12-2007

Development of a Nontidal Wetland Inventory and Monitoring Strategy for Virginia – Completion of Phase II (Coastal Plain and Piedmont Physiographic Provinces)

Center for Coastal Resources Management, Virginia Institute of Marine Science

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Final Report to the Environmental Protection Agency Region III

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

December 2007

Center for Coastal Resources Management

Virginia Institute of Marine Science

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.

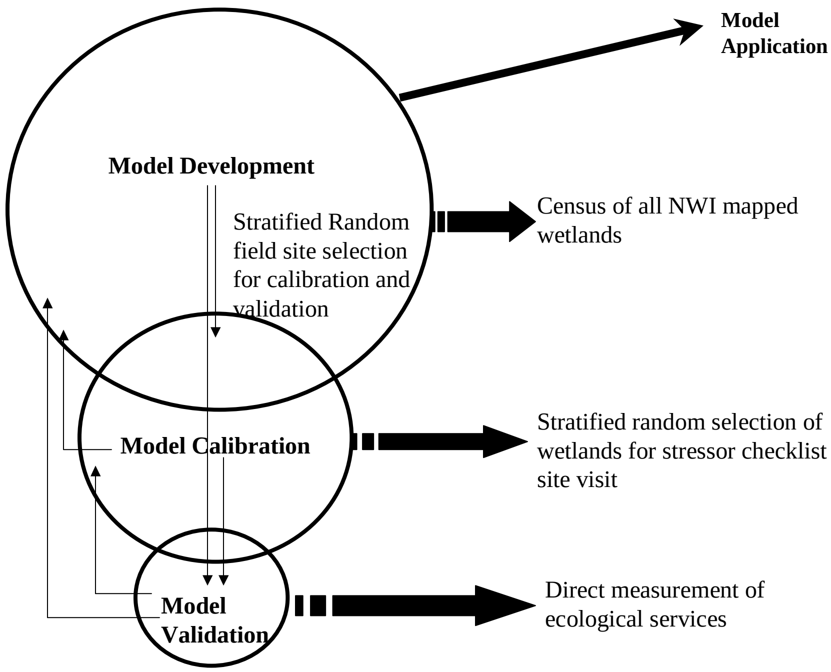


Figure 1. Multi-leveled wetlands assessment and monitoring protocol design.

The protocol was applied in Virginia with calibration in the coastal plain and piedmont. 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 and Piedmont (Figure 2).

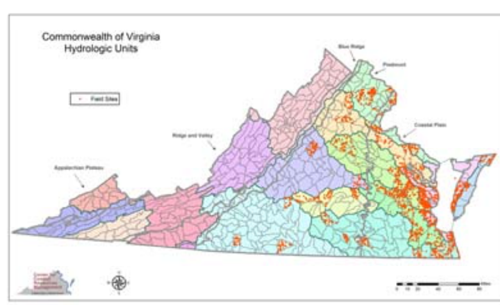


Figure 2. Hydrologic units (8 and 14 digit) of Virginia by physiographic province. Red dots depict Model Calibration assessment sites.

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.

<u>Model Calibration</u>

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, physiographic province, and permit activity (Figure 3). 1,326 sites were sampled in forty 14 digit HUCs in the Coastal Plain and 602 sites were sampled in twenty 14 digit HUCs in the Piedmont.

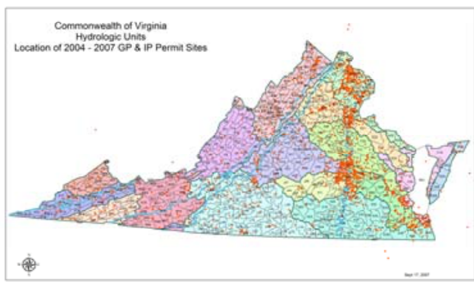


Figure 3. Location of wetland permits issued from 2004-2007.

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 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 4). A sample size of over 20 for each 14 digit HUC captures the stressor count variation in the coastal plain.

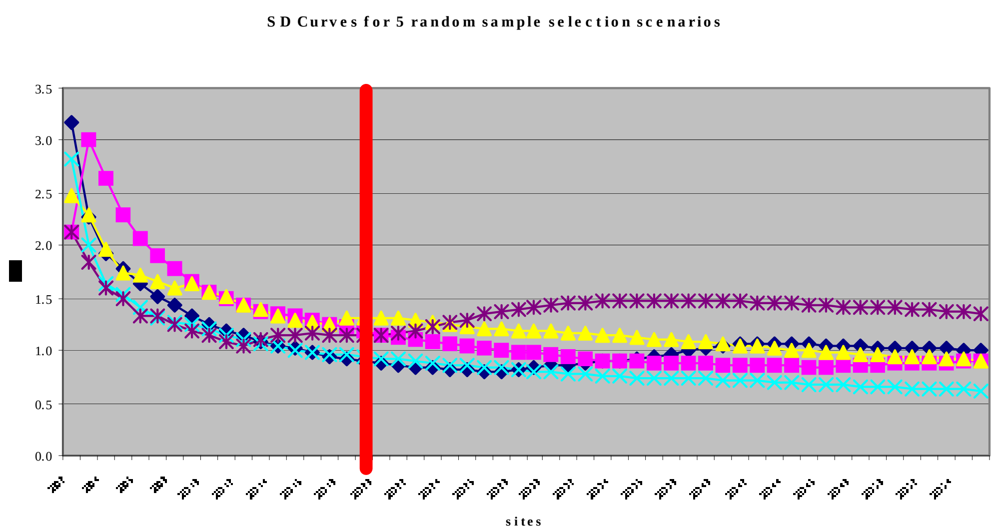


Figure 4. Running mean of standard deviation for five random sample scenarios.

<u>Model Validation</u>
Model validation was conducted by intensive sampling of direct ecological service endpoints in 27 sites throughout the coastal plain (Figure 5) of different hydrogeomorphic regimes and varying size (Table 4). Automatic sound

Figure 5. Validation site locations in the coastal plain.

recording devices were deployed during the summer to all 27 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

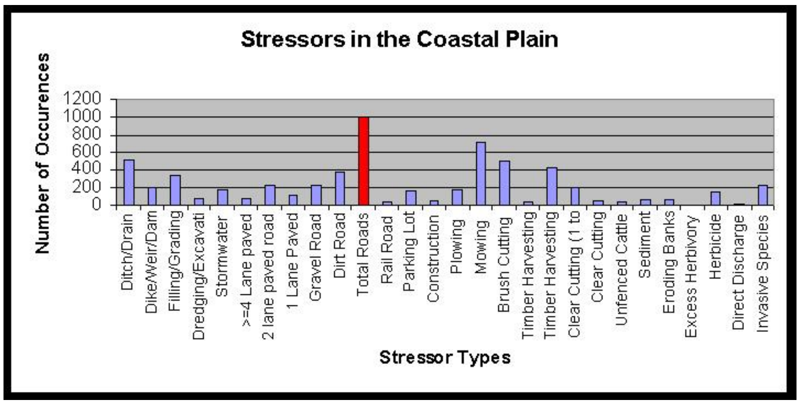
RICHARDSON CREEK	1.3	Headwater
LONG BRANCH CREEK	3	Headwater
ELK HORN CREEK	5	Headwater
MATTAWOMEN CREEK	2.4	Headwater

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 in the coastal plain while roads, mowing, brush cutting, and unfenced livestock access were the most common stressors in the piedmont. (Figure 6).



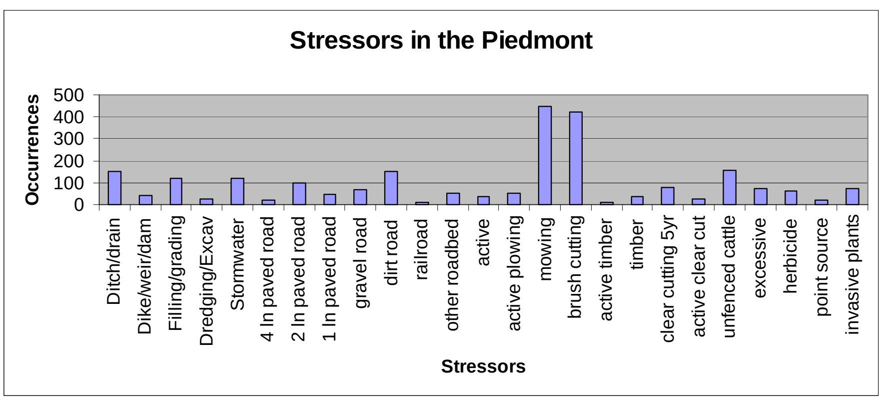


Figure 6. Stressors of coastal plain (n = 1,326) and piedmont (n = 602) wetlands.

Landcover metrics tabulated during the model development phase were correlated with stressor scores in the coastal plain and piedmont (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

Coastal Plain (n = 1,326)

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Pasture   0.347 p-value   0.000
Rowcrops -0.007 p-value   0.865
Natural  -0.424 p-value   0.000
Developed 0.228 p-value   0.000

Piedmont (n = 602)
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Table 5. Correlations between total stressor count and landcover in the 200m buffer in coastal plain and piedmont.

In the Coastal Plain, there was no significant difference between total stressor count and forested (FO) or shrub (SS) wetland type. There was a significant difference ($p = 0.000$) when forested and shrub were compared with emergent (EM). In the Piedmont there was no significant difference between total stressor count and emergent (EM) or shrub (SS) wetland type. There was a significant difference ($p = 0.000$) when emergent and shrub were compared to forested (FO) (Figure 6).

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Wetland type                           Based on Pooled StDev
Level       N      Mean     StDev   ----------+---------+---------+-----

EM        359     5.744     5.562                         (----*-----)
FO        577     4.360     4.849           (----*---)
SS        237     3.713     5.049   (-----*------)
                                    ----------+---------+---------+-----
Pooled StDev =    5.117                      4.0       5.0       6.0

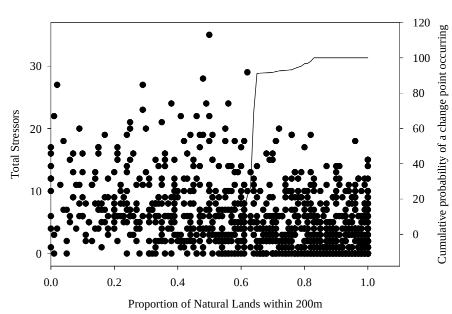
Wetland type                           Based on Pooled StDev
Level    N          Mean  StDev      -----+---------+---------+---------

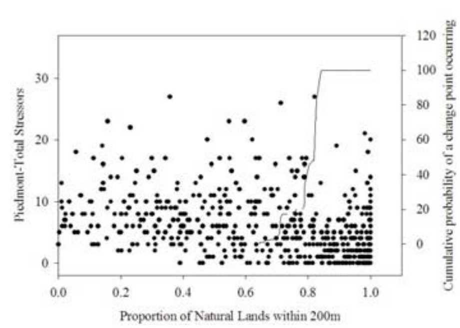
EM      200       6.310     5.183                        (------*------)
FO      231       4.182     4.186     (------*-----)
SS      168       5.875     5.526                   (-------*------)
                                       ----+---------+---------+---------
                                         4.0       5.0       6.0

Pooled StDev = 4.929
```

Table 6. Analysis of variance for total stressors and wetland types (EM=emergent, FO=forested, SS=Scrub/shrub) for the coastal plain and piedmont.

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





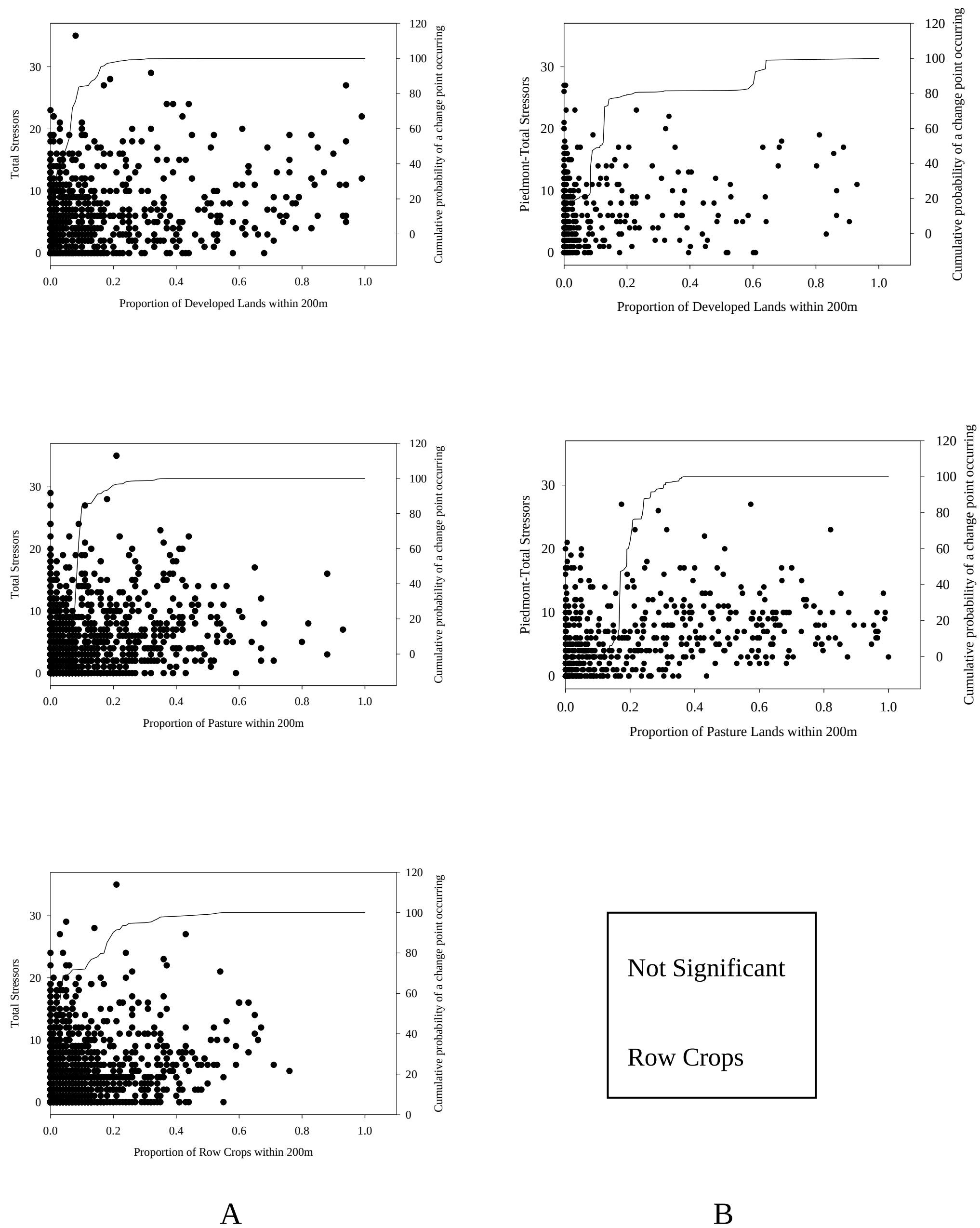


Figure 7. Changepoint analysis for determining landcover percentage versus stressor count habitat thresholds in Coastal Plain (A) and Piedmont (B).

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. The draft final scoring protocol will be further calibrated after completion of the validation analysis to produce the final scoring protocol.

Model Validation

Preliminary analysis of the validation sampling in the Coastal Plain for water quality shows a strong relationship between stressors, landuse metrics, and 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). In addition, surrounding developed landuse within a wetlands contributing drainage was correlated with incision ratio in headwater wetland streams (Pearson 0.70, p = 0.003).

For habitat ecological services in the Coastal Plain, distinct patterns between high and low stress and between surrounding natural, developed, and pasture landuse were discernable through wetland sound analysis (Figure 8) and were analyzed over a two year sample period (Figure 9, p = 0.00; ANOSIM).

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.

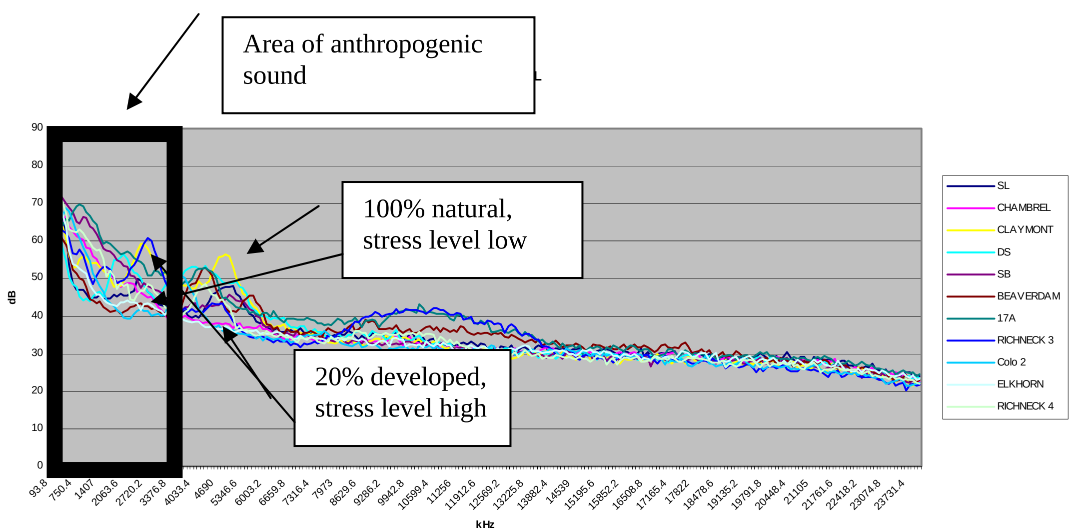


Figure 8. Site sound signatures in decibels and KHz.

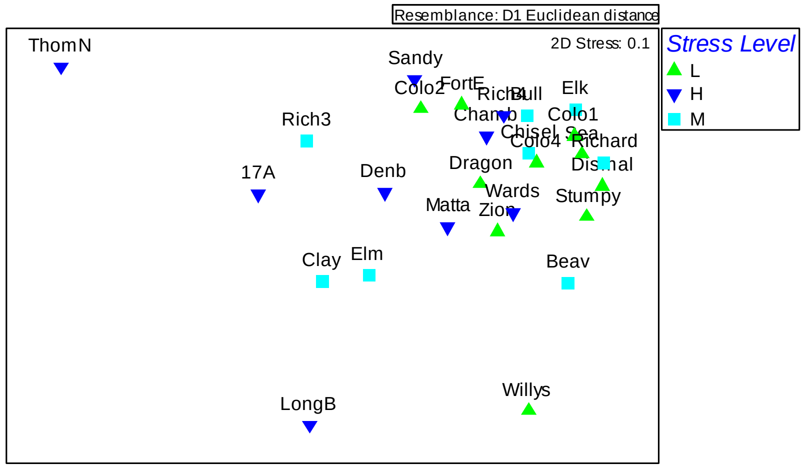


Figure 9. Sound signatures grouped by stress level for 2006 & 2007.

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.

Additional validation, including avian and amphibian standard method community structure studies, are ongoing for final refinement of the model protocol for coastal plain wetland condition assessment.