			
Pseudacris brimleyi	X	X	X	X	X	X	
Pseudacris feriarum	X						
Pseudacris crucifer	X	X	X	X	X	X	X
Acris crepitans	X	X	X	X		X	
Hyla chrysoscelis	X	X	X			X	X
Bufo fowleri	X	X	X				X
Gastrophryne carolinensis	X					X	
Ambystoma mabeei (listed State-threatened)	X	X		X			
Ambystoma opacum	X						
Amphiuma means		X					
TOTALS	12	8	7	6	3	6	3

* Considered disturbed by Rawinski (1997) due to past clear-cutting or mowing and containing a *Saccharum giganteum-Panicum rigidulum-Eleocharis tuberculosa* subassociation at its deepest point.

[1] Reference standard site.

Summary

This report encompasses the development of an HGM Woody Depression Wetland model for the coastal plain of Virginia. These results can serve as a foundation for subsequent studies to investigate development of a unifying model for the mid-Atlantic region of the United States.

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Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12:1113-1119.

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Skelly, D.K. E.E. Werner, and S.A. Cartwright. 1999. Long-term distribution dynamics of a Michigan amphibian assemblage. Ecology 80 (7): 2326-2337.

Temple, S.A. and J.R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biology 2(4): 340-347.

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Trombulak, S.C. and C. A. Frissel. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30.

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Venier, L.A. and L. Fahrig. 1996. Habitat availability causes the species abundance-distribution relationship. OIKOS 76: 564-570.

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Virginia Institute of Marine Science, 2003. Wetlands in Virginia. http://ccrm.vims.edu/wetlands/specreps.html.

Wickham, J.D., K. B. Jones, K.H. Riitters, T.G. Wade, and R.V. O'Neill. 1999. Transitions in forest fragmentation: implications for restoration opportunities at regional scales. Landscape Ecology 14: 137-145.

Yahner, R.H., W.C. Bramble, and W.R. Brynes. 2001. Response of amphibian and reptile populations to vegetation maintenance of an electric transmission line right-of-way. Journal of Arboriculture 27:215-221.

Selected Annotated Bibliography

Braccia, A. and D. P. Batzer. 2001. Invertebrates associated with woody debris in a southeastern U.S. forested floodplain wetland. Wetlands 21(1): 18-31.

The authors sampled invertebrates associated with woody debris within a forested floodplain system in the Coosawhatchie River basin in South Carolina. They sampled woody debris during both wet and dry seasons. The authors classified the invertebrates as perennial inhabitants (organisms always associated with wood), seasonal colonizers (organisms using woody debris exclusively during the wet period or dry periods), and seasonal refugees (terrestrial organisms using wood during flooded conditions and aquatic organisms using moist areas after floods recede). The authors found that woody debris was a 'hot-spot' for both aquatic and non-aquatic invertebrate richness and arthropod biomass. They concluded that "while submersed and dry wood contained mostly perennial inhabitants and seasonal colonizers, floating wood supported as many or more of these organisms, plus a large biomass of seasonal refugees. Floating wood is likely an important resource for maintaining invertebrate populations during floods".

Burdick, D.M., D. Cushman, R. Hamilton, J.G. Gosselink. 1989. Faunal changes and bottomland hardwood forest loss in the Tensas watershed, Louisiana. Conservation Biology 3(3): 282-292.

The authors used National Audubon Society Christmas bird counts and U.S. Fish and Wildlife Service breeding bird surveys in the Tensas River basin of Louisiana to examine if the number of forest bird species and the size of their populations decrease as bottomland hardwood forest area decreases. The authors found 11 of the 37 species observed declined in abundance as forest area declined. Three species showed increases: the fish crow, rufous-sided towhee, and Carolina wren. Red-headed and red-bellied woodpeckers, wood duck, Mississippi kite and red-eyed vireo showed a general trend of increasing numbers with an increase in percent forest along the survey route.

Croonquist, M.J. and R. P. Brooks. 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. Environmental Management 15(5): 701-714.

The authors used response guilds to assess the impact of anthropogenic activity on bird and mammal communities. They studied two watersheds with 12 sites per watershed. One watershed was relatively undisturbed (dirt roads- not maintained during winter, mostly forested) while the other was disturbed by agricultural and livestock operations as well as residential areas. They found that neotropical migrant birds and species that had specific habitat requirements were the guilds most sensitive to anthropogenic disturbances.

DeMaynadier, P.G. and M.L. Hunter, Jr. 1999. Forest canopy closure and juvenile emigration by pool-breeding amphibians in Maine. Journal of Wildlife Management 63(2): 441-450.

The authors studied populations of wood frogs and spotted salamanders in three upland, mixed-forest sites each with an adjacent recent clearcut (2-11 years old) and an adjacent mature stand (70-90 years old). They established transects through the forest edge and, using drift fences and pitfall traps, sampled amphibians moving through the sites. The authors also used an experimental design of four artificial ponds adjacent to a powerline cut and mixed softwood forest to test habitat preference of emerging juvenile wood frogs. The authors found a higher abundance of juvenile and adult wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*) in a gradient from 80m with a clearcut to the edge to 80m within the mature forest. In addition, they found that juvenile wood frogs showed an emigration preference for closed-canopy habitat with the highest capture rates occurring in microhabitats of dense foliage in both the understory and canopy layers.

Dickman, C.R. and C. P. Doncaster. 1989. The ecology of small mammals in urban habitats. II. Demography and dispersal. Journal of Animal Ecology 58:119-127.

The authors surveyed rodents in six habitat patches ranging in size from 0.20 to 1.31 ha and in disturbance from undisturbed by humans to heavily disturbed, defined as 10 to 25% pf patch area under continuous human management. The authors found most movement between urban patches of 100-300 m for juveniles, subadult and adult *A. sylvaticus* and *C. glareolus*. The authors also found longer resident time and higher survival of *A sylvaticus* in the undisturbed sites than the disturbed sites but no significant difference for *C. glareolus*.

Douglas, M.E. and B. L. Monroe Jr. 1981. A comparative study of topographical orientation in *Ambystoma* (Amphibia: Caudata). Copeia 1981 (2): 460-463.

The authors studied amphibian breeding migrations from a small (0.006 ha) woodland pond. They found that the salamander, *Ambystoma maculatum*, moved an average of 150 m from the pond into the surrounding forest community. They suggest that movement away from the pond has an upper limit beyond which it becomes energetically unfeasible for salamanders to move.

Findlay, C.S. and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14 (1): 86-94.

The authors used regression models to examine time lags relating species richness of wetland bird, plant and herptiles to road densities. They examined road densities from three time periods (1944, 1968, 1982) at distance intervals from the wetland edge of 0-250m, 0-500m, 0-1000m, and 0-2000m. They found that in most cases overall road density (paved and loose roads) did not increase over time however, paved roads did increase. They attributed this to the paving of existing loose roads. The authors found that the full effects of road construction on wetland biodiversity may be undetectable in some taxa for decades, particularly if the selected measurement used is species richness. However, the authors detected the negative effects of historical road density on adjacent lands up to 1 or 2 km form the wetland.

Findlay, C.S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11(4): 1000-1009.

The authors studied 30 wetlands to examine the relationship between adjacent road construction and forest removal/conversion on bird, mammal, herptile, and plant richness. Using a species-area model they predict that a reduction in wetland area of 50% would result in a loss of 10-16% of species in any taxonomic group and a decline in forest cover of 20% within 2km of a wetland will result in a decline in herptile and mammal species richness of 17% and 11%, respectively. For paved roads, their model predicts an increase in paved road density of 2m/ha within 1000m will lead to a 13% decrease in plant species richness, within 0-200m a 19% decline in herptile species richness, within 0-50m a 14% decline in bird species richness, and within 0-2000m a 12% decline in mammal species richness. When the authors looked at distance effects of paved roads they found the critical distance from the wetland edge for plants to be between 1 and 2 km, for birds between 500m and 1 km, and for herptiles and mammals to be 2 km.

Forman, R.T.T. and L. E. Alexander. 1998. Roads and their major ecological effects. In Annual Review of Ecology and Systematics 29: 207-231, D.G Fautin, D.J. Futuyman and F.C. James, eds., Annual Reviews, Palo Alto, California.

The authors present a comprehensive review of roads on the following topics 1) roadsides and adjacent strips; 2) road and vehicle effects on populations; 3) water, sediment, chemicals, and streams; 4) the road network; and 5) transportation policy and planning. The authors discuss the impact of roads and road alignment on stream sedimentation, chemical inputs, affects on animal home ranges, barrier effects, habitat fragmentation, and animal mortality and road avoidance.

Forsythe, S.W. and J.E. Roelle. 1990. The relationship of human activities to the wildlife function of bottomland hardwood forests: the report of the wildlife group. In Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems pp 533-546, J.G. Gosselink, L.L. Lee, and T.A. Muir, eds. Lewis Publishers, Inc. Chelsea, MI.

The authors summarize the discussions from three wildlife workgroups as part of three bottomland hardwood workshops. The workgroups attempted to identify habitat functions and subfunctions. Characteristics identified for wildlife habitat function included production hard and soft mast, presence of coarse woody debris, presence of tree cavities, and others. They also identified additional characteristics that would probably be associated with sites of high value to wildlife: 1) size of tract- larger is better; 2) connectivity of other habitats; 3) diversity; and 4) geographic location, both local (i.e. proximity to permanent waterbodies) and regionally (i.e. in line with migratory bird flyways). The workgroups also attempted to develop indices to access the magnitude of wildlife habitat function in bottomland forests (e.g. the importance of oak, *Quercus* spp).

Gibbs, J.P. 1998. Distribution of woodland amphibians along a forest fragmentation gradient. Landscape Ecology 13: 263-268.

The author conducted amphibian surveys along a continuous transect 10km by 2km along a forest cover gradient from about 5% in the urban area to about 95% at the rural area. The author found that wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystomia maculatum*) were absent when forest cover was reduced below 30% and red-spotted newts (*Notophthalmus v. viridescens*) were absent when forest cover was reduced below 50%. However, redback salamanders (*Plethodon cinereus*) and northern spring peepers (*Pseudacris c. crucifer*) were present along the entire gradient.

Haig, S.M., D.W. Mehlman, and L. W. Oring. 1998. Avian movements and wetland connectivity in landscape conservation. Conservation Biology 12(4): 749-758.

The authors reviewed literature regarding landscape, wetland connectivity, and individual avian species movement studies. The authors emphasize the importance of wetland complexes for between-season (migratory) movement, and between-year movements (breeding migration, or winter site fidelity and natal philopatry). They also suggest wetland complexes that have internal variability may be of higher overall quality than any one particular wetland.

Harris, L.D. and T.E. O'Meara. 1989. Changes in southeastern bottomland forests and impacts on vertebrate fauna. Freshwater Wetlands and Wildlife DOE Symposium series no. 61, R.R. Sharitz and J.W. Gibbons (eds.).

The authors present symptomatic changes in vertebrate fauna in the southeast United States as a result of past losses of bottomland forest. They present data on the increase in the number of breeding bird species in relation to an increase in forest tracts n increments of 5 ha to 25 ha. They also present data on the cumulative number of bird species in relation to forest tracts in increments of 20 ha to greater than 500 ha. Their data shows a threshold change (second increase) at around the 10-200 ha size. They also present data on numerous bird species requiring forested buffers greater than 50-60 meters in width. In addition, the authors discuss the implications of the loss of top level carnivores and the impact of various anthropogenic activities such as channelization, logging, clearcutting, and toxic discharge.

Haspel, C. and R.E. Calhoon. 1993. Activity patterns of free-ranging cats in Brooklyn, New York. Journal of Mammalogy 74(1): 1-8.

The authors surveyed the activity of free-ranging cats by capturing and fitting them with color-coded collars. The cats were then surveyed for 60 consecutive nights. The authors found more feral cat activity inn urban residential landcover areas.

Havens, K.J., H. Berquist, and W.I. Priest, III. 2003. Common Reed Grass, *Phragmites australis*, expansion into constructed wetlands: Are we mortgaging our wetland future? Estuaries 26(2B): 417-422.

The authors examined 15 created wetland sites for the presence of the invasive plant *Phragmites australis*. They compared data from the sites from a study 6 years earlier and found that 80% of the sites had been colonized by *P. australis*. In most cases the native vegetation had been displaced. They found *P. australis* expansion rates within the sites varied from 0.1 to 5.6/yr. They also found a decrease in *P. australis* where scrub-shrub vegetation had increased.

Havens, K.J., A. Jennings, and W.I. Priest, III. 1995. The use of night-vision equipment to observe wildlife in forested wetlands. Virginia Journal of Science 46 (4): 227-234.

The authors used night-vision equipment (image intensifiers), light meters, and noise level recorders to compare animal use between two wetlands: one surrounded by forest and one surrounded by residential development. They found extended light levels and higher noise levels in the residential-surrounded wetland. Deer, owls and bats were observed in the forest-surrounded wetland while dogs, cats, bats and humans were observed in the residential-surrounded wetland. Bat activity was longer in the residential-surrounded wetland which the authors attributed to the extended light level due to artificial lighting.

Havens, K.J., L.M. Varnell, and B.D. Watts. 2002. Maturation of a constructed tidal marsh relative to two natural reference tidal marshes over 12 years. Ecological Engineering 18: 305-315.

The authors investigated the ecological development of a constructed tidal marsh as compared with two adjacent natural marshes. The authors found significant differences in habitat function between the constructed and the natural marshes in three areas: 1) sediment organic carbon at depth, 2) mature saltbush density, and 3) bird utilization (related to saltbush density). The presence of shrub species played an important part in bird utilization of the marshes. Of the 162 observations of bird activity 49% occurred in the shrub community in the natural marshes.

Jones, J. A., F. J. Swanson, B.C. Wemple and K. V. Snyder. 2000. Effects of roads on hydrology, geomorphology, and distribution patches in stream networks. Conservation Biology 14(1): 76-85.

The authors reviewed recent and current research to develop a conceptual model of the interactions between roads and stream networks and how these interactions may affect biological and ecological processes in stream and riparian systems. They suggest that roads near ridges have little direct interaction with streams, however roads crossing small tributary streams at perpendicular angles can act as corridors for flows of water and can modify the magnitude and direction of flows, sediment input and organisms' access to floodplain and secondary channel areas.

Keddy, P.A. and C.G. Drummond. 1996. Ecological properties for the evaluation, management, and restoration of temperate deciduous forest ecosystems. Ecological Applications 6(3): 748-762.

The authors reviewed literature to identify macroscale properties that can easily monitor the condition of eastern deciduous forests as a whole. They offer 10 possible properties with assigned values representing a normal value, an intermediate value, and a heavily altered value. The 10 properties with the associated values are:

1) tree size; >29m2/ha, 20-29m2/ha,<20 m2/ha
2) canopy composition; proportion of shade-tolerate species >70%, 30-70%, <30%
3) coarse woody debris; large logs > 40cm dbh, presence defined as ≥ 8 logs/ha Firm and Crumbling large logs, Firm large logs, Crumbling large logs, no Firm or Crumbling large logs
4) herbaceous layer; ≥ 6 species, 2-5 species, < 2 species
5) cortculous bryophytes; ≥ 7 species, 2-6 species, < 2 species
6) wildlife trees; # cavity trees >50.8 cm dbh, ≥ 4 wildlife trees/ 10 ha, 1-3 wildlife trees/10 ha, <1 wildlife tree/10 ha
7) fungi:macrofungi; scale not given
8) avian community; # of species considered characteristic of primary forests; ≥ 5 species, 2-4 species, < 2 species
9) large carnivores; ≥ 6 species, 3-5 species, < 3 species
10) forest area; > 100,000 ha, 100-100,000 ha, < 100 ha

The authors also presented a literature review of mammal home ranges:
Black bear 5,630 ha
Eastern cougar 10,240 ha
Wolf 39,160 ha
Bobcat 3,070 ha

Red fox 410 ha
Grey fox 110 ha
Fisher 2,590 ha

Keyser, A. J., G. E. Hill and E. C. Soehren. 1998. Effects of forest fragment size, nest density, and proximity to edge on the risk of predation to ground-nesting passerine birds. Conservation Biology 12(5): 986-994.

The authors examined the relationship between forest fragment size and relative rates of nest predation in 12 forest fragments ranging in size from 4 to 849.4 ha. They placed 30 artificial nests 20m apart along transects oriented toward the center of the fragment. They found that intact nests tended to be deeper within the forest (mean distance 282.5m) though the trend was not significant (p=0.11). They conclude that the reduced forest size increases predation on ground nests and that clustered nests have increased large predator disturbance. They also suggest a casual link between increased predation rate, fragment size, and the observed abandonment of small forest fragments by neotropical migrant songbirds.

Kilgo, J. C., R. A. Sargent, R.V. Miller and B.R. Chapman. 1997. Landscape influences on breeding bird communities in hardwood fragments in South Carolina. Wildlife Society Bulletin 25 (4): 878-885.

The authors studied 36 hardwood stands ranging in size from 0.5 to 40 ha with some surrounded by closed canopy pine forest and some surrounded by field-scrub habitats. They found total bird abundance was more than twice as high in the hardwood stands surrounded by field-scrub habitat than those surrounded by pine forest. However, they also found that the presence of an adjacent closed-canopy forest allowed some species to exist in more abundance in the pine enclosed stands than in the field enclosed stands; particularly interior-edge and forest-interior neotropical migrants.

Kolozsvary, M.B. and R.K. Swihart. 1999. Habitat fragmentation and the distribution of amphibians: patch and landscape correlates in farmland. Can. J. Zool. 77: 1288-1299.

The authors sampled breeding pools and upland areas in 30 forest patches of different sizes (0.6-143.5 ha) and degrees of isolation (distance to nearest woodlot 10-710 m) surrounded by farmland. Amphibian species were sampled with pitfall traps and drift fences, call surveys, cover boards, and dip-nets for larvae. They found that species richness tended to be highest at sites with intermediate wetland permanency. They also found that the probability of occurrence of the redback salamander increased from about 10% for woodland areas under 1 ha to about 30% at 10 ha, approximately 70% at 100 ha, and near 90% for woodland areas approaching 1000 ha. They concluded that forest and wetland patch and landscape-level variables were good predictors of species richness. They also suggest that seasonal and semi-permanent wetlands associated with forest patches are important for maintaining amphibian species richness, though some species such as the American toad and gray tree frog appear to thrive in the presence of intensive agriculture. Forest-dependent species such as the spotted salamander, wood frog and redback salamander either were absent or showed sensitivity to reduced forest area.

Lehtinen, R. M., S. M. Gabtowitsch and J.R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19 (1): 1-12.

The authors studied amphibians in 21 wetlands less than 20 ha in size. Sites were sampled for amphibians by larval sampling, chorusing surveys, and visual encounter searches. They found in deciduous forests, amphibian species richness was reduced at sites with urbanized land use at 500, 1000, and 2500 m radius circles. Density of roads and the distance to the nearest neighbor wetland were significant predictors of amphibian species richness at all spatial scales. Urban land use within 1000 m radius circle had an r2 of roughly 88% and density of roads 42%. At the 2500 m scale species richness increased with decreasing urban land cover linearly (from 0-75%) with an R2 of approximately 91%. The relationship between species richness and distance to nearest neighbor wetland showed a linear relationship of decreasing species richness with increasing distance from 100 to approximately 700 m (R2 = 47%).

MacArthur, R.H. and J.W. MacArthur. 1961. On bird species diversity. Ecology 42(3): 594-598.

They authors examined plant species composition (structure) in sites in Vermont, Pennsylvania, Florida, Maryland, Maine, and Panama. They compared structure with bird censuses from the respective territories. They found bird diversity increased with foliage height diversity. They suggest that the patches forming the birds' environmental mosaic are sections of canopy over 25 feet, patches of bushes 2-25 feet, and herbaceous ground cover less than 2 feet. They also provide evidence of the importance of "inside" space (i.e. conifers or evergreen shrub).

Martin, A.C., H.S. Zim, and A.L. Nelson. 1961. American Wildlife and Plants: A guide to Wildlife Food Habitats. Dover Publications, Inc. New York.

The authors present a detailed analysis of the food and feeding habitats of more than 1,000 species of birds and mammals compiled from the literature on stomach, crop, and scat data. The authors also include a chapter titled "Wildlife Plants Ranked According to Their Value" which rates plant use by waterbirds, marsh/shorebirds, upland gamebirds, songbirds, fur and game animals, small mammals, and browsers.

McGee, G.G., D.J. Leopold, and R.D. Nyland. 1999. Structural characteristics of old-growth, maturing, and partially cut northern hardwood forests. Ecological Applications ((4): 1316-1329.

The authors studied sixteen sites in three northern hardwood forest stands. They measured the DBH of all trees ≥ 10.0 cm on 0.1 ha plots and estimated tree age. They also measured and aged downed woody debris and standing dead. They found higher volumes of downed woody debris and higher percentage of large standing dead in old-growth stands. The authors emphasize the importance of maintaining a percentage of large diameter trees in forest communities.

Mitchell, J. C. and R. A. Beck. 1992. Free-ranging domestic cat predation on native vertebrates in rural and urban Virginia. Virginia Journal of Science 43 (1B): 197-206.

The authors documented species killed by free-ranging domesticated cats in two landcover settings: urban and rural. A total of 27 species (8 bird, 2 amphibian, 9 reptile and 5 mammal) were documented in the rural setting and 21 species (6 bird, 7 reptile, and 8 mammal) were documented in the urban setting.

Mladenoff, D.J., M.A. White, and J. Pastor. 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications 3(2): 294-306.

The authors studied two forested landscapes of similar area, geomorphology, and soils but different land use history. The forests were mapped using 1:24000 color infrared photography. The minimum mapping unit was <1.0 ha for forest type and <0.5 ha for discrete wetland patches and patches defined by roads. The maps were digitized using ARC/INFO GIS. Map coverages were analyzed for patch type, area, number, size class distribution and importance. Fractal analysis was used to quantify patch size and shape relationships. The authors found that the disturbed landscape had significantly more small forest patches and fewer large, matrix patches that the intact landscape. In addition, forest patches in the fragmented landscape were significantly simpler in shape. The authors conclude that "although forest ecosystem maps convey many discrete forest patches, the highest contrast edges and most pronounced heterogeneity in a natural landscape (Sylvania) are due to structural differences between upland forest and wetland patch types".

Morse, S. F. and S. K. Robinson. 1998. Nesting success of a neotropical migrant in a multiple-sue, forested landscape. Conservation Biology 13 (2): 327-337.

The authors censused an area ranging from 60-150 ha with agricultural, clearcut, residential and mature forest landcover types for the Kentucky warbler, a neotropical migrant. They found the highest percentage of Kentucky warbler nests parasitized by cowbirds within 300 m of agricultural land (14%) dropping to below 3% at 1.5 km. They also found daily nest predation rates were highest in recent clearcut areas and lowest in the mature forest.

Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. The effects of roads on populations of small mammals. J. Applied Ecology 11(1): 51-59.

The authors studied seven sites along roadways in south-eastern Ontario which included two and four lane paved roads. The authors used trapping, observation and road mortality techniques. They found that road clearance was the most important inhibiting factor for movement of forest mammals. They also observed little difference between paved and gravel roads regarding inhibition to crossing but noted that paved roads resulted in higher traffic speeds and increased mortality. In addition their observations suggest that divided highways with clearances of 90m or more may have similar barrier effects on dispersal as water bodies twice as wide.

Pechmann, J.H.K., D.E. Scott, J. W. Gibbons, and R. D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. Wetlands Ecology and Management 1(1): 3-11.

The authors studied 3 wetlands ranging in size from 0.5 to 1 ha, depth from 0.35 to 1.04 m, and disturbance level from slight ditching to partially drained to man-made. They sampled amphibians migrating to and from the wetlands using terrestrial drift fences with pitfall traps. They sampled 75,644 individuals of 15 species. They found a strong positive correlation of both total number and species diversity of metamorphosing juveniles with increasing hydroperiod (to 275 days inundated). They point out that permanently inundated wetlands however usually support lower density and diversity of amphibians due to an increase in predators, particularly fish.They conclude that intermediately inundated or ephemeral ponds are more conducive to amphibian populations.

Pechmann, J.H.K., R. A. Estes, D.E. Scott and J.W. Gibbons. 2001. Amphibian colonization and use of ponds created for trial mitigation of wetland loss. Wetlands 21 (1): 93-111.

The authors monitored amphibian populations in created ponds, a filled wetland, and a nearby natural reference pond using drift fences, pitfalls, and minnow traps. The authors captured a number of amphibians during the breeding migration at the filled wetland despite the lack of water. They attributed this to the philopatric nature of many amphibian species to return to the same breeding site every year. After four years only one adult individual was captured at the filled site. They also found that the created pond amphibian community differed from the reference site and attributed this mainly to the more permanent inundation of the created sites. They also cited the several hundred meter forested terrestrial buffer surrounding the natural wetlands as a factor. The created sites were surrounded mostly by lawns, old fields, buildings, and parking lots. While they found that average size at metamorphosis of two salamanders was larger in the created pond, they also found that the mean size at metamorphosis of two chorus frog species was smaller in the created sites.

Richter, K.O. and A. L. Azous. 1995. Amphibian occurrence and wetland characteristics in the Puget Sound basin. Wetlands 15(3): 305-312.

The authors studied the physical characteristics of 19 wetlands (sizes ranging from 0.4 to 12.4 ha) to determine their affect on amphibian populations. The authors found that wetlands with watersheds in which more than 40% of the land area was urban were more likely to have low amphibian richness. They showed a linear relationship between amphibian species richness and percent urban land cover ranging from high species richness (mean urban land cover = 8.9%) to low species richness (mean urban land cover = 75.8%).

Rudis, V.A. 1995. Regional forest fragmentation effects on bottomland hardwood community types and resource values. Landscape Ecology 10 (5): 291-307.

The author compared bottomland forest fragment size class form south central United States (from USDA Forest Service Inventory and Analysis Survey data) with tree species composition and richness, ownership, physical parameters, and evidence of anthropogenic uses. The author found that species richness increased with forest fragment size peaking between 200-1000 ha.

Sakai, A.K., F.W. Allendorf, J.S. Holt, D.M. Lodge, J. Molofsky, K.A. With, S. Baughman, R.J. Cabin, J.E. Cohen, N.C. Ellstrand, D.E. McCauley, P. O'Neil, I. M.

Parker, J.N. Thompson, and S.G. Weller. 2001. The population biology of invasive species. In Annual Review of Ecology and Systematics 32: 305-332, D.G Fautin, D.J. Futuyman and H.B. Shaffer, eds., Annual Reviews, Palo Alto, California.

The authors present a comprehensive review of the ecological and genetic features of species with discussion of community properties that promote invasion. In addition they discuss the ecological and evolutionary effects of invasive species on communities. They note that human disturbance may have broadened the range of characteristics leading to successful colonization and increased frequency of invasion into existing communities.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12 (5): 1113-1119.

The author examined data from the literature on the use of terrestrial habitats by one group of pond-breeding salamanders (*Ambystoma* sp.). The author found that a review of the literature suggests that a buffer zone of 64.3 m would encompass 95% of the salamander population.

Skelly, D.K. E.E. Werner, and S.A. Cartwright. 1999. Long-term distribution dynamics of a Michigan amphibian assemblage. Ecology 80 (7): 2326-2337.

The authors studied 37 ponds in a 540 ha area (E.S. George Reserve) with aquatic habitats that include kettlehole ponds, swamps, marshes, and sphagnum bogs. They studied amphibians with an aquatic larval stage followed by a terrestrial adult stage (strictly terrestrial amphibians were not included). They defined ponds as permanent if they held water for the entire 5 year study period, temporary if they dried each year and intermediate if they dried some years but not all. The authors found that intermediate ponds had the highest recruitment (relative to a previous sampling time). They also found that the most stable populations were <150 m from other ponds with the least stable (where species were not present in either study) at around 500 m. They also point out that the study site has few human related disturbances that would restrict or inhibit amphibian movement which consequently may result in smaller isolation distances.

Temple, S.A. and J.R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biology 2(4): 340-347.

The authors investigated the effects of forest fragmentation on forest interior bird species using a stochastic simulation model based on field data and published information on reproductive performance. The authors found a distance-from-edge affect on the nest success of forest-interior birds to be 18% nest success at less than 100m, 58% at 100-200m, and 70% at greater than 200m. They also found that population dynamics in the unfragmented landscape resulted in a stable population with little fluctuation from year to year. The authors conclude that forest fragmentation on breeding grounds “may so disrupt the reproduction of forest-interior birds that their populations decline relative to the available forest habitat. The authors also cite Bond (1957) and Temple (1986) regarding forest size and the presence of redstarts (*Setophaga ruticilla*). Bond (1957) found redstarts in only 7% of woods of 4-9ha in size, 16% in woods of 10-20ha, and 39% in woods greater than 20ha. Temple (1986) found no redstarts in woods of less than 100ha and redstarts in 75% of woods greater than 100ha.

Trombulak, S.C. and C. A. Frissel. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30.

The authors reviewed the scientific literature on the ecological effects of roads. They list seven general effects: 1) mortality from road construction, 2) mortality from collision with vehicles, 3) modification of animal behavior, 4) alteration of the physical environment, 5) alteration of the chemical environment, 6) spread of exotic species, and 7) increased use of areas by humans.

Vaughan, T.A. 1978. Mammalogy. W.B. Saunders Company. Philadelphia, PA.

The author presents home ranges of various mammals from the literature:

Common shrew	0.3 ha
Varying hare	6.0 ha
Mountain beaver	0.1 ha
Least Chipmunk	0.8 – 2.0 ha (summer only)
Yellow-pine chipmunk	1.5 ha (males)
White-footed mouse	0.03 – 4.3 ha
Red-backed mouse	0.1 ha (winter only)
Prairie vole	0.04 ha (males)
Timber wolf	9,324 ha (pack of 2)
	139,859 ha (pack of 8)
Red fox	518 ha
Raccoon	5.4 – 33.8 ha
Badger	485.6 ha
Mountain lion	3,885 – 7,770 ha (males)
	1,295 – 6,475 ha (females)
Lynx	1,553 – 2,072 ha
White-tailed deer	51 – 114 ha

Venier, L.A. and L. Fahrig. 1996. Habitat availability causes the species abundance-distribution relationship. OIKOS 76: 564-570.

The authors used a spatially explicit, stochastic, individual-based simulation model to examine the effect of different amounts of available habitat on the relationship between distribution and abundance. They found a positive correlation between 1) abundance and the number of breeding habitat cells on the simulation landscape, 2) distribution and the number of breeding habitat cells on the landscape and 3) abundance and distribution. In their model all points below a distribution of 0.7 had less than 15% breeding habitat (cover in their simulation).

Wickham, J.D., K. B. Jones, K.H. Riitters, T.G. Wade, and R.V. O'Neill. 1999. Transitions in forest fragmentation: implications for restoration opportunities at regional scales. Landscape Ecology 14: 137-145.

The authors used GIS techniques to study landcover within eight-digit hydrologic units in the mid-Atlantic United States. They studied how human land cover patterns fragment forests in 130 watersheds. They found that significant transitions in forest connectivity occur at relatively low levels of conversion to non-forest cover (15 to 20%).

Appendix I. Woody Depressional wetland sampling protocol.

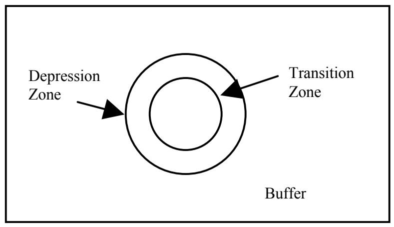
Woody Depressional wetland sampling protocol.

Main sampling method of an 11.35m radius plot = 1/10 acre = 404 m^2.

Depression zone – Area of dominant vegetation typically either forested or scrub-shrub located below the ordinary high water mark.

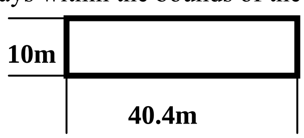
Depression Transition zone – Area sometimes present within the depression zone. Identified by a change in the dominant vegetation or strata beginning within the depression zone and extending to the ordinary high water mark. May be considered part of the forested zone.

Buffer zone – Area surrounding the depressional wetland (may be either upland or wetland), above the ordinary high water mark (or transition zone if present) of the depression.



Location and placement of Primary Sampling Unit (11.35 radius circular plots)

1. Locate a minimum of 1 plot in each of the depressional zone, transition zone, and buffer zone.
2. Plots should be placed within a homogenous community type.
3. If there is more than one community in a single zone then separate plots should be sampled in each community type.
4. Plots should be located in an area that is representative of the community within the zone
5. Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35m point to define the 11.35 m radius plot
6. If a zone is narrower than the plot diameter of 22.7m, construct a plot with the same area (0.1acre=404 m^2) that stays within the bounds of the vegetative community (give examples)



$V_{treedensity}$ (for sampling within the depression and transition forested zones)

Definition: $V_{treedensity}$ - density and relative density of trees ≥ 15cm DBH;

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: $V_{treebasal}$ is measured by recording DBH and species of all trees ≥ 15cm DBH in an 11.35m radius plot. DBH is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the DBH should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the DBH measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

Measurement Units: Number of trees (counts), DBH in cm to the nearest millimeter

Sampling Frequency: Once during the growing season.

Equipment: Meter tapes (2), dbh tape.

Data Management: Enter into database: site name, plot number, species, direct count, DBH,

V_{treeba}

Definition: Basal area of canopy trees within forested zone (≥ 15 cm DBH).

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Measure the DBH of all canopy trees ($\geq$ 15 cm DBH) within plot. DBH is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the DBH should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the DBH measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

Measurement Units: DBH canopy trees.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), DBH tape.
Data Management: Enter into database: site name, plot number, species, DBH.

$V_{saplingdensity}$

Definition: count of saplings > 1m high, DBH of 1 cm to 7.5 cm.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species of all saplings > 1m high with a DBH of 1 cm to 7.5 cm in 11.35m radius plot. DBH is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the DBH should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the DBH measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

Measurement Units: number of sapling trees (count) by species.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), DBH tape, meter stick.
Data Management: Enter into database: site name, plot number, species, count.

$V_{hydroalt}$

Definition: count of hydrologic stressors within 30m of assessment area.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot within the wetland assessment area

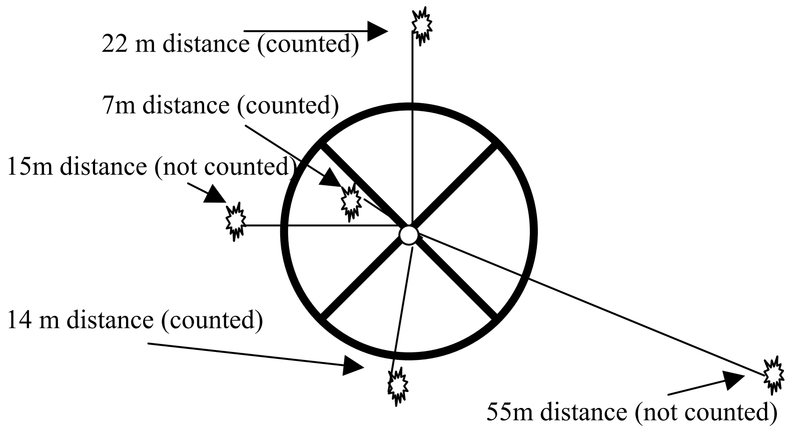
Protocol: . Record all hydrologic stressors (Appendix IV) within 30m of plot.
Measurement Units: number of stressors.
Sampling Frequency: Once.
Equipment: Meter tapes (2), DBH tape, meter stick.
Data Management: Enter into database: site name, plot number, species, count.

$V_{Stdeadbuff}$

Definition: presence of dead standing woody debris in buffer.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point. This defines the 11.35 meter radius plot. Measure out from plot center in each quarter slice to the nearest standing dead tree.

Protocol: $V_{stdeadbuff}$ is measured using a modified point quarter method. From the center of the 11.35 m radius plot measure the distance in meters from the plot center to the nearest standing dead tree ≥ 15cm dbh and > 2m high within each quarter (up to 50 m distant).



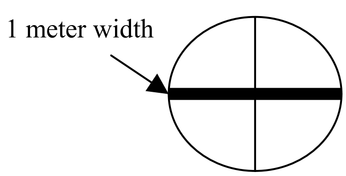
Measurement Units: Distance in meters, DBH in cm
Sampling Frequency: once
Equipment: Meter tapes (2), DBH tape
Data Management: Enter into database: site name, plot number, distance, DBH.

$V_{shrubsp}$

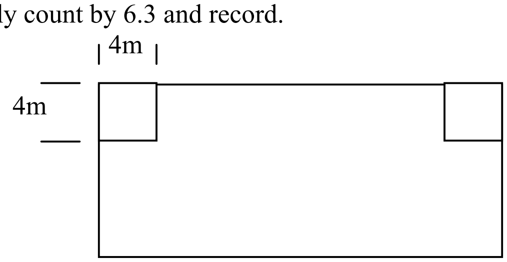
Definition: density of shrubs > 1m high. A shrub is defined as a single-stemmed woody plant between 1 meter and 3 m high or a multi-stemmed woody plant greater than 1 m high.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species and number of all shrubs within the 11.35m radius plot. **Special note: if site has an abundant coverage of shrubs the following alternative sampling methods can be used**.
For circle plots: Randomly select one of the two 22.7m transect lines and count all shrub clumps and stems within a 1m strip along the transect (total sample area = 22.7m^2). Multiply count by 17.8 and record.



For rectangular plots: In each corner of the rectangular plot establish a 4m x 4m plot. Count all shrub clumps and stems with each 16m^2 plot. Multiply count by 6.3 and record.



Measurement Units: Count by species.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), meter stick, pin flags.
Data Management: Entered in database as site name, plot number, species, count.

$V_{\%nativeveg}$

Definition: Presence of native and non-native plant species.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot.

Protocol: Record the species of all observed plants in the 11.35m radius plot and compare with Invasive Alien Plant Species of Virginia list (Appendix III).

Measurement Units: Plant species list.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), plant press or collecting bags for unknown specimens.
Data Management: Enter into database: site name, plot number, species.

$V_{Bufferba}$

Definition: Basal area of trees ≥ 15cm dbh.

Set-up: Lay out two 22.7 meter tapes that cross each other perpendicularly at the 11.35 meter point to define the 11.35 meter radius plot in the forested buffer.

Protocol: Measure the DBH of all canopy trees (≥ 15 cm DBH) within plot. DBH is measured at 1.3 m from the highest above-ground point of the tree trunk. If branches or bulges occur on the tree trunk the DBH should be recorded immediately below the branches or bulges. If trees have vines attached to the trunks at the point of the DBH measurement, attempt to pull the vine away so that you only measure the tree trunk. For trees with multiple trunk stems, stems are counted as individual trees if they split lower than 1.3 m from the ground. If a tree has more than one trunk stem but the split is over 1.3 m from the ground, only measure the main trunk at 1.3 m.

Measurement Units: DBH buffer canopy trees.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), DBH tape.
Data Management: Enter into database: site name, plot number, species, DBH

$V_{distancetoroads}$

Definition: Distance from the edge of the assessed wetland to the nearest paved road in meters.

Protocol: Using a scaled aerial photograph or GIS platform calculate the distance in meters from the edge of the wetland to the nearest paved road.

Measurement Units: meters.
Sampling Frequency: once.
Equipment: scaled aerial photograph, landcover data, GIS
Data Management: Enter into database: site name, distance to paved road in meters.

$V_{\%landcovernatveg}$

To measure $V_{\%landcovernatveg}$ overlay a dot matrix grid on a topographic map or recent aerial photograph. Delineate a 200 m buffer around the WAA. Geographic Information System (GIS) programs can be substituted if available. Determine the percentage of land cover types that encroach into the 200 m buffer and count the number of separate encroachments by land cover type. Landuse types should be sorted by Industrial, Urban – high developed, rural – low developed, Agricultural, and Forested/Wetland/scrub-shrub/open water categories. Wetland, forested, scrub-shrub, and water land over types should be considered natural vegetation.

$V_{tree\%oak}$

Definition: Presence of oak species in both the forested zone and the buffer.

Protocol: From the plant species list record the percentage of canopy trees that are oak species.

Measurement Units: Plant species list.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), plant press or collecting bags for unknown specimens.
Data Management: Enter into database: site name, plot number, species.

$V_{wildlifefood}$

Definition: Presence of plant species important in wildlife food value.

Protocol: From the plant species list record the number of plant species that have moderate or high wildlife food value and have moderate or high winter food value (Appendix I).

Measurement Units: Plant species list.
Sampling Frequency: Once during the growing season.
Equipment: Meter tapes (2), plant press or collecting bags for unknown specimens.
Data Management: Enter into database: site name, plot number, species.

Appendix II. List of plant species especially important for wildlife (modified from Martin et al.(1961).

Acer rubrum
Asimina triloba
Carex albolutescens
Carex comosa
Carex crinita
carex joori
Carex lupilina
Carex lurida
Carya glabra
Celtis spp
Clethra alnifolia
Diospyros virginiana
Hypericum virginicum
Hypericum walteri
Ilex spp
Itea virginica
Leucothoe racemosa
Liquidambar styraciflua
Liriodendron tulipfera
Lonicera japonica
Myrica cerifera
Nyssa sylvatica
Oxydendrum arboreum
Panicum dichotomiflorum
Panicum dichotomum
Panicum rigidulum
Panicum verrucasum
Panicum virgation
Peltandra virginica
Phytolacca americana
Pinus spp
Quercus alba
Quercus falcata
Quercus lyrata
Quercus michauxii
Quercus nigra
Quercus phellos
Quercus velutina
Rhododendron canescens
Rhus spp
Rubus cuneifolias
Sassafras albidum
Smilax spp
Symplocos tinctoria
Toxicodendron radicans
Vaccinum corymbosum

Bolded=mod/high wildlife winter value

Appendix III. Invasive Alien Plant Species of Virginia.

Appendix IV. Stressor checklist.

Wetland Level 2 Stressors Data Sheet

Site Name 0

Evaluation date yyyy/mm/dd

Investigator:

Community Type:
EEM
ESS
EFO
PEM
PSS
PFO
LEM
REM

HGM Classification:
Depression
Slope
Fringe
Mineral Flat
Organic Flat
Riverine
Headwater Floodplain
Mainstem Floodplain
Other

Forest Age Class:
Mature Forest > 50 years
Young Forest 25-50 years
Successional Forest 5-25 years
No Forest

GPS Coordinates (UTMs): 18 S

BAF 5 Count: 0

BAF 10 Count: 0

Comments

Hydrologic Modification | **Roadbeds** | **Sedimentation** | **Toxics** | **Vegetation Alteration**

Verification of Aerial Photos | **Buffer**

Hydrologic Modification Form

Site Name 0

Drain/Ditch (within 30m) ☐ **(30-100m)** ☐

Dike/Weir/Dam (within 30m) ☐ **(30-100m)** ☐

Beaver Dam (within 30m) ☐ **(30-100m)** ☐

Filling/Grading (within 30m) ☐ **(30-100m)** ☐

Dredging/Excavation (within 30m) ☐ **(30-100m)** ☐

Stormwater Inputs/Culvert/Ditch (within 30m) ☐ **(30-100m)** ☐

Other Hydrologic Modifications (within 30m) ☐ **(30-100m)** ☐

Hydrologic Comments

Roadbeds

Site Name 0

>= 4 Lane Paved (30m) ☐ **(30-100m)** ☐
2 Lane Paved (30m) ☐ **(30-100m)** ☐
1 Lane Paved (30m) ☐ **(30-100m)** ☐
Gravel Road (30m) ☐ **(30-100m)** ☐
Dirt Road (30m) ☐ **(30-100m)** ☐
Railroad (30m) ☐ **(30-100m)** ☐
Other Roadbed (30m) ☐ **(30-100m)** ☐

Road Comments

Sedimentation Form

Site Name ☐

Sediment Deposits/Plumes (within 30m) ☐ **(30-100m)** ☐
Eroding Banks/Slopes (within 30m) ☐ **(30-100m)** ☐
Active Construction (within 30 m) ☐ **(30-100 m)** ☐
Active Agriculture (within 30 m) ☐ **(30-100 m)** ☐
Unfenced Cattle Access (within 30m) ☐ **(30-100m)** ☐
Active Timber Harvesting (within 1 yr) (within 30 m) ☐ **(30-100m)** ☐
Active Clear Cutting (within 1 yr) (within 30m) ☐ **(30-100m)** ☐
Other Sedimentation (30m) ☐ **(30-100m** ☐

Sedimentation Comments

Toxicity/Acidification/Nutrification Form

Site Name 0

Point Source Discharge of Toxics/Nutrients (within 30m) ☐ **(30-100m)** ☐

Potential Non-Point Discharge of Toxics/Nutrients (within 30m) ☐ **(30-100m)** ☐

Other Toxic Activity (30m) ☐ **(30-100m)** ☐

Toxic Comments

Vegetation Alteration Form

Site Name 0

Mowing (within 30m) ☐ **(30-100m)** ☐

Brush Cutting (within 30m) ☐ **(30-100m)** ☐

Excessive Herbivory/Grazing (within 30m) ☐ **(30-100m)** ☐

Utility Easement Maintenance (within 30m) ☐ **(30-100m)** ☐

Herbicide Application (within 30m) ☐ **(30-100m)** ☐

Timber Harvesting (within 5 yrs) (within 30m) ☐ **(30-100m)** ☐

Clear Cutting (within 5 yrs) (within 30m ☐ **(30-100m)** ☐

Invasive Plants > 20% (within 30m) ☐

Invasive Species (within 30m)

Invasive Plants > 20% (30-100m) ☐

Invasive Species (30-100m)

Other Vegetation Alteration (30m) ☐ **(30-100m)** ☐

Field Verification of Aerial Photo

Site Name 0

	Area (sq. meters)		Area (sq. ha)
Planted Pine Forest (200m)		**(1km)**	
Agriculture/Pasture (200m)		**(1km)**	
Agriculture/Cropland (200m)		**(1km)**	
Industrial (200m)		**(1km)**	
Urban - High Intensity Residential (200m)		**(1km)**	
Rural - Low Intensity Residential (200m)		**(1km)**	
Roadway (200m):		**(1km)**	
Other (200m)		**(1km)**	

Field Verification Comments

Appendix V. Variables investigated but not used.

Buffer zone hardwood to softwood ratio. Measured as ratio between hardwood trees (i.e. oaks) and softwood trees (i.e. pines) at site. Highly variable and $V_{tree\%oak}$ was more discriminating between disturbed and undisturbed sites.

Stem count (density) of mid-story trees. Measured as count of mid-story trees (7.5<15 cm DBH). Highly variable among sites.

Ratio of canopy trees, mid-story trees, and saplings. Highly variable among sites.

Standing dead trees within 11.3 m radius plot. Sample plot too small to pick up standing dead. Sample methodology changed to modified point quarter method.

Coarse woody debris within depression. Measured with 11.3 m radius plot within depression. Too difficult to measure during normal or wet years. Assumed that standing dead variable will capture coarse woody debris contribution.

Density of vines. Very little variation. All sites had similar species.

State of decomposition of downed woody debris. Measured as new fallen, aged, or highly decomposed. Highly variable and apparently dependent on stochastic storm events.

Macrotopography within depression. Measured using point quarter method. Too difficult to measure during normal or wet seasons.

Depression depth. Measured as ordinary high water (water marks on vegetation) relative to depression rim. Too difficult to measure in larger sites.

Thickness of O horizon. Measured as depth of O horizon. No discernable pattern associated with disturbance.

Thickness of A horizon. Noted as presence and depth of A horizon. No discernable pattern associated with disturbance.

Consistence of A horizon. Measured in the A horizon using moist soil peds and described as loose, very friable, friable, firm, very firm, and extremely firm. No discernable pattern associated with disturbance.

Consistence of B horizon. Measured in the B horizon using moist soil peds and described as loose, very friable, friable, firm, very firm, and extremely firm. No discernable pattern associated with disturbance.

Depth to Pan. Measured as depth to and thickness of a confining layer (i.e. plow pan, fragipan, argillic horizon, etc.). Too difficult to discern in field and highly variable among sites.

Density of tree cavities. Measured as tree cavities with openings ≥ 2.5 cm within 2 m of the ground. Difficult to measure during normal or wet season within depression and closely correlated with mature canopy tree basal area variable.

Metapopulation. Measured as the number of additional depressional wetlands within 200m buffer around wetland. Incorporated into $V_{\%landcovernatveg}$.

Appendix VI. Digital Ortho Quarter Quads (DOQQ's) for each sample site with NWI coverage.