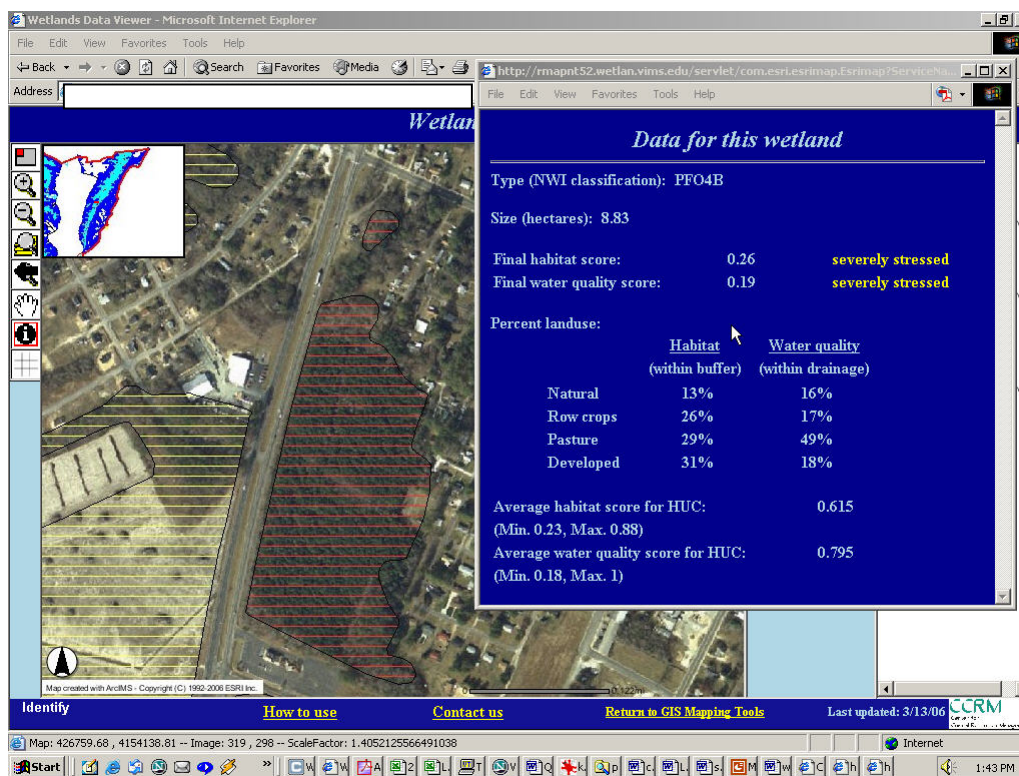


Development of a Nontidal Wetland Inventory, Condition Assessment, and Monitoring Strategy for Virginia 1.3

Final Report to the Environmental Protection Agency Region III

Center for Coastal Resources Management
Virginia Institute of Marine Science
College of William & Mary



Aerial imagery 2002 Commonwealth of Virginia

December 2006



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Introduction

We assess wetlands for a variety of reasons: to report their general condition; to track changes in condition; to estimate their capacity to provide certain services; to evaluate human impacts; to establish compensation requirements; etc. The common element in all of these efforts is an assumption that there are easily observable characteristics that are well correlated with how a wetland is functioning. We believe that we can measure plant community composition or describe microtopography or identify signs of altered hydrology, and from those observations know how the system differs from some optimal or desired condition.

Because they synthesize our understandings into a set of explicit relationships, assessment methods are basically models. Every method currently used is based on a set of assumptions about the relationships between observable characteristics in a wetland and performance of valued services. The assessment method essentially predicts the level of a wetland's performance. It does this not by measuring the performance directly, but rather by measuring characteristics we know or believe to be correlated with performance. Absent research that documents the accuracy of the underlying assumptions relating structure and performance, the model may or may not be valid.

This is a critical insight that should inform the ultimate usage of assessment method results. Knowing whether the assessment purports to say something about actual capacity to provide services, or simply similarity to benchmark systems is important.

There are two general approaches to wetlands assessment. The first presumes that a wetland is providing optimal benefits when it is in pristine condition. For convenience, we refer to this in the following text as the Pristine Optima (PO) model. Under the PO model deviation from a pristine condition is the appropriate metric for assessment. The second approach assumes that beneficial wetland services do not all operate as a linked set. Instead individual services (e.g. habitat functions or water quality functions) are controlled by specific sets of wetland characteristics, and therefore there may be no single optimal state. For convenience we refer to this as the Multiple Services (MS) model. Under the MS model there are typically assessment metrics for each service of interest.

The difference between these two approaches may not seem significant at first, but it can have important implications for the structure of the assessment method, and the kind of information the method can provide.

The PO model is generally implemented by identifying reference wetlands along a "disturbance" gradient extending from pristine to highly impacted. The underlying assumptions include: (1) there is a relationship between wetland services and the disturbance gradient; (2) the nature of the "shape" of that relationship (e.g. linear, stepped, hysteretic); and (3) easily observed parameters can appropriately describe the disturbance gradient. There are a variety of ways in which these assumptions can be tested, effectively calibrating and/or validating the model. PO model assessments vary widely in degree to which these steps have been completed.

An important characteristic of many PO model assessments is their reliance on empirical data to describe/define the optimum condition. Typically practitioners will define the disturbance gradient based primarily on best professional judgment, and then work diligently to describe the characteristics of wetlands they have assigned to the pristine end of the gradient. These characteristics then become the benchmarks for evaluation of other wetlands.

MS models can differ from PO models in several ways. Perhaps the most basic is the description/definition of optimal conditions. Under the MS model, each wetland service can have a set of physical, biological, or chemical conditions that improve the wetland's capacity to perform. For example, conditions that optimize habitat services may not be identical to those that are important for water quality services. Identification of the optimal set of conditions for each service is typically a conceptual rather than empirical effort. The model is defined based on best professional judgment or existing knowledge as a starting point. The utility of the model depends on the accuracy of these assumptions, and so validation is an important step.

MS models generate several assessments for each wetland. The assessments are service specific. Integrating service assessments to provide an overarching characterization for a wetland or population of wetlands can be accomplished, but requires an explicit protocol that is well understood. Combining individual service assessments inherently involves relative values. This is a management policy decision that cannot be ecologically based, and so should be very clear if undertaken.

A PO model is often implemented with a multilevel assessment in which the certainty of a wetland's position on the disturbance gradient is improved by more and more data collection. Typically, these efforts are characterized as Level 1, Level 2, and Level 3 assessments, with Level 1 being the simplest and fastest. An important characteristic of the PO model is that the various levels of effort can function independently. Each can result in a characterization of condition for an individual wetland or a population of wetlands.

MS models can be similarly implemented with multilevel protocols in which higher levels of effort are intended to reduce the uncertainty of the characterization.

Not all multilevel assessments are structured in this manner, however. The Virginia wetland condition assessment method is an MS model that involves three levels of data collection. Here the Level 2 and Level 3 sampling are intended to calibrate and validate the model that is applied at the Level 1 (model development) stage (Figure 1). The data collections are not designed to operate independently. In this method, the goal is to characterize the capacity of every mapped wetland to provide water quality and habitat services using remotely sensed data. The underlying models are based on existing research and best professional judgment. They specify the combination of landscape level parameters that are most likely predictive of these capacities. The model application produces a relative score for each wetland for each service.

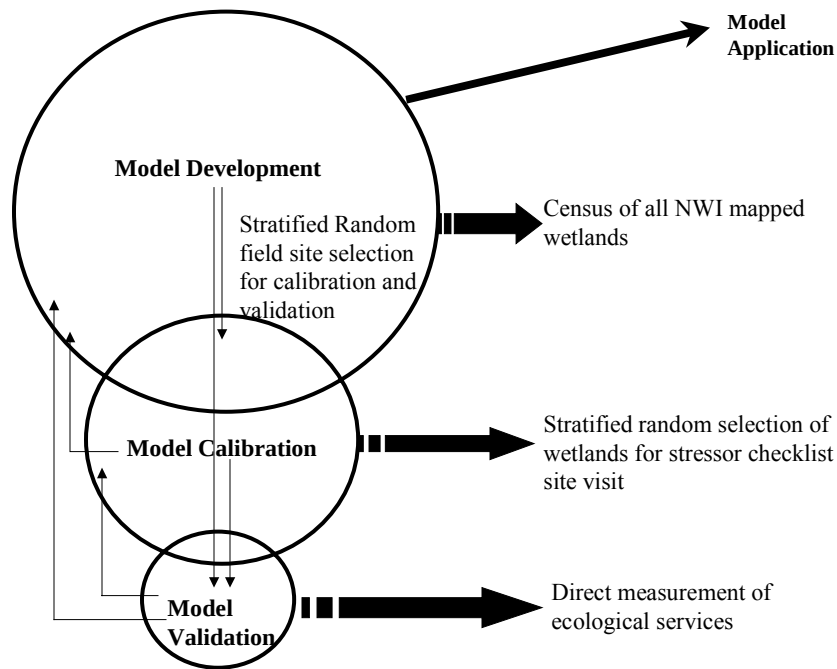


Figure 1. Multi-levelled wetlands assessment and monitoring protocol design.

The protocol was applied in Virginia with calibration and validation in the coastal plain. The completion of the Model Application phase provides a census-level assessment of mapped nontidal wetlands in Virginia (approximately 222,000 wetland units- polygons, arcs, points) by watersheds, utilizing a GIS-based analysis of remotely sensed information and Model Calibration sampling of the Coastal Plain (Figure 2).

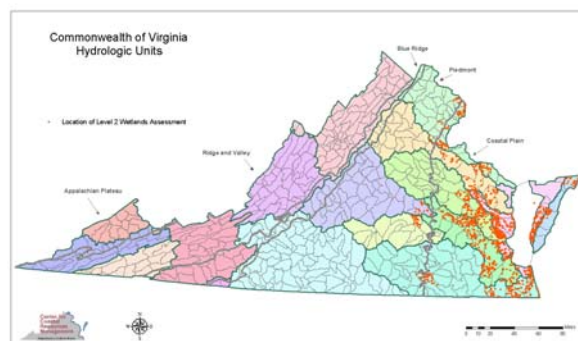


Figure 2. Hydrologic units (8 and 14 digit) of Virginia by physiographic province. Red dots depict Model Calibration assessment sites.

Model Application is a combination of Model Development, Model Calibration and Model Validation, and provides an evaluation of the capacity of wetlands to

provide ecosystem services based on their position in the landscape. This information is directly applicable to status and trends reporting under Clean Water Act Section 305(b), and can be utilized in permitting programs to assess cumulative impacts to wetlands within watersheds.

Methodology

Model Development.

The initial Model Development assessment is designed to characterize landuse patterns and features around wetlands as well as individual wetland characteristics to determine the wetlands overall condition as related to habitat and water quality functions (Table 1). The water quality analysis determines the percentages of different landcovers and features within the contributing drainage area of the targeted wetlands.

Variable
Wetland Type (EM,SS, FO)
Wetland Size (ha) #0.04 to >200
Landcover Type (natural, pasture, cropland, developed)
Density of Roads within 200m

Table 1. Model development assessment metrics.

In order to conduct the analysis, the watershed around each wetland is generated. The watershed delineation requires an elevation data source. We used the USGS National Elevation Dataset (NED), which is a 1:24,000 30-meter resolution dataset. The source of the wetlands data is the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service. The NWI and the NED are imported into ESRI ArcView 3.2; the NED is in ESRI GRID format and the NWI is in ESRI shapefile format. Then the hydrologic tools available in ArcView are used to create the watersheds. First, the isolated sinks in the NED are filled. These sinks are localized depressions in the elevation data, which are assumed to be anomalies. The new NED is used to generate a “flow direction” GRID; the flow direction GRID assigns numeric values to individual cells in the GRID based on the flow direction in that cell. Finally, each NWI wetland must be converted into a GRID format, and a watershed GRID is generated around it from the flow direction GRID.

The second part of this project uses USGS TIGER/Line 2000 roads data and the USGS National Land Cover Dataset (NLCD) 1999 in conjunction with the drainage watersheds created above and the NWI wetlands data. All raster data is converted to vector data and analyses are run in Workstation ArcInfo. Nontidal palustrine emergent, scrub/shrub, and forested (PEM, PSS, PFO) wetlands are assessed to determine their value for habitat suitability and water quality. Wetlands are segregated for habitat and water quality based upon their type, size, density of roads, and surrounding landcover.

Each wetland is buffered by 200m and combined with the land cover (NLCD). NLCD has 15 land cover classifications in Virginia, which we combine into 10 types for our initial analysis and ultimately four classifications in the final analysis (Table 2).

Land cover Type	
Wetland Forest Water	Natural
Pasture	Pasture
Cropland	Cropland
Bare rock/sand, Transition Residential Urban Industrial	Developed

Table 2. Landcover types.

Model Calibration

Model calibration is conducted on site utilizing a suite of anthropogenic stressors. The stressors selected are supported by extant literature and have the ability to be modified by a resource manager (Table 3). Mapped National Wetland Inventory wetlands were selected for sampling by a stratified random design. Wetlands were stratified by wetland type (FO, SS, EM), 14 digit hydrologic unit, and physiographic province (coastal plain). 1,326 sites were sampled in forty 14 digit HUCs.

Randomly selected wetlands were assessed at the polygon, arc, or point center. From the center point stressors within a 30m radius circle and between 30m and 100m radius circle were tabulated. Stressors used for the assessment were selected after a review of extant literature (Appendix III) and their applicability for management alteration (Table 3).

Sediment Deposits
Eroding Banks
Active Construction
Other sedimentation
Potential Source Discharge
Potential Non-Point Source Discharge
Other hydrologic alterations
Active Agriculture
Unfenced Cattle
Active Timber Harvesting (within 1 yr)
Active Clear Cutting (within 1 yr)
Other toxic inputs
Drain/Ditch
Filling/Grading
Dredging/Excavation

Stormwater inputs/culverts/input ditches
>= 4 lane paved road
2 lane paved road
1 lane paved road
gravel
dirt
railroad
Other roadways (parking lots)
utility easement maintenance
herbicide application
Dike/Weir/Dam
Beaver Dam
mowing
brush cutting
excessive herbivory
timber harvesting (1-5yrs)
clear cutting (1-5 yrs)
invasive species present
Other vegetative alteration

Table 3. Onsite stressor list.

Sample size was determined by oversampling some areas and examining the standard deviation around the running mean for stressor counts (Figure 3). A sample size of over 20 for each 14 digit HUC captures the stressor count variation in the coastal plain.

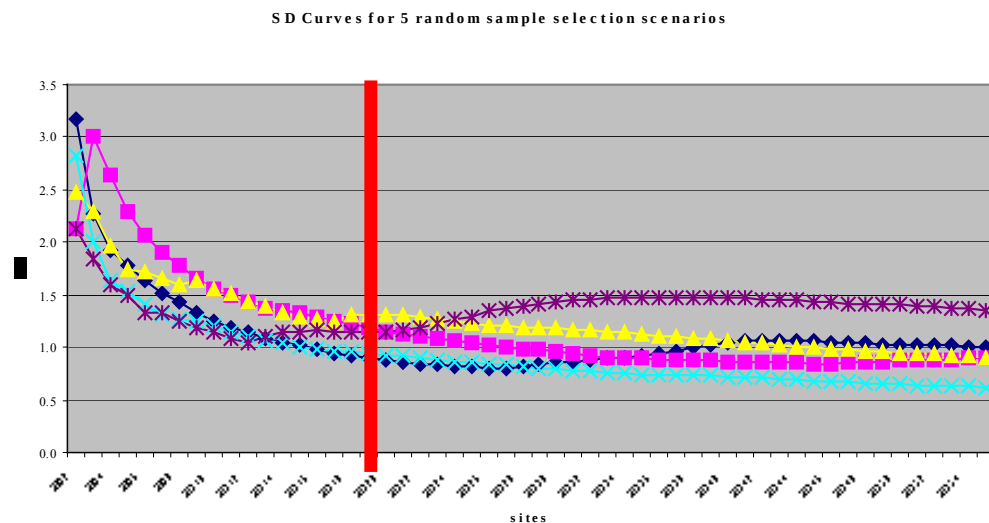


Figure 3. Running mean of standard deviation for five random sample scenarios.

Model Validation

Model validation was conducted by intensive sampling of direct ecological service endpoints in 28 sites throughout the coastal plain (Figure 4) of different hydrogeomorphic regimes and varying size (Table 4). Automatic sound



Figure 4. Validation site locations in the coastal plain.

recording devices were deployed during the summer to all 28 sites to test relationships between the ecological service of providing habitat for birds and amphibians. The system recorded the sound signature of each site by recording a fifteen minute segment at 6:00am and 9:00pm for three consecutive days. Relationships between sound signatures and surrounding landuse and stressor level were analyzed by calculating an Analysis of Similarities (ANOSIM).

Site	Size (acres)	HGM Classification
EL 1	1.6	Flat
DS 3	183.8	Flat
SF2	500.1	Flat
SB 2	2.1	Flat
TN	16.7	Flat
SL 1	307.1	Flat
RICH 3	0.5	Depression
17 A	0.7	Depression
RICH 4	1.5	Depression
FT. EUST 5	1.8	Depression
DENB 7	1.7	Depression
COLO1	13.8	Headwater
COLO2	21.4	Headwater
COLO4	2.7	Headwater
CHAMBREL	1.9	Headwater
CHISIL RUN	6.6	Headwater
CLAYMONT	2.3	Headwater
WARDS CREEK	0.5	Headwater
BEAVERDAM CREEK	5	Headwater
WILLYS	2	Headwater

ZION CREEK	5.4 Headwater
DRAGON RUN	7.2 Headwater
BULL SWAMP	3.8 Headwater
RICHARDSON CREEK	1.3 Headwater
LONG BRANCH CREEK	3 Headwater
ELK HORN CREEK	5 Headwater
GUILFORD CHURCH BRANCH	3.6 Headwater
MATTAWOMEN CREEK	2.4 Headwater

Table 4. Validation sites in the coastal plain of Virginia.

Results and Discussion

Model Calibration

Roads, modification of vegetation through mowing, brush cutting, and timber harvesting, and ditching were the most common stressors identified during the calibration phase (Figure 5).

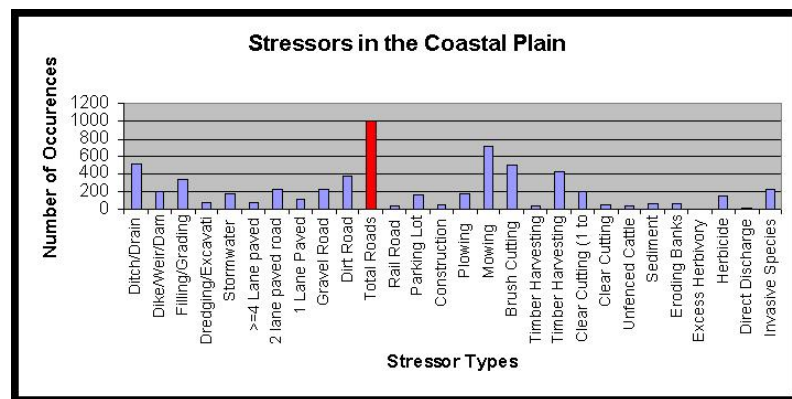


Figure 5. Stressors of coastal plain wetlands.

Landcover metrics tabulated during the model development phase were correlated with stressor scores (Table 5).

Pasture	0.280	p-value	0.000
rowcrops	0.226	p-value	0.000
natural	-0.493	p-value	0.000
developed	0.352	p-value	0.000

Table 5. Correlations between total stressor count and landcover in the 200m buffer.

There was no significant difference between total stressor count and forested (FO) or shrub (SS) wetland type. But there was a significant difference when forested and shrub were compared with emergent (EM) (Figure 6).

Wetland type				Based on Pooled StDev
Level	N	Mean	StDev	-----+-----+-----+-----
-				
EM	359	5.744	5.562	(-----*-----)
F0	577	4.360	4.849	(-----*-----)
SS	237	3.713	5.049	(-----*-----)
-				-----+-----+-----+-----
Pooled StDev =		5.117		4.0 5.0 6.0

Table 6. Analysis of variance for total stressors and wetland types (EM=emergent, F0=forested, SS=Scrub/shrub).

Changepoint analysis was used to define thresholds in nonlinear relationships for refinement of the scoring protocol (Figure 7).

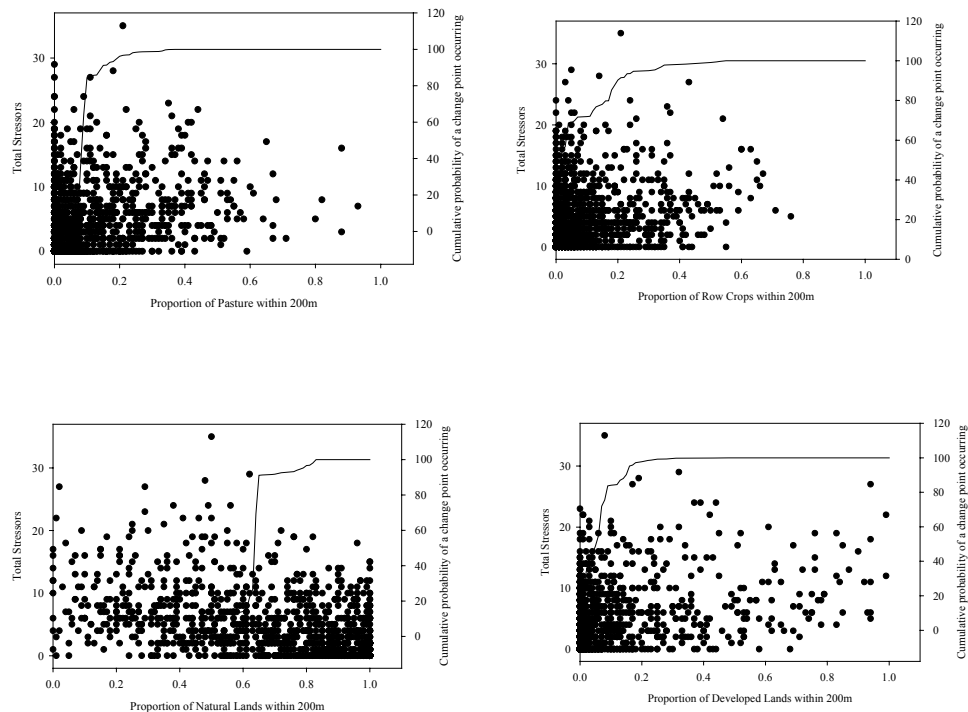


Figure 7. Changepoint analysis for determining landcover percentage versus stressor count thresholds.

Following calibration of the landuse metrics a draft final scoring protocol was developed for determining the level of stress on the capacity of coastal plain nontidal wetlands to perform the ecosystem services of providing habitat and affecting water quality (Appendix I). The draft final scoring protocol will be further calibrated after completion of the validation analysis to produce the final scoring protocol.

Preliminary analysis of the validation sampling shows a strong relationship between stressors, landuse metrics, direct ecological services with correlations

between percent pasture and total dissolved nitrogen (Pearson 0.63, $P = 0.005$) and between rowcrops and total dissolved nitrogen (Pearson 0.69, $P = 0.002$).

Model Validation

Distinct patterns between high and low stress and between surrounding natural, developed, and pasture landuse were discernable through wetland sound analysis (Figure 8) ($p = 0.00$; ANOSIM). Surrounding developed landuse within a wetlands contributing drainage was correlated with incision ratio in headwater wetland streams (Pearson 0.70, $p = 0.003$). Stressor sampling during the calibration phase established relationships between surrounding landuse metrics and onsite stressors. Present information validates surrounding landuse and stressor level impacts on the direct ecological service of habitat provision though continued seasonal sampling is necessary to complete the validation process and is ongoing.

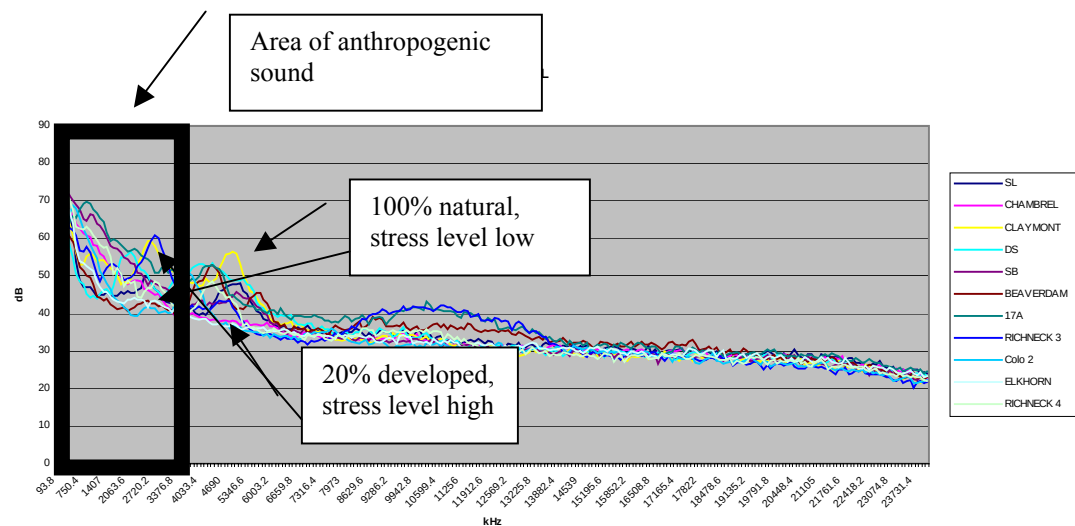


Figure 8. Site sound signatures in decibels and KHz.

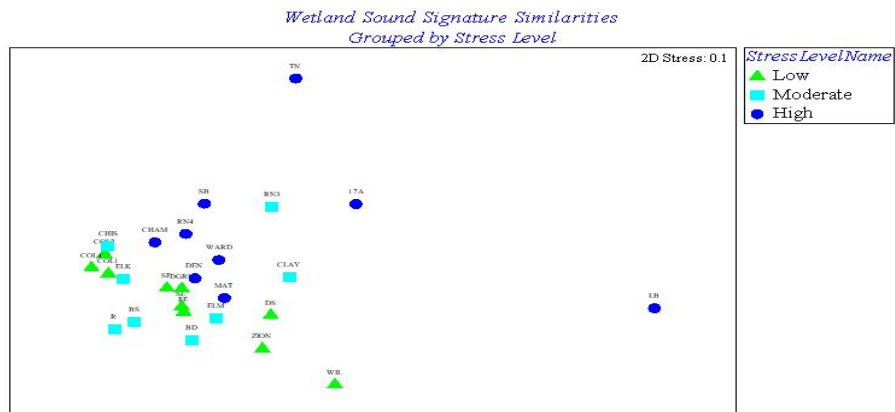


Figure 9. Sound signatures grouped by stress level.

Model development and calibration information has been analyzed and transferred to a prototype web based system. The system has been designed to allow quick utilization of wetland condition information at various scales. Samples of the system are displayed in Appendix II.

Additional validation is ongoing for final refinement of the model protocol for coastal plain wetland condition assessment.

Appendix I. Wetland Scoring Protocol After Level II Calibration

Habitat

Natural

=IF(%natural=0,0,(IF(natural>=0.8,1,otherwise natural =natural/0.8)))

If %natural equals 0 then score equals 0. If %natural is greater than or equal to 0.8 then score equals 1. All other scores equal %natural divided by 0.8.

Pasture

=IF(%pasture-0.08<=0,1,(IF(%pasture>=0.2,0.6,(1-((%pasture-0.08)/0.12)*0.4))))

If %pasture minus 0.08 is less than or equal to 0 then score equals 1. If %pasture is greater than or equal to 0.2 then score equals 0.6. All other scores equal 1 minus %pasture minus 0.08 divided by 0.12 times 0.4.

Rowcrops

=IF(%rowcrops=0,1,(IF(%rowcrops>=0.3,0.4,(1-((%rowcrops/0.3)*0.6))))

If %rowcrops equals 0 then score equals 1. If %rowcrops is greater than or equal to 0.3 then score equals 0.4. All other scores equal 1 minus %rowcrops divided by 0.3 times 0.6.

Developed

=IF(%developed<0.02,1,(IF(%developed>=0.16,0,(1-((%developed-0.02)/0.14))))

If %developed is less than 0.02 then score equals 1. If %developed is greater than or equal to 0.16 then score equals 0. All other scores equal 1 minus %developed minus 0.02 divided by 0.14.

Wetland Size

=IF(size>100,1,IF(size>40,0.9,(IF(size>20,0.8,(IF(size>10,0.6,(IF(size>3.4,0.4,(IF(size>0.3,0.2,(IF(size>0.04,0.1,0))))))))))))

If size is greater than 100 score equals 1. If size is greater than 40 score equals 0.9. If size is greater than 20 then score equals 0.8. If size is greater than 10 then score equals 0.6. If size is greater than 3.4 then score equals 0.4. If size is greater than 0.3 then score equals 0.2. If size is greater than 0.04 then score equals 0.1. If size is less than 0.04 then score equals 0.

Wetland Prox.

% of wetlands within 200m buffer

Score equals percent of wetlands within 200m buffer.

Road Density (linear meters within 200m buffer divided by area times 100)

=IF(roaddensity=0,1,(IF(roaddensity>=1,0,(1-(((2.78+(8*roaddensity))/10))))

If roaddensity equals 0 then score equals 1. If roaddensity is greater than or equal to 1 then score equals 0. All other scores equal 1 minus 2.78 plus 8 times roaddensity divided by 10.

Wetland type

=IF(\$type\$1=P2,0.8,1)

If type equals PEM then score equals 0.8. All others score 1.

Habitat Score

=(((nat+dev+rowcrops+pasture)/4)+((size+wet prox+type)/3)+roaddensity)/3

natural score + developed score + rowcrops score + pasture score divided by 4 plus size score + wet proximity score + type score divided by 3 plus roaddensity score. Entire equation divided by 3.

Water Quality

Natural

=IF(%natural=0,0,(IF(%natural>=0.75,1,%natural/0.75)))

If %natural equals 0 then score equals 0. If %natural is greater than or equal to 0.75 then score equals 1. All other scores equal %natural divided by 0.75.

Pasture

=IF(%pasture-0.1<=0,1,(IF(%pasture>=0.18,0.7,(1-((%pasture-0.1)/0.08)*0.3))))

If %pasture minus 0.1 is less than or equal to 0 then score equals 1. If %pasture is greater than or equal to 0.18 then score equals 0.7. All other scores equal 1 minus %pasture minus 0.1 divided by 0.08 times 0.3.

Rowcrops

=IF(%rowcrops<0.07,1,(IF(%rowcrops>=0.2,0.5,(1-(((%rowcrops-0.07)/0.13)*0.5))))

If %rowcrops is less than 0.07 then score equals 1. If %rowcrops is greater than or equal to 0.2 then score equals 0.5. All other scores equal 1 minus %rowcrops minus 0.07 divided by 0.13 times 0.5.

Developed

=IF(%developed<0.03,1,(IF(%developed>=0.09,0,(1-(((%developed-0.03)/0.06))))

If %developed is less than 0.03 then score equals 1. If %developed is greater than or equal to 0.09 then score equals 0. All other scores equal 1 minus %developed minus 0.03 divided by 0.06.

Road Density

=IF(roaddensity=0,1,(IF(roaddensity>=1,0,(1-((3.8+(2.9*(roaddensity)))/10))))

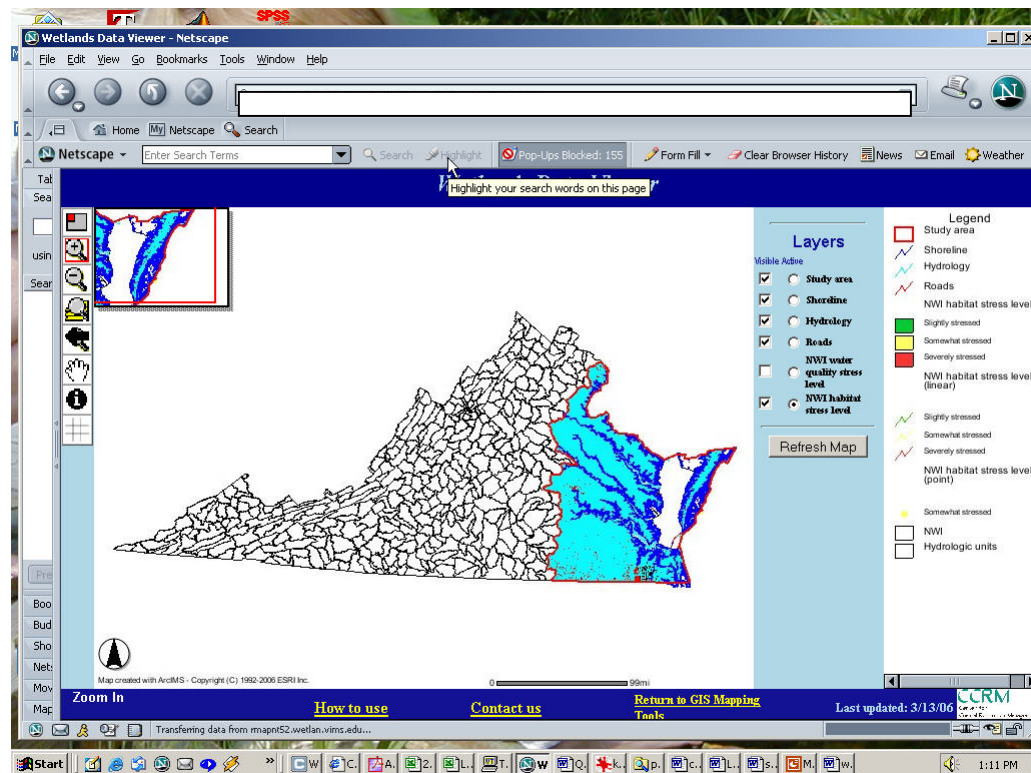
If roaddensity equals 0 then score equals 1. If roaddensity is greater than or equal to 1 then score equals 0. All other scores equal 1 minus 3.8 plus 2.9 times roaddensity divided by 10.

Water Quality Score

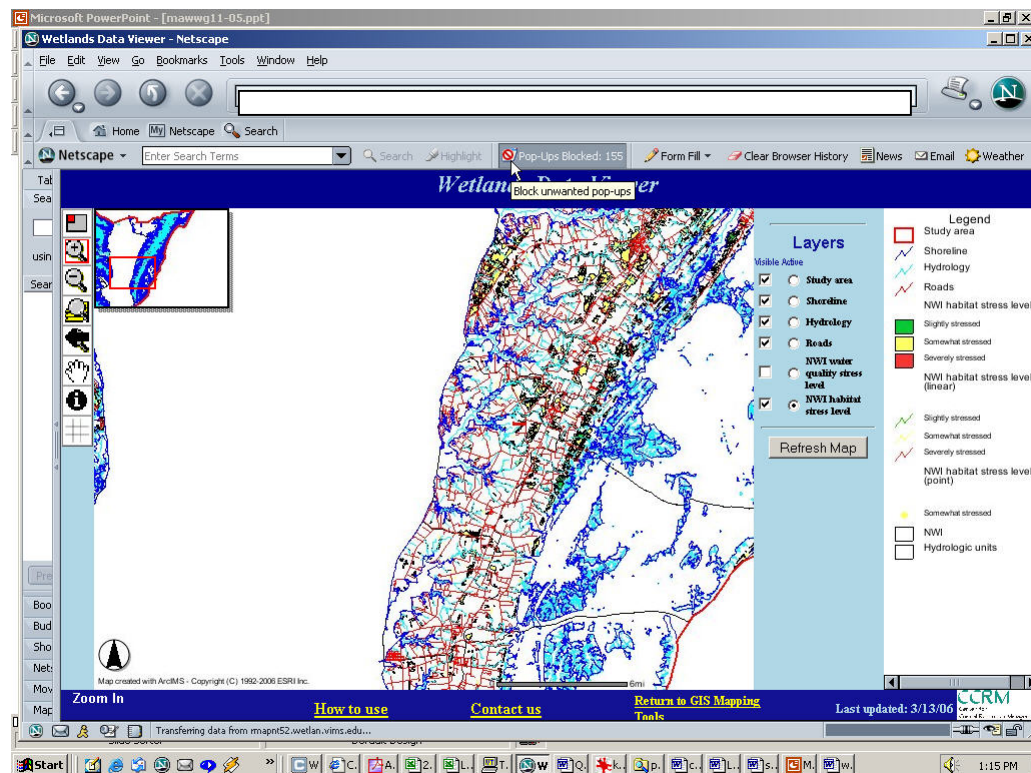
=(nat+pasture+rowcrops+developed)/4+roaddensity/2

natural score + pasture score + rowcrops score + developed score divided by 4 plus roaddensity score. Entire equation divided by 2.

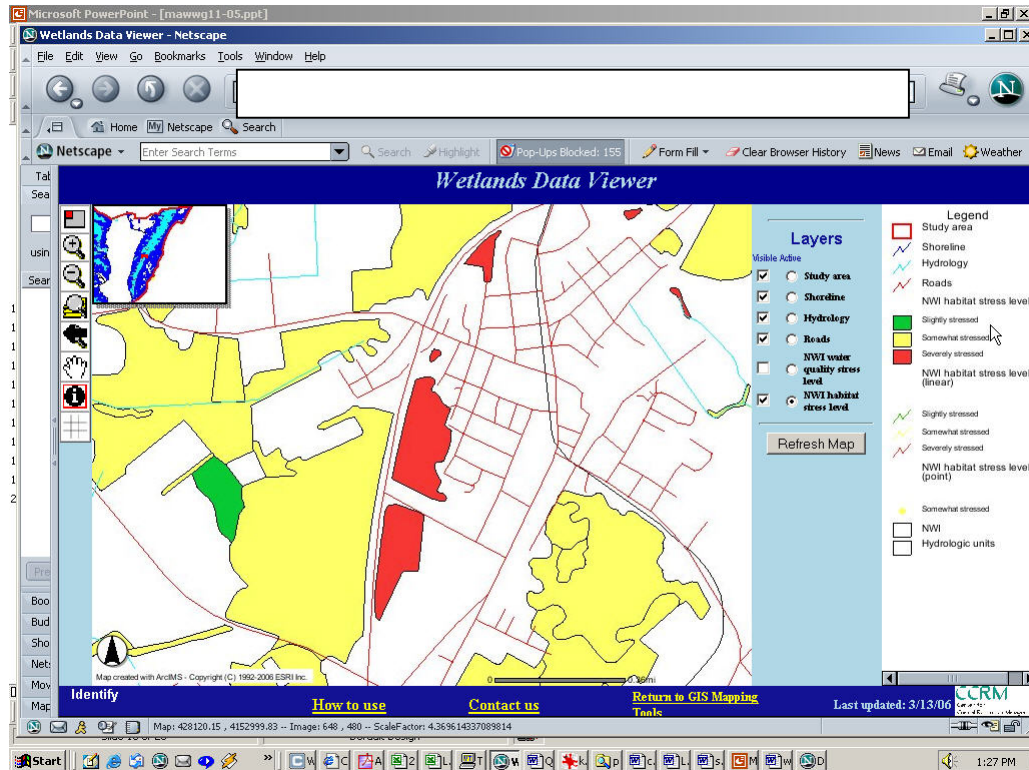
Appendix II. Interactive web based wetland condition assessment program.



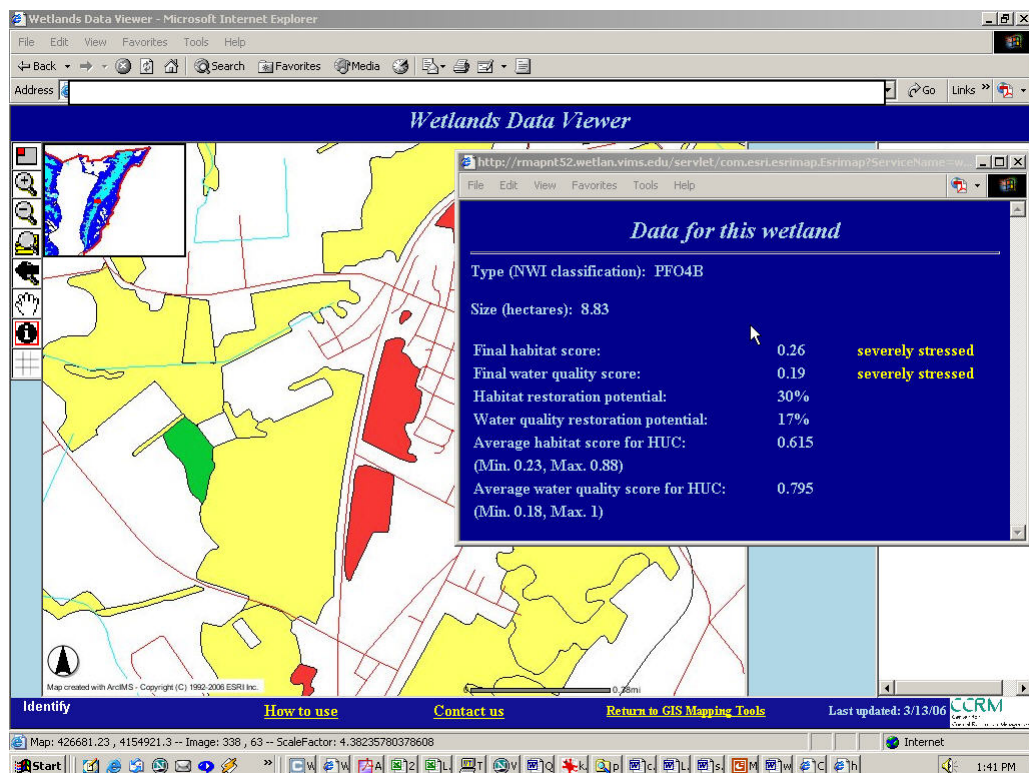
Coastal Plain wetland condition assessment.



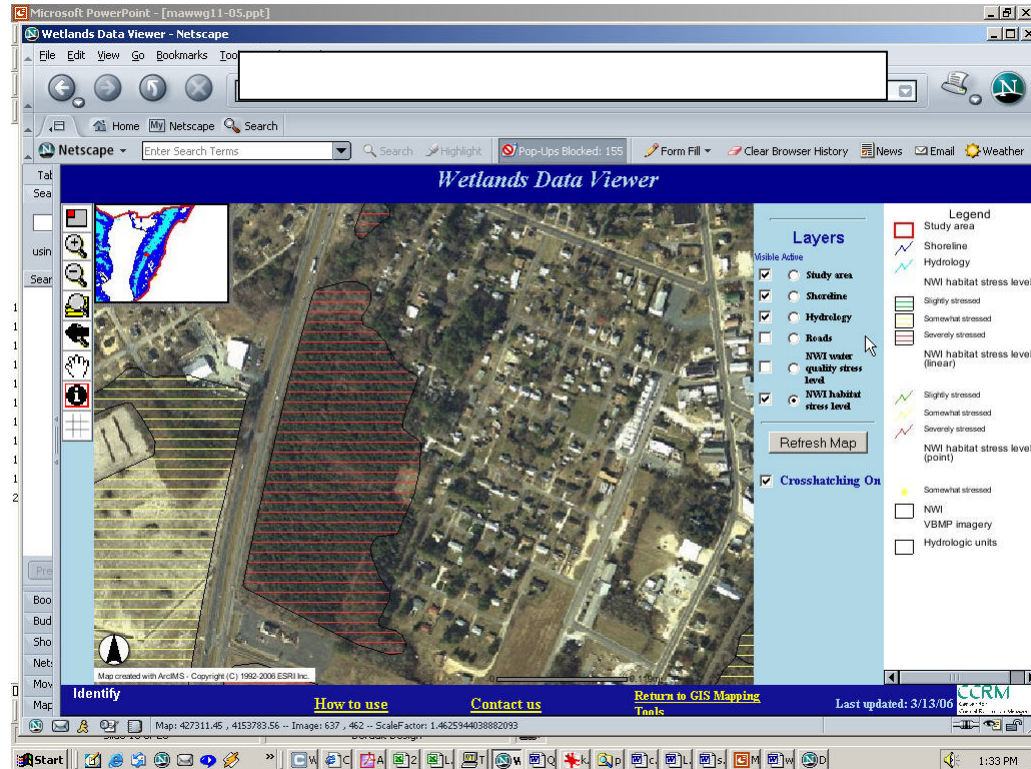
Zoom capability to area of interest.



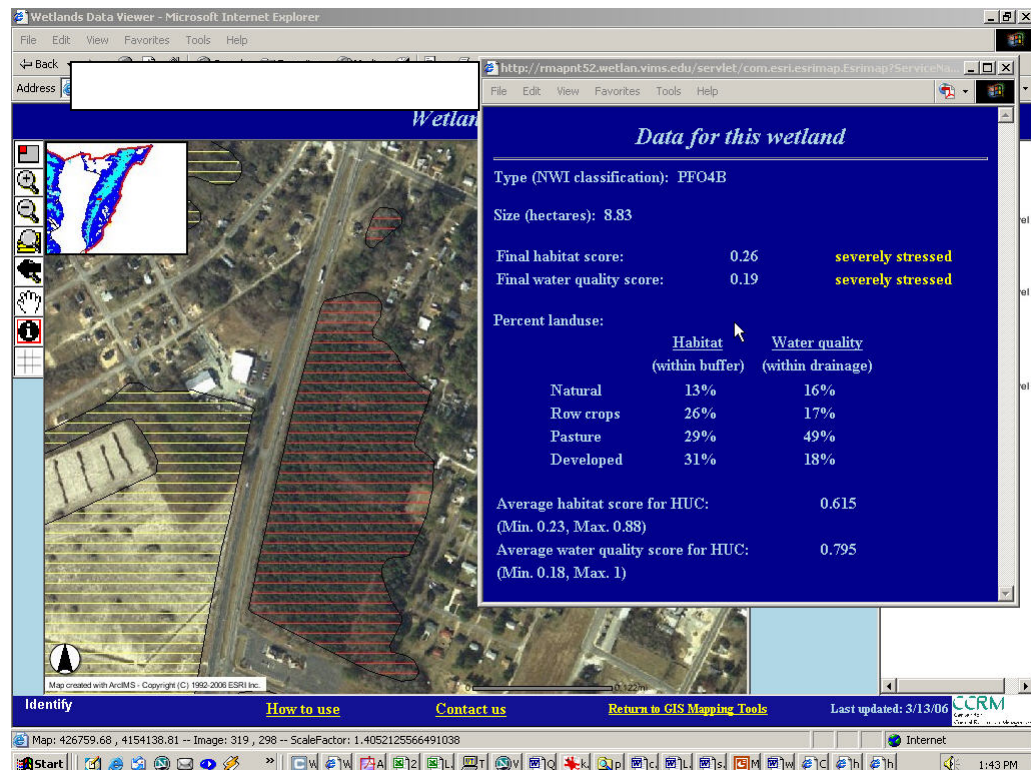
Wetland condition assessment scoring code.



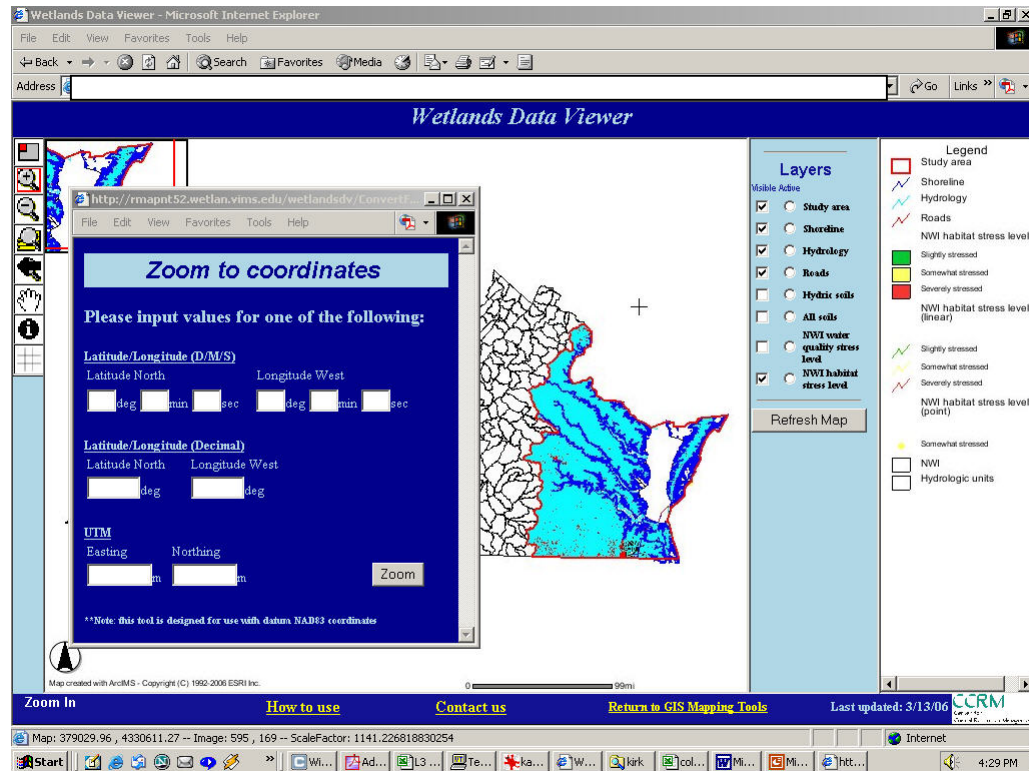
Attribute table describing specific wetland of interest.



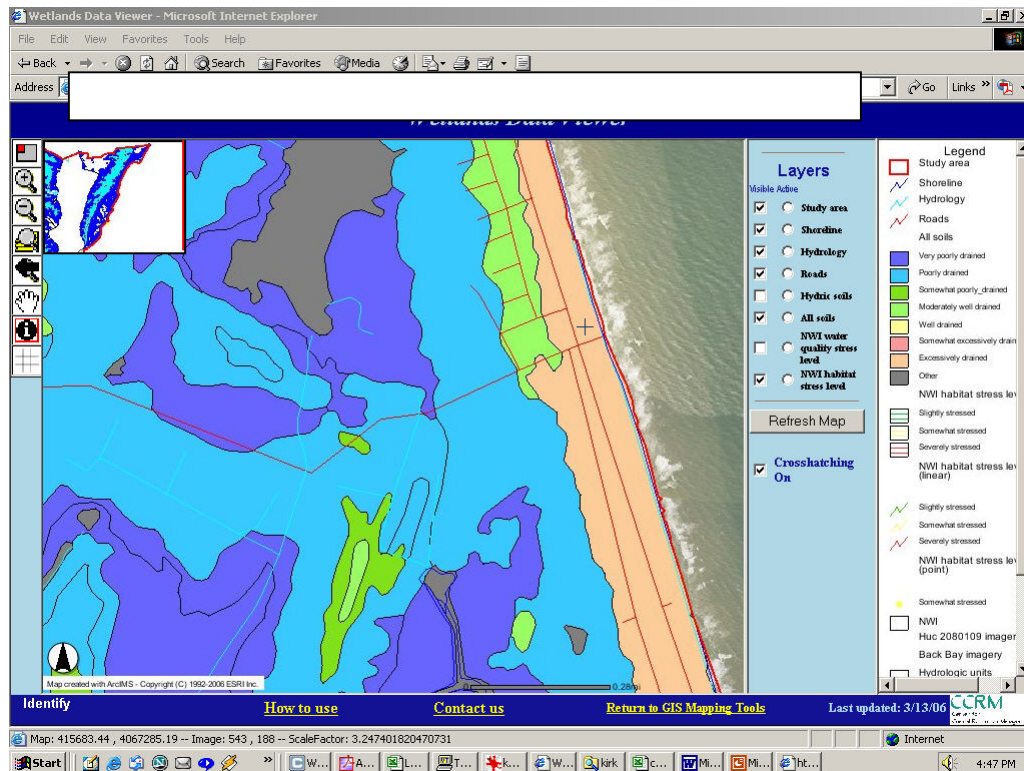
Zoom capability to base aerial photo (Aerial imagery 2002 Commonwealth of Virginia)



Surrounding landuse percentages for wetland of interest (Aerial imagery 2002 Commonwealth of Virginia).



Zoom to specific wetland coordinate capability.



Additional information added as possible (such as soil type).

Appendix III. Supporting literature.

Alvarez-Cobelas M., S. Cirujano, and S. Sanchez-Carrillo. 2001. Hydrological and botanical man-made changes in the Spanish wetland of Las Tablas de Daimiel Biological Conservation 97:89-98.

Armstrong A. C., S. C. Rose, and F. Arfa-Zangeneh. 2000. Impacts of Wetness Enhancement Measures on the Hydrology of a Lowland Wetland: Marsh Gibbon Case Study. *Physical, Chemical and Earth Science* 25:617-622. Impacts of artificial enhancement schemes on the hydrology of the River Ray at Marsh Gibbon near Bicester, Oxfordshire in the UK are examined. The measures will aim to raise the water levels, or retain the flood waters, with the intention of enhancing the status of the wetland vegetation. However, this must be achieved within the constraints of the existing patterns of land use, land tenure, and infrastructure. The use of hydrological models to predict the flows in the catchment, and the construction of a hydraulic model to define the height of the flood waters, is described, and the impacts on the floodplain then mapped. Crucial to such studies is the collection of detailed topographic information. Experience with the use of GPS surveying systems in this environment is described.

Ausden M., M. Hall, P. Pearson, and T. Strudwick. 2005. The effects of cattle grazing on tall-herb fen vegetation and molluscs *Biological Conservation* 122:317-326. The effects of light year-round cattle grazing on tall-herb fen vegetation and wetland molluscs were compared to the effects of non-intervention over a period of four years using grazing exclosures. The distribution of cattle within the area of fen was investigated by plotting the position of the herd at 3–4 day intervals throughout the year. Cattle distributed themselves randomly throughout the fen in spring, autumn and winter, but showed a more aggregated distribution in summer. Grazing reduced the biomass of *Phragmites australis* and increased stem densities of *Glyceria maxima*, resulting in a shift of dominance from *Phragmites* to *Glyceria*. Plant species-richness was also significantly higher in areas open to grazing. Grazing decreased total densities of molluscs and substantially reduced densities of the rare snail *Vertigo moulinsiana*. *V. moulinsiana* was particularly associated with areas of fen that had a high water table and high biomass of ungrazed *Carex riparia*. However, because of the patchy nature of the grazing, *V. moulinsiana* survived at reasonably high densities in patches of ungrazed vegetation within the grazing unit.

Aust M. W., R. Lea. 1992. Comparative effects of aerial and ground logging on soil properties in a tupelo-cypress wetland. *Forest Ecology and Management* 50:57-73. A palustrine water tupelo (*Nyssa aquatica* L.)-baldcypress (*Taxodium distichum* (L.)) swamp in southwestern Alabama was subjected to three types of disturbances during the fall of 1986. Disturbance treatments were those associated with clearcutting of timber: log removal by helicopter, simulated rubber-tired skidder log transport, and herbicide control of vegetative regrowth. An adjacent undisturbed stand served as a reference. Post-harvest measurements of soil physical and chemical properties were collected in 1987 and 1988.

Results indicated that saturated hydraulic conductivity is the dominant influence on soil functions within this ecosystem. Skidder trafficking significantly reduced saturated hydraulic conductivity within 50 cm of the soil surface, thereby decreasing water percolation and drainage on trafficked areas. The reduction of saturated hydraulic conductivity resulted in chemical reduction, decreased oxygen content and increased pH values in the soil of trafficked areas.

Aust M. W., S. H. Schoenholtz, T. W. Zaebst, and B. A. Szabo. 1997. Recovery status of a tupelo-cypress wetland seven years after disturbance: silvicultural implications *Forest Ecology and Management* 90:161-169. Three disturbance treatments were imposed on a palustrine forested wetland (*Nyssa aquatica*-*Taxodium distichum*) located in southwestern Alabama in 1986: (i) clearcutting with helicopter log removal (ELI), (ii) HELI followed by rubber-tired skidder traffic simulation (SKID) and (iii) HELI followed by removal of all vegetation during the first two growing seasons via glyphosate herbicide application (GLYPH). After two growing seasons, it was hypothesized that eventual woody plant growth would be best in the HELI-treated areas, because SKID plots had reduced rates of water movement and soil aeration. However, measurements at stand age seven years indicate that SKID actually has greater total above-ground biomass (65979 kg/ha) than HELI (46748 kg/ha) and SKID plots have a higher proportion of the most desirable timber species (*Nyssa aquatica*). GLYPH areas resemble freshwater marshes, although the areas are being invaded by *Salix nigra* seedlings. All disturbance treatments have significant groundflora components that have increased sediment accumulation 70-175% relative to an undisturbed reference area. By age seven years, regrowth of vegetation has lowered the water table during the growing season but has had little effect on soil redox potential and pH. Our observations suggest that this wetland system is rapidly recovering from logging disturbance seven years ago. .

Aust W. M., S. F. Mader, L. J. Mitchell, and R. Lea. 1990. An approach to the inventory of forested wetlands for timber-harvesting impact assessment. *Forest Ecology and Management* 33-34:215-225. A methodology for assessment of timber-harvesting impacts in a tidal freshwater *Nyssa-aquatica/ Taxodium-distichum* palustrine wetland in southwestern Alabama, USA was developed. The inventory objective was to provide data based upon relevant biophysical and socio-economic parameters to assist wetland regulatory and policy-making agencies. In addition to estimating stand timber stocks, the approach assessed the degree of disruption of ecosystem functions and processes. Specifically, indices were chosen to detect changes in net primary productivity, plant nutrient assimilative capacity, soil nutrient retention and transformation, decomposition, sedimentation rate, hydrology, and provision of wildlife habitat. Methods were chosen for data collection efficiency, interpretive simplicity, and ability to provide a relative index of the integrity and recovery rates of a disturbed ecosystem. This assessment enables wetland managers to determine which parameters are sensitive to functional changes, as well as the relative effects of various harvesting methods for use in promoting best forest management practices.

Babbitt K. J., G. W. Tanner. 2000. Use of temporary wetlands by anurans in a hydrologically modified landscape. *Wetlands* 20:313-322. We examined larval anuran assemblages at 12 temporary wetlands occurring on the MacArthur Agro-Ecology Research center (MAERC) in southcentral Florida. MAERC is an active cattle ranch, and the wetlands on the site are heavily influenced by an extensive series of ditches that drain the landscape. Ditching has resulted in a change from a historically extensive marsh system to a series of isolated wetlands surrounded by upland habitats. Because a majority of anurans in Florida breed exclusively or facultatively in wetlands whose drying regime excludes fish, we were interested in determining the value of these modified wetlands as breeding sites. We examined the effect of wetland size and hydrology on anuran use, and compared breeding activity across three summers that varied greatly in rainfall pattern. We sampled tadpoles from May 93 to August 93 and from May 94 to September 95. A total of 3678 tadpoles from 11 species was collected. *Rana utricularia* was the most abundant species and the only species found in every wetland. Species richness was related positively to wetland size ($r = 0.65$, $p = 0.023$) but not hydroperiod ($r = 0.03$, $p = 0.93$). Tadpole abundance was not related to wetland size ($r = 0.35$, $p = 0.29$) nor hydroperiod ($r = 0.40$, $p = 0.22$). Annual variation in rainfall resulted in significant changes in species composition. A drought during 1993 resulted in no breeding. A high water table in the spring of 1995 resulted in localized flooding in early summer on part of the ranch. Wetlands in these areas were exposed to spillover of water from ditches containing fishes. Wetlands so impacted showed significant changes in species composition from the previous year ($x^2 = 1008$, $p < 0.0001$), whereas wetlands that were not impacted did not differ in composition. The wetlands at MAERC provide dynamic habitats that offer varying breeding opportunities that are highly dependent on meteorological conditions.

Bedford B. L., E. M. Preston. 1988. Developing the scientific basis for assessing cumulative effects of wetland loss and degradation on landscape functions: Status, perspectives, and prospects. *Environmental Management* 12:751-771. The incongruity between the regional and national scales at which wetland losses are occurring, and the project-specific scale at which wetlands are regulated and studied, has become obvious. This article presents a synthesis of recent efforts by the US Environmental Protection Agency and the Ecosystems Research Center at Cornell University to bring wetland science and regulation into alignment with the reality of the cumulative effects of wetland loss and degradation on entire landscapes and regions. The synthesis is drawn from the other articles in this volume, the workshop that initiated them, and the scientific literature. It summarizes the status of our present scientific understanding, discusses means by which to actualize the existing potential for matching the scales of research and regulation with the scales at which effects are observed, and provides guidelines for building a stronger scientific base for landscape-level assessments of cumulative effects. It also provides the outlines for a synoptic and qualitative approach to cumulative effects assessment based on a reexamination of the generic assessment framework we proposed elsewhere in this volume.

The primary conclusion to be drawn from the articles and the workshop is that a sound scientific basis for regulation will not come merely from acquiring more information on more variables. It will come from recognizing that a perceptual shift to larger temporal, spatial, and organizational scales is overdue. The shift in scale will dictate different—not necessarily more—variables to be measured in future wetland research and considered in wetland regulation.

Berdard-Haughn A., A. L. Matson, and D. J. Pennock. Article in Press. Land use effects on gross mineralization, nitrification, and N₂O emissions in ephemeral wetlands. *Soil Biology and Biochemistry* :Stable ¹⁵N isotope dilution and tracer techniques were used in cultivated (C) and uncultivated (U) ephemeral wetlands in central Saskatchewan, Canada to: 1) quantify gross mineralization and nitrification rates and 2) estimate the relative proportion of N₂O emission from these wetlands that could be attributed to denitrification versus nitrification-related processes. In-field incubation experiments were repeated in early May, mid-June and late July. Mean gross mineralization and nitrification rates (10.3 and 3.1 mgkg⁻¹d⁻¹, respectively) did not differ between C and U wetlands on any given date. Despite these similarities, the mean NH₄⁺ pool size in U wetlands (17.2mgkg⁻¹) was two to three times that of the C wetlands (6.7 mgkg⁻¹) whereas the mean NO₃⁻ pool size in U wetlands (2.2 mgkg⁻¹) was less than half that of C wetlands (5.8 mgkg⁻¹). Mean N₂O emission ranged only from 31.8 to 51.1ng N₂O/m² per s over the same period. This trend is correlated to water-filled pore space in C wetlands, demonstrating a soil moisture influence on emissions. Denitrification is generally considered the dominant emitter of N₂O under anaerobic conditions, but in the C wetlands only 49% of the May emissions could be directly attributed to denitrification, decreasing to 29% in July. In contrast, more than 75% of the N₂O emissions from the U wetlands arose from denitrification of the soil NO₃⁻ pool throughout the season. These land use differences in emission sources and rates should be taken into consideration when planning management strategies for greenhouse gas mitigation.

Bossio D. A., J. A. Fleck, K. M. Scow, and R. Fujii. 2006. Alteration of soil microbial communities and water quality in restored wetlands *Soil Biology and Biochemistry* 38:1223-1233.

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”.

Brinson M. M. 1988. Strategies for assessing the cumulative effects of wetland alteration on water quality. *Environmental Management* 12:655-

662. Assessment of cumulative impacts on wetlands can benefit by recognizing three fundamental wetland categories: basin, riverine, and fringe. The geomorphological settings of these categories have relevance for water quality. Basin, or depressional, wetlands are located in headwater areas, and capture runoff from small areas. Thus, they are normally sources of water with low elemental concentration. Although basin wetlands normally possess a high capacity for assimilating nutrients, there may be little opportunity for this to happen if the catchment area is small and little water flows through them. Riverine wetlands, in contrast, interface extensively with uplands. It has been demonstrated that both the capacity and the opportunity for altering water quality are high in riverine wetlands.

Fringe wetlands are very small in comparison with the large bodies of water that flush them. Biogeochemical influences tend to be local, rather than having a measurable effect on the larger body of water. Consequently, the function of these wetlands for critical habitat may warrant protection from high nutrient levels and toxins, rather than expecting them to assume an assimilatory role. The relative proportion of these wetland types within a watershed, and their status relative to past impacts can be used to develop strategies for wetland protection. Past impacts on wetlands, however, are not likely to be clearly revealed in water quality records from monitoring studies, either because records are too short or because too many variables other than wetland impacts affect water quality. It is suggested that hydrologic records be used to reconstruct historical hydroperiods in wetlands for comparison with current, altered conditions. Changes in hydroperiod imply changes in wetland function, especially for biogeochemical processes in sediments. Hydroperiod is potentially a more sensitive index of wetland function than surface areas obtained from aerial photographs. Identification of forested wetlands through photointerpretation relies on vegetation that may remain intact for decades after drainage. Finally, the depositional environment of wetlands is a landscape characteristic that has not been carefully evaluated nor fully appreciated. Impacts that reverse depositional tendencies also may accelerate rates of change, causing wetlands to be large net exporters rather than modest net importers. Increases in rates as well as direction can cause stocks of materials, accumulated over centuries in wetland sediments, to be lost within decades, resulting in nutrient loading to downstream aquatic ecosystems.

Brinson M. M., R. Rheinhardt. 1996. The role of reference wetlands in functional assessment and mitigation. *Ecological Applications* 6:69-76. Compensatory mitigation for damages to wetlands in the United States occurs largely without explicit analysis and replacement of wetland functions. We offer an approach to standardize such analyses and strengthen the connection between ecological principles and policies for wetland resources. By

establishing standards from reference wetlands chosen for their high level of sustainable functioning, gains and losses of functions can be quantified for wetlands used in compensatory mitigation. Advantages of a reference wetland approach include (1) making explicit the goals of compensatory mitigation through identification of reference standards from data that typify sustainable conditions in a region, (2) providing templates to which restored and created wetlands can be designed, and (3) establishing a framework whereby a decline in functions resulting from adverse impacts or a recovery of functions following restoration can be estimated both for a single project and over a larger area accumulated over time. To establish reference standards, conditions inherent to highly functioning sites must be identified for classes of wetlands that share similar geomorphic settings. Ecological functions are then identified, and variables used to model the functions are employed in developing reference standards. Variables range from the highest levels of sustainable functioning to the complete absence of functions when a wetland ecosystem is displaced. An example given for wet pine flats in the North Carolina coastal plain illustrates how to determine the loss of a given function for an impacted wetland, how to calculate recovery (gains) in function through compensatory mitigation, and how to use the relationships between the two (loss vs. gain in function) to set minimum replacement ratios of restored to impacted area. In all cases, data from reference wetlands provide the benchmarks for making these estimates and for directing restoration or creation of wetlands toward the standards established for the wetland class. Programs to implement the use of reference wetlands require regional efforts that build upon the knowledge base of existing wetlands and their functioning.

Brown R. G. 1985. Effects of an urban wetland on sediment and nutrient loads in runoff. *Wetlands* 4:147-158. An urban wetland in the Minneapolis-St. Paul Metropolitan Area was found to retain sediment and nutrient loads in runoff routed through the wetland. Sediment and nutrient loads in runoff were measured during 1982 at the inlet and outlet of the 6.4-hectare urban wetland. Retention of sediment and nutrient loads in the wetland was associated with sedimentation processes. Dissolved nutrients generally were not retained in the wetland because the residence time of water passing through was not long enough for removal by biological processes. Effectiveness of the wetland in retaining sediment and nutrient loads in runoff varies annually. Long-term and short-term impacts of the retention of sediment and nutrients in the wetland on wetland flora and fauna are unknown. .

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.

Burgess, N.D. Evans, C.E. Thomas, G.J. 1990. Vegetation change on the Ouse Washes Wetland, England, 1972-88 and effects on their conservation importance. *Biological Conservation* 53:173-189. A re-survey of wetland vegetation on the Ouse Washes in 1988 shows that it has changed dramatically in 16 years. *Glyceria maxima* swamp (National Vegetation Classification S5) and *Agrostis stolonifera*-*Alopecurus geniculatus* inundation grassland (NVC S13) have more than doubled their area, whereas *Phalaris arundinacea* swamp (NVC S28), *Holcus lanatus*-*Deschampsia cespitosa* coarse grassland (NVC MG9) and *Carex riparia* swamp (NVC S6) have declined by at least three-quarters of their previous area. Increased flooding, especially in the late spring and early summer, and reduced levels of grazing and hay-making are believed to have caused these changes, with increased flooding probably the single most important factor. The vegetation changes have resulted in a reduction of plant species diversity in grazed, hayed and unmanaged Washes, but especially in the unmanaged Washes. They may have also affected ornithological use of the site but this requires fuller investigation.

Butet A., A. B. A. Leroux. 2001. Effects of agricultural development on vole dynamics and conservation of Montagu's harrier in western French wetlands. *Biological Conservation* 100:289-295. Nesting populations of Montagu's harrier (*Circus pyragus*) are declining in most parts of Europe; in France, western marshes remain the most important nesting sites in terms of breeding pairs. In this open field landscape dominated by grasslands, the common vole (*Microtus arvalis*) displays regular population outbreaks and constitutes a favorite prey of this raptor. Twelve years of field data indicated significant variations in nesting population size and young harriers produced, which correlated with yearly differences in vole densities. Up to 10 years ago, these marshes were traditionally used as extensive pastures but recent agricultural changes have resulted in almost 50% of the pastures being converted to drained agricultural production, as already observed in many localities of this region next to our study area. Our data, together with previous data collected from 1968 in this region, demonstrate that agricultural changes have resulted in a decrease of frequency and intensity of vole population peaks. A summer density of 100 voles/ha appears as a threshold value to support a good breeding success of harriers. These modifications of the vole fluctuation pattern suggest that nesting populations of Montagu's harrier from western French marshes could be endangered in future under these current trends in agricultural changes.

Cattin M., G. Blandenier, C. Banasek-Richter, and L. Bersier. 2003. The impact of mowing as a management strategy for wet meadows on spider (Araneae) communities *Biological Conservation* 113:179-188.

Cedfeldt P. T., M. C. Watzin, and B. D. Richardson. 2000. Using GIS to Identify Functionally Significant Wetlands in the Northeastern United States *Environmental Management* 26:13-24.

Childers D. L., J. G. Gosselink. 1990. Assessment of cumulative impacts to water quality in a forested wetland landscape. *Journal of Environmental Quality* 19:455-464. Assessment of cumulative impacts requires a landscape approach and large-scale analysis. In the authors' procedure for determining cumulative impacts in bottomland hardwood forests (BLHF), changes in landscape integrity over time were assessed using structural and functional ecosystem indices. In this article researchers present a historical analysis of water quality in the Tensas Basin, Louisiana, USA, as part of the cumulative impacts analysis of this BLHF landscape. Historical records of suspended sediment, N, P, and turbidity from three streams in the Tensas Basin were analyzed. Significant positive relationships between water levels in these streams and concentrations of total P, total Kjeldahl N, total suspended sediment, and turbidity confirmed a loading phenomenon characteristic of watersheds in which much of the original forest cover has been cleared. Eighty-five percent of the original forest in the Tensas Basin has been converted to agricultural fields. Temporal trends in nutrient concentration show that water quality has been declining steadily since 1958 in one river, whereas in the other two the decline largely occurred before then. A goal-oriented management plan for improved water quality in the Tensas Basin was devised based on this cumulative impact assessment. .

Cohen M., C. Lane, K. Reiss, S. J., E. Bardi, and M. Brown. 2005. Vegetation based classification trees for rapid assessment of isolated wetland condition *Ecological Indicators* 5:189-206. Biological metrics are increasingly employed by regulatory agencies to assess ecosystem condition for the purposes of conservation, restoration, mitigation and creation. While indices of biotic integrity (IBI) have been shown to correspond strongly with anthropogenic disturbance, they are time consuming and expensive to implement and require advanced taxonomic knowledge. Regulatory implementation frequently necessitates simplified indicators of community composition that do not excessively sacrifice ecological specificity. Detailed observations of vegetative community composition and structure in isolated depressional herbaceous (n = 75) and forested (n = 118) wetlands were undertaken to identify integrative biotic metrics of community condition. Habitat-specific wetland condition indices (WCI) composed of five to six relativized biotic metrics (% non-native plant species, % tolerant and % sensitive plant species, perennial-to-annual/biennial ratio, mean floristic quality, species hydric status) were previously developed. From these quantitative indices of condition, classification (CT) and regression tree (RT) models were developed for categorical/continuous prediction based on presence/absence data for species and ecologically appropriate groups of species. Optimal categorical resolution with respect to model validation accuracy was achieved for three impact categories (minimally, moderately, and severely disturbed). Overall cross-validation efficiencies were 77% and 74% for herbaceous and forested

wetlands, respectively. Error was primarily observed in the moderate degradation class for both systems and misclassified sites tended to fall near categorical threshold values. High validation specificity was observed for severely degraded sites (89% for both systems) and minimally impacted sites (>90% for both systems). The advantages of CT models for regulatory application include interpretive simplicity, ecological specificity, standardized repeatable assessment between assessors, and reduced botanical expertise requirements. .

Conner W. H. 1994. Effect of forest management practices on southern forested wetland productivity

Wetlands 14:27-40. In the interest of increasing productivity of forested wetlands for timber production and/or wildlife value, management schemes that deal mainly with water-level control have been developed. The three forest types in the southeastern U.S. most commonly affected are cypress/tupelo forests, bottomland hardwood forests, and wet pine sites (including pocosins). In forested wetlands, hydrology is the most important factor influencing productivity. In bottomland and cypress/tupelo forests, water-level control can have mixed results. Alterations in natural hydrologic patterns leading to increased flooding or drainage can cause decreased growth rates or even death of the forest. Bottomland hardwoods respond favorably in the short term to water-level management, but the long-term response is currently under study. In wet pine sites, timber volume can be increased significantly by water-level management, but the impact upon other ecological functions is less understood. It is difficult to adequately describe productivity relations in wetland forests because of the great diversity in habitat types and the lack of data on how structure and function might be affected by forestry operations. There is a definite need for more long-term, regional studies involving multidisciplinary efforts. .

Cooper A., T. Shine, T. McCann, and D. A. Tidane. 2006. An ecological basis for sustainable land use of Eastern Mauritanian wetlands. *Journal of Arid Environments* 67:116-141. The temporary wetlands of Eastern Mauritania in the Sahel region of Africa, are productive systems in an arid environment.

Traditionally managed wetlands provide habitats for a wide range of plant and animal species and support local livelihoods through multiple land use. The heterogeneity and socio-economic importance of the wetlands is reflected in a cultural nomenclature, but the land use, environmental and biological basis of the nomenclature has not been studied. In this paper, the cultural typology is described from a structured field survey of site biophysical and land use attributes recorded in a regional site inventory.

A numerical classification of inventory sites based on the plant species used for food and materials (resource species), showed that it was significantly associated with the cultural typology. Ordination of the sites showed that key underlying environment gradients significantly influencing resource species composition were water availability and land use intensity. Each cultural type occupied a unique location in ordination space corresponding to its hydrology and land use. A site ordination based on animal wildlife species composition

showed that the duration of standing water was a key significant explanatory variable, with land use intensity of secondary importance.

Analysis supports the view that traditional land use is based on understanding environment, plant growth and wildlife interactions and that is the basis of sustainable management. Recent schemes to develop single-use agricultural systems by changing wetland shape and hydrology do not take cultural typology or traditional use systems into account. We propose that decisions on land use change at site and regional landscape scales would benefit from considering traditional management practices and that the cultural typology can be used as an indicator of site development potential.

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.

Detenbeck N. E., Taylor D.B., A. Lima, and C. Hagley. 1996. Temporal and spatial variability in water quality of wetlands in the Minneapolis/St. Paul, MN metropolitan area: Implications for monitoring strategies and designs. *Environmental Monitoring and Assessment* 40:11-40. Temporal and spatial variability in wetland water-quality variables were examined for twenty-one wetlands in the Minneapolis/St. Paul metropolitan area and eighteen wetlands in adjacent Wright County. Wetland water quality was significantly affected by contact with the sediment (surface water vs. groundwater), season, degree of hydrologic isolation, wetland class, and predominant land-use in the surrounding watershed ($p < 0.05$). Between years, only nitrate and particulate

nitrogen concentrations varied significantly in Wright County wetland surface waters. For eight water-quality variables, the power of a paired before-and-after comparison design was greater than the power of a completely randomized design. The reverse was true for four other water-quality variables. The power of statistical tests for different classes of water-quality variables could be ranked according to the predominant factors influencing these: climate factors>edaphic factors>detritivory>land-use factors>biotic-redox or other multiple factors. For two wetlands sampled intensively, soluble reactive phosphate and total dissolved phosphorus were the most spatially variable (c.v.=76–249%), while temperature, color, dissolved organic carbon, and DO were least variable (c.v.=6–43%). Geostatistical analyses demonstrated that the average distance across which water-quality variables were spatially correlated (variogram range) was 61–112% of the mean radius of each wetland. Within the shallower of the two wetlands, nitrogen speciation was explained as a function of dissolved oxygen, while deeper marsh water-quality variables were explained as a function of water depth or distance from the wetland edge. Compositing water-quality samples produced unbiased estimates of individual sample means for all water quality variables examined except for ammonium.

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% of 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*.

Donderes T. H., F. Wagner, and H. Visscher. 2005. Quantification strategies for human-induced and natural hydrological changes in wetland vegetation, southern Florida, USA *Quaternary Research* 64:333-342. An accurately dated peat profile from a mixed cypress swamp in the Fakahatchee Strand Preserve State Park (FSPSP, Florida, USA) has been examined for pollen and spores. The near-annual resolved pollen record shows a gradual shift from a wet to a relatively dry assemblage during the past 100 years. Timing of drainage activities in the region is accurately reflected by the onset and duration of vegetation change in the swamp. The reconstructed vegetation record has been statistically related to pollen assemblages from surface sediment samples. The response range of the FSPSP wetland to environmental perturbations could thus be determined and this allows better understanding of naturally occurring vegetation changes. In addition, the human impact on Florida wetlands becomes increasingly apparent. Superimposed high-frequency variation in the record suggests a positive correlation between winter-precipitation and pollen productivity of the dominant tree taxa. However, further high-resolution analysis is needed to confirm this relation. The response range of the FSPSP wetland to environmental perturbations on both annual- and decadal scales

documented in this study allows recognition and quantification of natural hydrological changes in older deposits from southwest Florida. The strong link between local hydrology and the El Niño Southern Oscillation makes the palynological record from FSPSP highly relevant for studying past El Niño-variability. .

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.

Ehrenfeld J. G., J. P. Schneider. 1993. Responses of forested wetland vegetation to perturbations of water chemistry and hydrology. *Wetlands* 13:122-129. Nineteen mature Atlantic white-cedar swamps, located in four categories of undeveloped and suburban watersheds of the New Jersey Pinelands, were studied to determine the relationship between perturbations of water quality and hydrology and changes in species composition and community structure. Rank-orders of the 19 sites were compared for key variables (ground-water and surface-water NH sub(4) and PO sub(4), mean water-table level and water-table range). Rank orders for the sites were different for the various parameters, suggesting little congruence among water quality and hydrologic changes at wetlands within urban basins. Changes in species composition, measured as the number of invading species, were correlated with the number of perturbed chemical and hydrologic parameters and were not related to the absolute magnitude of any one parameter. Sites in developed watersheds supported a larger fraction of facultative upland and upland species than did sites in undisturbed watersheds; this change could affect wetland delineation of urban wetlands. Urbanization thus increases variability in environmental quality among sites of a given type of wetland and fosters an increase in proportion of non-hydrophytic vegetation within such wetlands. .

Ehrenfeld J. G., J. P. Schneider. 1991. *Chamaecyparis thyoides* wetlands and suburbanization: effects on hydrology, water quality and plant community composition. *Journal of Applied Ecology* 28:467-490. (1) Atlantic white cedar (*Chamaecyparis thyoides*) wetlands in the New Jersey Pinelands were studied along a gradient of suburban development defined by increasingly intrusive road and house construction close to the site. Water table level, water chemistry, plant species composition and community structure were recorded to assess the effects of increasing levels of upland disturbance on the adjacent wetlands. (2) Some increases in nitrogen, phosphorus, and chloride occurred in both surface and groundwater within wetlands beside septic system drain fields. Much larger increases in these parameters, plus increases in heavy metal concentrations, occurred in sites receiving both septic tank drainage and road run-off. (3) Hydrology was only affected by the presence of dams on the streams traversing the wetlands, and by ditches dug in association with stormwater sewer outfalls.

(4) With increasing levels of suburban disturbance, there was an increasing loss of indigenous herbaceous species and an increasing incursion of upland and exotic species. Ground cover by *Sphagnum* spp. and cedar seedling densities all declined with increasing suburban development. Woody plant community composition and structure showed little change over the gradient. Changes in water quality were more important in determining changes in community composition and structure than were changes in hydrology. (5) The changes in species composition associated with changes in water quality support the theory that species-richness follows an optimization curve with respect to nutritional quality of the wetland. (6) The results suggest that the maximum buffer width provided for by law be required for all upland development adjacent to white cedar wetlands.

Eppink F., van den Bergh, J., and P. Rietveld. 2004. Modelling biodiversity and land use: urban growth, agriculture and nature in a wetland area *Ecological Economics* 51:210-216. Wherever human land use is located near sensitive natural areas, such as wetlands, it has significant impacts on biodiversity in those areas. Both species richness and species composition are affected. As biodiversity is lost, conservation efforts increase and act as a constraint on land use options. Given these links, land use is a central factor in an ecological-economic analysis of biodiversity. This paper presents a general, dynamic simulation model of the interaction between wetland biodiversity and land use. Results for a set of scenarios suggest that urban growth is unsustainable and that there may be a conflict between conservation of distinct aspects of biodiversity.

Euliss N. H. J., D. M. Mushet. 1996. Water-level fluctuation in wetlands as a function of landscape condition in the prairie pothole region *Wetlands* 16:587-593. We evaluated water-level fluctuation (maximum water depth - minimum water depth/catchment size) in 12 temporary, 12 seasonal, and 12 semipermanent wetlands equally distributed among landscapes dominated by tilled agricultural lands and landscapes dominated by grassland. Water levels fluctuated an average of 14.14 cm in wetlands within tilled agricultural landscapes, while water levels in wetlands within grassland landscapes fluctuated an average of only 4.27 cm. Tillage reduces the natural capacity of catchments to mitigate surface flow into wetland basins during precipitation events, resulting in greater water-level fluctuations in wetlands with tilled catchments. In addition, water levels in temporary and seasonal wetlands fluctuated an average of 13.74 cm and 11.82 cm, respectively, while water levels in semipermanent wetlands fluctuated only 2.77 cm. Semipermanent wetlands receive a larger proportion of their water as input from ground water than do either temporary or seasonal wetlands. This input of water from the ground has a stabilizing effect on water-levels of semipermanent wetlands. Increases in water-level fluctuation due to tillage or due to alteration of ground-water hydrology may ultimately affect the composition of a wetland's flora and fauna. In this paper, we also describe an inexpensive device for determining absolute maximum and minimum water levels in wetlands.

Ewing K. 1996. Tolerance of four wetland plant species to flooding and sediment deposition. *Environmental and Experimental Botany* 36:131-146. greenhouse assessment of the physiological responses of four common Pacific Northwest wetland plant species (*Carex rostrata* and *Carex stypata* (sedges) and the flood-tolerant trees *Alnus incana* (red alder) and *Fraxinus latifolia* (Oregon ash)) to flooding and sediment deposition was conducted. Experiments simulated two ecosystem perturbations which occur when watersheds are urbanized: (1) alteration of hydroperiod and (2) deposition of sediment along channels and in wetlands. Sedges were subjected to alternating flooding and drying cycles and to sediment deposition with different flooding levels. The trees were subjected to static flooding, cycled flooding and drying, and sediment deposition. *C. rostrata* and *C. stypata* were resilient to cycles of flooding and drying, but sediment deposits resulted in decreased biomass which was diminished further by high water levels. Static flooding to or above the soil surface killed saplings of *A. incana* and *F. latifolia* in less than a week. *A. incana* saplings exhibited decreased photosynthesis and growth when subjected to cycles of flooding and drying, more so if the soil were completely saturated during flooding cycles. *F. latifolia* saplings showed no significant response to cycles of flooding and drying. Sediment addition to the soil surface resulted in an immediate drop in photosynthesis for *A. incana*. These experiments showed that sediment negatively impacted the sedges and trees, and that flooding differentially affected the trees, with *A. incana* being more sensitive than the other three species. .

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 from 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. Futuyma 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, effects on animal home ranges, barrier effects, habitat fragmentation, and animal mortality and road avoidance.

Forsyth D. J., Martin. P.A., and G. G. Shaw. 1997. Effects of herbicides on two submerged aquatic macrophytes, *Potamogeton pectinatus* L. and *Myriophyllum sibiricum* Komarov, in a prairie wetland. *Environmental Pollution* 95:259-268. Clopyralid, picloram, 2,4-D and a mixture of 2,4-D plus picloram, (Tordon 202C) were added to the water of 1 m square enclosures in a prairie wetland in Saskatchewan, Canada to produce concentrations of 0.01 and 0.1 mg active ingredient litre(-1). Effects on the submersed macrophytes, *Potamogeton pectinatus* and *Myriophyllum sibiricum*, were monitored by taking repeated measurements of plant weight, flower and tuber production and inspecting for injuries at 30 and 60 days after application. Clopyralid did not inhibit weight gain (growth) in either species, but stimulated growth and flowering by *M. sibiricum* at 0.01 mg litre(-1) and tuber production by *P. pectinatus* at both rates. The low rate of 2,4-D stimulated flowering by *M. sibiricum* and tuber production by *P. pectinatus*, whereas the high rate inhibited growth of *M. sibiricum* and injured both species. Picloram did not affect growth of either species, but injured *M. sibiricum* at both concentrations and inhibited flowering at 0.1 mg litre(-1). Tordon 202C at 0.1 mg litre(-1) caused reduced growth and flowering in *M. sibiricum* and injured both species; 0.01 mg litre(-1) also injured *M. sibiricum*. Mortality resulted only from Tordon 202C and 2,4-D. Field data are lacking to assess the extent to which submerged macrophytes in prairie ponds are exposed to harmful concentrations of herbicide from aerial spraying, drift from ground application, runoff or wind erosion of soil.

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).

Galatowitsch S. M., D. C. Whited, R. Lehtinen, J. Husveth, and K. Schik. 2000. The vegetation of wet meadows in relation to their land-use. *Environmental Monitoring and Assessment* 60:121-144. Wetland biomonitoring approaches are needed to determine when changes in response to stressors are occurring and to predict the consequences of proposed land-use changes. These approaches require an understanding of shifts in biota that occur in response to land-use, data that are lacking for most kinds of wetlands. Changes in floristic composition corresponding to landuse differences at multiple scales (site to 2500 m radius) were characterized for 40 wet meadows associated with prairie glacial marshes in Minnesota (U.S.A.). In general, guild was more useful than species composition for indicating land-use impacts. Site impacts (stormwater, cultivation) and landscape disturbance (agriculture and urbanization, combined), coincide with a reduction in native graminoid and herbaceous perennial abundance (e.g., *Carex lasiocarpa*, *Calamagrostis canadensis*, *Spartina pectinata*). This vegetation is replaced with annuals (e.g, *Bidens cernua*, *Polygonum pensylvanicum*) in recently cultivated sites or introduced perennials (e.g., *Phalaris arundinacea*, *Typha angustifolia*) and floating aquatics (lemnids) in stormwater impacted wetlands. Ditches also reduce native perennial importance and increase perennials, but only when they are in highly impacted landscapes. .

Gerakis A., K. Kalburtji. 1998. Agricultural activities affecting the functions and values of Ramsar wetland sites of Greece. *Agriculture, Ecosystems and Environment* 70:119-128. Agricultural activities in the agroecosystems neighboring wetland ecosystems are considered a major threat to the latter in all Mediterranean countries. This threat was investigated in thirteen internationally important wetland sites (Ramsar sites) of Greece. The effects of ten activities commonly practiced in the surrounding agroecosystems on four wetland functions and four wetland values were evaluated. The functions were: nutrient removal/ transformation, sediment/ toxicant retention, flood flow alteration, and ground water discharge. The values were: biodiversity, fishing, hunting, and recreation. It was found that the Adamus' Wetland Evaluation Technique is useful even in the little studied Ramsar sites of Greece. Irrigation is the most decisive activity negatively influencing all functions and values, followed by cropland expansion and overgrazing. Coastal lagoons are the least affected by agricultural activities. It is concluded that in Greece the sustainability of wetland ecosystems depends to a significant degree on the sustainability of

agroecosystems. The reverse is also true because wetlands provide irrigation water, crop pollinators, some frost protection, and predators of crop pests. The two ecosystem types are functionally closely linked. Therefore, a national policy for the sustainable development of the soil, water, and genetic resources of Greece must integratively consider both these ecosystem types.

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 (*Ambystoma 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.

Gibbs J. 2000. Wetland loss and biodiversity conservation. *Conservation Biology* 14:314-317. Most species of wetland-dependent organisms live in multiple local populations sustained through occasional migration. Retention of minimum wetland densities in human-dominated landscapes is fundamental to conserving these organisms. An analysis of wetland mosaics was performed for two regions of the northeastern United States to assess the degree to which historical wetland loss alters the metrics of wetland mosaics and to assess potential future effects mediated by differently structured wetland regulations. These analyses indicated that profound reductions in wetland density and proximity are associated with increased human populations and that protections for all wetlands >1 acre (0.4 ha) are likely required to retain wetland densities minimally sufficient to sustain the wetland biota.

Glenn E. P., C. Lee, R. Felger, and S. Zengel. 1996. Effects of water management on the wetlands of the Colorado River delta, Mexico *Conservation Biology* 10:1175-1186. The lower delta of the Colorado River has been severely affected by the upstream diversion of water for human use. No river water is officially appropriated to support delta wetlands, yet large marsh areas of conservation interest still exist below the agricultural fields in Mexico. These are supported by flood water, agricultural drainage water, municipal sewage effluent, and seawater in the intertidal zone. From 1973 to 1993 the area of freshwater and brackish marsh varied widely, from 5800 to 63,000 ha. A new opportunity exists to restore wetlands in the delta now that the upstream water impoundments on the Colorado River are filled and flood flows are once again being directed to the delta. But flood control structures now channel most of the flood water directly to the sea, and most of the effluent waters are deposited in evaporation basins rather than used to support wetlands. If the Yuma Desalting Plant in the United States becomes operational and if the Rio Hardy wetlands continue to be drained, the area of brackish wetlands could decrease to less than 2000 ha in the near future. Preserving the remaining wetlands will require a binational water management plan. The plan maximize the benefits to wetlands

of flood and irrigation return flows that enter the delta, and it should minimize flood risks. .

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. 1988. The nature of cumulative impacts on biotic diversity of wetland vertebrates. *Environmental Management* 12:675-693. There is no longer any doubt that cumulative impacts have important effects on wetland vertebrates. Interactions of species diversity and community structure produce a complex pattern in which environmental impacts can play a highly significant role. Various examples show how wetlands maintain the biotic diversity within and among vertebrate populations, and some of the ways that environmental perturbations can interact to reduce this diversity.

The trophic and habitat pyramids are useful organizing concepts. Habitat fragmentation can have severe effects at all levels, reducing the usable range of the larger habitat generalists while threatening the genetic integrity of small, isolated populations. The complexity of trophic interactions, and the propensity, or necessity, of vertebrates to switch from one food source to another—something we know little about—makes using food chain support as a variable for predicting environmental impacts very questionable.

Historical instances illustrate the effects of the accumulation of impacts on vertebrates. At present it is nearly impossible to predict the result of three or more different kinds of perturbations, although long-range effects can be observed. One case in point is waterfowl; while their ingestion of lead shot, harvesting by hunters during migration, and loss of habitat have caused waterfowl populations to decline, the proportional responsibility of these factors has not been determined.

Further examples show multiplicative effects of similar actions, effects with long time lags, diffuse processes in the landscape that may have concentrated effects on a component subsystem, and a variety of other interactions of increasing complexity. Not only is more information needed at all levels; impacts must be assessed on a landscape or regional scale to produce informed management decisions. I conclude that a system of replicate wetland reserves that are allowed to interact naturally with the surrounding landscape will be more effective in preserving biotic diversity than isolated sanctuaries.

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 in 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 in 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.

Hecnar S. J., R. T. M'Closkey. 1996. Amphibian species richness and distribution in relation to pond water chemistry in south-western Ontario, Canada. *Freshwater Biology* 36:7-15.1. We assessed the patterns of amphibian species richness and distribution in relation to water chemistry over a large geographical area in 1992–94.2. Thirteen amphibian species were observed at 180 ponds, with mean species richness 3.5 ± 0.13 species per pond (range zero to nine). Water samples were collected from 143 ponds, analysed for fifteen chemical variables, and further analysed by multivariate statistical techniques.

3. Water in the study area was hard, alkaline and well-buffered against pH change, and most ponds were eutrophic. Amphibian species richness was negatively correlated with five chemical variables (chloride, conductivity, magnesium, total hardness, turbidity).4. Principle components analysis reduced the data set to four chemical components that explained 65.4% of the variance in the original variables. Principle component scores were retained for use in further multivariate tests. Multiple regression accounted for only 19.0% of the variance in amphibian species richness. Discriminant function analysis (DFA) was used to determine if water chemistry variables discriminated among species, but it was only able to classify 17.5% of cases correctly. DFA was also used to determine if water chemistry distinguished between used and unused sites for individual species. DFA was moderately successful, classifying 61–77% of cases correctly. 5. General water chemistry appears to play only a minor part in affecting amphibian species richness in south-western, Ontario. However, chemical variables may be helpful to distinguish between used and unused sites for some species.

Hemond H. F., J. Benoit. 1988. Cumulative impacts on water quality functions of wetlands

Environmental Management 12:639-653. The total effect of cumulative impacts on the water quality functions of wetlands cannot be predicted from the sum of the effects each individual impact would have by itself. The wetland is not a simple filter; it embodies chemical, physical, and biotic processes that can detain, transform, release, or produce a wide variety of substances. Because wetland water quality functions result from the operation of many individual, distinct, and quite dissimilar mechanisms, it is necessary to consider the nature of each individual process.

Sound knowledge of the various wetland processes is needed to make guided judgements about the probable effects of a given suite of impacts. Consideration of these processes suggests that many common wetland alterations probably do entail cumulative impact. In addition to traditional assessment methods, the wetland manager may need to obtain appropriate field measurements of water quality-related parameters at specific sites; such data can aid in predicting the effects of cumulative impact or assessing the results of past wetland management.

Hongo H., M. Masikini. 2003. Impact of immigrant pastoral herds to fringing wetlands of lake Victoria in Magu district Mwanza region, Tanzania *Physics*

and Chemistry of the Earth 28:1001-1007. The assessment of impacts of pastoral herds to the fringing wetlands of Lake Victoria in Magu district in Mwanza region was carried out in 1999/2000. Lamadi village located along Speke Gulf of Lake Victoria was chosen. The main farming systems in the area are agriculture, agro-pastoralism, and pastoralism. The wetlands are heavily used for livestock grazing during the dry season. Since 1990s the area has been experiencing a high influx of immigrant pastoral herds from drought prone districts. The increasing livestock numbers have led into serious degradation of wetlands. The type of damages includes: soil erosion, loss of vegetation cover and deforestation. This lead to pollution of Lake Victoria along the Speke gulf in particular as the wetlands was buffering a lot of pollutants from the catchments. The range condition at Lamadi was rated fair. The carrying capacity of rangelands was estimated at 3.57–6.75 ha/LU and the wetlands were seriously degraded causing heavy soil erosion and environmental pollution during rainy season. It was recommended to raise people's awareness on conservation of environment and mobilise communities to take responsibility on management of the environmental resources. .

Houlahan J. E., C. S. Findlay. 2003. The effects of adjacent land use on wetland amphibian species richness and community composition. *Canadian Journal of Fisheries and Aquatic Sciences* 60:1078-1094. Habitat destruction and fragmentation have been identified as possible causes of large-scale amphibian declines. Here, we examine the effects of adjacent land use and water quality on wetland amphibian species richness, abundance, and community composition in 74 Ontario wetlands. Species richness was positively correlated with wetland area, forest cover, and the amount of wetlands on adjacent lands and negatively correlated with road density and nitrogen levels. The land-use effects peak at 2000–3000 m. Amphibian abundance was positively correlated with forest cover, distance to wetlands >20 ha, and amount of marsh habitat and negatively correlated with road density. The effects of adjacent land use were strongest at around 200 m. Land-use and water quality effects varied widely across species, although most species are positively correlated with forest cover and amount of wetlands on adjacent lands and negatively correlated with road density and water quality. These results suggest that the effects of adjacent land use on amphibian communities can extend over comparatively large distances. As such, effective wetland conservation will not be achieved merely through the creation of narrow buffer zones between wetlands and intensive land uses, but rather will require maintaining a heterogeneous regional landscape containing relatively large areas of natural forest and wetlands.

Johnston C. A. 1994. Cumulative impacts to wetlands *Wetlands* 14:49-55. "Cumulative impact," the incremental effect of an impact added to other past, present, and reasonably foreseeable future impacts, was reviewed as it pertains to southern forested wetlands. In the U.S., the largest losses of forested wetlands between the 1970s and 1980s occurred in southeastern states that had the most bottomland hardwood to begin with: Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South

Carolina. These losses were due primarily to forestry and agriculture. Other sources of cumulative impact include decrease in average area of individual wetlands, shift in proportion of wetland types, change in spatial configuration of wetlands, and loss of cumulative wetland function at the landscape scale. For two wetland-related functions, flood flow and loading of suspended solids, watersheds that contained less than 10% wetlands were more sensitive to incremental loss of wetland area than were watersheds with more than 10% wetlands. The relative position of wetlands within a drainage network also influenced their cumulative function. Geographic Information Systems (GIS) are becoming an important tool for evaluating cumulative impacts and their effects.

Johnston C. A., Detenbeck, N.E., and G. J. Niemi. 1990. The cumulative effect of wetlands on stream water quality and quantity. A landscape approach. *Biogeochemistry* 10:105-141. A method was developed to evaluate the cumulative effect of wetland mosaics in the landscape on stream water quality and quantity in the nine-county region surrounding Minneapolis—St. Paul, Minnesota. A Geographic Information System (GIS) was used to record and measure 33 watershed variables derived from historical aerial photos. These watershed variables were then reduced to eight principal components which explained 86% of the variance. Relationships between stream water quality variables and the three wetland-related principal components were explored through stepwise multiple regression analysis. The proximity of wetlands to the sampling station was related to principal component two, which was associated with decreased annual concentrations of inorganic suspended solids, fecal coliform, nitrates, specific conductivity, flow-weighted NH₄ flow-weighted total P, and a decreased proportion of phosphorus in dissolved form ($p < 0.05$). Wetland extent was related to decreased specific conductivity, chloride, and lead concentrations. The wetland-related principal components were also associated with the seasonal export of organic matter, organic nitrogen, and orthophosphate. Relationships between water quality and wetlands components were different for time-weighted averages as compared to flow-weighted averages. This suggests that wetlands were more effective in removing suspended solids, total phosphorus, and ammonia during high flow periods but were more effective in removing nitrates during low flow periods.

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.

Kadlec R. H. 1983. The Beliaire wetland: Wastewater alteration and recovery. *Wetlands* 3:44-63. The village of Bellaire, MI, has discharged wastewater from their stabilization lagoons to a 18 hectare wetland for eleven years at about 30 million gallons per year. For the last eight of those years, studies of hydrology, water quality, vegetation and soils have been conducted. Discharges terminated in 1981, with a resultant recovery of the ecosystem. During irrigation, wastewater parameters were dramatically improved by waste treatment standards, but not by receiving ecosystem standards. Mass balances for water and chloride agreed reasonably well. All surface inflows and outflows and precipitation were measured; and evapotranspiration was calculated from climatic data.

Kalisinska E., W. Salicki, P. Myslek, K. M. Kavetska, and A. Jackowski. 2004. Using the Mallard to biomonitor heavy metal contamination of wetlands in north-western Poland *Science of the Total Environment* 320:145-161. Contents of iron, zinc, copper, manganese, nickel, lead and cadmium were determined in the brain, pectoral muscle, kidney, liver and bones of the Mallard (*Anas platyrhynchos*), a cosmopolitan, herbivorous duck species. Both immature (im; in the first year of life) and older (adult, ad) ducks were studied. The birds originated from wetlands in two areas in north-western Poland, one located in the Slonsk waterfowl reserve (ns32 imq24 ad) and the other { near the city of Szczecin (ns21 imq21 ad). There were numerous significant age-dependent differences in the metal contents of the organs of the Mallards obtained from near Szczecin (Sz) and/or Slonsk (S). Copper contents in the { brain (Sz and S), muscles (Sz) and kidneys (Sz) as well as cadmium contents in the liver (Sz, S), kidneys (Sz, S) and muscles (S) were observed to increase with age. Between-area differences in metal contents of individual organs were recorded as well. The S Mallard showed higher contents of iron and copper (in muscles, liver and kidneys), zinc (in liver and kidneys) and cadmium (in muscles, liver and kidneys), while the Sz ducks revealed higher contents of manganese and lead (in brain and bones). The differences observed may be related to the habitat specificity: the Slonsk reserve is periodically flooded by the River Odra (Oder) waters that carry pollutants from a copper mining { area 250 km away. On the other hand, the mid-field ponds near Szczecin are affected by pollutants, including those that are manganese-rich, generated by agriculture and traffic. .

Kaminski R. M., H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat *Journal of Wildlife Management* 45:1-15. Responses of breeding dabbling ducks (*Anatini*) and aquatic macroinvertebrates to experimental modifications of cover: water ratio and basin surface were investigated in 1977 and 1978 within an impounded whitetop rivergrass (*Scolochloa festucacea*) meadow on the Delta marsh, south0central Manitoba. Three areal percentage ratios of emergent hydrophytes to open water (30:70, 50:50 or 70:30) and 2 basin treatments (mowing of existing emergents or scarification by rototilling) were tested. Between years, pair numbers of mallards (*Anas platyrhynchos*) and blue-winged teal (*A. discors*) declined, whereas pair numbers of northern shovelers (*A.*

clypeata), gadwalls (*A. strepera*), and pintails (*A. acuta*) were comparable. The greatest density and species diversity of dabbling duck pairs occurred on 50:50 plots in both years. Only blue-winged teal and pintail pair densities in 1978 were greater on mowed than on rototilled areas. Within years, species diversity of dabbling ducks was unaffected by mowing or rototilling. More pursuit flights arose from 50:50 plots and mowed areas compared to alternative treatments. Composition and resource levels (abundance, biomass, and number of families) of aquatic macroinvertebrate communities varied within and between years in response to basin treatments. These results imply prescriptions for wetland habitat management.

Kassenga G. R. 1997. A descriptive assessment of the wetlands of the Lake Victoria basin in Tanzania. *Resources, Conservation and Recycling* 20:127-141. Lake Victoria is the second largest freshwater body in the world by surface area. It is a very important water body for the livelihood of people, particularly those living in its basin. The lake is currently facing many problems such as serious environmental degradation, pollution and overfishing. Mismanagement of wetlands which is another problem threatening the hydrological and ecological balance of the lake is discussed. This report provides: an overview of the Lake Victoria ecosystem; describes major wetlands of the Lake Victoria basin in Tanzania and their uses; identifies water supply, agriculture, fishing, conversion into other uses (mainly residential); and cattle grazing as main uses of wetlands; and discusses threats and changes faced by wetlands. Direct anthropogenic activities such as irrational uses of wetlands for agriculture, pollution and conversion of wetlands into settlement areas are responsible for wetland degradation and loss. Problems of sedimentation as a result of agricultural activities, hydrological changes of wetlands due to road construction and subsidence of wetlands due to excessive extraction of water are indirect results of human actions. Drought is the common natural cause for the change or loss of wetlands in the lake basin. Absence of wetlands policy, conflicting sectoral policies on issues related to wetlands, deficient planning concepts, limited information and awareness on the importance of wetlands and absence of an institution to deal specifically with wetland management contribute to degradation and loss of wetlands. A number of recommendations for sustainable use of wetlands are put forward. Formulation of the National Wetlands Policy and launching of awareness campaigns on wise use of wetlands are recommended. The presentation also emphasizes carrying out of research on the proper utilization of wetlands monitoring of wetland uses and provision of sustainable exploitation of wetland resources extension services.

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:

tree size; >29m²/ha, 20-29m²/ha, <20 m²/ha

canopy composition; proportion of shade-tolerant species >70%, 30-70%, <30%

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

herbaceous layer; ≥ 6 species, 2-5 species, < 2 species

corticolous bryophytes; ≥ 7 species, 2-6 species, < 2 species

wildlife trees; # cavity trees >50.8 cm dbh, ≥ 4 wildlife trees/ 10 ha, 1-3 wildlife
trees/10 ha, <1 wildlife tree/10 ha

fungi:macrofungi; scale not given

avian community; # of species considered characteristic of primary forests; ≥ 5
species, 2-4 species, < 2 species

large carnivores; ≥ 6 species, 3-5 species, < 3 species

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 causal 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.

Kimbrough K. L., R. M. Dickhut. 2006. Assessment of polycyclic aromatic hydrocarbon input to urban wetlands in relation to adjacent land use *Marine Pollution Bulletin* Article in Press:

Kittle D. L., J. B. McGraw, and K. Garbutt. 1995. Plant litter decomposition in wetlands receiving acid mine drainage. *Journal of environmental quality* 24:301-306. The impact of acid mine drainage on the decomposition of wetland plant species of northern West Virginia was studied to determine if the potential exists for nutrient cycling to be altered in systems used to treat this drainage. There were two objectives of this study. First, decomposition of aboveground plant material was measured to determine species decomposition patterns as a function of pH. Second, decomposition of litter from various pH environments was compared to assess whether litter origin affects decomposition rates. Species differences were detected throughout the study. Decomposition rates of woolgrass [*Scirpus cyperinus* (L.) Kunth] and common rush (*Juncus effusus* L.) were significantly lower than those of calamus (*Acorus calamus* L.) and rice cutgrass (*Leersia oryzoides* L.). Differences among species explained a large proportion of the variation in percentage of biomass remaining. Thus, differences in litter quality among species was important in determining the rate of decomposition. In general, significantly more decomposition occurred for all species in high pH environments, indicating impeded decomposition at low pH. While decomposition of some species after differed depending on its origin, other species showed no effect. Cattail (*Typha latifolia* L.), in particular, was found to have lower decomposition rates occurring with material grown at low pH. Lower decomposition rates could result in lower nutrient availability leading to further reduction of productivity under low pH conditions.

Klopatek J. M. 1988. Some thoughts on using a landscape framework to address cumulative impacts on wetland food chain support. *Environmental Management* 12:703-711. Problems of using food chain support as a functional attribute of a wetland are discussed. It is suggested that primary production may not be the metric that best evaluates food chain support. Environmental constructs of the wetland and resultant habitat variables appear to yield more information on life-support functions. A landscape-oriented approach is derived to separate hierarchically the wet-lands into ecological regions and landscape elements. This classification scheme allows for predetermination of environmental constraints and the possible natural limits of wetland food chain support. It is

proposed that models derived from spatial location theory be used to determine the movement of animals from wetland patches experiencing impacts on food chain support. Patch size, distance between patches, habitat diversity, and environmental constraints are incorporated in these models.

Knutson M. G., J. R. Sauer, D. A. Olsen, M. J. Mossman, L. M. Hamesath, and M. J. Lannoo. 1999. Effects of Landscape Composition and Wetland Fragmentation on Frog and Toad Abundance and Species Richness in Iowa and Wisconsin, U.S.A. *Conservation Biology* 13:1437-1446. Management of amphibian populations to reverse recent declines will require defining high-quality habitat for individual species or groups of species, followed by efforts to retain or restore these habitats on the landscape. We examined landscape-level habitat relationships for frogs and toads by measuring associations between relative abundance and species richness based on survey data derived from anuran calls and features of land-cover maps for Iowa and Wisconsin. The most consistent result across all anuran guilds was a negative association with the presence of urban land. Upland and wetland forests and emergent wetlands tended to be positively associated with anurans. Landscape metrics that represent edges and patch diversity also had generally positive associations, indicating that anurans benefit from a complex of habitats that include wetlands. In Iowa the most significant associations with relative abundance were the length of the edge between wetland and forest (positive) and the presence of urban land (negative). In Wisconsin the two most significant associations with relative abundance were forest area and agricultural area (both positive). Anurans had positive associations with agriculture in Wisconsin but not in Iowa. Remnant forest patches in agricultural landscapes may be providing refuges for some anuran species. Differences in anuran associations with deep water and permanent wetlands between the two states suggest opportunities for management action. Large-scale maps can contribute to predictive models of amphibian habitat use, but water quality and vegetation information collected from individual wetlands will likely be needed to strengthen those predictions. Landscape habitat analyses provide a framework for future experimental and intensive research on specific factors affecting the health of anurans.

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.

Larson J. S., Mueller, A.J. MacConnell. W.P. 1980. A model of natural and man-induced changes in open freshwater wetlands on the Massachusetts coastal plain. *Journal of Applied Ecology* 17:667-673. (1) Natural succession and man-induced changes in open freshwater wetlands were measured over a 20-yr period using panchromatic aerial photographs. Over the period 1951-71 nearly one-half of 3958.9 ha of these wetlands showed a change in vegetation class. (2) Change in wetland vegetation class due to natural succession exceeded all man-induced changes. Agriculture, cranberry culture and highway construction were the leading man-induced causes of wetland change. (3) Current public policy in the United States towards wetland protection and management treats wetlands as static entities. A partial model of wetland change is presented to suggest that wetlands should be managed as dynamic elements on the landscape.

Lee A.A. , Bukaveckas P.A. 2002. Surface water nutrient concentrations and litter decomposition rates in wetlands impacted by agriculture and mining activities *Aquatic Botany* 74:273-285. Decomposition rates of a site-specific dominant litter, a standard litter (*Typha latifolia*), and cellulose were quantified in 10 western Kentucky wetlands using the litterbag technique. Short-term (60 and 42 days) incubations were conducted during fall 1998 and spring 1999. The effect of variable tissue nitrogen content on decomposition rates was evaluated by comparing mass loss among site-specific dominant species from each wetland. Effects of variable surface water and sediment nutrient concentrations on decomposition were assessed by measuring mass loss of standard litter materials (*Typha latifolia* and cellulose) of uniform C:N ratio. Decomposition of the site-specific dominant litter was significantly correlated with tissue C:N ratios and phosphorus concentrations in wetland waters and sediments. Water column and sediment phosphorus were also significant predictors of decomposition rates for the standard litter types. Nitrogen concentrations in surface waters were not significant predictors of decomposition for any of the substrates in either season. Wetlands impacted by mine drainage exhibited slower decomposition rates and lower nutrient levels in comparison to wetlands occurring in predominantly agricultural areas.

Lee C. Y., C. C. Lee, F. Y. Lee, S. K. Tseng, and C. J. Liao. 2004. Performance of subsurface flow constructed wetland taking pretreated swine effluent under heavy loads *Bioresource Technology* 92:173-179. Subsurface flow constructed wetlands (SSFCW) subjected to changing of loading rates are poorly understood, especially when used to treat swine waste under heavy loads. This study employed a SSFCW system to take pretreated swine effluent at three hydraulic retention times (HRT): 8.5-day HRT (Phase I), 4.3-day HRT (Phase II), and 14.7-day HRT (Phase III). Results showed that the system responded well to the changing hydraulic loads in removing suspended solids (SS) and carbonaceous oxygen demands. The averaged reduction efficiencies for four major constituents in the three phases were: SS 96–99%, chemical oxygen

demand (COD) 77–84%, total phosphorus 47–59%, and total nitrogen (TN) 10–24%. While physical mechanisms were dominant in removing pollutants, the contributions of microbial mechanisms increased with the duration of wetland use, achieving 48% of COD removed and 16% of TN removed in the last phase. Water hyacinth made only a minimal contribution to the removal of nutrients. This study suggested that the effluent from SSFCW was appropriate for further treatment in land applications for nutrient assimilation. .

Lee L. C., J. G. Gosselink. 1988. Cumulative impacts on wetlands: Linking scientific assessments and regulatory alternatives. *Environmental Management* 12:591-602. This article is an extension and application of Preston and Bedford (1988), especially as relevant to bottomland hardwood (BLH) forests of the southeastern United States. The most important cumulative effects in BLH forests result from incremental forest loss (nibbling) and from synergisms resulting from this nibbling. Present regulatory procedures are ineffective in preventing incremental forest loss because of the focus on permit site evaluation, rather than on large landscapes. Three examples are given to illustrate the need for a landscape focus. This perspective requires preplanning or goal-setting to establish the desired conditions to be maintained in the regulated landscape unit.

Spatial and temporal scales are of particular concern for landscape impact assessment. Natural drainage basins of about 106 ha, as identified in U.S. Geological Survey hydrologic units, appear to be appropriate spatial units: they have fairly natural boundaries, are of sufficient size to support populations of large, wide-ranging mammals, and are compatible with existing maps and databases. Time scales should be sufficiently long to include recovery of wetland ecosystems from human perturbations. In practice, available data sets limit analysis to no longer than 50 yr. Eight indicators of landscape integrity are identified, based on generally available long-term data sets.

Linking technical information concerning cumulative effects on landscapes to the evaluation of cumulative impacts in regulatory programs (i.e., goal-setting) is a serious issue that can benefit from precedents found in the field of epidemiology, and in the establishment of clean air and clean water standards. We suggest that reference data sets must be developed, relating BLH function to structure (forest area). These can be used to set goals for individual watersheds, based on their present conditions and the magnitude and type of perceived development pressures. Thus the crucial steps in establishing a successful program appear to be (1) establish study unit boundaries, (2) assess the condition of study unit landscape integrity, (3) set goals, and (4) consider the impacts of permit proposals with both goals and the existing condition of the study unit landscape in mind.

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 r^2 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 R^2 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 ($R^2 = 47\%$).

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 D. B., W. A. Hartman. 1987. The effect of cultivation on sediment composition and deposition in prairie pothole wetlands. *Water, Air and Soil Pollution* 34:45-53. Texture, major nutrient content, and deposition rate of sediments were compared for five prairie pothole wetlands surrounded by native grassland and seven otherwise similar wetlands surrounded by row crop and small grain farmland. Specific differences in the nature of the sedimentation cycle of cultivated and noncultivated watersheds were indicated. Flux of total inorganic material into sediments averaged 80 and 43 mg cm⁻² yr⁻¹ in cultivated and grassland wetlands, respectively. Cultivated sediments contained significantly higher clay percentages, but lower percentages of silt and sand than grassland sediments. Deposition rates of clay at cultivated sites averaged five times that of grassland locations. Enrichment ratios (the quotient of sediment concentration divided by upland soil concentrations) suggested that sand was selectively retained in equal proportions on uplands in both types of watersheds, that silt was selectively removed (although in different proportions) from uplands in both types of watersheds, and that clay was selectively retained only on grasslands. Total N and organic matter concentrations were significantly higher in both the soils and sediments of grassland watersheds, but there were no differences in total P concentrations with respect to land use. Sediment flux rates for total N and organic matter were similar in the two land use types; however, P was transported at nearly twice the rate to cultivated wetlands. Enrichment ratios indicated that N and P were selectively removed in similar proportions from upland soils in both types of watersheds.

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.

McLaughlin J. W., M. R. Gale, M. F. Jurgensen, and C. C. Trettin. 2000. Soil organic matter and nitrogen cycling in response to harvesting, mechanical site preparation, and fertilization in a wetland with a mineral substrate. *Forest Ecology and Management* 129:7-23. Forested wetlands are becoming an important timber resource in the Upper Great Lakes Region of the US. However, there is limited information on soil nutrient cycling responses to harvesting and post-harvest manipulations (site preparation and fertilization). The objective of this study was to examine cellulose decomposition, nitrogen mineralization, and soil solution chemistry four years after a forested, mineral soil wetland in Northern Michigan was whole-tree harvested, site prepared, and fertilized: (N, P, N + P). Organic matter decomposition was greatest in the site preparation bedding treatment and lowest in whole-tree harvested with no mechanical site preparation treatment. Both N and P additions, alone and in combination resulted in increased cellulose decomposition regardless of site preparation treatment (15-38% for the harvest-only treatment, 20-40% for the bedded treatment, and 15-44% for the trenched treatment). However, based on dissolved organic carbon concentrations in the soil solution, organic matter decomposition was inhibited on an overall plot basis; that is, outside the area of cellulose strip placement. The site preparation bedding treatment resulted in a net mineralization of N (9.2 g-N m^{-2}) over a 10 week incubation period. The disc trench and harvest-only treatments resulted in a net immobilization of N (3.1 g-N m^{-2} and 1.5 g-N m^{-2} , respectively). Nitrogen, P, and N + P inhibited N mineralization in the bedded treatment by 10-25% over the control. There was a fertilizer-induced increase in N immobilization of 50-40% and 25-50% in the harvest-only and trenched treatments, respectively. It appears that soil microorganisms at this site are limited by soluble C more than N or P. By adding cellulose strips to the soil, the soluble C limitation was, in part, overcome. Once the soluble C limitation was alleviated, then the soil microorganisms responded positively to N and P additions.

Mensing D. M., S. M. Galatowitsch, and J. R. Tester. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape *Journal of Environmental Management* 53:349-377. Land uses such as forestry and agriculture are presumed to degrade the biodiversity of riparian wetlands in the northern temperate regions of the United States. In order to improve land use decision making in this landscape, floral and faunal

communities of 15 riparian wetlands associated with low-order streams were related to their surrounding land cover to establish which organismal groups are affected by anthropogenic disturbance and whether these impacts are scale-specific. Study sites were chosen to represent a gradient of disturbance. Vascular plants of wet meadow and shrub carr communities, aquatic macro-invertebrates, amphibians, fish and birds were surveyed, and total abundance, species richness and Shannon diversity were calculated. For each site, anthropogenic disturbances were evaluated at local and landscape scales (500, 1000, 2500 and 5000 m from the site and the site catchment) from field surveys and a geographic information system (GIS). Land use data were grouped into six general land use types: urban, cultivated, rangeland, forest, wetland and water. Shrub carr vegetation, bird and fish diversity and richness generally decrease with increasing cultivation in the landscape. Amphibian abundance decreases and fish abundance increases as the proportions of open water and rangeland increases; bird diversity and richness increase with forest and wetland extent in the landscape. Wet meadow vegetation, aquatic macro-invertebrates, amphibians and fish respond to local disturbances or environmental conditions. Shrub carr vegetation, amphibians and birds are influenced by land use at relatively small landscape scales (500 and 1000 m), and fish respond to land use at larger landscape scales (2500, 5000 m and the catchment). Effective conservation planning for these riparian wetlands requires assessment of multiple organismal groups, different types of disturbance and several spatial scales. .

Miller J. N., R. P. Brooks, and M. Croonquist. 1997. Effects of landscape patterns on biotic communities *Landscape Ecology* 12:137-153. A comparative evaluation was performed using descriptors of landscape and land cover patterns as to how they relate to varying levels of anthropogenic disturbance and the structure of biotic communities. A spatial analysis program (a modified version of SPAN) was used to compute measures of land cover diversity, dominance, contagion, scaled dominance and contagion, fractal dimension of land cover patches, mean forest-wetland patch size, amount of forest edge, clustering of selected forest types, and the largest cover patches within two 100-km² watersheds of the Ridge and Valley province of central Pennsylvania. Landscape pattern analysis was conducted on a subwatershed basis, emphasizing different levels of residential/agricultural versus forest land cover, the major difference between the two watersheds. Bird and vascular plant guilds were chosen to represent the overall biotic community. The general descriptors of diversity, contagion, mean forest-wetland patch size, proportion of forest cover, and the amount of forest edge were most effective in reflecting the disturbance levels within the watersheds and changes in guild composition for both birds and plants.

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 than 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".

Moore M., J. J. Rodgers, C. Cooper, and S. J. Smith. 2000. Constructed wetlands for mitigation of atrazine-associated agricultural runoff. *Environmental Pollution* 110:393-399. Atrazine was amended into constructed wetlands (59-73x14x0.3 m) for the purpose of monitoring transport and fate of the pesticide to obtain information necessary to provide future design parameters for constructed wetlands mitigation of agricultural runoff. Following pesticide amendment, a simulated storm and runoff event equal to three volume additions was imposed on each wetland. Targeted atrazine concentrations were 0 $\mu\text{g/l}$ (unamended control), 73 $\mu\text{g/l}$, and 147 $\mu\text{g/l}$. Water, sediment, and plant samples were collected weekly for 35 days from transects longitudinally distributed throughout each wetland and were analyzed for atrazine using gas chromatography. Between 17 and 42% of measured atrazine mass was within the first 30-36 m of wetlands. Atrazine was below detection limits (0.05 $\mu\text{g/kg}$) in all sediment and plant samples collected throughout the duration of this study. Aqueous half lives ranged from 16 to 48 days. According to these data, conservative buffer travel distances of 100-280 m would be necessary for effective runoff mitigation.

Morse, S. F. and S. K. Robinson. 1998. Nesting success of a neotropical migrant in a multiple-use, 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.

Musacchio L., W. Grant. 2002. Agricultural production and wetland habitat quality in a coastal prairie ecosystem: simulated effects of alternative resource policies on land-use decisions *Ecological Modelling* 150:23-43.

Nakamura F., S. Kameyama, and S. Mizugaki. 2004. Rapid shrinkage of Kushiro Mire, the largest mire in Japan, due to increased sedimentation associated with land-use development in the catchment *CATENA* 55:213-229. The suspended sediment discharge in the Kuchoro River, a tributary of the Kushiro River, showed that wash load was about 90% of the yearly total suspended load carried into the wetland from the entire watershed. Seasonal floods associated with typhoons and snowmelt carried a large volume of wash load, 44% and 37%, respectively, of the yearly total wash load. The deposition of suspended sediment in the channelized section has aggraded the riverbed by 2 m in the past two decades, which has reduced the cross-sectional area of the channel, so that turbid water spills over and carries wash load and suspended sediment deep into the wetlands. Flooding of turbid water, in association with aggradation of the riverbed, was detected by using a Water Turbidity Index. The flooding and turbidity have significantly increased between 1984 and 1994. Similarly, a Normalized Difference Vegetation Index map showed that forest establishment has continued from the wetland margins and in areas adjacent to the river channel. The suspended sediment carried and deposited by floods and sediment-associated nutrients should alter the edaphic environment from wet nutrient-poor soil to dry nutrient-rich soil providing regeneration habitats for tree species. The vegetation in turn adds resistance and friction against flows and contributes to additional sedimentation. However, flooding and the associated high water table causes stress for trees and may lead to premature decay. Environmental variables, such as water level, water content, organic content and grain size, varied significantly along cross-sectional distance, and are likely regulated by deposition of fine sediments transported by floods. Electrical conductivity and total nitrogen in groundwater varied significantly along the longitudinal distance. Basal areas of willow and alder stands correlated with variables related to spread of turbid water, which indicates that eutrophication of groundwater indirectly affects marsh forest expansion. .

Nichols S. A., R. C. Lathrop. 1994. Cultural impacts on macrophytes in the Yahara lakes since the late 1800s. *Aquatic Botany* 47:225-247. Vegetation changes in the Yahara lakes around Madison, Wisconsin, USA, are evaluated using historical data. Present vegetation is less diverse and less extensive, produces less biomass and is composed of more disturbance tolerant species than it was 80-100 years ago. Many changes are related to human impacts that began about 150 years ago which directly altered plant habitat, decreased water clarity, were toxic to plants, removed plant biomass or reproductive structures, or resulted from exotic invaders. The impacts are interrelated and overlap in time and space so change did not occur from simple cause and effect relationships. However, cumulative effects of the impacts are very evident. Management recommendations are made that are applicable to North American lakes with a similar history.

O'Brien A. L. 1988. Evaluating the cumulative effects of alteration on New England wetlands. *Environmental Management* 12:627-636. In New England, patterns of glacial deposition strongly influence wetland occurrence and function. Many wetlands are associated with permeable deposits and owe their existence to groundwater discharge. Whether developed on deposits of high or low permeability, wetlands are often associated with streams and appear to play an important role in controlling and modifying streamflow. Evidence is cited showing that some wetlands operate to lessen flood peaks, and may have the seasonal effect of increasing spring discharges and depressing low flows. Wetlands overlying permeable deposits may be associated with important aquifers where they can produce slight modifications in water quality and head distribution within the aquifer. Impacts to wetlands undoubtedly will affect these functions, but the precise nature of the effect is difficult to predict. This is especially true of incremental impacts to wetlands, which may, for example, produce a change in streamflow disproportionate to wetland area in the drainage basin, i.e., a nonlinear effect as defined by Preston and Bedford (1988). Additional research is needed before hydrologic function can be reliably correlated with physical properties of wetlands and landscapes. A model is proposed to structure future research and explore relationships between hydrologic function and physical properties of wetlands and landscapes. The model considers (1) the nature of the underlying deposits (geologic type), (2) location in the drainage basin (topographic position), (3) relationship to the principal zone of saturation (hydrologic position), and (4) hydrologic character of the organic deposit.

Otte M. L. 2001. What is stress to a wetland plant? *Environmental and Experimental Botany* 46:195-202. The definitions of the term 'stress' and its applications are reviewed in relation to wetland plants. Three views on the use of the term stress prevail; (1) that it should not be used at all; (2) that it defines any situation which leads to a decrease from optimum performance; and (3) that it should only apply to extreme conditions, outside the normal range of the organism. It is argued here that View 3 should be accepted only; i.e. that stress should only be regarded to be arising from changes in environmental conditions outside the normal range encountered by plants. Conditions normally encountered by wetland plants, such as waterlogged, anaerobic soils and salinity, are not stressful to such plants, but only to non-adapted dryland plants. Stress occurs only when plants are exposed to environmental conditions outside the range they are normally exposed to due to natural or anthropogenic changes. Such conditions are found in agriculture—when plants are grown in places they would not naturally grow, in rapidly changing environments—for example when hydrology is changed due to subsidence or engineering works, and under conditions of environmental pollution. The actual stress imposed on wetland plants may be secondary to the factor thought to cause the stress. Very few studies exist showing direct stress on wetland plants. .

Owen C. R. 1999. Hydrology and history: land use changes and ecological responses in an urban wetland *Wetland Ecology and Management* 6:209-219. The impacts of changing land use on hydrology and dominant plant species

from 1850–1990 were investigated in a palustrine wetland in southern Wisconsin, USA. Aerial photographs, historic maps and water levels of the area were used to determine changes in land use, wetland vegetation, and groundwater and surface flows over time. Piezometers and water table wells were monitored weekly for two years. Vegetation was quantified in four onesquare meter quadrats at each water level measurement site. Linear regression models and multivariate ordinations were used to relate wetland plant species to hydrologic, chemical and spatial variables. The current hydrologic budget of the wetland was dominated by precipitation and evapotranspiration, although overland flow into the wetland from the subwatershed has increased twenty-fold since 1850. Water level stabilization in the adjacent Yahara River, creek channelization, and groundwater pumping have decreased inputs of groundwater and springfed surface water, and increased retention of precipitation. *Typha* spp. and *Phalaris arundinacea* L. have increased in the wetland, while *Carex* spp. have decreased. *Phalaris arundinacea* was found most often in the driest sites, and the sites with the greatest range of water levels. *Typha* spp. dominated in several hydrologic settings, indicating that water depth was not the only factor controlling its distribution. The distributions of dominant plant species in the wetland were most closely correlated with site elevation and average water levels, with some weaker correlations with vertical groundwater inflows and specific conductance.

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.

Pant H. K., K. R. Reddy. 2003. Potential internal loading of phosphorus in a wetland constructed in agricultural land *Water Research* 37:965-972. Wetland construction on agricultural or dairy lands could result in solubilization of phosphorus (P) stored in soils and release to the water column. To study the extent of P flux during the start-up period of a constructed wetland, intact soil-cores from areas used for dairy operations, in Okeechobee, Florida, USA were obtained and flooded with adjacent creek water. In the first 28-day hydraulic-retention period, P concentration in the water column increased several fold due to rapid P flux from impacted soils. A continuous decrease in P flux to the water column until the third hydraulic retention cycle (initial influent P concentration 0.2 mg L⁻¹).

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.

Pezeshki S. R. 2001. Wetland plant responses to soil flooding *Environmental and Experimental Botany* 46:299-312. Wetland plants possess various characteristics that enable them to survive periodic soil saturation and the accompanying changes in soil chemistry. These changes include the lowering of soil redox potential (Eh) which translates into a progressively greater demand for oxygen within the soil and hence additional stress on the roots. However, information on the relationship between flood-response of wetland plants and reducing soil conditions is limited. In particular, the relationship between soil reduction and plant photosynthesis is largely unknown, but the literature reveals a range of photosynthetic sensitivities to the intensity of soil reduction among wetland species. Initial reductions in net photosynthesis immediately after soil flooding are common among species representing various wetland ecosystems including marshes, forested wetlands, and riparian wetlands. At the whole-plant level, the photosynthetic reductions are attributed to diffusional limitations due to stomatal closure and to metabolic (non-stomatal) inhibition of photosynthesis. Low soil Eh may lead to photosynthetic reduction due to decreased leaf water potential resulting from root dysfunction, reduced activity of major photosynthetic enzymes, disruption in photosynthate transport,

alteration in source-sink relationship or reduced sink demand. Furthermore, while root oxygen-deficiency may partially account for the reduction in net photosynthesis, soil phytotoxins produced as by-products of low soil Eh conditions may play a major role in the observed photosynthetic sensitivities. Clearly, the high oxygen demand in soil resulting from intense reduction exerts profound influence on oxygen transport and release to the rhizosphere. However, methods are needed to differentiate wetland plant responses to low oxygen conditions and soil phytotoxins that are byproducts of soil reduction.

Pontier H., J. B. Williams, and E. May. 2004. Progressive changes in water and sediment quality in a wetland system for control of highway runoff *The Science of the Total Environment* 319:215-224.

Preston E. M., B. L. Bedford. 1988. Evaluating Cumulative effects on wetland functions: A conceptual overview and generic framework. *Environmental Management* 12:565-583. This article outlines conceptual and methodological issues that must be confronted in developing a sound scientific basis for investigating cumulative effects on freshwater wetlands. We are particularly concerned with: (1) effects expressed at temporal and spatial scales beyond those of the individual disturbance, specific project, or single wetland, that is, effects occurring at the watershed or regional landscape level; and (2) the scientific (technical) component of the overall assessment process. Our aim is to lay the foundation for a research program to develop methods to quantify cumulative effects of wetland loss or degradation on the functioning of interacting systems of wetlands. Toward that goal we: (1) define the concept of cumulative effects in terms that permit scientific investigation of effects; (2) distinguish the scientific component of cumulative impact analysis from other aspects of the assessment process; (3) define critical scientific issues in assessing cumulative effects on wetlands; and (4) set up a hypothetical and generic structure for measuring cumulative effects on the functioning of wetlands as landscape systems.

We provide a generic framework for evaluating cumulative effects on three basic wetland landscape functions: flood storage, water quality, and life support. Critical scientific issues include appropriate delineations of scales, identification of threshold responses, and the influence on different functions of wetland size, shape, and position in the landscape.

The contribution of a particular wetland to landscape function within watersheds or regions will be determined by its intrinsic characteristics, e.g., size, morphometry, type, percent organic matter in the sediments, and hydrologic regime, and by extrinsic factors, i.e., the wetland's context in the landscape mosaic. Any cumulative effects evaluation must take into account the relationship between these intrinsic and extrinsic attributes and overall landscape function. We use the magnitude of exchanges among component wetlands in a watershed or larger landscape as the basis for defining the geographic boundaries of the assessment. The time scales of recovery for processes controlling particular wetland functions determine temporal boundaries. Landscape-level measures are proposed for each function.

Richardson C. J. 1994. Ecological functions and human values in wetlands: a framework for assessing impact. *Wetlands* 14:1-9. The term "value" usually connotes something of use or desirable to *Homo sapiens*. Values ascribed to many wetlands include providing habitats for fishing, hunting, waterfowl, timber harvesting, wastewater assimilation, and flood control, to name a few. These perceived values arise directly from the ecological functions found within the wetlands. Ecosystem functions include hydrologic transfers and storage of water, biogeochemical transformations, primary productivity, decomposition, and community/habitat. An analysis of the relationship among wetland functions and values showed that over-utilization or intensive removal of wetland values (e.g., timber harvesting with drainage), can often result in a loss of specific wetland functions. An assessment procedure comparing changes in wetland function from both a disturbed and reference wetland was developed. This approach scales the wetland functions in a reference system to 100% and then compares the altered wetlands' functional response. Methods to analyze wetland functions in the field are outlined along with examples of the effects of forestry activities on wetland response.

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%).

Risser P. G. 1988. General concepts for measuring cumulative impacts on wetland ecosystems. *Environmental Management* 12:585-589. Because environmental impacts accumulate over space and time, analysis is difficult, and we must incorporate the most recent scientifically defensible information and methods into the process. Methods designed to deal specifically with cumulative impacts include checklists of characteristics or processes, matrices of interactions (rated according to their level of importance) between disturbance activities and environmental conditions, nodal networks or pathways that depict probable effects of disturbances, and dynamic system models. These methods have been tested over the past decade and have proven generally successful. Landscape perspectives have emerged as especially helpful in analyzing cumulative effects, and have focused specific attention on questions of spatial and temporal scale, while leading to recognition of the complexity of ecosystem processes in general. An evaluation of several cases studies by the Commission on Life Sciences of the U.S. National Academy of Sciences emphasizes the importance of interactions and cumulative effects, but recognizes that current knowledge of the processes involved is insufficient to make specific recommendations for conceptual frameworks.

The conceptual approach suggested by Preston and Bedford (1988) addresses many critical issues, such as the need to define dimensions of scale, and the

importance of wetland size, shape, and location in the landscape. This approach and similar ones must be tested and evaluated so that a consensus may eventually emerge.

A cumulative impact matrix is proposed that sets up additive, synergistic, and indirect categories, each capable of variation in space and time. Every interaction would be carefully examined to determine the likelihood of cumulative impact in any of the six categories. Because of its magnifying glass approach, such a matrix could be a very useful analytical tool, using existing methods to uncover all the information presently available about the behavior of the ecosystem of concern.

Roe J. H., J. Gibosn, and B. Kingsbury. 2006. Beyond the wetland border: Estimating the impact of roads for two species of water snakes Biological Conservation 130:161-168. We used models integrating road maps, traffic volume, and snake movements to examine the potential for roads to contribute to mortality in two species of water snakes that differ in their vagility, use of terrestrial habitats, and conservation status. Road networks and traffic volumes typical of three regions in Indiana, USA, may account for mortality of 14– 21% of the population per year in the more vagile, terrestrial, and imperiled copperbelly water snake (*Nerodia erythrogaster neglecta*) but only 3–5% mortality in the more sedentary, aquatic, and common northern water snake (*Nerodia sipedon*). The majority (>91%) of road crossings and associated mortality are predicted to occur during overland migrations to other wetlands, suggesting roads bisecting travel routes between wetlands may function as mortality sinks. Our models highlight the proportionately greater risk of mortality for the more vagile and imperiled species, *N. e. neglecta*, and suggest current wetland conservation strategies that focus on the wetland alone are unlikely to adequately protect wetland biodiversity from certain types of anthropogenic habitat modification. What is needed is a landscape approach to wetland conservation that considers not only the quality of wetlands and nearby terrestrial habitats, but also ensures that terrestrial corridors between wetlands remain permeable and offer safe passage for wildlife.

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 from 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.

Schulz R., S. K. C. Peall, C. Hugo, and V. Krause. 2001. Concentration, load and toxicity of spraydrift-borne azinphos-methyl at the inlet and outlet of a constructed wetland *Ecological Engineering* 18:239-245.

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.

Shepard J. P. 1994. Effects of forest management on surface water quality in wetland forests

Wetlands 14:18-26. A literature review on the effects of silvicultural practices on water quality in wetland forests was conducted. The review summarized results from nine wetland forests in five states (AL, FL, MI, NC, and SC). Silvicultural practices assessed were timber harvesting (including thinning and clearcutting), site preparation, bedding, planting, drainage, and fertilization. Many of the studies reviewed observed increased concentrations of suspended sediment and nutrients following silvicultural operations when compared with undisturbed controls. Water quality criteria were rarely exceeded by silvicultural operations, however, and effects on water quality were transient. Water quality parameters returned to undisturbed levels within a period ranging from months to several years. .

Siegel D. I. 1988. Evaluating cumulative effects of disturbance on the hydrologic function of bogs, fens, and mires. *Environmental Management* 12:621-626. Few quantitative studies have been done on the hydrology of fens, bogs, and mires. Consequently predicting the cumulative impacts of disturbances on their hydrologic functions is extremely difficult. For example, few data are available on the role of bogs and fens with respect to flood desynchronization and shoreline anchoring. However, recent studies suggest that very small amounts of groundwater discharge are sufficient to radically modify mire surface-water chemistry, and consequently, vegetation communities and their associated surface-water hydrology. Bogs and fens are, in a sense, hydrobiologic systems, and any evaluation of cumulative impacts will have to (1) consider the complicated and little understood interactions among wetland hydrology, water chemistry, and biota, and (2) place the effect of individual wetland impacts within the context of the cumulative impacts contributed to the watershed from other geomorphic areas and land uses. It is difficult to evaluate the potential cumulative impacts on wetland hydrology because geologic settings of wetlands are often complex and the methods used to measure wetland streamflow, groundwater flow, and evapotranspiration are inexact (Winter 1988). This is especially so for bogs, fens, and mires underlain

by thick organic soils. These wetlands, found in the circumboreal areas of North America, Europe, and Asia, are major physiographic features in eastern North America, northern Europe, and Siberia (Kivenen and Pakarinen 1981, Gore 1983, Glaser and Janssens 1986). Their very scale makes it difficult to quantify the hydrologic function accurately. The hydrology of small bogs and fens found elsewhere is just as poorly understood because of conflicting conceptual models of pertinent hydrologic processes.

This article (1) reviews our current understanding of the hydrologic function of bogs, fens, and mires at different scales and in different physiographic settings and (2) presents hypotheses on potential cumulative impacts on the hydrologic function that might occur with multiple disturbances.

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.

Snodgrass J. W., M. J. Komoroski, A. L. J. Bryan, and J. Burger. 2000. Relationships among Isolated Wetland Size, Hydroperiod, and Amphibian Species Richness: Implications for Wetland Regulations. *Conservation Biology* 14:414-419. Wetland development within the United States is regulated primarily by size. Decisions concerning wetland destruction or conservation are therefore based in part on three inherent assumptions: (1) small wetlands contain water for short portions of the year; (2) small wetlands support few species; and (3) species found in small wetlands are also found in larger wetlands. We tested these assumptions using data on wetland size, relative hydroperiod (drying scores), and relative species richness of amphibians in depression wetlands of the southeastern United States. We found a significant ($p = 0.03$) but weak ($r^2 = 0.05$) relationship between hydroperiod and wetland size and no relationship ($p = 0.48$) between amphibian species richness and wetland size. Furthermore, synthetic models of lentic communities predict that short-hydroperiod wetlands support a unique group of species. Empirical investigations support this prediction. Our results indicate that hydroperiod length should be included as a primary criterion in wetland regulations. We advocate a landscape approach to wetlands regulation, focused in part on conserving a diversity of wetlands that represent the entire hydroperiod gradient.

Sriyaraj, K. Shutes, R.B.E. 2001. An assessment of the impact of motorway runoff on a pond, wetland and stream. *Environmental International* 26:433-439. The impact of soil filtered runoff from a section of the M25 outer London motorway (constructed in 1981) on a pond, wetland and stream in a nature reserve was investigated by monitoring water, sediment. The tissues of the emergent plants *Typha latifolia* and *Glyceria maxima* collected from the pond were analysed for the heavy metals, Cd, Pb, Cu and Zn. Macroinvertebrates were monitored in the stream and biotic indices applied to the data. The plant tissue concentrations for *Typha* and *Glyceria* show decreasing metal concentrations from root to rhizome to leaf. This trend has previously been reported for *Typha* exposed to runoff although the tissue concentrations are lower in this study with the exception of Cd in root tissue. The Biological Monitoring Working Party (BMWP) score and Average Score Per Taxon (ASPT) for the stream at sites above and below the pond outlet are lower than the scores recorded by the Environment Agency for England and Wales at an upstream site above the Pond/Wetland. The sites have an Overall Quality Index of 'moderate water quality', and there is no evidence of a deterioration of biologically assessed water quality between them. The results of the study show the long-term impact on sediment of filtered road runoff discharges to a natural wetland and pond located in a nature reserve. The use of natural wetlands for the discharge of road runoff is inadvisable. Constructed wetlands in combination with other structures including settlement trenches and ponds should be considered as an alternative treatment option.

Stewart L. K., P. F. Hudak, and R. D. Doyle. 1998. Modeling hydrologic alterations to a developing wetland in an abandoned borrow pit *Journal of Environmentla Management* 53:231-239.

Sun G., S. G. McNulty, J. P. Shepard, D. M. Amatya, H. Riekerk, N. B. Comerford, W. Skaggs, and L. J. Swift. 2001. Effects of timber managements on the hydrology of wetland forests in the southern United States. *Forest Ecology and Management* 143:227-236. The objectives of this paper are to review the hydrologic impacts of various common forest management practices that include harvesting, site preparation, and drainage. Field hydrological data collected during the past 5–10 years from ten forested wetland sites across the Southern United States are synthesized using various methods, including hydrologic simulation models and Geographic Information Systems. Wetland systems evaluated include red river bottoms, black river bottoms, pocosins, wet mineral flats, cypress domes, and pine flatwoods. Hydrologic variables used in this assessment include water table level, drainage, and storm flow on different spatial and temporal scales. Wetland ecosystems have higher water storage capacity and higher evapotranspiration than uplands. Hydrologic impacts of forest management are variable, but generally minor, especially when forest best management practices are adopted. A conceptually generalized model is developed to illustrate the relative magnitude of hydrologic effects of forest management on different types of wetlands in the Southern United States. This model suggests that in addition to soils, wetland types, and management practice options, climate is an important factor in controlling wetland hydrology

and the magnitude of disturbance impacts. Bottomland wetlands, partial harvesting, and warm climate usually offer conditions that result in low hydrologic impact.

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.

Thibodeau F. R. 1985. Changes in a wetland plant association induced by impoundment and draining. *Biological Conservation* 33:269-279. In 1977 a newly constructed gravel access road blocked water flow across a shrub swamp in Tewksbury, Massachusetts, draining one section and impounding another. Within one year, the vegetation in the drained area shifted substantially toward a denser and more species-rich association. After three years the changes slowed, but they had not stopped after six. Many of these changes would not be expected to reverse themselves once a more normal flooding pattern was established. In the newly flooded area there was little change for the first three years, but after that time many species began to decline in numbers, with the most pronounced effect occurring after five years. Even short-term alterations in the flooding cycle can be expected to have substantial and long-lasting effects on wetland vegetation.

Thurston K. 1999. Lead and petroleum hydrocarbon changes in an urban wetland receiving stormwater runoff *Ecological Engineering* 12:387-399. The hydrology and water quality of an urban wetland receiving stormwater runoff from a municipal maintenance garage were measured during the summer of 1993 to evaluate the wetland's water quality enhancement function. Surface water accounted for half of the inflow and more than 80% of the outflow. Stormwater runoff and dry period water samples were analyzed for total lead and total petroleum hydrocarbons. Lead and petroleum were present at higher levels in stormwater runoff samples than in the weekly samples. Average mass loadings of these constituents were higher at the wetland inlet than at the outlet. Levels of lead and petroleum hydrocarbons in sediments were higher near the inlet than elsewhere on the site. Hydrologic and analytical data together suggest that sedimentation was the primary mechanism actively reducing water column

concentrations of lead and petroleum hydrocarbons introduced to the wetland via stormwater runoff. .

Touzard B., B. Amiaud, E. Langlois, S. Lemauiel, and B. Clement. 2002. The relationships between soil seed bank, aboveground vegetation and disturbances in an eutrophic alluvial wetland of Western France *Flora* 197:175-185. We studied the species composition of vegetation and seed bank in an experiment with grassland and oldfield plots in an eutrophic alluvial wetland (called "Marais de Redon") of Western France. In this wetland, artificial disturbances (mowing) and natural disturbances (cattle, roebucks, boars, voles...) are very frequent. In order to mime these natural disturbances, experimental disturbances were generated in March 1996 after the end of the winter flooding and the seedlings counted three months later. The seed bank, the undisturbed vegetation and seedlings emerging in disturbed quadrats were sampled. Detrended Correspondence Analysis (DCA) of the undisturbed quadrats, disturbed quadrats and seed bank samples showed significant differences of species composition. Similarity between seed bank and undisturbed aboveground vegetation was low and not very different between grassland and oldfield. Very few seedlings emerged in undisturbed vegetation both in grassland and oldfield, which indicates the importance of gaps for seed bank expression. The great majority of seedlings emerging after experimental disturbances were mainly recruited from the soil seed bank. This result contrasts with other studies where the seed bank contributed very little to the seedling flora and vegetative regrowth clearly predominated recolonisation after disturbances. In the seed bank, few species lost after succession from grassland to oldfield vegetation were still present as seeds in the soil, but in most cases, species lost were not recorded in the seed bank. The two hypotheses about changes in the seed bank during secondary succession, predicting decrease in species richness or species diversity and seed density were only confirmed for seed density parameter. .

Tretting C. C., M. Davidian, M. F. Jurgensen, and R. Lea. 1996. Organic Matter Decomposition following Harvesting and Site Preparation of a Forested Wetland *Soil Science Society of America Journal* 60:1994-2003. Organic matter accumulation is an important process that affects ecosystem function in many northern wetlands. The cotton strip assay (CSA) was used to measure the effect of harvesting and two different site preparation treatments, bedding and trenching, on organic matter decomposition in a forested wetland. A Latin square experimental design was used to determine the effect of harvesting, site preparation, and relative position within the wetland on organic matter decomposition at soil depths of 5, 10, and 20 cm. Repeated measures analysis of variance was used to test for treatment effects on organic matter decomposition, soil temperature, and soil oxidation depth. Cellulose decomposition increased at each soil depth as site disturbance increased, with bedding > trenching > whole-tree harvest > reference. The cellulose decomposition response was correlated with changes in soil temperature; the temperature coefficient Q_{10} equaled 6.0, which is greater than previously reported values. Position within the wetland relative to an adjoining river affected the decomposition and soil oxidation depth. Because the rate of decomposition is strongly controlled by temperature,

higher rates of organic matter decay are expected to continue on harvested and regenerated sites until canopy closure reduces soil temperature.

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).

Vickers C. R., L. D. Harris, and B. F. Swindel. 1985. Changes in herpetofauna resulting from ditching of cypress ponds in coastal plains flatwoods. *Forest Ecology and Management* 11:17-29. Three ditched and three unditched cypress ponds in north Florida were surveyed to assess the effects of ditching on their herpetofauna (amphibians and reptiles). Predominantly aquatic and semi-aquatic amphibians were captured. Unditched ponds had more persistent surface water and more consistent water depths than ditched ponds. No differences in mean numbers of individuals, numbers of species, or species diversity were detected between ditched and unditched ponds. However, species richness was reduced in ditched ponds in dry weather and relative abundances of species in the two types of ponds were different: more terrestrial species were associated with ditched ponds; more aquatic species were associated with unditched ponds. Herpetofauna were most abundant and species richness was greatest along pond edges. .

Walbridge M. R., B. G. Lockaby. 1994. Effects of forest management on biogeochemical functions in southern forested wetlands *Wetlands* 14:10-17. Southern forested wetlands perform two important biogeochemical functions on the landscape: 1) nutrient (N and P) removal from incident surface, subsurface, and ground waters, and 2) export of organic carbon and associated nutrients to aquatic ecosystems downstream. In addition to P sediment deposition, which can range from 1.6 to 36.0 kg/ha/yr P, denitrification of NO₃-N (0.5 to 350 kg/ha/yr) and P adsorption (130 to 199 kg/ha/yr) can be important mechanisms associated with N and P removal, respectively. Biological processes, uptake by plants (15.0 to 51.8 kg/ha/yr for N; 0.2 to 3.8 kg/ha/yr for P) and microorganism absorption (16.2 to 87.0 kg/ha/yr for N; 6.6 to 40.0 kg/ha/yr for P) are also important and are intimately associated with organic matter export. Clearcut harvests (ground-based or aerial), followed by natural regeneration, are the most common silvicultural techniques used in forested floodplains in the South. Ground-based methods have been shown to increase soil bulk density and decrease hydraulic conductivity and redox potential in wetter soils. In addition to the increases in soil temperature and soil wetness that frequently occur following forest harvesting, these added effects may be responsible for the reduced productivity and altered species composition observed following ground-based vs. aerial harvests. Changes in denitrification will be a function of the degree to which harvesting affects soil redox potential, substrate (C) availability, and nitrate production. In theory, denitrification rates should increase following harvesting, but low nitrate availability in acid soils may limit this effect. The effects of harvesting on P adsorption processes in forested wetland soils have not been studied. Reductions in plant uptake and litterfall and changes in species composition following harvesting could alter both nutrient

retention/transformation and organic C export functions. On wetter sites, canopy removal may stimulate algal populations, providing a short-term mechanism for conserving geochemical exports. Clearcut harvest systems that minimize alterations in soil hydrology and promote rapid vegetation regrowth should have the least effect on biogeochemical functions in southern forested wetlands. .

Wang G., J. Liu, and J. Tang. 2004. The long-term nutrient accumulation with respect to anthropogenic impacts in the sediments from two freshwater marshes (Xianghai Wetlands, Northeast China) *Water Research* 38:4462-4474. Sediment cores, representing a range of watershed characteristics and anthropogenic impacts, were collected from two freshwater marshes at the Xianghai wetlands (Ramsar site no. 548) in order to trace the historical variation of nutrient accumulation. Cores were ^{210}Pb - and ^{137}Cs -dated, and these data were used to calculate sedimentation rates and sediment accumulation rates. Ranges of dry mass accumulation rates and sedimentation rates were 0.27–0.96 g m.

Wardrop, D.H., R. P. Brooks. 1998. The Occurrence and Impact of Sedimentation in Central Pennsylvania Wetlands. *Environmental Monitoring and Assessment* 51:119-130. Sedimentation rates and deposited sediment characteristics in twenty-five wetlands in central Pennsylvania were measured during the period Fall 1994 to Fall 1995. Wetlands were located primarily in five watersheds, and represented a variety of hydrogeomorphic (HGM) subclasses and surrounding land use. Sedimentation rates were measured via the placement of 135 Plexiglas disks. Annual organic and inorganic loadings were determined. Sedimentation rates ranged from 0 to 8 cm/year, with sedimentation rates significantly correlated with surrounding land use and HGM subclass. Overall mean mineral and organic accretion rates were 778 g m² yr⁻¹ (+/- 1417) and 550 g m² yr⁻¹ (+/- 589), respectively. Mean mineral and organic accretion rates were significantly different by HGM subclass. The highest mineral accretion rates were for headwater floodplains, followed by impoundments, riparian depressions, mainstem floodplains, and slopes. The highest organic accretion rates were for riparian depressions, followed by impoundments, slopes, headwater floodplains, and mainstem floodplains. The potential effects of landscape disturbance on these sedimentation rates was also investigated, in order to develop a conceptual model to predict sedimentation rates for a given wetland in a variety of landscape settings. Different HGM subclasses exhibited significantly different mineral and organic accumulation rates, and varied in their responses to landscape disturbance and spatial variability in sedimentation patterns. Characterization of wetland plant communities in these same wetlands showed clear associations between individual plant species and ability to tolerate sediment. Species were categorized as very tolerant, moderately tolerant, slightly tolerant, and intolerant based on their association with environments of varying sedimentation magnitude. In general, species that were categorized as very tolerant or moderately tolerant increased their percent cover (dominance) over the sedimentation gradient. These observations were supported by greenhouse germination trials of eight species of wetland plants under a variety of sediment depths, ranging from 0 to 2 cm.

Weller M. W. 1988. Issues and approaches in assessing cumulative impacts on waterbird habitat in wetlands. *Environmental Management* 12:695-701. Wetlands are attractive to vertebrates because of their abundant nutrient resources and habitat diversity. Because they are conspicuous, vertebrates commonly are used as indicators of changes in wetlands produced by environmental impacts. Such impacts take place at the landscape level where extensive areas are lost; at the wetland complex level where some (usually small) units of a closely spaced group of wetlands are drained or modified; or at the level of the individual wetland through modification or fragmentation that impacts its habitat value. Vertebrates utilize habitats differently according to age, sex, geographic location, and season, and habitat evaluations based on isolated observations can be biased. Current wetland evaluation systems incorporate wildlife habitat as a major feature, and the habitat evaluation procedure focuses only on habitat. Several approaches for estimating bird habitat losses are derived from population curves based on natural and experimentally induced population fluctuations. Additional research needs and experimental approaches are identified for addressing cumulative impacts on wildlife habitat values.

Weller M. W., D. K. Voigts. 1983. Changes in the vegetation and wildlife use of a small prairie wetland following a drought. *Proceedings of the Iowa Academy of Science* 90:50-54. Several transect methods were used to study marsh vegetation resulting from drought-induced mud flats of a 1.7ha wetland in northwestern Iowa. All three methods produced comparable results, but point-count and interval transects were most rapid and reflected submergent and floating as well as emergent plants. Most wet meadow plants were eliminated in about three years, whereas shallow marsh and deep marsh species survived until muskrats eliminated all emergent plants. Both vegetation and wildlife responses were typical of shallow prairie wetlands of the region.

Werner K. J., J. B. Zedler. 2002. How sedge meadow soils, microtopography, and vegetation respond to sedimentation. *Wetlands* 22:451-466. The expansion of urban and agricultural activities in watersheds of the Midwestern USA facilitates the conversion of species-rich sedge meadows to stands of *Phalaris arundinacea* and *Typha* spp. We document the role of sediment accumulation in this process based on field surveys of three sedge meadows dominated by *Carex stricta*, their adjacent *Phalaris* or *Typha* stands, and transitions from *Carex* to these invasive species. The complex microtopography of *Carex* tussocks facilitates the occurrence of other native species. Tussock surface area and species richness were positively correlated in two marshes (r^2 .

Whigham D. F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: A landscape perspective. *Environmental Management* 12:663-671. In this article, we suggest that a landscape approach might be useful in evaluating the effects of cumulative impacts on freshwater wetlands. The reason for using this approach is that most watersheds contain more than one wetland, and effects on water quality depend on the types of wetlands and their position in the landscape. Riparian areas that border uplands appear to be important sites for nitrogen processing and retention of large

sediment particles. Fine particles associated with high concentrations of phosphorus are retained in downstream wetlands, where flow rates are slowed and where the surface water passes through plant litter. Riverine systems also may play an important role in processing nutrients, primarily during flooding events. Lacustrine wetlands appear to have the least impact on water quality, due to the small ratio of vegetated surface to open water. Examples are given of changes that occurred when the hydrology of a Maryland floodplain was altered.

Whiteley J. D., F. Murray. 2005. Autocatalyst-derived platinum, palladium and rhodium (PGE) in infiltration basin and wetland sediments receiving urban runoff *Science of the Total Environment* 341:199-209.

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%)

Wilcox D. A. 1995. Wetland and aquatic macrophytes as indicators of anthropogenic hydrologic disturbance. *Natural Areas Journal* 15:240-248. Hydrologic disturbance can affect wetland and aquatic macrophyte communities by creating temporal changes in soil moisture or water depth. Such disturbances are natural and help maintain wetland diversity; however, anthropogenic changes in wetland hydrology may have negative effects on wetlands. Since plant communities respond to habitat alterations, observations of plant-community changes may be used to recognize effects of hydrologic disturbances that are otherwise not well understood. A number of plants, including *Typha angustifolia* (narrow-leaf cattail) and *Lythrum salicaria* (purple loosestrife), are recognized as disturbance species; they are often found in roadside ditches, in wetlands that have been partially drained, or in low areas that have been flooded. Other species commonly occur on mudflats exposed by lowering of water levels. In addition, wetland shrubs and trees invade or die as a result of draining or flooding. In more subtle terms, the relative composition of plant communities can change without the addition or loss of species, and zonation patterns may develop or change as a result of altered hydrology. Remote sensing (photointerpretation) and field vegetation studies, coupled with monitoring of water levels, are recommended for gaining an understanding of hydrologic disturbances in wetlands. .

Winter T. C. 1988. A conceptual framework for assessing cumulative impacts on the hydrology of nontidal wetlands. *Environmental Management* 12:605-620. Wetlands occur in geologic and hydrologic settings that enhance the accumulation or retention of water. Regional slope, local relief, and permeability of the land surface are major controls on the formation of wetlands by surface-water sources. However, these landscape features also have

significant control over groundwater flow systems, which commonly play a role in the formation of wetlands. Because the hydrologic system is a continuum, any modification of one component will have an effect on contiguous components. Disturbances commonly affecting the hydrologic system as it relates to wetlands include weather modification, alteration of plant communities, storage of surface water, road construction, drainage of surface water and soil water, alteration of groundwater recharge and discharge areas, and pumping of groundwater. Assessments of the cumulative effects of one or more of these disturbances on the hydrologic system as related to wetlands must take into account uncertainty in the measurements and in the assumptions that are made in hydrologic studies. For example, it may be appropriate to assume that regional groundwater flow systems are recharged in uplands and discharged in lowlands. However, a similar assumption commonly does not apply on a local scale, because of the spatial and temporal dynamics of groundwater recharge. Lack of appreciation of such hydrologic factors can lead to misunderstanding of the hydrologic function of wetlands within various parts of the landscape and mismanagement of wetland ecosystems.

Woo M. 1979. Effects of power line construction upon the carbonate water chemistry of part of a mid-latitude swamp. CATENA 6:219-233. Beverly Swamp in southern Ontario is typical of a wetland in carbonated terrain. At two sites in the swamp, a study was conducted between 1975 and 1977 to determine the impact of a power-line construction program upon the carbonate water chemistry of the perched ground water. Construction activities included deforestation along a narrow corridor across the swamp as well as drilling, pumping and grouting during the erection of the towers. The latter resulted in 1) contamination of the perched ground water by the alkaline water forced to the surface from near the dolomite rock and 2) disturbance of the peat and marl structure. These in turn induced higher pH, total hardness and bicarbonate concentrations in the perched ground water. Although such effects persisted beyond the construction period, the spatial patterns exhibited by the pertinent hydrochemical variables indicated that the impacts were spatially confined. It is inferred that recurrent flooding will enhance recovery of the disturbed sites.

Xu Y., J. A. Burger, W. M. Aust, S. C. Patterson, M. Miwa, and D. P. Preston. 2002. Changes in surface water table depth and soil physical properties after harvest and establishment of loblolly pine (*Pinus taeda* L.) in Atlantic coastal plain wetlands of South Carolina. Soil and Tillage Research 63:109-121. The surface water table is an important factor determining soil chemical, physical and biological processes, and thus affects the functions of forested wetlands. The objective of this study was to assess surface water table dynamics from timber harvesting through early forest plantation establishment in a coastal plain wetland area located in the southeastern United States. Simulated harvesting patterns included two replicates of clear-cutting when soils were dry (dry-weather harvest), three replicates of clear-cutting when soils were wet (wet-weather harvest), and one replicated of uncut control in three 20 ha wetland loblolly pine (*Pinus taeda* L.) forests of ages 20, 23 and 25 years. After harvesting, two site preparation levels (non-bed and bed; bedding is a tillage

process of preparing a series of parallel ridges) were randomly assigned to both dry-weather and wet-weather harvested plots, while an additional level (mole-plow + bed) was assigned only to the wet-weather harvested plots. The harvest treatments were designed to create a broad gradient of surface soil disturbance, while the site preparation treatments were done to encompass a range of site drainage and aeration conditions. Areal changes in soil bulk density, macro-and total porosities, and saturated hydraulic conductivity following harvesting were quantified. The depths of water table were recorded at monthly intervals on a 20m x 20m grid across the 15 clear-cut and three uncut control plots (a total of 1409 PVC slotted wells) over 6 years (1992-1998), subdivided into five periods; pre-harvest, post-harvest, site preparation, and first year and second year after forest plantation establishment. The results showed that compared to the uncut control, the surface water table depth during a 1-year post-harvested period rose 14 cm for the dry-weather harvested site and 21 cm for the wet-weather harvested site. The difference in the water table rise between the two harvest treatments was small during the dormant season (<2cm) but large during the growing season (>10cm). These results indicated the large influence of tree removal on the surface hydrology in forested wetlands and the strong impact of wet-weather harvesting on transpiring ground vegetation due to a larger surface area of soil disturbance. Bedding initially lowered water tables on both dry-weather and wet-weather harvested sites. However, this effect decreased rapidly during the first 2 years after forest plantation establishment. Among all treatments the dry-weather harvested sites without bedding presented the fastest recovery of water table depth to that of the non-harvested references, suggesting that bedding may have been a further disturbance with respect to wetland surface hydrology.

Yin Z. Y., G. A. Brook. 1992. Impact of the Suwannee River Sill on the surface hydrology of Okefenokee Swamp, USA *Journal of Hydrology* 136:193-217. Okefenokee Swamp, located in southeastern Georgia and northeastern Florida, is one of the largest freshwater wetland complexes and a National Wildlife Refuge in the United States. A low earthen dam, the Suwannee River Sill, was built on the largest outlet stream of Okefenokee Swamp in the early 1960s. The purpose was to raise the water level and thus reduce fire frequency in this National Wildlife Refuge. In this study, hydrologic conditions in the swamp prior to (1937-62) and after (1963-86) sill construction were compared by statistical procedures. An average 9 cm increase in swamp water level at the Suwannee Canal Recreation Area was attributed to the sill. Increased precipitation and decreased evapotranspiration during the study period caused another 5 cm increase in water levels. Seasonal changes in climatic factors were also responsible for seasonal changes in water levels and streamflow in the pre- and post-sill periods. Although the effect of the sill on water level was more significant during dry periods, it is doubtful that the Suwannee River Sill actually prevented occurrence of severe fires in the post-sill period, which was wetter than the period before sill construction. The sill diverted 2.6% of swamp outflow from the Suwannee River to the St. Mary's River. Diversion of flow was more marked during low flow periods. Therefore, the discharge of the St. Mary's River in the post-sill increased more than the discharge of the Suwannee

River and its variability became lower than that of the Suwannee River. The relationships between swamp water level, streamflow and precipitation were also changed due to construction of the sill. .

Yue T. X., J. Y. Liu, S. E. Jorgensen, and Q. H. Ye. 2003. Landscape change detection of the newly created wetland in Yellow River Delta Ecological Modelling 164:21-31. Four models are employed in the landscape change detection of the newly created wetland. The models include ones for patch connectivity, ecological diversity, human impact intensity and mean center of land cover. The landscape data of the newly created wetland in Yellow River Delta in 1984, 1991, and 1996 are produced from the unsupervised classification and the supervised classification on the basis of integrating Landsat TM images of the newly created wetland in the four seasons of the each year. The result from operating the models into the data shows that the newly created wetland landscape in Yellow River Delta had a great change. The driving focus of the change are mainly from natural evolution of the newly created wetland and rapid population growth, especially non-peasant population growth in Yellow River Delta because a considerable amount of oil and gas fields have been found in the Yellow River Delta. For preventing the newly created wetland from more destruction and conserving benign succession of the ecosystems in the newly created wetland, six measures are suggested on the basis of research results. .

Zedler J. B. 2003. Wetlands at your service: reducing impacts of agriculture at the watershed scale *Frontiers in Ecology and the Environment* 1:65-72. In the Upper Midwestern region of the US, three ecosystem services (flood abatement, water quality improvement, and biodiversity support) declined when about 60% of the region's historical wetland area was drained, mostly for agriculture. Some of the lost services could potentially be regained through wetland restoration measures authorized in the 2002 Farm Bill. Because no single wetland can provide all ecosystem services indefinitely, ecologists can help to identify combinations of projects that will best restore ecosystem services within watersheds. "Strategic" restoration would use an adaptive management approach, targeting former wetlands with marginal crop production, and prioritizing the location, size, and type of wetland needed for a watershed to provide optimal levels of all three services. Given that the Farm Bill includes over \$1 billion per year to conserve natural resources on agricultural lands, we are in an excellent position to increase the effectiveness of wetland restoration. .